village modeling

a chinese recipe for blending
general equilibrium and household modeling

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Village Modeling -
A Chinese Recipe for Blending General Equilibrium and Household Modeling

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des namiddags te half twee in de Aula.

Ieder bewijs van onmogelijkheid
plaatst geen nieuw obstakel in de richting van de toekomst,
maar haalt er juist een weg…

Denis Guedj (2001). *De Stelling van de Papegaai*, p.471.
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The contents of this thesis reflect only part of the rich personal experience that my Ph.D. research has been. Of course there were many hours behind a computer, processing data and trying to get the model running. But there were also more unusual experiences. I got to share sunflower seeds with a Chinese grandfather on the train towards the research area. I visited the Chinese countryside, meeting villagers that were as friendly as they were surprised of having Westerners in their village. I also took one of the night buses from Jiangxi Province to Shanghai, a trip unlike the bus rides I made in other parts of the world. The anxiety of the rural migrants about their uncertain future was so obvious that it went right through the language barrier, making the modeling work in this thesis much more than academic exercise.

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CHAPTER 1

setting the stage

Thinking of China, you may see numerous farmers working small plots in a landscape of endless paddy fields. Arriving in China, you will see sky scrapers and multi-story supermarkets in a landscape of endless newly build urban areas. Within the time-span of less than a generation, the Chinese turned an inward-looking agricultural society into an outward-looking increasingly industrialized country. The opening of the Chinese economy, combined with an increasing reliance on markets, has led to unprecedented growth rates. China's WTO accession in 2002 confirmed China's increasingly outward orientation, and is expected to sustain the growth of the Chinese economy in the future.

High growth rates over the past decades have made China's economy the sixth largest in the world by 2002. When ranked in terms of total GDP measured in purchasing-power parity China only finds the United States ahead (Economist, 2003a). Economic growth has reduced the number of rural poor to 34 million in 1999, down from 250 million at the start of the reforms in 1978[1] (Stern, 2002). In percentage terms this amounts to a drop in rural poor from about 30 percent before reforms to 3 percent in 2000. Although one may discuss the appropriate measure of poverty, economic growth has irrefutably increased the well-being of a massive number of people.

Benefits of economic growth, however, are not distributed evenly. Economic growth concentrates in the coastal provinces, because of geographical advantages, like proximity to cities and easy access to export markets by sea, but also by deliberate policies aimed at promoting development in the coastal provinces (Démurger *et al.*, 2002). In contrast with experiences in other formerly centrally planned economies, China's transformation to a market economy is characterized by gradualism. Reforms are generally implemented through a two-tier system, with planned and market-based systems coexisting. This allows economic agents and the government to gain experience with the new institutional structure, and aims at reducing the disruption of system change. In the case of the opening of the Chinese economy, such a two-tier system was implemented by establishing special economic zones in coastal regions, where industries were stimulated to participate in the international market (Peng, 1999; Yao, 1999). This initial preferential treatment may have led to a stronger concentration of economic development in the coastal

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[1] These numbers are based upon China's official poverty line, which is 30 percent lower than the World Bank's $1 per day international poverty line (Stern, 2002:110).

province than would have occurred otherwise, since manufacturing is generally characterized by local externalities and economies of scale.

Apart from preferential treatment of coastal regions, restrictions on the movement of labor also increased inequalities. Despite the fast transition to a industry- and service-based economy, a large number of people still reside in the rural areas. This is not because of lack of income incentives for moving to the urban areas. Official estimates indicate urban incomes to be three times the rural incomes, while others estimate a six-fold difference (Economist, 2003b). These large income differences are due to a urban- and industry biased public investment policy, with only limited attention for investments in the rural areas (Fan *et al.*, 2002). The biased investment policy was combined with deliberate policy measures to keep people from moving to the urban areas, through residence permits and exclusion of rural migrants from social welfare systems in the urban areas. These formal restrictions did not stop the migration flow, but did increase uncertainty and costs for rural migrants (Hare, 1999).

The rapid transformations of the economic structure, in combination with policies hampering the spread of economic benefits across regions and across people, resulted in a rising income inequality. This inequality is an increasing cause for concern, since it threatens social stability and may impede future growth (Kanbur and Zhang, 2001). Acknowledging the political importance of the growing gap between rural and urban incomes, the central government has recently put forward a policy for boosting rural incomes. This comprehensive policy (Central Committee, 2004) calls for measures to improve income derived from agricultural production, but explicitly acknowledges that agricultural production alone cannot bring rural incomes at par with urban incomes. Apart from a set of measures to improve crop and livestock production, measures are called for to promote industrial development in the rural areas and to facilitate the rural-urban migration. The impact of differential access to resources and income-earning opportunities is thus becoming a prime policy concern.

1.1 building a chinese case for village-level modeling

Economic research on China has experienced a boom matching the growth rates of the Chinese economy. Next to renewed access to a country off-limits to the international research community for a number of decades, the shift from a centrally planned to a market economy provided an unusual opportunity for studying institutional change. Reflecting economic research methods used elsewhere, analyses focused on aggregate patterns at national or provincial or county level or on the impact of the transformation on household decisions and incomes (see for example Diao *et al.*, 2003; Huang *et al.*, 2003; Qiao *et al.*, 2003; Taylor *et al.*, 2003).

Households, however, do not operate in a vacuum, but are part of a local community in which they interact with other households. Apart from social interactions, presence of goods and factors that are traded only within a village (village nontradables) result in households interacting through village markets. The resulting linkages and feedback affect household decisions and changes initially affecting only a limited group of households, may work their way through the village economy. Taylor and Adelman (1996) therefore propose the use of general equilibrium models at village level, allowing a quantitative analysis of the impact of interactions among households on household response.

The work of Taylor and colleagues mainly focused on Mexico (see for example Taylor *et al.*, 1999a; Taylor *et al.*, 1999b), but a convincing case for applying such a village-level model in China can be made. Given the recent transformations in China, markets are still developing and imperfections can be expected to be abound. Studies of factors influencing migration decisions (Hare, 1999; Murphy, 2000; Rozelle *et al.*, 1999a; Rozelle *et al.*, 1999b) and of patterns in inequality (Benjamin and Brandt, 1999), refer to imperfect land, labor and credit markets as being relevant in the Chinese context. Such a partial integration in markets may give rise to nonseparability of household production and consumption decisions, or may create (thin) local markets through which household decisions affect each other (Holden *et al.*, 1999).

If households interact in local village markets, and these markets are not integrated with markets outside of the village, local general equilibrium effects occur. Studies of market integration in China find villages to be integrated in markets for major outputs (Huang *et al.*, 2003) and for fertilizer (Qiao *et al.*, 2003). While villages can thus be assumed to be integrated in agricultural input and output markets, integration of factor markets is limited. Labor markets are highly segmented (Gilbert and Wahl, 2003), resulting in a rural labor surplus (Cook, 1999). Village agricultural labor markets, however, can be expected to be thin. Due to the collective ownership of land, all households have access to land. Lacking landless households and generally having similar agricultural production patterns, there is little scope for village agricultural labor markets. Local nonagricultural employment, however, will exist in the local service sector. The importance of a village service sector for generating local general equilibrium effects will depend on the access to services from outside the village, as well as on the size of the village.

While limiting the prospect for local agricultural labor markets, collective ownership of land results in village land markets. Land rights remain unclear, in spite of land tenure reforms that have granted household user rights for 30 years (Huang and Rozelle, 2004). Land is allocated on the basis of demographic criteria, and readjustments occur to adjust for changes in household size, despite formal household user rights. The result is an ambiguous land tenure situation (Ho, 2001), in which households have an incentive to keep their land cultivated to avoid loosing it during a next readjustment. Households that migrate to urban areas therefore often rent their land out to other households to maintain their claim to the land in case they are unable to secure a living in the urban areas. Given the ambiguity of land tenure, land rental markets are restricted to villagers, resulting in local land markets.

Village interactions may also arise through informal credit markets. Government intervention in the formal banking sector remains strong. Regulated interest rates are well below market clearing levels, while soft loans to state enterprises seize a large share of available funds. Rural households are thus rationed out of credit markets. In the late 1980s, rural cooperative funds developed, targeted at rural households. These funds proved too successful competitors of existing rural credit cooperatives and were dissolved in 1999 (Park *et al.*, 2003). As a result of the lack of formal credit options, household generally have to rely on loans from friends and relatives, generating local informal credit markets.

Reflecting the dual approach to transition in China, the functioning of markets for agricultural output stands in sharp contrast to the fragmented and government controlled markets for factors of production. We thus hypothesize that Chinese villages are integrated in markets for main agricultural outputs and external inputs, while village factor markets exist. Data from the case study village of this study confirms this hypothesis (Xiaoping *et al.*, 2004). Inputs are purchased outside from the village or produced on the farm, while output remaining after satisfying household consumption needs are sold outside the village. Local factor markets exist for irrigated land, draught animals, tractors, and to a limited extent for agricultural labor. These local markets result in linkages and feedback among households, necessitating the use of a village-level model for analyzing household response.

Although other studies mention imperfect land, labor and credit markets as being relevant in the Chinese context (Benjamin and Brandt, 1999; Hare, 1999; Murphy, 2000; Rozelle *et al.*, 1999a; Rozelle *et al.*, 1999b), their impact has not been analyzed using a quantitative village model. Apart from providing the first quantitative analysis of a Chinese village economy, thus study makes three methodological contributions to the existing literature on village equilibrium models.

This study first of all pays due attention to nonseparability of household production and consumption decisions when analyzing the impact of interactions within a village on household response. Accounting for nonseparability affects all aspects of the village model, including the way in which the village social accounting matrix (SAM) is constructed. The household-specific production response allowed by the model developed in this study forms a major departure from existing village models assuming a uniform production response for all households.

Accounting for the impact of migration on household consumption needs is the second difference between this study and existing village models. Existing models only account for the impact of migration on the availability of labor for production and the inflow of remittances. Another innovative aspect of the approach taken in this study, is the use of household survey data to calibrate elasticities needed to model consumption and production decisions consistent with the assumptions made in the village model. This contrasts with the common practice in general equilibrium modeling of using elasticities from the literature that may be inconsistent with model assumptions.

Empirically testing the separability of factors and intermediate inputs provides the third contribution of the village equilibrium model of this study. Existing village models follow the common practice in general equilibrium modeling of assuming separability of decisions on factors and intermediate inputs. Dealing with a micro-level analysis as in a village study, such an assumption does not seem appropriate for capturing the production decisions of rural households. After testing rejected separability of factors and intermediate inputs, we calibrate activity-specific production structures. The resulting production functions capture differences in separability of inputs across activities, as well as differences across households in access to inputs. As with the consumption decisions, substitution elasticities needed to parameterize the production functions are calibrated on household survey data and thus fully consistent with the model assumptions.

Apart from contributing to the academic study of China, the development of a quantitative village model has clear policy relevance. The two-tier approach to reforming the economy results in market and centrally planned spheres in the economy coexisting, as well as in differences in access to income-earning opportunities. These features of the Chinese economy are also apparent at the village level, with households having differential access to non-land resources and income-earning opportunities and with prevailing impediments to factor markets. Differential access to resources causes idiosyncratic household response, that cannot be captured by existing village models assuming a uniform production response across households. Furthermore, as discussed above recently formulated policy aims at facilitating (temporary) rural-urban migration to increase rural incomes. Migration of household members implies a reduction in household consumption demand, raising the income available for remaining household members. This welfare-enhancing impact of migration is lacking in existing village models, while being important for assessing the full impact of migration on rural households. Apart from off-farm income, the recent policy also calls for increasing agricultural incomes. To analyze household response to changes in the agricultural incentives, production functions need to capture the existing substitution possibilities. In contrast to the generic production functions in existing village equilibrium models, the model in this study includes activity and household-specific production functions. Combined with the nonseparability of household decisions, this allows an analysis of household response to changes in production incentives that accounts for both technical and socio-economic constraints facing households. The methodological innovations in the village equilibrium model developed in this study thus make it well-suited for analyzing current policy issues in China.

1.2 objectives of this study

This study focuses on analyzing the impact of interactions within a Chinese village community on rural household decisions. Accounting for the feedback between households modifies household response compared to results obtained from a separate household analysis, and may thus alter implications for policy-making. Although the applied village model focuses on a Chinese case study village, the methodology employed in this study is relevant for villages in other settings as well. Sufficient methodological detail is therefore provided, to allow replication of the methodology developed in this study in a different setting.

The study consists of two parts. The first part is devoted to identifying an appropriate approach to modeling interactions among rural households while capturing differences in access to resources an income earning opportunities across households. The second part focuses on developing an applied Chinese village model.

1.2.1 part one: identifying the building blocks of the village equilibrium model

The present study blends household modeling approaches with applied general equilibrium modeling. Although household and general equilibrium modeling are analytically identical, in practice these are two separate streams of literature with different conventions, placing emphasis on different aspects of the model. Our work aims at being accessible to scholars from both streams by discussing the basics of both types of models.

Blending two different streams of modeling work implies that the mixture will look different from the two initial ingredients. This mixing requires a careful consideration of features that may be standard for either a household or a general equilibrium model, but may not suffice in case of a village equilibrium model. Apart from catering to different audiences, the discussion of the basics of both types of models thus also serves as a basis for assessing which aspects of household and general equilibrium models need to be maintained in the village model.

A review of existing models serves as input to assess which components of household and general equilibrium models need to be incorporated in the village model. To be able to look beyond details of a specific application at the underlying modeling assumptions, we develop a general framework for assessing the strengths and weaknesses of models of rural household decisions. This framework allows us to consistently compare a wide variety of approaches to modeling household decisions and interactions among households. The dimensions of this framework are broader than the scope of the village equilibrium model developed in this study. This allows us to identify the limitations of this study and possible directions of future research in the concluding chapter by scrutinizing the village equilibrium model in the same way as we reviewed existing models.

1.2.2 part two: blending household and general equilibrium modeling to model a chinese village

In the second part of this study we develop an applied village equilibrium model for a Chinese village. Development of an applied model requires switching back and forth between theory and data, in order to obtain a theoretically consistent model capturing the essence of the specific situation being analyzed. The chapters developing the applied model pay considerable attention to choices made during modeling, and the way these choices are implemented in the applied model. This documentation of the model is necessary because by blending two types of models, the resulting model differs from existing ones. A more fundamental reason for documenting model development is that choices made for the Chinese village model may not be appropriate in other settings. By discussing alternative approaches, readers interested in developing a village equilibrium model in a different setting can determine whether the structure of the Chinese model fits other circumstances. If not, the discussion intends to provide a starting point for an alternative approach.

The central theme of the second part of the study is to look at general equilibrium modeling from a household perspective. This perspective results in changes of key parts of the standard approach to applied general equilibrium models, including the existing village models based on the work by Taylor and Adelman (1996). In addition to the household perspective, the cross-sectional household survey data play an important role in developing the village equilibrium model. We find household survey data to pose limitations due to their cross-section character, as well as opportunities due to their detail and compatibility with the village model. Data availability plays an important role in choice of functional forms and the calibration of model parameters. The household perspective on general equilibrium modeling affects the structure of the village social accounting matrix (SAM) on which the model is build, the village market mechanisms, calibration of consumption decisions, and modeling of production decisions. The resulting hybrid model overcomes limitations of both household and general equilibrium models, while yielding insights that can be used in either applied household or general equilibrium models.

Given the current economic developments in China, the importance of migration is expected to increase further in the future. The common thread throughout the chapters developing the applied village model is therefore an exogenous increase in inter-province migration. This analysis of migration captures only one aspect of the changes occurring in China, ignoring for example changes in relative input and output prices following from the increased participation of China in the global economy. Limiting the simulations to an increase in migration, however, offers three main advantages. First of all, analyzing the impact of a change in a single shock to the model facilitates the analysis of model results by allowing a clear view on mechanisms driving household and aggregate village-level responses to exogenous shocks. The second advantage of using the same shock throughout this study is to allow an assessment of robustness of results to changes in model structure made in subsequent chapters. The third advantage of only analyzing an increase in migration opportunities is that direct effects are limited to the households involved in migration. Households not involved in migration are indirectly affected through interactions within the village economy, offering a direct view of the additional insight gained from using a village-level model as opposed to a household-level analysis.

1.3 structure of the study

The first part of this study is devoted to identifying an appropriate approach to modeling interactions among rural households, and consists of two chapters.

Chapter 2 develops a framework for assessing model approaches. It identifies key choices that need to be made when developing an applied model. The chapter results in a matrix identifying the key elements of a model of rural household decisions in their socio-economic and bio-physical context. This matrix provides a structure for comparing different applied models without getting bogged down in the details of a specific study.

Chapter 3 compares a variety of household- and village- or regional-level models. It identifies the strong points as well as limitations of different approaches and introduces theoretical concepts used in later chapters. The chapter results in a motivation of the choice for household and general equilibrium modeling and reviews the literature on which the village equilibrium model developed in this study is building. Based on this review the general structure of the village model used in this study is described.

The second part of this study shifts gears to developing an applied model of a Chinese village. The case-study village is a typical rice producing village in the plain areas of North-East Jiangxi Province. Reflecting the macro-level changes described at the start of this chapter, off-farm employment and especially migration to coastal provinces provides an important source of income in the case study village (70 percent of the households is involved in outside province migration, which yields 25 percent of total village valued added). Representative household groups are therefore constructed on the basis of access to outside-province employment, next to ownership of draught power to capture agricultural income opportunities. Different versions of the applied village equilibrium model, reflecting different methodological innovations, are then used to analyze the impact of an increase in outside province migration on different household groups in the village.

Chapter 4 discusses the village SAM on which the village equilibrium model is calibrated. It develops a SAM which captures the differences in production and consumption across household types, needed to model household decision-making in the presence of imperfect factor markets. The chapter results in a consistent data set and, by estimating household-specific shadow prices, provides important information on the functioning of village markets.

Chapter 5 develops the first version of the applied village equilibrium model. It uses the information gained from constructing the SAM to develop a model structure which fits with the specifics of the case study village. The chapter results in an applied model focusing on village market mechanisms and how these transmit an increase in income from migration through the village.

Chapter 6 focuses on household consumption decisions. It captures the impact of migration on household consumption, both through increasing remittances and by reducing subsistence consumption levels. The chapter results in a second model version, capturing market mechanisms and shifts in consumption following an increase in migration, with consumption parameters calibrated on the available household survey data.

Chapter 7 focuses on production decisions. It develops nested production functions that are consistent with the household survey data, both in terms of structure and substitution elasticities. The chapter results in a third model version, capturing specifics of the case study in terms of market mechanisms, consumption and production decisions.

Chapter 8 concludes by returning to the matrix developed in Chapter 2 to assess the strengths and weaknesses of the village equilibrium model developed in this study. It identifies the contribution of this study to the existing literature as well as directions for future research.

CHAPTER 2

key issues in modeling rural household behavior

Rural households are the basic unit of analysis in this study. Rural households engage in agricultural activities on their own farm. They may also be involved in off-farm activities, either working for other farmers, or working outside the agricultural sector. Household family labor is an important input in all activities, while part of the own agricultural production is consumed by the household. This yields a mixture of production and consumption decisions that generally cannot be separated from each other. Interrelated production and consumption decisions may be analyzed through a farm household model (see for example Singh *et al.*, 1986a). Such a model consists of a description of production decisions (input use, technology choice) and of consumption decisions (leisure, consumption of goods).

Modeling household decisions covers only part of the story. Households do not operate in a vacuum; they interact with each other, and with their biophysical and socio-economic environment. Because of these interactions it is difficult to disentangle different forces affecting household decisions. A food price increase, for example, may increase food production by making its production more attractive. It also increases household income, which may lead to an increased food consumption. Depending on whether or not the income effect outweighs the production response, net marketed surplus will decrease or increase in response to the food price increase. Given the presence of opposing forces a quantitative assessment is needed to establish the impact of a change in the external environment on household response. Models are a useful tool for such an assessment by making assumptions explicit, and by allowing analysis of highly complex issues in a stepwise fashion while imposing consistency between different steps in the analysis.

Modeling is the construction of a simplified representation of reality. When developing a model of household behavior, choices have to be made on which aspects of the household and its environment are included in the model, and which aspects are left out. These choices are generally not discussed explicitly, clouding a comparison of applied models and identification of assumptions driving model results.

The main contribution of this chapter is the development of a consistent framework for assessing models of rural household behavior. This framework provides a concise overview of fundamental choices that need to be made when modeling rural household behavior. To this end separate strands of literature are pulled together in a matrix with key elements and key issues as its two dimensions (Table 2.1). The *key elements* describe the elements that cover the essentials of the household and its environment. The *key issues* describe fundamental choices that need to be made when representing each element in a model. Analyzing a specific model with this matrix provides a systematic overview of assumptions made during model development, as will be seen in Chapter 3.

Table 2.1: A matrix of key choices in modeling rural household behavior (sections discussing the entries)

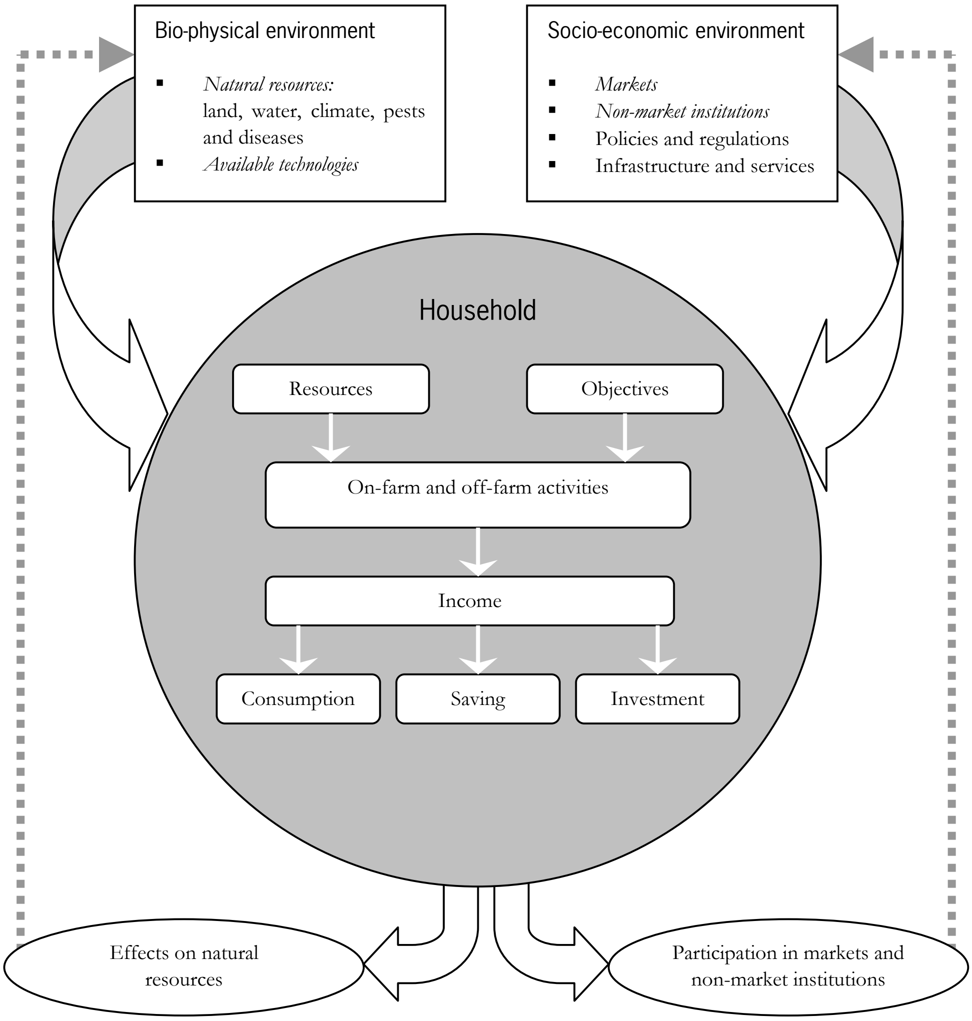
Key issues: / **Key elements:**	*Conceptualization*	*Interaction*	*Aggregation*	*Dynamics*
Natural resources	(2.2.1)	(2.3.1)	(2.4.1)	(2.5.1)
Technology	(2.2.2)	(2.3.2)	(2.4.2)	(2.5.2)
Household	(2.2.3)	(2.3.3)	(2.4.3)	(2.5.3)
Markets	(2.2.4)	(2.3.4)	(2.4.4)	(2.5.4)
Non-market institutions	(2.2.5)	(2.3.5)	(2.4.5)	(2.5.5)

The five key elements of a model of rural household decisions are natural resources, technology, household, markets and non-market institutions. For each of these five elements there are four key issues that need to be addressed. First of all, the elements need to be *conceptualized* or represented in the model. After this definition of model elements, *interactions* among similar elements (among households, for example) and different elements (among households and natural resources, for example) can be defined. The remaining two key issues are *aggregation* (how to deal with differences among individual units) and *dynamics* (how to deal with changes over time).

This chapter does not aim at giving a complete coverage of all literature. Rather, of each issue a concise and non-technical summary is provided, focusing on the type of modeling decisions that need to be made. References with each issue provide a starting point for readers interested in a more detailed or formal treatment. Although most of the issues are also relevant for macro-level models separating household consumption and firm production decisions, the scope of this chapter is limited to modeling rural households taking both production and consumption decisions.

Section 6 concludes by summarizing the discussion for each entry of the matrix outlined in Table 2.1. The resulting matrix of key issues first serves as the backdrop for the comparison of different modeling approaches. Using this matrix, the scope and limitations of a variety of modeling approaches are analyzed in a consistent way in Chapter 3. Second, the matrix serves as a reference point throughout this study, providing a context for topics addressed in the different chapters. Finally, the matrix is used in the concluding chapter to identify the contributions and limitations of the village model developed in this study.

Figure 2.1: Household decision-making in its bio-physical and socio-economic context (key elements in italics)



2.1 key elements of a model

Households take their decisions in a complex environment as outlined in Figure 2.1. The bio-physical environment sets boundaries to the production possibilities of the household, and determines production risks. The socio-economic environment sets further boundaries on household decisions. Within this context households select on-farm and off-farm activities in line with their objectives and resources. The income derived from the activities is used for consumption, saving and investments. The production activities and consumption pattern of the household affects its external environment through possible effects on natural resources, and participation in markets or non-market institutions.

The *bio-physical environment* can be divided in two parts: natural resources and available technologies. The common definition of natural resources is stretched somewhat in Figure 2.1. Next to land (soil and vegetation) and water resources, it also encompasses climate, pests, and diseases. These elements captured under the heading of natural resources have in common that they constrain the output that may be derived from the biophysical environment.

Technologies determine the physical relations governing the transformation of natural resources into products for human consumption. Technological change may relax boundaries set by natural resources, and is strongly influenced by limitations posed by a specific biophysical setting. Technologies are developed by humans and therefore also affected by the socio-economic environment. Development of new agricultural technologies, for example, may be influenced by the amount invested in agricultural research and development. Interest groups may influence the focus of research efforts to develop technologies that serve their interest (Roseboom, 2002). Being beyond the direct influence of rural households, a further discussion of interactions between technology and the socio-economic environment is beyond the scope of this chapter focusing on household behavior. Figure 2.1 therefore assumes that the bio-physical and socio-economic environment pose two separate sets of constraints on rural households.

The *socio-economic environment* can be divided in four parts: markets; non-market institutions; policies and regulations; infrastructure and services. Institutions encompass both market and non-market institutions. Whereas markets form the core of economic theory, non-market institutions (patron-client relations, for example) appear much less frequently in economic models. Therefore a distinction is made between markets and non-market institutions.

Policies and regulations provide the context in which market and non-market institutions operate. Individual households generally cannot (directly) influence policies and regulations, nor participate in selection of policy instruments. Furthermore, most quantitative household models are developed to support policymaking, with policies defined as exogenous variables whose impact on household response is analyzed. Since household cannot directly influence policies, and to allow support of policymaking, policies and regulations are treated as exogenous constraints on household behavior.

A second aspect of the context in which markets and other institutions function are infrastructure (roads, irrigation works, communication networks) and services (extension, research, education). Infrastructure and services determine access (in terms of availability and costs) to markets and non-markets institutions, and to natural resources and technologies. All-weather roads may provide access to regional markets, or to forest areas. Irrigation works affect technological options of farmers and mitigate weather risk. Communication networks facilitate participation in institutions like farmers' organizations. Extension, research and education facilitate access to alternative agricultural practices and new technologies. As with policies and regulations, individual households can be assumed not to be able to (directly) influence infrastructure and service provision. These are therefore treated as exogenous constraints on household behavior.

The household is the central element in Figure 2.1. Within the limits set by its bio-physical and socio–economic environment, the household matches its resources and objectives through selection of on-farm and non-farm activities. These activities generate income (possibly in kind, like food crops) that is divided between consumption, saving and investment[1]. The household interacts with its bio-physical environment by affecting natural resources (for example through erosion or nutrient depletion), and interacts with its socio-economic environment through participation in markets and non-market institutions.

Taking the household's sphere of influence as a criterion to determine the elements that need to be addressed in a model, five elements of Figure 2.1 remain: natural resources, technology, the household, markets, and non-market institutions. Households can choose from available technologies and households may choose to participate in specific market and non-market institutions[2]. Furthermore by choosing technologies, (or developing new ones), the household may relax constraints posed by natural resources, placing the impact of natural resources (partly) within the sphere of influence of the household. Irrigation, for example, reduces the influence of rainfall on production. Policies, regulations, infrastructure and services are treated as exogenous parameters in the modeling exercise, since they cannot be (directly) influenced by the household.

To include the five key elements in a quantitative model they need to be made operational, *i.e.* represented by specific variables and parameters. This involves a number of fundamental choices that may be grouped in four key issues: conceptualization, interaction, aggregation and dynamics. The implication of each of these key issues for each key element will be addressed in the following sections.

2.2 conceptualization

The complexity of household decision-making, and the number of opposing forces affecting household decisions limit the use of strictly analytical models, in the sense of being abstract theoretical constructs without an application to empirical data (Kaimowitz and Angelsen, 1998). Analytical models soon become intractable, or contain counteracting forces of which the outcome can only be determined quantitatively. Moving from an abstract analytical model to a quantitative model requires conceptualization of general theoretical constructs (*e.g.* utility) into a specific operational definition (*e.g.* full income). Conceptualization is a first major step in developing a quantitative model. It involves specification of the different elements of the model in terms of the variables and parameters measuring them. The assumptions guiding this step from theory to application, drive the outcome of the quantitative models.

2.2.1 natural resources

Starting at the bio-physical side we need to define the **natural resources** included in the model. Dealing with rural household behavior, natural resources affecting rural household decisions need to be identified. Land is the first natural resource that comes to mind. The most basic approach to

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[1] In case of income in kind like food crops one also needs to account for losses during harvesting and storage.

[2] Whereas households generally have a choice with regard to participation in a specific market, participation in non-market institutions like village insurance schemes may be strongly determined by social relations and less thus less of a household choice. If participation in a non-market institution is not a household choice, it becomes an exogenous constraint on household decision-making.

introducing natural resources is to define the amount of land to which the household has access for agricultural production. Most economic models do not move beyond this although a more elaborate inclusion of natural resources is possible, defining land in terms of soil nutrients, accounting for water availability or presence of pests and diseases.

Apart from including natural resources that affect household decisions, usually by serving as inputs in the production set discussed below, one may include natural resources that are affected by rural household decisions but do not enter in the decision-making process. One may for example compute the amount of pollution resulting from household activities, without linking the levels of pollution to production possibilities or household welfare. Such an *ex post* computation could serve as a crude indicator of the sustainability of household decisions, but does not allow households to anticipate the future impact of their decisions.

2.2.2 technology

Specifying natural resources is closely linked to the second biophysical conceptual issue of defining a production set. A **production set** describes the available technologies, by specifying the relations between inputs and outputs. Inputs applied in the production process like labor, seeds, impact of weather, notably rainfall, are obvious elements to be considered, just as the output of crop or livestock products. Most production functions in economic models do not go beyond this. However, such a specification ignores the effects of soil characteristics on yields, as well as the possible effects (positive or negative) of agricultural production on soil quality. From a biophysical perspective, the contribution to, and effect on a range of characteristics such as soil depth, soil density, nutrient contents, acidity, *etc.* should be accounted for when estimating the production function. Unfortunately, complex interactions between bio-physical processes and agricultural production make it difficult, if not impossible, to generate such a complete specification disentangling the impact of different soil characteristics on production (Kruseman and van Keulen, 2000). Generally, the amount of detail in conceptualizing natural resources in rural household models will be determined by the available data for quantifying the link between natural resources and produced output.

2.2.3 household

When modeling household behavior, first the household itself needs to be defined. Which persons belong to a household depends on the socio-cultural context. In the African countries the household may consist of an extended family, while in Western countries only consisting of parents with their children. Associated with the definition of the household is defining which resources (land, capital goods) the household controls.

In the specification of household behavior there are three major conceptual issues: objectives, separability, and risk. The standard household model consists of a general utility function that is maximized, subject to a number of constraints (Singh *et al.*, 1986b). When specifying household **objectives,** a choice has to be made between a primal and a dual formulation of household decisions. In the primal formulation, used in mathematical programming models, an objective function is explicitly specified. Since utility can not be measured, this creates the problem of defining an objective function in terms of measurable units that reflects households decision-making. In the dual formulation, used in general equilibrium models, demand functions are estimated based on the first order conditions of constrained utility maximization. Only a limited number of demand functions have an analytical primal form, *i.e.* the utility function can be recovered from the estimated demand functions. In case of goods for which prices can not observed, like household nontradables, estimation of demand functions becomes difficult (Ginsburgh and Keyzer, 1997:74). When specifying household objectives, a choice thus has to be made between specifying an unobservable utility function, or specifying demand functions for a number of nontraded goods with unobservable prices.

A prime issue in the literature on modeling rural household behavior in developing countries, is **separability** of production and consumption decisions. Responses to price changes may be weaker or even reversed, if one switches from assuming separable to non-separable decision-making. Production, labor supply and consumption decisions can be separated (and thus analyzed recursively) if all markets function perfectly (Sadoulet and de Janvry, 1995; Singh *et al.*, 1986a). In such a situation, the consumption and labor supply decisions of a household do not affect the household's production decisions. Perfect markets are a sufficient, but not necessary condition for separability: imperfect markets do not automatically imply interlinked production, labor and consumption decisions. To illustrate this point, consider an output that has to be sold to a government board against a fixed price. Such a monopsony does not cause non-separability of household decisions, since the output price is still exogenous to the household. In most situations, the effect of market imperfections will not be as clear-cut as in this example. Therefore, the impact of market imperfections has to be carefully examined, before deciding to model household behavior as either recursive or simultaneous decision-making, while also taking into account that market imperfections might only affect part of the population (see for example Sadoulet *et al.*, 1996). Even if all markets are perfect, nonseparability may still occur if consumption and labor quality are linked. In so-called efficiency-wage models, labor needs to be produced through consumption of food providing a direct link between consumption and production decisions (Dasgupta and Ray, 1986).

A third important aspect of household behavior is associated with the issue of **risk**, especially in developing countries were low-income households generally lack the resources to deal with fluctuations in income. To conceptualize risk, first the types of risk households faces have to be determined (production, price or market, institutional, personal, financial). Then the chance of each risk occurring and its consequences for the household need to be determined. After this conceptualization of risks, the attitude of the household towards these risks has to be specified. Given the subjective nature of this attitude, it is not easy to quantify household risk aversion (Hardaker *et al.*, 1997). The last element of incorporating risk is the specification of mechanisms through which the household may cope with risk. These vary from reducing the variability of agricultural practices (cultivating a variety of different soil types, intercropping, cultivating drought resistant crops), diversifying income sources by working off-farm, and institutional arrangements to pool risk among households (share-cropping, social networks) (Bardhan and Udry, 1999).

2.2.4 markets

The standard institutional setting in economic models is one of perfect competition. In such an idealized setting firms maximize profits and consumers maximize utility, taking prices as given. Prices convey all available information about the traded commodity and are such that the market clears, *i.e.* demand equals supply (Mas-Colell *et al.*, 1995:314). When modeling actual markets, a divergence from this ideal setting may occur due to incomplete markets, asymmetric information, externalities, or imperfect competition.

Incomplete markets may be the result of rough, thin or non-existent markets. Markets can be qualified as rough when different qualities of a commodity are traded against the same price. This will generally lead to a production of low-quality commodities only. Markets can be qualified as thin when there is very little trade in a commodity. Lack of trade implies lack of information on prices for future trade, hampering market transactions (Black, 1997). Markets may also not be existing at all. This is the most common form of incomplete markets in quantitative models. A common assumption in neoclassical farm-household models, for example, is the absence of a land market. Non-existence or imperfections of markets have important implications for modeling household behavior, since it affects separability of production and consumption decisions.

Perfect markets require complete information, *i.e.* all economic agents know their own preferences and plans, the decisions of all other agents, the technology, and the state of nature (Black, 1997). Given the almost unlimited amount of information needed to attain complete information, decisions are always taken on the basis of incomplete information. It is therefore not the amount of information, but especially the distribution of information that matters for market functioning. If there is **asymmetric information**, some agents have information other agents do not have. This affects price-formation, implying a departure from the ideal of a perfect market.

Externalities occur when the decisions of one agent directly affect utility or profit of another agent (Gravelle and Rees, 1992:517). Important to note is that the effect should be direct and not through prices, which is the standard mechanism through which agents affect each other in markets. Externalities are often associated with the notion of public goods provided by the government. In terms of modeling, however, it is not the provider of the good which matters, but whether consumption is nonrival and nonexcludable. Only if these two characteristics apply, commodities need a different treatment than regular commodities to determine their supply and price. Apart from commodity characteristics, externalities may arise at the consumption side because interdependence of utility functions, *i.e.* households derive utility from the consumption of other households (Ginsburgh and Keyzer, 1997:Chapter 9).

The concept of a competitive market assumes that all agents take prices as given. If one or more of the agents is able to influence prices, **imperfect competition** results. Market prices are then no longer determined by supply and demand, but by the strategic decisions of all agents. This is often modeled through mark-up rules, increasing the price beyond the marginal cost of producing the good (Ginsburgh and Keyzer, 1997:126).

2.2.5 non-market institutions

The importance of markets for household behavior has been mentioned in the discussion of separability. Other institutions besides markets, such as property rights or patron-client relations, for example, may also have a strong impact on the behavior of rural households. Economic models tend to limit a description of the institutional environment to (formal) markets. A major reason for this limited definition of the institutional context in which households operate, is the lack of an operational theory that can be used to describe the role and development of non-market institutions (Lin and Nugent, 1995; Roumasset, 1995). This in contrast to a well-developed theory of the role of markets, that forms the core of standard economic theory. As a result, most authors recognize the importance of institutions other than markets, but then tend to neglect them as soon as formalization of the model starts (Kaimowitz and Angelsen, 1998).

Indicative of the lack of an operational theory of institutions is the lack of a general agreed upon definition of institutions. They vary from very broad statements referring to human interaction in general, to more specific definitions referring to how institutions may affect economic activities. This variety of definitions is due to defining institutions at different **levels**. Institutions may be defined in terms of cultural values governing all types of human interactions[3], in terms of laws and regulations defining the 'rules of the game' in a society[4], or in terms of specific contractual arrangements and transactions[5] (Adelman and Head, 1986). Associated with the level at which institutions are defined is the extend to which they can be changed in the short run. Specific contracts may change from transaction to transaction, laws and regulations need a longer time to be adjusted, while cultural values take even longer to adjust (Williamson, 1998).

In addition to the level at which institutions are defined, two other factors affect the way in which institutions are modeled: institutional goals and institutional structure. Institutions can be characterized by the **goals** for which they are established. Goals may be subdivided in four groups: (1) growth, (2) insurance, (3) distribution and transfer, and (4) enforcement, regulation and control. Most institutions will serve multiple goals or may serve different goals for different participants (Adelman and Head, 1986). This even holds for markets. For example, a regional market for an agricultural commodity may achieve all four goals. For producers the market provides and outlet for surplus production, allowing growth of production and incomes. For consumers the market may reduce the impact of within-region weather differences, if one region produces less another region maybe produces more. The market may thus reduce the risk of food shortages and large price fluctuations. The way in which prices are determined, affects the distribution of income between producers and consumers. Finally, by imposing quality standards on traded produce, like a maximum amount of pesticide residues, the government may enforce food safety regulation. Market and non-market institutions thus serve a mixture of goals, and this mixture may differ among different actors involved in the institution.

Next to their goals, institutions can be characterized by their **structure**. The organization of institutions may be described in terms of five aspects: (1) division of labor, (2) resource allocation, (3) transfer type, (4) entry and exit rules, and (5) interaction with the environment. Tasks may be assigned on the basis of comparative advantage, habit, age, sex or caste. This *division of labor* may be fixed, or there may be mobility, for example on the basis of age, achievements, or personal preferences. To determine the *resource allocation*, first the resources controlled by the institution have to be identified. Allocation of resources can be governed by sharing, voting, on the basis of need, or on the basis of the role of each actor in the institution (Adelman and Head, 1986).

The standard assumption in economics is that the *transfer* of economic goods (goods that are exchanged and to which a price may be attached) occurs as the result of an exchange: assets are

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[3] "Institutions are the social rules, conventions, and other elements of the structural framework of social interaction." (Bardhan, 1991:3)

[4] "Institutions are the rules of the game in a society, or more formally, are the humanly devised constraints that shape human interaction. In consequence they structure incentives in human exchange, whether political, social, or economic." (North, 1995:3)

[5] "Economic institutions include markets and property rights, systems of land and animal tenure, obligations of mutual insurance within lineage groups, and other systems of exchange that are determined by implicit contracts or social norms." (Hoff *et al.*, 1993:1)

rearranged but the net worth of each part remains the same. The standard example is market exchange in which a commodity is exchanged for an amount of money equal to its value. After the exchange, money and commodity have changed owner, but both parties have the same net worth as before the exchange. Two other transfer types, next to exchange, are relevant for the functioning of institutions: malevolence and benevolence. These are distinguished from exchange in that net worth changes because of a rearrangement of assets. Malevolence and benevolence are distinguished from each other in the incentives underlying the transfer. In the case of malevolence this is a threat (physical threat, threat of confiscation of resources, threat of loss of reputation, *etc.*). In the case of benevolence it is concern with the welfare of the receiving party (charity, transfers within families) (Boulding, 1973). Threats can be included in a quantitative economic model, but requires changes to fundamental aspects of economic theory like the definition of market equilibrium (see for a further discussion Keyzer and Wesenbeeck, 2003).

Entry and exit rules are a fourth aspect of institutional structure. Whether or not members can easily join or leave an institution will affect its functioning, and the behavior of its members. Competition between different institutions, for example, may arise if membership is not fixed (through 'voting-by-feet'). With fixed membership different dynamics will occur since institutions do not have to change their policies to attract and keep members (Caplin and Nalebuff, 1997). Assumptions on whether or not institutions may be left can also be found in mainstream economic analyses of imperfect and missing markets. Some models assume fixed membership, for example distinguishing between net buyers, net sellers and self-sufficient households. Other models make this an endogenous decision, allowing households to switch their position in the market based on price-rules.

Interaction with the environment is a fifth aspect of institutional structure. Interactions with the socio-economic environment may occur through rules and regulations on how institutions should function. The bio-physical environment may also affect the structuring of institutions. For example, harsh and volatile environmental conditions promote the development of institutions serving as insurance for survival. In case of a stable and plentiful environment the need for insurance is less pronounced, which may lead to development of different institutions (Binmore, 1998:401-422).

2.3 interaction

Conceptualizing renders a specification of the key elements included in the model. The next step is to specify interactions. Interactions may occur among elements of a single category, for example between different natural resources. Or interactions may occur among different types of key elements, for example between markets and non-market institutions. This section first discusses interactions within key elements, followed by a short discussion of interactions among key elements.

2.3.1 natural resources

Land units can interact through flows of soil and water, transporting nutrients, organic matter, pesticide residues, *etc.* These flows can result in off-site effects that are either negative (*e.g.* siltation of reservoirs and rivers) or positive (*e.g.* increased fertility through downstream sedimentation). The spatial scale can affect the estimated impact of external effects to a large extent. A study of erosion in an agricultural basin, indicates that 92 percent of eroded soil ends up as a sediment in the lower parts of the basin, only 8 percent is actually lost from the basin (Trimble, 1999). Looking at soil loss in the upper part of the basin only, or accounting for the interactions between the lower and upper parts of the basin, thus provides a very different perspective. Such **spatial interactions between land units** can only be accounted for by including spatial dimensions in the model.

Presence of spatial interactions is also relevant for the definition of sustainability because of its strong impact on the restrictions imposed on resource use: the higher the spatial level, the less restrictive the sustainability requirements (van Pelt, 1993). For example, if erosion causes soil nutrient and productivity losses upstream, but, through deposition, improves soil fertility and productivity downstream, the sustainability of land use at watershed level may not be affected.

2.3.2 technology

Interdependencies among different production activities create a second set of biophysical interactions. Interactions occur first of all through competition for constrained inputs, such as land, labor and capital. These are included in all models describing more than one activity. We therefore focus on **complementarities among activities**. These can be bio-physical, as for crop and livestock systems that are linked through the exchange of manure and fodder. Complementarities can also originate from socio-economic circumstances. For example, when access to fertilizer is limited to farmers growing a specific cash crop (*e.g.* cotton in some West-African countries), fertilizer availability for other crops will be linked to cash crop production.

When defining technologies, not only interactions among activities occur. There are also interactions among different inputs for a single activity. Interactions among inputs refer to both substitution (where inputs can compensate for each other) and synergy (where the effect of a particular input depends on the presence of other inputs). **Substitution** can exist between factors of production, a standard concept in economics, but also between external inputs (*e.g.* fertilizer) and soil characteristics (*e.g.* soil nutrient contents). Accurate quantitative specification of the latter type of substitution is important for assessing the sustainability of the system in terms of soil quality. If soil fertility (defined in physical and chemical characteristics) can at all times be restored through the use of external inputs, there is no risk of technically impairing the production possibilities of future generations. However, thresholds may exist, below which the decline in soil quality becomes irreversible (Erenstein, 1999). This limits the scope for restoring soil fertility through external inputs and increases the need for more judicious behavior.

Complex interactions exist between the physical, chemical and biological characteristics of the soil, complicating the definition of soil quality (Jaenicke and Lengnick, 1999), and thus the quantification of sustainability of land use. In addition, this complexity affects the specification of the input-output relations. For example, the response of crops to chemical fertilizer applications is positively related to the soil organic matter content (and hence to the use of animal manure and/or crop residues). Capturing the **synergy** among inputs implies abandoning the continuous concave production functions (as commonly used in economic models) in favor of *e.g.* discrete input-output coefficients (Kruseman and van Keulen, 2000). This, however, yields problems with scale and factor substitutions that both play a prominent role in economic analyses of land use (Ruben *et al.*, 1998).

As synergistic interactions between inputs create problems in linking biophysical and economic models, some important aspects of the production process have to be sacrificed at either the economic or the at biophysical side of the model.

2.3.3 household

When translating the concept of utility to a quantifiable concept, generally a number of components rendering utility will be identified. These components may interact with each other. Striving for a high cash income, for example, may involve high risks, thus requiring balancing of income maximization and risk objectives. To quantify the behavior of the household as a whole, some kind of **weighing of components** is necessary. Different approaches are available for eliciting utility functions, through construction of hypothetical situations, or by using observed behavior (Amador *et al.*, 1998).

Another issue when modeling the household are **intra-household interactions**. The standard approach in farm household modeling it to treat the household as a single decision-making unit. In reality the household will generally consist of a number of individuals that differ in preferences, but possibly also in control over household resources. An example are differences in control over land and labor according to age, gender and marital status (see for example Thorsen, 2002). Pursuit of individual interests with different access to resources will generally not be represented well by a treating the household as a single unit. A unitary approach to modeling household behavior requires strict assumptions on the utility functions of the constituent household members, such that aggregate demand of the household is not affected by the distribution of utility among different members (Bardhan and Udry, 1999). Collective household models deal explicitly with intra-household interactions, using cooperative or non-cooperative game-theory. Although empirical evidence indicates that the unitary household model could lead to different policy predictions than the collective model (Alderman *et al.*, 1995), the unitary model is not consistently rejected by existing empirical studies (Schultz, 2001).

Next to interactions within a single household, households also interact with each other. These interactions take place through markets and through non-market institutions.

2.3.4 markets

Interaction between markets is a core aspect of mainstream economics. Based on the extend of the coverage of the markets of an economy **partial or general equilibrium** approaches can be distinguished. A partial equilibrium approach focuses on a single market or on a very limited number of markets. Links with other markets in the economy (through consumption or demand for intermediary products) are assumed to be negligible for the outcome. The studied part of the economy is thus treated as a closed system, changes of which do not affect the remainder of the economy. General equilibrium approaches cover all markets in an economy. The most important difference with partial equilibrium models, however, is the inclusion of income and expenditure links in general equilibrium models, thus providing a complete description of the economy.

2.3.5 non-market institutions

Non-market institutions may also interact with each other. Non-market institutions are not frequently included in quantitative models, modeling of interactions among these institutions is even less frequent. An example of **interdependencies among institutions** is described in Alderman *et al.* (1995). They describe how better access to common resources changes the non-cooperative threat-point used in intra-household negotiations on distributing income and may cause a more equal distribution of income within the household. The effect of this interaction on income depends on the way in which the common property regime is changed, and the way in which intra-household allocations are negotiated.

2.3.6 interactions among key elements

Next to interactions within key elements, described above, interactions among key elements may occur as well. Given the focus on household behavior of this chapter, the household will interact with all other elements included in the model. Interaction between technology and the socio-economic environment has already been addressed in the definition of key elements and when discussing complementarities between activities. Interactions between natural resources and institutions were hinted at when discussing the structure of institutions. Harsh and volatile environmental conditions may promote different institutional developments compared to stable and plentiful environments (see also Diamond, 1998 for an extensive theory on this link). Geographical characteristics of natural resources may also affect market functioning, *e.g.* transport costs could be higher in mountain areas.

Markets and non-market institutions interact as well. An example is linking of markets. Credit market failure[6] may give rise to a contract in which the household obtains credit in kind as fertilizer (that the household could otherwise not afford), in exchange for selling (part of) the output to the fertilizer supplier. A credit market failure then gives rise to an institutional arrangement affecting the output market.

Interactions among elements will affect the shape of the elements. In the example above (part of) the output will always be sold to the fertilizer supplied, thus affecting household output supply decisions. Interactions will thus be implicitly included in a model through the way in which the key elements are conceptualized. Most interactions among key elements will not change during the analysis, for example, geographical influences on market functioning tend to be fixed. If there are changes, these are generally modeled as exogenous changes in the key elements.

2.4 aggregation

Modeling involves development of a simplified representation of reality. This process of simplification requires aggregation over individual units (for example, individual plots, crop types or

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[6] A market fails when an economic actor willing to pay the going market price for a commodity is unable to participate in the market. In the case of a credit market failure a household would thus be willing to borrow at the going interest rate but is still unable to obtain credit.

households) to aggregate units (for example, total land endowment, a limited number representative crop and household types). Moving from individual units to an aggregate representation generates problems in (1) maintaining the assumption of exogeneity for some critical variables, (2) incorporating the diversity of smaller units, and (3) dealing with non-linearities. Although these problems translate to specific issues for each key element, analytically they pose similar problems. Therefore we first provide an explanation of these three aggregation problems, after which implications for each key element are discussed.

First, variables that are exogenous at one level can become endogenous when moving to a higher level of analysis. Prices are an obvious example: economic agents take prices as given, *i.e.* for them prices are exogenous, while for the market as a whole prices are endogenous. Moving to a higher level of analysis may thus require specification of how previously exogenous variables are determined endogenously.

Second, diversity of smaller units will result in different responses to changes in exogenous parameters. A classic example is the Chayanov farm household model, in which differences in demographic structures of households determine production decisions (Ellis, 1988). The issue of different response due to different characteristics can partially be solved by constructing representative units. One then classifies units on the basis of characteristics that are crucial for the response of each unit (which depends on the research question of interest), and assumes all units within a class to behave identical to a single representative unit for each class. One practical problem with the construction of a representative unit is that units need to be classified in groups based on similar responses to exogenous changes. This classification, however, has to take place at the start of the modeling exercise when the response of the units is not yet known. If it would be known the modeling would not be needed (Hazell and Norton, 1986:148). Furthermore, the characteristics used for classification should be stable over the range of analyzed changes. Otherwise units would change class when parameters change, and classification becomes pointless.

Third, non-linear relationships cause an aggregation problem that is not solved by constructing representative units. When a concave relationship exists between a change in a decision variable and the response of the micro-unit, using that concave specification for the representative unit will result in an overestimation. The reverse holds in case of a convex relation. When the specification of the functional relationship at the micro-level and the distribution of the explanatory variable(s) over the micro-units, are both (approximately) known, this type of aggregation bias can be corrected at the aggregate level (see Heerink, 1994; Heerink and Folmer, 1994)[7]. A graphical illustration of the overestimation of productivity by using average soil quality can be found in Antle and Stoorvogel (2000). In this example productivity can be related to land quality through a concave function. By Jensen's inequality, using the productivity of the average land quality as representative of the whole distribution of land quality overestimates land productivity. If both land quality – productivity relationship and the distribution of land quality are known, the productivity based on the average land quality can be corrected for the aggregation bias.

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[7] For convex relationships, the aggregation bias is in fact a measure of the degree of inequality in the distribution of the explanatory variable over the relevant population. The shape of the micro-relationship determines the exact specification of the inequality measure that is needed to correct for the aggregation bias.

2.4.1 natural resources

All three aggregation issues play a role for natural resources. First, initially exogenous **variables may become endogenous** at higher levels of analysis. Incidence of pests and diseases are an agronomic example. At the regional level the cropping pattern can affect population dynamics of pests and diseases, making their impact an endogenous factor (Bouman *et al.*, 2000). Another example are the off-site effects of erosion. At plot level analysis of erosion may be limited to lost top-soil, at watershed level sedimentation needs to be accounted for. Second, **natural resources are heterogeneous**. Crop responses to fertilizer or manure applications may vary considerably among plots, for example, depending on soil type and quality, water availability, and other land characteristics. Third, relations between natural resource characteristics and productivity are often **non-linear**, as the example above of the concave land quality – productivity relationship in Antle and Stoorvogel (2000) illustrates.

2.4.2 technology

For technology endogeneity of variables and heterogeneity play a role. First, **economies of scale** implies that variables are endogenous at higher levels of analysis. In case of constant returns to scale an identical input-output relation holds at all levels of analysis. With increasing or decreasing returns to scale input and output relations depend on the level (*e.g.* plot or farm) at which production is analyzed. Second, technologies may refer to a **specific activity or a composite output**. Different varieties of the same crop may respond differently to input. Hybrid rice, for example, is generally more responsive to chemical fertilizers. The level at which technologies are defined may introduce an aggregation bias, technologies could be defined for each variety (*e.g.* distinguishing hybrid and non-hybrid rice) or for a crop (*e.g.* rice). In some models, especially econometric ones, technologies aggregate over different crops, resulting in a production function for 'agricultural output'.

2.4.3 household

For households heterogeneity and nonlinearity play a role. First, **heterogeneity among households** in terms of endowments of land and labor, production system, skills, education and age, and so on, will all affect the way they respond to changes in their environment. Second, household response to changes in their environment will generally be **nonlinear**. Thus when introducing a representative household, an aggregation bias may be introduced at the same time.

2.4.4 markets

For markets two issues related to endogeneity play a role. First, **endogenous prices** at higher levels of analysis, which is one of the most commonly treated aggregation problems in the economic literature. Changes in demand and supply of a single household can be assumed not to affect market prices, these may thus be taken as exogenous for the household. When moving to higher levels of analysis, changes in demand and supply of groups of households may become significant, and prices can no longer be assumed exogenous. The extent to which prices can be taken as exogenous depends on the size of the market, which is affected by the second aggregation issue for markets: **tradability**.

Commodities can be classified as nontradable and tradable, based on their characteristics and the level of analysis. For example, services may be traded inside a country, but not between countries since that would involve (temporary) migration. Services would then be tradable at country level, but nontradable at higher levels of analysis. Nontradability as defined here is a fixed characteristic of a commodity, depending on the level of analysis and type of commodity. Tradable goods may be traded or not, depending on the circumstances. The difference between nontraded and nontradable commodities is that nontraded goods could be traded if circumstances change, while nontradable commodities are never traded (Kuyvenhoven, 1978). The difference between household chores and subsistence crops can be used to illustrate this difference. Household chores (cooking, cleaning, child care) are generally a nontradable service (although part may be substituted by hired services). Food crops cultivated only for household consumption are a nontraded commodity. If circumstances change a surplus can be produced that is sold on the market and the crop becomes a traded commodity. In both circumstances, however, the food crop is a tradable commodity. The household services are nontradable, whatever large changes in the circumstances; these services are only produced for the household itself.

Tradability depends on the level of analysis. Commodities that are traded at a low level of analysis may not be traded at higher levels. Land, for example, may be traded between households within a village but not with the outside world, due to its immobility. At household level land would then be a tradable (depending on its circumstances households may or may not rent land), while at village level it is a nontradable (whatever change in circumstances, land will not be rented outside the village). At higher the levels of analysis more commodities will be nontradable or nontraded.

The distinction between tradables and nontradables is important from a modeling perspective since relevant prices will differ for the different categories of commodities. This point will be taken up in more detail in later chapters when discussing the impact of nonseparability on developing a village model. The distinction between tradables and nontradables also has policy relevance. Tradables can provide an engine for growth. By linking local communities into larger system production can expand beyond local demand, accelerating growth.

2.4.5 non-market institutions

For non-market institutions a major aggregation issue is whether **institutions emerge from human behavior or are an entity** themselves. Institutions may be analyzed on the basis of individual behavior, the approach taken in methodological individualism. Analysis of institutions is then based on the rationality of the individuals participating in it (Bardhan and Udry, 1999:5-6). Another approach is to treat institutions as entities themselves, without referring to the individuals composing them. This approach is used in evolutionary approaches of the development of institutions (Adelman and Head, 1986). It should be noted that, although institutions may be taken as given entities in the short term, all institutions are ultimately devised by humans and thus emerge from human behavior.

2.5 dynamics

In the preceding section we have dealt with aggregation over different units at the same point in time. In this section we shift our attention to aggregating over different time periods, which we consider a last key issue in modeling household behavior and its context.

2.5.1 natural resources

A main reason for including a more elaborate specification of natural resources in a model of rural household decisions is to analyze **sustainability,** which relates to assessing the impact of human decisions on natural resources. An often cited definition of sustainable development is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987:43). Being related to balancing the needs of current and future generations, sustainability thus deals with the dynamics of natural resources. This temporal component in the definition of sustainability creates a number of controversies, due to uncertainty with respect to the needs of future generations, and their capacity to meet these, taking into account the possibilities of technological innovations (van Pelt, 1993).

The definition of sustainability given above is cited often since it leaves sufficient room for completely opposite views on the impact of human action on natural resources. Controversies regarding sustainability start when it has to be made operational. Gerlagh (1999) presents a useful typology of different perspectives on sustainability derived from Schwarz and Thompson (1990). Different views on the stability of the economic system are key to different views on sustainability, *i.e.* to what extent current actions compromise future generations. Figure 2.2 summarizes four different perspectives on environmental dynamics. The two perspectives in the top part of the figure reflect opposite views on the impact of perturbations on the environmental system. The 'nature ephemeral' perspective considers the system to be unstable, a small perturbation will lead to a destruction of the system. The 'nature benign' perspective takes the opposite perspective, considering the system to be stable and thus able to withstand perturbations. The lower part of the figure depicts two intermediate positions. The 'nature capricious' perspective considers the system to be chaotic, moving in different directions with even minor perturbations. Finally, the 'nature tolerant' perspective considers the environment as locally stable, thus able to deal with small but not with large perturbations.

In the context of including natural resources in a model of rural household decisions, the first two perspectives do not result in a meaningful economic analysis. If even small perturbations lead to degradation, any use of the natural resource has to be avoided. In case of modeling of agricultural activities of rural households this would imply direct abandonment of agriculture to minimize disturbance of the environmental system. Apart from being an unrealistic policy option, this position seems overly restrictive given the capacity of environmental systems to deal with disturbances. The contrasting view, that environmental systems are stable, seems overly optimistic in ignoring irreversiblilities of natural processes (Gerlagh, 1999).

This leaves the two perspectives in the lower part of Figure 2.2 as meaningful but rather different perspectives on sustainability. In case the environmental system is seen as unpredictable, rural household decisions would not determine sustainability of the environmental system. Economic analysis would then focus on ways in which rural households adapt to an erratic environment, *i.e.* shift from sustainability of natural resource use to sustainability of rural households in an unpredictable environment.

Figure 2.2: Four perspectives on environmental dynamics

Nature ephemeral → minimize disturbance

Nature benign → laissez faire

Nature capricious → adaptation

Nature tolerant → development paths

Source: adapted from Gerlagh (1999:9-10)

In the context of analyzing sustainability of rural household decisions, only the last perspective on sustainability thus results in a meaningful economic analysis. This would imply searching for development paths that utilize natural resources without threatening their future flow of services, *i.e.* accounting for the presence of thresholds beyond which damage becomes irreversible. In terms of an economic model, such a sustainable development path may be made operational as a steady state, *i.e.* a model solution in which variables related to natural resources do not change over time (see for a further discussion Gerlagh, 1999).

Arriving at a steady state requires accounting for the impact of current decisions on future decisions. Whether households account for this future impact depends on the visibility of degraded natural resources and whether it affects households' production possibilities. Most soil degradation processes are slow and therefore not visible in the short-run when households take decisions. Households can therefore be expected not change their production practices until resource depletion visibly affects their production. And even if the effects of resource depletion are visible households may not take countervailing measures if these require large investments in the short run, while yielding benefits only in the long run. Poverty, for example, may result in high time preferences that yield investment in soil conservation unprofitable (Holden *et al.*, 1998). Unsustainable production practices may also result in visible but off-site effects, like sedimentation of water reservoirs or downstream water pollution. In this case the households do not have an incentive in incurring costs of changing their production practices, unless they would receive compensation for doing so.

2.5.2 technology

Changes in the production environment (both biophysical and socio-economic) can induce technological innovations. Technological change can be modeled as **exogenous or endogenous**. If technological change is modeled as exogenous, productivity of factors is changed with a fixed rate, or alternative technological options are added to the model. Linking technological change to investment is a one way of making technological change endogenous, often used in macro-level growth models (Barro and Sala-i-Martin, 1995). The induced innovation model building on the work by Hayami and Ruttan (1985) offers a more elaborate theory of technological change. In this model changes in factor supplies, product demand and institutional change drive technological change, while technological change in combination with factor supplies and product demand drive institutional change (Koppel, 1995).

2.5.3 household

Two issues of dynamics play a role when modeling the household: household composition and inter-generational welfare distribution. **Household composition** is not stable over time, but changes due to natural processes (deaths, births, aging of household members), and due to permanent or temporary migration of household members. Changes in household composition affect the production side (available labor force) as well as the consumption side (number of consumers in the household).

In case of a time-horizon of more than one period, costs and benefits occurring at different points in time need to be compared. Through **discounting** income flows over time can be made comparable. The issue is to select a discount rate reflecting the interest of both current and future generations. This total discount rate can be divided in two parts. One part accounts for the expected increase in future consumption, for example due to productivity-increasing technological change. The second part is the relative weight attached to future generations' welfare. In economic literature, this distinction between consumption and well-being components of the discount rate is often not made explicit. If an increase in consumption is expected, applying a positive consumption discount rate only serves to partition this welfare gain (possibly generated through investments in technology development by earlier generations) equally between generations. This rate for distributing consumption gains among generations can be positive, even if the well-being discount rate is zero, *i.e.* if welfare of different generations receives equal weight. A measure of the welfare of future generations (such as average welfare over all generations) may be added to the sum of total discounted welfare, to do justice to the interests of both current and future generations (Chichilnisky, 1997; Dasgupta and Mäler, 1995).

2.5.4 markets

The functioning of markets may change in response to changes in other variables in the model. For example, an investment in infrastructure may reduce transaction costs, offering households access to markets previously not available to them. Depending on whether **market participation is exogenous or endogenous**, use of markets by households is exogenously fixed or endogenously determined in the model. This is related to the issue of tradability discussed with aggregation. In the case of market participation, however, the issue refers to a single level of aggregation and only refers to tradable commodities, since nontradables cannot be traded even if circumstances change. An example of an endogenous market is the price-band approach to modeling household tradables (de Janvry *et al.*, 1991). Tradable commodities with a price-band may be traded or non-traded, depending on the location of the shadow price relative to effective market prices[8].

2.5.5 non-market institutions

Depending on the theoretical approach taken in the analysis, changes in non-market institutions can be modeled in terms of **cost-benefit, conflict or evolution**. The neoclassical approach to institutional development focuses on costs and benefits of institutional arrangements. If benefits exceed the costs, the institution will exist and be efficient for society at large. Some qualifications of this argument can be made. There may be free-rider problems and lobbying by interest groups, preventing second-best solutions from the perspective of society. The most well-known stream of literature concerning institutions in developing countries, the transaction cost approach, also uses a neoclassical starting point. Institutional arrangements like sharecropping or inter-linked markets are explained in terms of overcoming transaction costs resulting from imperfect information and incomplete markets. In this approach changes in the costs and benefits of institutions foster institutional change.

The political-economy approach to institutional development focuses on conflicts. If institutional relations create a large gap between actual and potential production, potential benefits from change are large and class struggle will occur. The resulting change will not be a smooth process, but a jump to a new institutional arrangement. Conflicts, and not a cost-benefit comparison, determine institutional arrangements and changes.

The evolutionary approach to institutional development assumes that activities take place on basis of routines. Changes occur in the long run by development of new routines, on which a selection mechanism operates. In contrast to the maximization behavior assumed in neoclassical models, evolutionary models assume habit-driven behavior. Furthermore, they have a much longer time-horizon than commonly used in neoclassical analyses.

Whether or not changes in non-market institutions need to be accounted for in the model depends on the way in which institutions are defined. Cultural values change only slowly and thus generally will not change in the period covered by the modeling exercise. Laws and regulations are more changeable, and changes may need to be accounted for. Finally, contracts and specific transactions may change in the short run (Williamson, 1998).

2.6 a matrix of key elements and key issues

The key elements and key issues can be represented in a matrix describing fundamental choices that need to be made in developing a quantitative model with rural household behavior. Table 2.2 provides an overview of the key issues for every element in the model. Interactions among different

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[8] Chapter 3 discusses details of the price-band model and its implications for tradable commodities.

key elements are not explicitly included in Table 2.2. As discussed in Section 2.4.6 these will implicitly be accounted for by the conceptualization of key elements, or changed in an exogenous fashion by changing key elements in the model.

Table 2.2: A matrix of key choices in modeling rural household behavior

Key issues: / **Key elements:**	*Conceptualization*	*Interaction*	*Aggregation*	*Dynamics*
Natural resources	▪ resources affecting or affected by rural household decisions	▪ spatial interactions	▪ variables turning endogenous ▪ heterogeneous resources ▪ nonlinear relations	▪ sustainability
Technology	▪ production set	▪ complementarities among activities ▪ substitution among inputs ▪ synergy among inputs	▪ economies of scale ▪ activity specific or composite output	▪ exogenous or endogenous technological change
Household	▪ objectives ▪ separability ▪ risk	▪ weighing components ▪ intra-household interactions	▪ heterogeneous households ▪ nonlinear responses	▪ household composition ▪ discounting
Markets	▪ market structure (incomplete markets, incomplete information, externalities, imperfect competition)	▪ partial versus general equilibrium	▪ endogenous prices ▪ tradability	▪ fixed or endogenous market participation
Non-market institutions	▪ level ▪ goals ▪ structure	▪ inter-dependencies between institutions	▪ emerging from individuals or institution as entity	▪ cost-benefit, conflict or evolution as source of change

The matrix of modeling choices can serve as a point of reference for comparing model approaches, mapping differences between specific models, identifying the contribution of individual models to the literature, and identifying gaps in the current literature on rural household behavior.

Choices made on each of the issues in Table 2.2 affect the model outcomes. These choices are partly driven by the selected model approach. This point will be taken up in the next chapter, comparing household and equilibrium models on the basis of this matrix. Different choices can also be made within the same modeling approach. This point will appear in the modeling chapters of this study. Differences between the models developed in this study can be traced to different assumptions on key issues identified in Table 2.2.

CHAPTER 3

comparing approaches to modeling rural household behavior

The previous chapter identified key issues one encounters when developing a quantitative model for understanding rural household behavior. In addition to key choices regarding conceptualization, interaction, aggregation and dynamics, a modeling approach has to be chosen. A theoretical model can be transformed into an applied model using different approaches. An applied rural household model, for example, can be written in reduced-form, as a system of equations, or as an optimization model. Although stemming from the same theoretical household model, these applied models differ both in mathematical structure and in data requirements. The chosen modeling approach affects the way in which the key issues are dealt with, a point taken up at the end of this chapter when comparing modeling approaches.

The first aim of this chapter is to identify opportunities and limitations of different approaches to modeling rural household behavior. Two groups of modeling approaches are discussed: rural household models and village or sub-regional models. As in the previous chapter, the scope of this chapter is limited to modeling approaches that explicitly account for (interdependent) household production and consumption decisions. Since rural households are taken as the basic unit of analysis in this study, household models are discussed first. The second set of modeling approaches consists of village and sub-regional models. These are micro-level approaches in which household models are embedded, allowing an analysis of interactions among households. Modeling approaches at more aggregated levels are not discussed. Most of these models separate production from consumption decisions, *i.e.* separately model firms and consumers, which is beyond the scope of this chapter. In case interdependent household production and consumption would be covered their analytical structure would be similar to the village and sub-regional approaches discussed in this chapter.

The second aim of this chapter is to place the village equilibrium model developed in later chapters into the context of the existing literature. The discussion of the different modeling approaches allows an identification of the theoretical origins of the village equilibrium model developed in later chapters, as well as identifying ways in which it contributes to the existing literature. This point will be taken up again in the concluding chapter of this study, where the contributions of the modeling work will be identified in more detail.

The third aim of this chapter is to provide basic assumptions and model elements that are used in subsequent chapters. For example, nonseparability is discussed in detail when discussing household models, being an important aspect of the village model developed in this study.

The final aim of this chapter is to present the structure of the village equilibrium model as developed in this study and placing it in the perspective of the existing literature. This model structure also determines the structure of the Chinese village SAM developed in Chapter 4.

The first section presents main features of theoretical rural household models. This theoretical framework forms the starting point of different approaches to applied household models discussed in Section 2, as well as the core of the village and sub-regional models discussed in Section 3. Section 4 identifies opportunities and limitations of the different modeling approaches, against the backdrop of the matrix of key issues developed in Chapter 2. Section 5 presents the structure of the village equilibrium model and provides a first identification of this study's contribution to the existing literature.

3.1 rural household theory

Agricultural household models provide a flexible framework for modeling production, consumption and labor supply decisions of households. Barnum and Squire (1979) developed the neoclassical household model, which has its roots in Chayanov's work on the impact of demographics on household response in the 1920s (Sadoulet and de Janvry, 1995:141). The agricultural household model as outlined in Singh *et al.* (1986a), is the starting point for most current microeconomic studies of the agricultural sector in developing countries. After an initial development of household models for analyzing price policies, applications extended to diverse topics like off-farm labor, migration, nutrition and health, savings, credit constraints, and environmental issues (Taylor and Adelman, 2003).

We start with looking at the interrelations between production and consumption decisions. A typical characteristic of many rural households in developing countries is the integration of decisions that are separately analyzed in economic models of industrial countries: consumption, production and labor supply decisions. Rural households buy inputs and sell products. They also take decisions on consumption of food and other commodities. Finally, they decide on the allocation of labor between work (on and off- farm) and leisure. In many developing countries decisions on production, consumption and labor supply cannot be separated from each other due to market imperfections. The predicted response of the household then becomes complex and may counteract results obtained from a separate analysis of the three types of decisions (Singh *et al.*, 1986a).

Next we investigate a prime cause for nonseparable household decisions in developing countries: price-bands between buying and selling prices. Price-bands and the resulting different response of net buying, net selling and autarkic households play an important role in applied household models for developing countries.

3.1.1 nonseparability of household production and consumption decisions

In the most general terms an agricultural household model can be described as a constrained maximization of a discounted stream of expected utility derived from household-produced goods, purchased goods and endowments. Including household produced goods in the utility function provides a link between production and consumption decisions, while specifying a time endowment to be allocated between production and consumption (leisure) incorporates labor supply decisions. Analytical tractability, data limitations, and research interests generally result in a simplified static objective function, without accounting for risk. Constraints are commonly reduced to a production function, a household family time endowment, a cash constraint, a fixed amount of land, and fixed prices for traded commodities. The resulting model is then solved for output supply, input demand, consumption demand, marketed surplus of traded commodities, and prices for nontraded and nontradable commodities (Taylor and Adelman, 2003).

The hallmark of agricultural household models is an interrelation between consumption and production decisions. This relation can either be recursive (consumption decisions can be solved after solving the production decisions), or simultaneous (consumption decisions affect production decisions and need to be solved simultaneously). Irrespective of whether decisions are recursive or simultaneous, standard results from production theory (marginal rate of technical substitution equals the input price ratio) and consumption theory (marginal rate of substitution equals the product price ratio) hold and may be used in deriving the solution of the household model.

The difference between a recursive or a simultaneous relation between production and consumption decisions is endogeneity of prices. With simultaneous decisions, consumption decisions affect the prices used in production decisions and thus need to be accounted for when making production decisions. With a recursive relation, consumption does not affect prices at the production side and the consumption decisions can be derived after solving the production side of the household. Figure 3.1 outlines the links between production, consumption and labor supply decisions of a rural household.

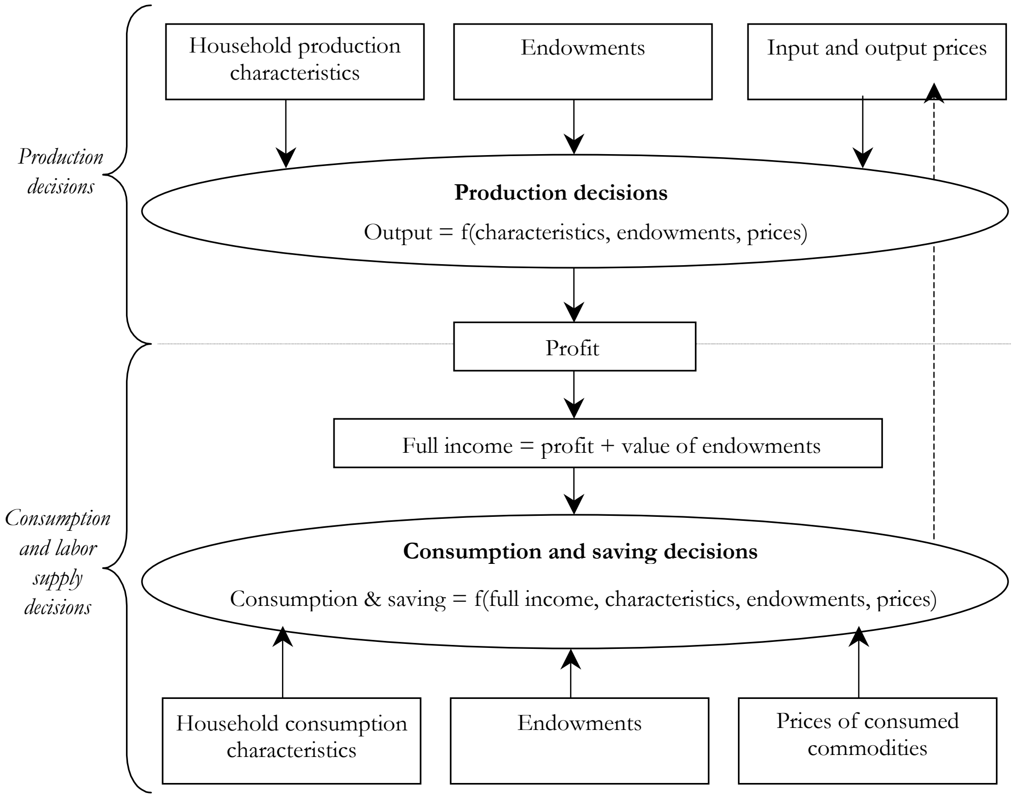
The upper part of Figure 3.1 depicts production decisions. The household produces output that maximizes profit, depending on household production characteristics, endowments, and prices of inputs and outputs. The profit from the production side (which may include off-farm income) provides the link with the consumption side of the household. This profit together with the value of the household endowments provides the full income which is available for consumption.

The household then selects a consumption pattern that maximizes utility subject to the full income constraint, household characteristics in consumption, endowments and prices. This determines both consumption and labor supply decisions, since consumption includes a decision on the allocation of available family time between leisure and production.

A crucial point is whether consumption decisions affect production decisions. If consumption decisions affects the prices of inputs or outputs used in production (indicated by the dashed arrow in Figure 3.1) the model can no longer be solved recursively. Profit then determines consumption, while at the same time being affected by consumption decisions. Production and consumption then have to be dealt with simultaneously: the model becomes nonseparable.

To illustrate a number of points regarding household models a simple model is postulated. The household is assumed to maximize utility derived from the consumption of an agricultural commodity C_a (*e.g.* a food crop produced by the household) and leisure C_l. The household faces a production technology producing the food crop (Q_a) with family labor (L_f), hired labor (L_h), and a fixed input ($\overline{q}$). The household may also work off-farm (*L_o*), but total labor use cannot exceed the family time-endowment ($\overline{T}$). The cash constraint provides a third constraint on utility maximization; goods can only be bought if money is earned. In this simple model without savings and transfers this constraint translates to requiring the inflow of money to equal to the outflow.

Figure 3.1: Relations between production, consumption and labor supply decisions of a rural household



This very basic household model can mathematically be described as:

$$\max_{C_a, C_l, L_f, L_h} u(C_a, C_l) \qquad \text{utility function} \qquad (3.1)$$

subject to,

$$Q_a = f(L_f, L_h, \overline{q}) \qquad \text{production function} \qquad (3.2a)$$

$$L_f + L_o + C_l = \overline{T} \qquad \text{time constraint} \qquad (3.2b)$$

$$pQ_a + wL_o = pC_a + wL_h \qquad \text{cash constraint} \qquad (3.2c)$$

where, in addition to the variables defined before, p denotes the price of the food crop and w the wage rate. The three constraints may be collapsed into a single full income constraint, by substituting the production function and time constraint in the cash constraint, and rearranging:

$$p[f(L_f, L_h, \overline{q}) - C_a] = w[L_h - (\overline{T} - L_f - C_l)] \qquad \text{full income constraint} \qquad (3.2)$$

Maximization of the utility function (3.1) subject to the full income constraint (3.2) yields input demand, output supply and consumption decisions of the household.

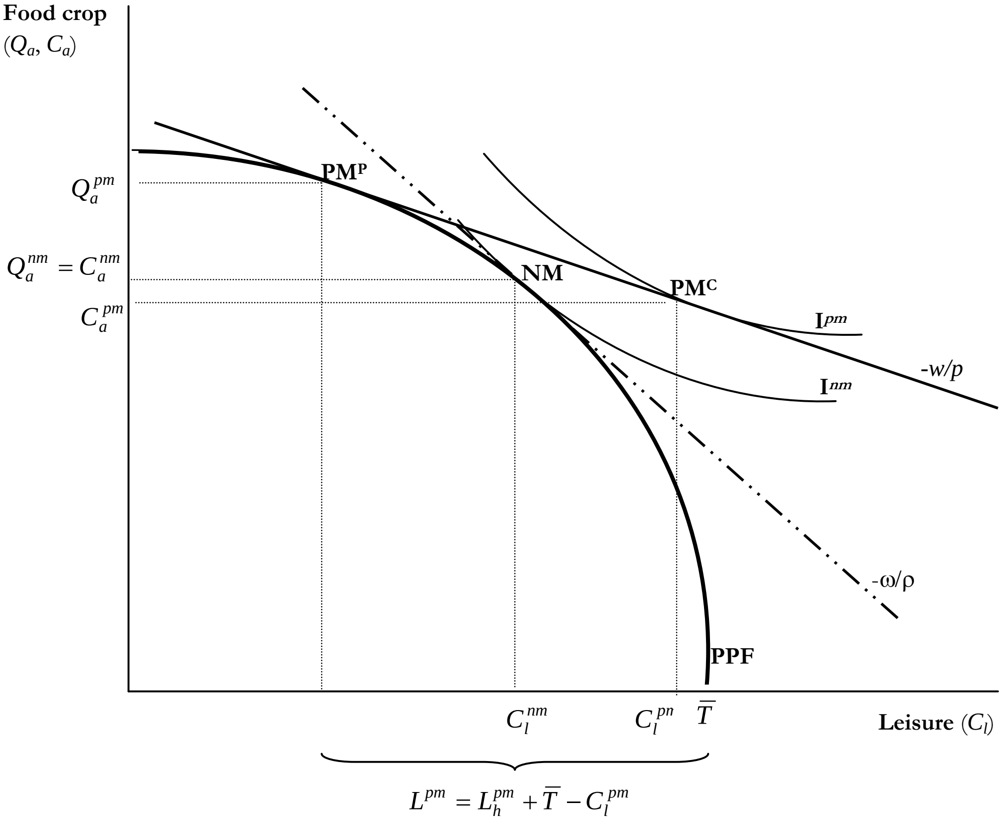
In the mathematical description the interaction between production and consumption decisions is not immediately obvious. Due to its simplicity the model can also be solved graphically, which does allow a direct view on (non-)separability of household decisions (Taylor and Adelman, 2003). The mathematical description assumes perfect markets for food and labor, which can be purchased and sold at fixed prices p and w. No distinction is made between own produced and purchased food, nor between family and hired labor. Due to the fixed prices, production and consumption decisions can be separated, as is illustrated in Figure 3.2.

The household faces a trade-off between producing food crop and leisure, depicted by the production possibility frontier (PPF). The optimal production level with perfect markets (PM^P) is at the point where the slope of the PPF equals the price-ratio between labor and food. Optimal consumption with perfect markets (PM^C) is at the point where the marginal rate of substitution equals the price ratio. These are standard micro-economic results from producer and consumer theory, reflecting the neoclassical nature of the model. The graphical representation illustrates that first the production problem is solved (moving the line representing the price-ratio until it just touches the PPF), after which the solution to the consumption problem is found (finding the highest indifference curve (I) still touching the relative price line).

The opposite extreme from perfect markets is an absence of all markets. In this case prices are no longer given, but determined by the interplay of production and consumption decisions. In terms of Figure 3.2 this implies finding the point (NM) where the indifference curve I^{nm} touches upon the PPF. In this point the household consumes all the output it produces, and the amount of labor it uses equals the time-constraint minus leisure. In this case the prices of food and labor are no longer exogenous. Instead they are endogenous shadow prices (ω and ρ) that cannot be observed in the absence of trade with the outside world. The graphical representation illustrates the nonseparability: the optimal point is now found by simultaneously dealing with consumption decisions represented by the indifference curve and production decisions represented by the production possibility frontier.

This basic household model and its graphical solution illustrate a number of points that are essential to rural household modeling. First, standard economic rules for production and consumption remain valid. Differences with a separate analysis of production and consumption decisions occur because of endogenous prices, not because of different behavior by the household. This result implies that standard approaches to modeling production and consumption decisions may be also followed. Although the analytical framework remains the same, endogenous household prices complicate the development of an applied model. The household shadow prices are an analytical construct and thus cannot be directly observed. This complicates the estimation of demand and supply functions for nonseparable household models.

Figure 3.2: Household production and consumption decisions with perfect markets (pm) and no markets (nm) for food and labor



Source: adapted from Taylor and Adelman (2003)

Second, with perfect markets production and consumption decisions are separable. Presence of perfect markets is a sufficient, but not a necessary condition for separability of household decisions. As long as consumption decisions do not affect production decisions the model may be solved recursively. For example, if there are missing markets for a number of consumption goods that are not produced by the household, decisions remain separable. Similarly, if there are missing markets for a number of production inputs that are not consumed, decisions remain separable as well. Thus, to determine whether market imperfections cause nonseparability of household decisions, the role of the affected commodities at the production and consumption side of the household needs to be examined.

Third, a common implicit assumption in neoclassical household models is a missing land market, *i.e.* the fixed input $\overline{q}$ in the production function (3.2a). This missing land market generates decreasing returns to labor, generating the concave shape of the PPF. It also generates a nonseparable model when one additional market is assumed missing, for example a labor market.

According to Walras' law, equilibrium in N -1 markets implies an equilibrium in the N^th^ market. In terms of the household model this implies that if there is only one missing market, the equilibrium in this market will be fully determined by the other markets and will therefore not differ from a situation of perfect markets. Only when there are at least two missing markets, prices may become endogenous possibly creating nonseparability (again, depending on the role the commodities play at the production and consumption side of the household). When one missing market is explicitly introduced, after which the nonseparability of household decisions is analyzed, a missing land market is implicitly assumed (see for example Sadoulet *et al.*, 1998).

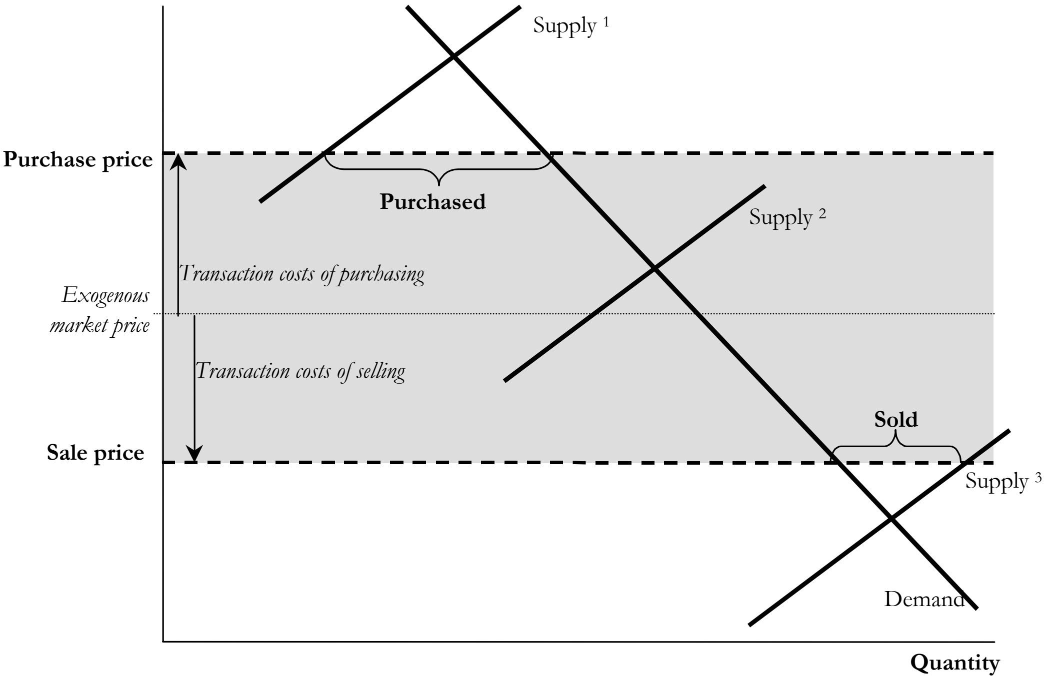
Fourth, household models tend to generate ambiguous result and easily become analytically intractable. Ambiguous results may already occur with perfect markets. In the graphical example given above, assume that prices for food increase The price-ratio line will flatten and the point of tangency to the PPF will be at a higher level of food production. The increase in production and prices increases income of the household. The household will be able to shift to a higher indifference curve and increases its food consumption. The increase in food consumption may outweigh the increase in food production, depending on the preferences of the household. The food price increase then does not lead to an unequivocal increase in marketed surplus. If an analytical solution of the household model can be derived, it will generally be difficult to sign because of counteracting effects on the production and consumption sides of the household. In models with multiple missing markets interdependencies between variables will prevent derivation of an analytical solution. Problems in deriving an analytical solution and ambiguous results of analytical solutions, if they can be derived, are important reasons for the development of quantitative household models.

Fifth, accounting for different levels of market integration of households has clear policy relevance. As the graphical solution in Figure 3.2 illustrates, integration in markets increases the welfare of the household. Apart from the welfare implications for the household, interaction between producer and consumer decisions may result in unexpected results. For example, if the objective of a food price policy is to increase the marketed surplus, limited market integration of households may yield adverse results. Household models help in understanding counterintuitive response to policy changes, as well as identifying possible complementary policies that promote the desired response.

3.1.2 price bands as a source of nonseparability

Nonseparability of household production and consumption decisions occurs when the effective price of a commodity used both in production and consumption is not exogenous to the household, but is determined endogenously by household demand and supply. In this case decisions at the production side will affect demand and supply of the commodity and thus its price, which affects consumption decisions, and vice versa. Such nonseparability occurs if households are not price-takers in a market, if markets are missing, or if there is a gap between buying and selling prices (Löfgren and Robinson, 1999). The seminal paper of de Janvry, Fafchamps and Sadoulet (1991) shows how rational behavior of farmers in combination with market failures may give rise to sluggish or counterintuitive household responses. Both missing markets and differences between buying and selling prices can be analyzed with a price band model, illustrated in Figure 3.3.

Figure 3.3: Household supply response with price bands



Source: adapted from Sadoulet and de Janvry (1995)

Starting from an exogenous market price, transaction costs increase the effective purchase price, and decrease the effective sales price faced by the household. Household demand and supply then determine the household shadow price of the commodity, with effective purchase and sales prices forming upper and lower boundaries. Figure 3.3 shows the supply curve for three different types of households. Depending on the intersection of the demand and supply curve, a household is (*1*) a net buyer, (*2*) self-sufficient, (*3*) a net seller of the commodity. If the household is a net buyer or seller, the household shadow price equals the effective purchase or sales price. If the household is self-sufficient, the household shadow price is endogenously determined within the price band. A missing market can be conceptualized in this model as a wide price band (in the most extreme case, a sales price of zero and an infinite purchase price), such that all households always operate within it.

Household response then consists of two decisions, (*i*) a discrete decision on market-position, determining their position as net buyer, net seller or not participating; (*ii*) a continuous decision on production and consumption levels, determining supply response. The position of the household in the market determines the effective decision-making prices for the second decision. Net buyers will respond differently to a price increase than net sellers, while households operating within their price band will not show any response to the price change. The position of the household in the market, which may change when prices change, thus has an important impact on the household response to price incentives.

Intersection of household demand and supply relative to the effective buying and selling prices determines the rate and direction of household response. Changes in the external environment may affect the effective price by changing the market price, or by changing the transaction costs. Investments in infrastructure, for example, can reduce the width of the price band, thereby stimulating household response to price incentives.

3.2 household models: approaches to applied models

The general household model can be used to develop quantitative household models. In translating the theoretical framework to a quantitative household model three approaches can be followed: a reduced-form approach, a system of equations, or an optimization model. Although using the same theoretical model as starting point, the structure of the resulting quantitative models is very different. This difference has implications for the way in which the key issues defined in Chapter 2 are dealt with.

3.2.1 household models in reduced-form

Quantitative household models are developed to address a specific research question, for which it may not be necessary to estimate a complete household model. Instead of estimating all equations describing household behavior, reduced-form equations may be estimated, describing how an endogenous variable relates to a number of exogenous variables. These equations are derived by solving the first-order conditions of the household maximization problem for the endogenous variables of interest (see for example Paolisso *et al.*, 2002; Smale *et al.*, 2001; Woldenhanna and Oskam, 2001).

Specification of the utility and production functions is not needed for derivation of a household model in reduced-form. It suffices to specify the variables that enter the equations and postulating general conditions on the functional form. Based on these assumptions first-order conditions can be derived which are then rewritten to establish which exogenous variables enter the reduced-form equation for the endogenous variable of interest. The resulting reduced-form equation is then estimated econometrically.

Reduced-form models do not provide an insight in the internal adjustments within the household. Households may thus seem unresponsive, while in fact shadow prices show large adjustments. For example, households that operate within the price-band may not switch to selling or purchasing when an exogenous price changes. However, a structural household model reveals that shadow prices do change, affecting the location of the household within the price band (de Janvry *et al.*, 1991). These internal adjustments affecting household welfare are not detected by a quantitative model in reduced-form. Furthermore, the absence of a utility function from the estimated model limits the analysis of changes in household welfare

3.2.2 household models as a system of equations

In case not one specific endogenous variable, but several aspects of household decisions are of interest, all structural equations of a household model may be estimated. In this case the first-order conditions of the household maximization problem are used to determine a system of equations that describe a household's production and consumption decisions. Depending on whether decisions are separable the model may be estimated recursively, *i.e.* first the production then consumption decisions, or jointly (see for example Davis and Zong, 2002; Lopez, 1986). Instead of an econometric estimation the model may also be solved numerically, possibly after estimating part of it econometrically (see for example de Janvry *et al.*, 1991).

Functional forms for the demand and supply functions need to be chosen when estimating structural equations of a household model. These may be derived from utility and production functions, or may be postulated. Estimation of the structural equations can be complicated because of endogenous variables, because of indeterminate signs of coefficients making it difficult to distinguish true inference from spurious correlation (Kruseman, 2000:61), and because of high data requirements.

3.2.3 household optimization models

Estimation of a household model in reduced-form or as a system of equations may not be possible for several reasons. First, the structure of the household model may be too complex to analytically derive a limited number of equations linking endogenous and exogenous variables. In case of nonseparable household models, interdependencies between production and consumption decisions easily generate a complex structure that cannot be analytically solved. Second, econometric estimation may be hindered by unobservable variables. If the household produces commodities for internal use only, or uses labor in production and for leisure but does not participate in labor markets, prices of these commodities cannot be observed. Third, data limitations may prevent estimation. Econometric estimation poses high requirements in terms of number of observations, time-horizon and variation in variables.

A household model as a system of equations requires derivation of demand and supply equations. Not all functional forms are differentiable. Thresholds in production, for example, may prevent derivation of input demand and output supply functions.

A third option is therefore to develop a household optimization model (see for example Kruseman, 2003; Omamo, 1998). Such an optimization model has the same structure as the general household model: an objective function is maximized, subject to a number of constraints. In contrast to the other two household modeling approaches, no first-order conditions are derived. A household optimization model thus requires specification of the utility function, which is difficult given the unobservable character of utility. A household optimization model allows a combination of econometrically estimated parameters with postulated parameters, reducing data requirements compared to a full econometric estimation but increasing the need to validate model results. After specifying the model structure and its parameters, the model is solved through an optimization algorithm.

3.3 village and sub-regional models

Nonseparability of household decisions follows from market imperfections. In a similar way as limited market access may create interdependencies between production and consumption decisions within households, it can create interdependencies between households within a rural community. Lack of access to external markets, combined with heterogeneity between households, can result in local markets with endogenous prices and expenditure linkages (Holden *et al.*, 1999). In a similar vein as with nonseparable household decisions, counterintuitive policy responses can arise if indirect effects (from interactions between households) outweigh direct effects (as predicted with separate household models).

The presence of interactions between households in a village has been acknowledged in descriptive studies (see for example Hayami and Kikuchi, 1981; for a recent study on village bullock markets see Mueller *et al.*, 2002). De Janvry *et al.* (1991) also mention local general equilibrium effects, which may trap households within a price band in case of shallow markets because all households are net buyers or net sellers at the same time. Compared to the ubiquitous household models, studies at village (or sub-regional) level are scarce. Models either focus at household level, accounting for interactions between production and consumption decisions, or they focus at regional or national level, modeling producers and consumers as separate decision-making entities.

Quantitative village models include interactions among households as an additional layer to the framework provided by household models. Three different approaches to modeling these interactions can be distinguished: a representative village agent, partial equilibrium analysis, and general equilibrium analysis. The representative village agent approach has a similar structure as used in household optimization models. A single objective function is maximized, combining the objectives of representative households. In partial equilibrium analysis interactions in major markets are accounted for. This can vary from interactions in a single market, to a large number of markets. In general equilibrium models the entire economy is in covered by the model, including income and expenditure links that are absent from partial equilibrium models.

3.3.1 a representative village agent approach to village modeling

Management of natural resources at village level, and natural processes like erosion and deforestation that are not bound by farm borders led to the development of models of West African villages (Benoit-Cattin *et al.*, 1991). Similar model structures have been used in Costa Rica to model sub-regional agricultural land use (Schipper, 1996).

The analytical structure of these models is identical to those of household optimization models: an objective function (farm income (Benoit-Cattin *et al.*, 1991) or expected income (Barbier, 1998)) is maximized subject to a number of constraints on land, labor and capital. The resource constraints combine household resources into a single pool of resources. Although they include both consumption and production, they are agricultural production models in spirit. The major part of the model consists of a description of (new) technologies and the impact of technology choice on production resources. Consumption decisions are kept simple, for example by specifying fixed consumption levels, as in Benoit-Cattin *et al.* (1991).

The models are solved as (nonlinear) mathematical programming models in which prices of traded commodities are exogenous. The objective function consists of the sum of representative household incomes, which is maximized subject to the pooled resources, as if a single representative village agent takes all production and consumption decisions. Interactions among households are implicit in this approach. They can be deduced afterwards, for example comparing the labor availability with labor used, but do not affect the decisions. In the absence of transfers the resulting decisions may not reflect individual rationality; income of one household can be sacrificed to increase aggregate income of the village or sub-region as a whole.

3.3.2 a partial equilibrium approach to village and sub-regional modeling

Partial equilibrium models describe interactions in one or more markets. They are partial models in the sense of not covering the entire economy. Such a partial focus is appropriate if the modeled part of the economy is small relative to the remainder of the economy, and/or there are few links with the rest of the economy. Changes in the modeled part of the economy then do not cause significant changes in the rest of the economy, which can be treated as exogenous.

Most partial equilibrium models are macro-level models dealing with a specific sector, like agriculture. A major difference with the representative village agent approach is the use of first-order conditions to derive demand and supply equations. Prices then adjust until demand equals supply in all markets. In contrast to the representative village agent approach, the partial equilibrium corresponds with each agent maximizing its individual objective function. Because of the sector focus these partial equilibrium models do not account for consumption decisions. This is reflected in the often cited argument for moving to a general equilibrium model, namely the need to account for income effects.

Since the scope of this chapter is limited to models that account for the interdependencies between production and consumption decisions of households, the sector-oriented partial equilibrium models will not be discussed further. Instead, we retrace our steps to the definition of partial equilibrium models as dealing with only part of the economy. Using this criterion there are two models that are partial in the sense of dealing with part of the economy, while considering both production and consumption decisions.

The Multilevel Analysis Tool for the Agricultural sector (MATA) model, developed by Deybe and others (for a concise summary of the model see Deybe, 2000), is a partial model focusing at the agricultural sector. It is not a partial model in the usual sense, since it does not derive demand and supply functions from first-order conditions. It is a kind of a hybrid model, combining the representative village agent approach discussed before, with a market equilibrium model. The model is solved recursively. In the first step production of agricultural commodities is determined for different regions. Production decisions follow from maximizing expected regional income, which is the sum of expected farm income, given expected prices. This part of the model has a similar structure as the village models described above, with regions playing the part the village had before. In the second step total agricultural output from the different regions is confronted with consumer demand. This yields a price which balances the now fixed output and price-dependent consumer demand. The equilibrium price (adjusted for transaction costs) is then used to calculate farmers income, savings and so on, which completes one cycle of the model. The justification for the two-step approach is that farmers take decisions during the production season, based on expected prices. Actual prices are determined afterwards, when the product is sold on the market. MATA fits within the scope of this chapter since consumption decisions of farmers are accounted for during the first step, when the production levels are determined.

A second example of a partial equilibrium model that accounts for interdependent production and consumption decisions is the model developed by Kruseman (for a concise summary of the model see Kruseman and Bade, 1998). This model consists of mathematical programming models of representative households. Households take production and consumption analyses based on exogenous prices. To account for the impact of household decisions on product markets a partial equilibrium module confronts demand and supply. Supply and demand equations are derived from the mathematical programming models by solving for various prices. This creates a data set from which the demand and supply functions, summarizing the underlying household models including biophysical constraints to production, are estimated. The partial equilibrium model thus has demand and supply equations, but these do not follow from analytically solving the maximization problem, but instead are derived from the mathematical programming model.

3.3.3 a general equilibrium approach to village modeling

The absence of income effects is a common distinction between partial and general equilibrium models. In general equilibrium models households' income is derived from payments to factors owned by the households, profits and taxes. When production changes it affects factor payments, consumption demand then changes through the effect on the consumer income, which in turn affects production. Partial equilibrium models at macro or meso level generally lack this link through consumer income. Consumer income is taken as given, and the analysis focuses on changes in the decisions of producers.

The focus in this chapter is on models accounting for possible interdependencies between production and consumption decisions of households. By including both production and consumption, from the onset income effects are included in the partial models discussed above. The difference between general and partial models is therefore more gradual at the micro level. It depends on scope of the models, *i.e.* the extent to which interactions among households are accounted for, and not on adding an endogenous consumption component to the model.

The key feature of general equilibrium models is that they cover the entire economy. Generally build on a single Social Accounting Matrix (SAM), they provide a snap-shot view of all flows of commodities and expenditures in an economy. The SAM is used for calibrating functional forms of the model, and for checking whether the model reproduces the base-year economy.

General equilibrium models are derived from the neoclassical Arrow-Debreu model of competitive equilibrium. This model can be described by three conditions: (1) producers maximize profits; (2) consumers maximize utility; (3) there is no excess demand in any market. These three conditions can be expressed formally as (Ginsburgh and Keyzer, 1997:3):

1) *Profit maximization*: Each firm j maximizes its profits (π_j) by choosing a production plan ($\boldsymbol{y}_j$)[1] from the production set (Y_j) for given (equilibrium) prices ($\boldsymbol{p}^*$):

$$\pi_j(p^*) = \max_{y_j}\{\boldsymbol{p}^*\boldsymbol{y}_j \mid \boldsymbol{y}_j \in Y_j\} \qquad \forall j. \qquad (3.1)$$

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[1] Bold characters denote vectors; multiplication of two vectors implies that the first vector is transposed.

2) *Utility maximization*: Each consumer *i* maximizes its utility (u_i) derived from consumption ($\boldsymbol{x}_i$), subject to its income (h_i):

$$\max_{x_i \geq o} \{u_i(\boldsymbol{x}_i) \mid \boldsymbol{p}^* \boldsymbol{x}_i \leq h_i^*\}, \; h_i^* = \mathbf{p}^* \boldsymbol{\omega}_i + \sum_j \theta_{ij} \pi_j^* + t_i, \qquad \forall i, \; \sum_i \theta_{ij} = 1 \tag{3.2}$$

where $\boldsymbol{\omega}_i$ are endowments, and θ_{ij} shares consumer i owns in firm j and t_i are taxes.

3) *Market clearance*:

$$\sum_i \boldsymbol{x}_i^* - \sum_j \boldsymbol{y}_j^* - \sum_i \boldsymbol{\omega}_i \leq 0 \, . \tag{3.3}$$

Because consumption and production decision are homogeneous of degree zero in prices, these equilibrium conditions only determine relative prices (Gunning and Keyzer, 1995:2029). A quantitative model thus either needs to add a price normalization equation to fix the price level in the economy, or there should be at least one price that is fixed exogenous (like an import or export price) providing an implicit normalization.

The three conditions above describe the two main types of equations in an applied general equilibrium model: behavioral and accounting relations. Behavioral equations describe the decisions of agents in the economy. In the case of a village equilibrium model, households simultaneously take production and consumption decisions. As discussed with the household models, this results in a utility maximization problem subject to a full income constraint that includes the production function. In an applied village equilibrium model, however, separate profit and utility maximization conditions can be found. This similarity with macro-level models is possible since, as discussed before, even with nonseparable household decisions, production can still be described in terms of profit maximization, but with endogenous prices that are affected by consumption decisions.

The accounting relations distinguish a general equilibrium from a partial equilibrium model. In a general equilibrium model, all flows of goods and the accompanying flows of money are traced throughout the economy. Thus all income that is earned needs to be spend (including on savings), and all output that is produced needs to be sold (or put in stocks). The level of analysis determines to which level flows are followed. A household model can also be seen as a micro general equilibrium model. It has behavioral equations (utility maximization) and accounting relations (time and cash constraints). Depending on the level of integration of the households in the economy prices are exogenous, and quantities adjust to establish 'household market' clearing. Or household decisions may be nonseparable, with household shadow prices adjusting to clear 'household markets'.

In the case of village general equilibrium models an additional layer of interactions among households is added to household models. This implies that flows of goods and money are traced among households in a village, but not outside the village. Analogous to the household, the village may be fully integrated in outside markets, and quantities adjust to clear village markets. Or there are village markets separated from the outside world, in which demand and supply by households determine village prices that clear the markets.

Such village-level general equilibrium models have only been developed very recently. To our knowledge only two models of this type have been developed: one by Taylor and others (see for example Taylor and Adelman, 1996; Taylor *et al.*, 1999b) and one by Löfgren and Robinson[2] (1999). Taylor and Adelman (1996) pioneered the application of SAMs and general equilibrium models at village level. Taylor and others build on this first analysis in two studies of Mexican village and town economies (Taylor *et al.*, 1999a; Taylor *et al.*, 1999b). These models have the same analytical structure as open economy models.

The model developed by Taylor and Adelman (described in chapter 8 of Taylor and Adelman, 1996) consists of a household maximizing utility, subject to a cash-income constraint, production technology, a family time constraint, and a remittance function (to model the impact of migration). These are the behavioral equations of the model plus household-level accounting relations. In addition there are four sets of village-level accounting relations to account for the interactions among households in the village: a balance of goods, a balance of factors, a local capital market, and a village balance of payments.

The balance of goods imposes that the total production of goods in the village by all households equals the sum of total household consumption, local government demand, investment demand, and the marketed surplus. For goods that are traded with the outside world this accounting relation determines the amount imported or exported against a fixed price. For goods that are not traded with the outside world the equation determines an endogenous village price. The accounting relation for factor markets stipulates that village demand for factors equals village supply of factors, plus import of factors. Family labor is not included in this equation, village markets for family labor are assumed to be missing. To account for missing credit markets, as is frequently the case in developing countries, there is a village capital market balancing village savings and investment. The last village accounting relationship is the village balance of payments, equating the total inflow of money from remittances and exports, with the outflow of money through imports.

Together these accounting equations trace all flows of money and commodities, within households, within the village and between the village and the outside world. The applied model is constructed using the first-order conditions to derive supply and demand equations describing household behavior.

The mathematical description of the model distinguishes family and hired labor in production, has the household consuming leisure and has a missing village market for family labor. This is a common feature of household-farm models with incomplete labor markets (de Janvry *et al.*, 1991; Lopez, 1986; Singh *et al.*, 1986a). Household decisions may become nonseparable, with household shadow wages for family labor being affected by household characteristics, like the labor endowment and consumption preferences. If there is an endogenous, household-specific shadow wage, production decisions may also differ among households, being dependent on relative prices. The SAMs included in the book by Taylor and Adelman (1996), as well as the GAMS code of their village model, indicate that production is determined by activity (*e.g.* crop production or livestock production), effectively separating production and consumption decisions. This approach follows macro-level general equilibrium conventions, and does not allow household-specific production decisions.

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[2] The stylized illustration of the model of Löfgren and Robinson is at the national level. However, with their focus on endogenous nonseparability of household decisions their model structure can be directly applied at the micro level, and is therefore included as an example of micro economy-wide modeling.

The impact of nonseparability of household decisions is the focal point of the model developed by Löfgren and Robinson (1999). Although their (stylized) application refers to a national-level model, its structure is closely related to the household-level price-band model of de Janvry *et al.* (1991) and is therefore directly applicable at micro level. Despite the national-level application, the Löfgren and Robinson model uses essentially the same framework as Taylor and Adelman: market clearance conditions are added to a collection of microeconomic household models. First-order conditions of profit and utility maximization are again used to model behavior; in case of nonseparability profit maximization takes place on the basis of endogenous household prices.

A crucial difference with the Taylor and Adelman model is a specification of both activities and commodities. Activities are household-specific, commodities are not. This allows determination of a common commodity price by clearing markets for traded goods. These prices are then translated into household-specific activity prices by adding fixed input requirements associated with buying or selling a commodity. The result is a household- and activity-specific price, with endogenous transaction costs depending on the price of the inputs used for buying and selling.

Capital and land are household-specific and nontradable, a household-specific price will be thus be determined, resulting in household-specific production decisions. This contrasts with the activity specific price in the Taylor and Adelman model. Complementarity constraints are used to model price bands (at household and national level), free disposal in commodity markets (at household and national level), and a choice between alternative technologies (modeled as Leontief production functions). The model is kept simple in all other respects (family and hired labor, for example, are prefect substitutes), to focus on the way in which institutions and activities are modeled. No savings and investment, nor a government are included in the model (Löfgren and Robinson, 1999).

The complementarity constraints used for modeling price bands allow commodities to shift between being traded (purchased or sold) or nontraded. This contrasts with the approach in the Taylor and Adelman model, also used in farm household models, where tradability is exogenously determined by assigning commodities to the set of tradables or nontradables. Tradable commodities always have an exogenous price, whereas in the Löfgren and Robinson model prices of tradables could become endogenous if the household operates within its price-band. This approach is identical to trade models with countries switching between being importers, self-sufficient or exporters.

The width of the wedge between selling and buying prices is endogenously determined by the prices of transaction inputs. Which inputs are used in transactions, however, is not specified in the Löfgren and Robinson model. Implicitly it is assumed that transaction inputs are tradable at national level; they do not appear in the commodity balances and thus only enter in the budget constraint through their impact on their household-specific prices. This specification reduces the nonlinearity of the model. However, if production factors, for example labor time spend traveling to markets, is an important share of transaction costs this specification is not realistic.

3.4 comparing different approaches to modeling household behavior

Our discussion of the different modeling approaches so far focused on how household behavior was modeled. Along the way some major differences between approaches have already been highlighted. For a more systematic view at the strength and weaknesses of different approaches, the matrix of key issues developed in Chapter 2 will be used to compare the different modeling approaches.

3.4.1 a summary of approaches to modeling rural household behavior

Before embarking on a comparison of different modeling approaches, we start by briefly summarizing the approaches discussed above. Although the model approaches at household and village or sub-regional models were discussed under different headings, they can be summarized in a common framework as presented in Table 3.1. To get concise and consistent names for each modeling approach two approaches are renamed. Household models as a system of equations are renamed household equilibrium model. They are constructed using supply and demand equations, as in applied general equilibrium models. And all household models are essentially general equilibrium models at household level. The representative village agent approach to village modeling has been renamed village optimization model since its structure mimics the household optimization model.

Table 3.1: Summary of approaches to modeling rural household behavior

Modeling approach	*Household models*	*Village or sub-regional models*
Reduced-form	**Household reduced-form model** Derive relation for limited number of endogenous variables to exogenous variables; estimated econometrically	
System of equations:		
• partial equilibrium		**Partial village equilibrium model** Derive demand and supply equations from first-order conditions covering part of the market interactions among households; estimated econometrically or solved numerically
• general equilibrium	**Household equilibrium model** Derive demand and supply equations from first-order conditions; estimated econometrically or solved numerically	**Village equilibrium model** Demand and supply equations covering all market interactions among households, solved numerically
Optimization model	**Household optimization model** Maximization of household utility subject to constraints; solved numerically	**Village optimization model** Centralized maximization of aggregate household utility subject to aggregated constraints; solved numerically

Besides summarizing the approaches discussed before, the two empty cells in Table 3.1 suggest gaps in the discussion of approaches. Approaches that appear to be missing are reduced-form village or sub-regional models and partial household equilibrium models.

A reduced-form approach to village or sub-regional modeling would require derivation of expressions linking endogenous variables of interest to exogenous variables. Compared to household-level models, village or sub-regional models have a large number of endogenous variables. The number of endogenous variables in models with interacting households, possibly with nonseparability of production and consumption decisions, prohibits the use of econometric models. To our knowledge there is one econometric study at village level by Lanjouw (1999) which uses a reduced-form approach. This study of land leasing markets in an Indian village is limited to a single market, and only accounts for the production decisions of households, putting it beyond the scope of this chapter. It relies on a unique panel data set to deal with endogeneity problems. The econometric problems caused by a large number of endogenous variables in a general equilibrium setting are also emphasized by the absence of econometric macro-level general equilibrium models.

The second empty cell in Table 3.1 consist of partial households models. One way to construct a partial household model would be to limit the model to either the production or consumption side of the household. Although such models exist, especially for modeling agricultural production, these farm production models have been excluded from the discussion in this study. In the context of modeling rural household decisions in developing countries, interdependencies between production and consumption are essential. Furthermore, farm production models can be seen as a special case of rural household models discussed in this chapter. A second way to construct a partial household model is to limit the activities that are included in the model, similar to the partial models discussed at regional and village level. In the context of a household-level model this makes less sense. Data on all activities are generally collected when performing a household survey, partly because it may not be clear beforehand what the main activities are. In case the applied model focuses on a specific issue or activity, activities of interest can be aggregated into composite activities in the applied model, thus still covering the whole household although with varying detail.

The empty cells accounted for, we are left with six different approaches to modeling rural household behavior. There is a close relation between the approach taken to develop an applied model and whether the models is econometrically estimated or solved numerically, as the entries in Table 3.1 indicate. The main contrast is between household and village or sub-regional models, with the latter always being solved numerically, independent of the approach taken. Using econometrics or numerical methods has strong implications for the key issues identified in Chapter 2. This will become clear in the discussion of the six approaches to modeling rural household behavior.

3.4.2 household reduced-form model

Data requirements posed by econometric estimation has strong implications for the way in which the key issues of Chapter 2 are dealt with. Natural resources tend to be absent from household reduced-form models. Collecting the economic data needed for estimation already poses a considerable challenge for these models, collecting data on natural resources is generally beyond the (financial) scope of the data collection efforts. Furthermore, measurable changes in natural resources often occur only in the medium to long run, which are difficult if not impossible to capture in the typical cross-section data set. This extends to the economic realm as well, the common use of cross-section data does not allow a study of dynamic effects. The only exception with respect to inclusion of natural resources is land, which may be an explicit input in the production function. Differences in land quality and the way it is affect by production, however, are not accounted for by the specification of production.

This brings us to the second key issue, technology. Household models in reduced-form do not require specification of functional forms (including a production function), it suffices to pose general conditions (continuous, concave, differentiable) that allow derivation of first-order conditions. These general conditions are standard in economic models, but imply that features of agronomic models, like for example thresholds, are ignored. Furthermore, to reduce the complexity of the model, production of different agricultural products is often aggregated to a single composite good, agricultural output. This allows the model to abstract from the allocation of inputs across different goods, keeping the model analytically tractable, and reducing the number of endogenous variables.

Moving on to the way household behavior is modeled, the same holds as for the production function. There is no need to fully specify an utility function. It suffices to specify the elements entering the function and impose some general conditions on its form to be able to derive first-order conditions. The entries into the utility function can be classified in three groups: own produced goods, purchased goods and leisure. Depending on the research question of interest different sub-divisions can be made.

Nonseparability also plays an important role in applied reduced-form models. From a mathematical point of view, nonseparability complicates derivation of the reduced-form. In practice this can be dealt with by having all exogenous variables entering the reduced-form. Household labor endowment, for example, then enters the production decisions. This actually provides a way of testing for separability: if household decisions are separable, household characteristics like endowments do not have an impact on production decisions. Although nonseparability can be dealt with by having all exogenous variables that may affect production and consumption decisions included in the reduced-form, there remains the difficulty of signing coefficients. Intractability of the analytical solution implies that coefficients cannot be signed *a priori*, making it difficult to distinguish true inference from spurious correlation (Kruseman, 2000:61).

A second issue related to nonseparability is the market position of households. As has been discussed above, whether a household is a net buyer, a net seller or not participating in a market affects the effective price which is used in the decision-making. This can be dealt with by estimating different functions for each of these three types of households (see for example Brière, 2000).Other studies take a two-step approach in which first the position in the market is determined, after which the response is estimated (Goetz, 1992; Key *et al.*, 2000). Household-level models by definition do not deal with interactions among households. Although households may decide on participation in markets, this does not influence the market; if considered explicitly markets and non-market institutions are exogenous to the model.

3.4.3 household equilibrium model

Households models written as a system of nonlinear equations can be seen as household equilibrium models. They cover all household 'markets' by specifying household demand and supply functions. Household demand and supply of nontradable and nontraded commodities are equated through shadow price adjustments. Demand and supply of traded commodities are equated by quantity adjustments against a fixed price.

Household equilibrium models are rare in the literature. They can be estimated econometrically, which is a complex endeavor because of the endogeneity of variables typical of general equilibrium models. If the research question of interest can be addressed by a reduced form specification, the estimation is greatly facilitated. In any case, if the structural equations of the household model are estimated econometrically, it has the same implications for the key issues as discussed with the reduced-form model. The only difference is that a household equilibrium model requires specification of functional forms of the supply and demand functions (though not of the underlying production technology, nor the utility function).

Household equilibrium models can also be solved numerically. Parts of the model may still be estimated, but the eventual solution is derived by numerically solving the ensuing system of equations. Applications involving numerical household models, however, generally opt for the primal approach, *i.e.* solve the model as a utility maximization problem, instead of a dual household equilibrium model. This is mainly due to a long tradition of optimization models in agricultural economics, which resulted in well-established and readily available solution algorithms for optimization models. If the model is solved numerically the implications for the key issues will be similar to those of the optimization model. These implications will be discussed in the next part since household optimization models are much more common in the literature.

3.4.4 household optimization model

In contrast to the stringent data requirements posed by reduced-form models, household optimization models can incorporate information from different sources which offers more flexibility in dealing with the key issues. Data from household surveys, field experiments and expert opinions on key parameters can all be incorporated. This flexibility explains the use of optimization models for analyzing natural resource issues, especially related to the introduction of new technologies. Not limited by the need for actual observations, optimization models allow an exploration of long run implications of land use on natural resources, and dynamics in general. Use of postulated parameters, however, does require careful validation of model results.

The downside of this data flexibility is a lack of rigorous testing of the model results, making it difficult to judge to what extent the model results reflect actual outcomes. Furthermore, these models have a tendency of becoming 'black boxes'. In contrast to a few equations in household reduced-form models, household optimization models easily contain hundreds or even thousands of equations, from which it is hard to tell what is actually driving the model results. In order to address the impact of a shock, its impact has to be traced working its way through the equations of the model, which can be a tedious exercise.

The one issue where household optimization models offer less flexibility than reduced-form models is household heterogeneity. Where reduced-form models thrive by variation across households, which facilitates econometric estimation, practical limitations imply that optimization models are generally constructed for a very limited number of representative households although in theory a model could be constructed for every individual household. Any representative household will be a compromise with respect to the variety observed in the data. The main objective in aggregating households into representative groups is to identify household characteristics that greatly affect household responses to changes in their external environment, to get as close as possible to actual household responses. If the relation between the household characteristics used for grouping and the response is known, the distribution of these characteristics can be used to derive a distribution of household responses after the model has been solved (see also the discussion of aggregation in Chapter 2).

The use of an optimization model requires the specification of an objective function. In the case of a household optimization model this amounts to specifying the household utility function. Given the unobservable nature of utility this is not straightforward. In many (agricultural) household optimization models utility is modeled as (expected) full income. Specification of a utility function is avoided by the other two household modeling approaches, that only require general restrictions on the functional form (reduced-form approach) or specification of supply and demand equations that can be observed in a household data set (household equilibrium model).

3.4.5 village optimization model

The village optimization model mimics the structure of the household optimization model, and with this its opportunities and limitations in dealing with the key issues. Village or sub-regional optimization models offer more opportunities for dealing with spatial interactions between natural resources than household optimization models. The fact that natural processes, like erosion, are not confined to farm boundaries provides a rationale for developing village and sub-regional models. This also provides an easier link to bio-physical models that tend not to focus at farms but at higher-level units, like watersheds.

By using representative village agent that pools all households resources, village optimization models do not offer much in terms of modeling interactions among households in markets or non-market institutions. Interactions with the conflicting interests that invariably result, cannot be accounted for by these model lacking household-level constraints. The main advantage of using a village optimization model lies in its ability to deal with biophysical processes that extend beyond the farm boundaries and which do not require modeling of interactions among households.

3.4.6 partial village equilibrium models

The discussion of partial village equilibrium models can be kept short. The two partial models discussed in Section 3.3 are relying on numerical models of households, using a representative village agent approach or a household optimization model to determine agricultural production. The opportunities and limitations of these types of models have been discussed above. Price-formation in the markets takes place by confronting supply with demand, having prices adjust until the markets clear. To this end supply and demand functions need to be specified. That approach is identical to the way in which equilibrium is attained in general equilibrium models and will be discussed below.

3.4.7 village equilibrium models

Village equilibrium models link household models by defining local markets in which households interact. The limited number of existing village equilibrium models describe behavior in terms of demand and supply functions, derived from first-order conditions. These models are solved numerically because of the large number of endogenous variables. Numerical solving creates flexibility in terms of the key issues, as discussed above. Commonly general equilibrium models are solved in the dual form and not in primal form (*i.e.* as an optimization problem) because of problems of aggregating utility of different households[3]. The way in which key issues are dealt with at household level is therefore identical to the household equilibrium model.

The layer of village interactions, added to the modeling of household behavior, offers scope for modeling household interactions in markets and nonmarket institutions. These interactions, and especially the effect they have on individual household behavior, are the main motivation for developing village equilibrium models. The crucial issue when developing a village equilibrium model is the presence of local markets isolated from the rest of the world. As a result demand and supply need to balance within the village, creating local markets with endogenous prices. Household decisions then have repercussions for other households, by changing local prices through changed demand or supply. Since there are not many places left where villagers live in complete isolation of the rest of the world, this raises the issue of whether it is necessary to develop a village equilibrium model if there are only a few local markets with endogenous prices.

A general equilibrium approach to village modeling offers two main advantages over a partial equilibrium approach: accounting consistency and theoretical consistency (Hertel, 1990). By covering the complete economy general equilibrium models require all flows of goods and money to be accounted for. This provides a powerful check on whether model and data are consistent with each other. A similar check could also be done in the case of household equilibrium and optimization models, since these cover all activities of the household. If the household data would be structured as a household SAM, it can easily be checked if the structure imposed by the model accurately reflects the data, and if the data are consistent with the model structure (a rare example of a household SAM can be found in Freeman *et al.*, 1997). In practice there appears to be no systematic check of consistency between data and model structure in household modeling.

As stated before, numerically solved models, being it household or village-level models, have a tendency of becoming black boxes. In dealing with this black box character, the second main advantage of general equilibrium modeling is the use of Walras' law as a theoretical consistency check. This provides a powerful and easy to implement check on whether adjustments to the model have been made appropriately. Again, the same check can be applied in household-level equilibrium or optimization models, although this appears not to be done.

Complete coverage of the economy and accounting consistency also has a downside in terms of data requirements. Compared to household-level models, additional data are needed on the source and destination of all commodities that are not commonly collected in household surveys. Furthermore, every commodity needs to be classified in terms of tradability at household and at village level, possibly accounting for the presence of price bands.

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[3] General equilibrium models can also be solved in the primal form using the Negishi format, as discussed in the appendix on the development of an applied general equilibrium model.

Table 3.2: Summary of opportunities and limitations of modeling approaches in terms of key issues

Level	*Approach*	*Opportunities and limitations*
Household	**Reduced-form**	- natural resources cannot be included, apart from land area + no need to specify a production function, general restrictions on its form suffice - despite their generality these restrictions do not accommodate features of production important from a biophysical perspective + no need to specify a utility function, general restrictions on its form suffice - endogeneity of variables creates problems in the estimation - data availability generally prohibits analysis of dynamic issues - market and nonmarket institutions are exogenous, if included
	Equilibrium	+ natural resources can be included if solved numerically + no need to specify a production function, specification or estimation of demand and supply equations suffices; numerically solved models can accommodate biophysical features of production - market and nonmarket institutions are exogenous, if included
	Optimization	+ flexible data requirements allow about any specification of the key issues including dynamics - no rigorous testing whether the model reflects the actual situation - utility function needs to be specified and parameterized - market and nonmarket institutions are exogenous, if included
Village	**Optimization**	Mimics household optimization models and has a similar assessment, with two main differences: + higher level of aggregation allows study of biophysical processes that cross farm boundaries - representative village agent approach removes interactions among households from the model and may result in outcomes that are not rational for individual households
	Partial equilibrium	Numerical solving offers same data flexibility as mentioned with the household optimization model, and with the same qualifications in terms of the solution reflecting the actual situation. In addition: + modeling of interactions among households preserves individual rationality
	General equilibrium	Same opportunities and limitations as the partial equilibrium model, and in addition: + powerful accounting and consistency checks + include income and expenditure links between households - need comprehensive data on flows of commodities

3.4.8 summarizing opportunities and limitations of modeling approaches

Table 3.2 provides a concise summary of the opportunities and limitations of the different modeling approaches discussed in this chapter. The way in which the key issues are dealt with depends strongly on the selected modeling approach. This can be most clearly observed in the case of the household reduced-form model, with its strong limitations posed by the data requirements of econometric estimation. On the other hand, it can easily incorporate household heterogeneity and provides a transparent model structure.

The eventual choice of an approach is determined by the research questions to be answered with the model, and by data availability. But some general guidelines can be derived from the discussion above:

- questions related to diversity among households are best answered by an econometrically estimated household model, preferably in reduced-form;
- addressing a household-level question with data from different sources that are incomplete (for example because of a new technology that has not been used yet) a household optimization model is the way to go;
- if interactions among households are important for the behavior of households, and data allow construction of SAM, a village equilibrium model is the way to go because of the accounting and theoretical consistency checks.

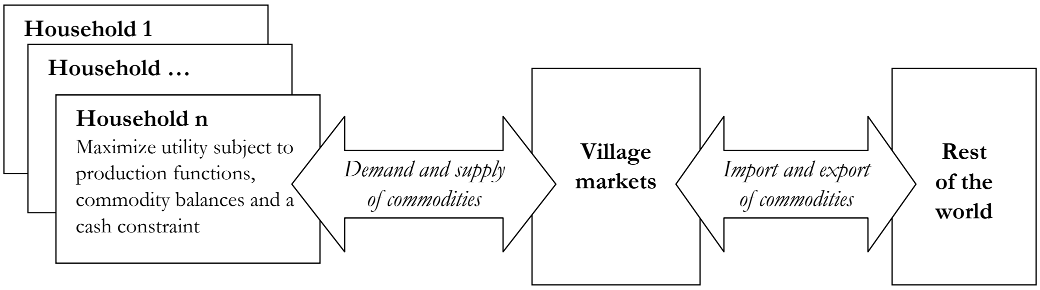
Discussing household- and village-level models in a consistent framework also suggests two ways to improve existing household equilibrium and optimization models. Since these models can be seen as micro-level equilibrium models; they can exploit the same accounting and theoretical consistency checks that are used in macro-level general equilibrium models. Given the complex structure of these models the value of such consistency checks is high, both in building and in using the models.

3.5 structure of the village equilibrium model

This study focuses on modeling the impact of interactions among households on household response. The above assessment of modeling approaches indicates that village models are promising in the sense of capturing interactions among households that may affect household response. The assessment also indicated that the existing village models do not adequately reflect the findings of the household literature on the impact of market imperfect on household decisions. The remaining chapters of this study are therefore devoted to the development of an applied village equilibrium model paying due attention to nonseparability of household decisions. A general equilibrium instead of a partial equilibrium approach is taken to be able to capture income and expenditure links among households and to utilize the accounting and consistency checks of general equilibrium theory when developing the applied model.

The structure of the village equilibrium model follows the approach described in Taylor and Adelman (1996). The model contains three elements: households, within village transactions and transactions with the rest of the world (Figure 3.4). Each of these three elements may be further sub-divided (depending on the issue of interest), by distinguishing types of households, markets for different commodities, and domestic and foreign imports and exports. Note that throughout the text the term commodities is used to refer to both factors and goods.

Figure 3.4: Elements (□) and interactions (⇔) of the village equilibrium model



Behavior of rural households is defined in line with the standard model of Singh, Squire and Strauss (1986b), that forms the basis of the extensive literature on rural household behavior. In this standard model, households maximize utility, subject to production technology, time, and a cash constraint. In the general village equilibrium model, this standard household model is formulated in more general terms: households maximize utility subject to a production function, commodity balances, and a cash constraint. This generalization draws attention to the role of different variables and underlying assumptions, that are easily missed in the details of a more specified model.

Transactions between households in the village are described by trade balances and a balance of payments. Interactions with the rest of the world (imports and exports) are also captured by these balances.

In the mathematical model description, variables are defined such that subscripts indicate a specific commodity and superscripts indicate the type of use made of the commodity. Sets are indicated with capital letters, set elements with lower case letters. This reliance on sets does not improve readability of the model description. But it does focus the attention on the role of different variables in the model. It also allows a straightforward translation to GAMS code and a translation of this code to different model settings. Appendix A contains a list of sets, parameters and variables used in the general model.

3.5.1 household behavior

The objective of household h is to maximize utility, u, derived from consuming (c) quantities (q) of commodities j (q_{hj}^{c})[4]:

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[4] The convention followed in this study is that superscripts indicate the type of use made of a commodity. Household consumption is thus denoted by q_{hj}^{c} where q indicates we are dealing with a quantity, superscript c denotes that the commodity us used for consumption, while subscripts h and j indicate that consumption of commodity j is household-specific. The letter used to indicate the type of use corresponds to the name of the set, in the case of consumption all commodities J in set C can be consumed.

$$\max_{q_{hj}^{c},s_h} u_h(q_{hj}^{c}) \,. \qquad \forall\, h \in H \qquad (3.1)$$

Set C of consumed commodities includes both goods and factors. This specification thus allows for the consumption of labor as leisure, a feature often encountered in household models.[5]

Production technology provides the first constraint to utility maximization. Production is defined in terms of household-specific activities. Defining production in terms of activities instead of output has advantages for modeling nonseparable household decisions and for introducing alternative technologies. With nonseparable household decisions production becomes household specific. In case of labor market imperfections, for example, family labor may be valued against a shadow wage that differs across households. With input prices determining production decisions, different shadow prices lead to different production decisions and production thus needs to be defined at household level. However, markets are not household specific but commodity specific, *e.g.* rice produced by different households will receive the same price at the market (assuming no quality differences). We thus want to allow for differences in production decisions, while still producing the same type of output. We achieve this by separating production activities from produced goods.

The second advantage of separating activities and produced goods is that alternative technologies can be introduced to the model by expanding the set of activities the household may choose from, without having to change the set of commodities in the model. This implies that the attractiveness of a new production technology can be analyzed in a straightforward manner. If the new technology is more attractive it will (partly) replace the previous production technology, otherwise it will not be used. The choice is thus endogenous and may depend on changes in other model parameters, like import prices.

Total quantity produced (o) of commodity j (q_{hj}^{o}) is the sum of the output of household activities a. The output of each activity is a function[6] $g_{ha}^{o}(\cdot)$ of commodities used as inputs (i) in the activity (q_{haj}^{i}):

$$q_{hj}^{o} = \sum_{a \in A} g_{ha}^{o}(q_{haj}^{i}) \,. \qquad \forall\, h \in H, j \in J \qquad (3.2)$$

Use of household specific activities allows for commodity and household specific production technologies. Furthermore, outputs and inputs are defined generically as commodities. This allows, first of all, the use intermediate goods (*i.e.* goods produced by other activities) in production. Secondly, it allows production of factors. Although factors are generally considered as fixed in supply, modeled as endowments, in the case of labor this assumption is sometimes relaxed. Efficiency wage models assume that (high quality) labor needs to be produced, implying definition of a production function for labor.

Commodity balances form the second set of constraints to utility maximization. The relevant restriction on the availability of a commodity depends on its tradability. As discussed in Chapter 2,

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[5] Dealing with a static model we do not include savings. Results of an intertemporal utility maximization can be mimicked in an atemporal specification by treating savings as a commodity in the utility function (Howe, 1975). Including savings in a static model, however, remains awkward. There is no rational for households to forego current consumption in the absence of a future period.

in the section on aggregation issues in markets, commodities can be classified as being nontradable or tradable. Nontradable goods are never traded, while tradable goods can be traded or nontraded, depending on relative prices. In terms of households commodities three groups of commodities are distinguished: nontradables, traded, and price band commodities. Household nontradables are never traded, *i.e.* markets are missing for these commodities and household supply needs to meet household demand at all times.

Tradable commodities can be traded or nontraded depending on the circumstances. If markets function perfectly buying and selling prices are identical. Depending on relative prices the household will be a net buyer or seller of the commodity (since buying and selling occur at the same price only net sales can be determined). Note that relative prices could be exactly such that the household ends up not buying or selling, if its demand exactly meets its supply. This is a precarious equilibrium point due to identical prices, and a minimal change in relative prices will shift the balance to the household being a net buyer or seller. Commodities with perfect functioning markets are therefore referred to as traded commodities.

In the context of modeling rural households in developing countries perfect tradability can generally not be assumed. However, missing markets is generally also too strong an assumption. Commodities with a tradability in between the two extremes of perfect tradability and nontradability are therefore modeled as commodities for which price bands exist. In the case of price-bands purchasing and selling prices differ. This price wedge may be so large as to effectively have the market for purchasing the commodity fail, have the market for selling the commodity fail, or have the markets for both purchasing and selling fail.

Despite the fact that price band commodities can, in principle, cover the whole spectrum from nontradable commodities (infinite price band) to traded commodities (zero price band), the general village equilibrium model includes them as three separate types of commodities. Defining three types of commodities highlights their different roles in household decisions, which is easily lost in a more general specification. Furthermore, when moving to an applied model it makes shifts between models with only nontradables and traded, or models with all three types of commodities, only requires set elements need to be changed.

Tradability of commodities is modeled by defining three types of sets. The set of household traded commodities, HT, contains commodities with perfect markets, *i.e.* equal selling and purchasing prices. Commodities with a price band are modeled with two sets: one for purchased commodities P and one for sold commodities S. By including a commodity both in set P and S a price band is effectively introduced for this commodity. By including a commodity only in the set P or the set S a failing purchase or selling market is introduced in the model. Nontradable commodities can be introduced by not including a commodity in either of the three household tradability sets, which implicitly states that the commodity cannot be traded.

With these sets defining tradability, the second constraint on household utility maximization, commodity balances, can be specified. A commodity balance specifies that the use of commodities (from consumption, inputs in production or sale) cannot exceed the availability of commodities (from production, endowments and purchases):

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[6] A more general specification would allow for correspondences. For simplicity we assume that the relation between inputs and outputs can be described by a function.

$$q_{hj}^{c} + \sum_{a \in A} q_{haj}^{i} + q_{hj}^{s} + q_{hj}^{ht} \leq q_{hj}^{o} + \overline{q}_{hj}^{\omega} + q_{hj}^{p}, \qquad \forall\ h \in H, j \in J$$

where, in addition to the variables defined before, q_{hj}^{s} is the amount sold of a price-band commodity, $\overline{q}_{hj}^{\omega}$ is the fixed household factor endowment, and q_{hj}^{p} is the amount purchased of a price-band commodity.

For traded commodities purchase and selling prices are identical, thus only the net marketed surplus can be determined (the household can buy and subsequently sell an infinite amount of these commodities). Including these commodities in the sets P and S would prevent a unique solution to the model; an infinite number of combinations of imports and exports can generate the same net surplus. To prevent such an outcome these commodities are instead identified by the variable q_{hj}^{ht}, denoting a household's net marketed surplus of traded commodities. This also implies that commodities belonging to the set HT, cannot be included in the set P or S: $P \cap HT = \varnothing$, $S \cap HT = \varnothing$.

The commodity balance of nontradable commodities restricts the options of the household. This can easily be seen by dropping the variables related to tradables from equation 3.3:

$$q_{hj}^{c} + \sum_{a \in A} q_{haj}^{i} \leq q_{hj}^{o} + \overline{q}_{hj}^{\omega}. \qquad \forall\ h \in H, j \in J \qquad (3.3')$$

The amount the household may consume or use as inputs of nontradables cannot exceed the amounts produced or available as endowments. The commodity balance for household nontradables determines their (unobservable) shadow price, which may differ across households.

By contrast, the commodity balance of household tradables does not directly limit their use since these commodities may bought, thus loosing the constraints posed by availability from production and endowments. In the absence of quantitative restrictions on amounts sold and purchased, transactions of the household tradables are restricted by the cash constraint and not their commodity balance. In most household models these commodities are therefore left out of the commodity balance. Goods purchased for consumption, for example, then enter the utility function directly, while in the specification used here they are first 'transformed' to consumption goods by their commodity balance. The specification chosen in this model allows the specification of a single commodity balance, highlights the general structure of the household model, and makes assumptions regarding tradability explicit by specifying the set to which commodities belong.

The family time constraint can serve as an example of making assumptions on market failure more explicit. A family time constraint is omnipresent in household models, and can also be found in the standard model of Singh *et al.* (1986b). The time constraint equates leisure and time spend on production (on and off-farm) to the total time available to the family. In terms of equation 3.3:

$$q_{hj}^{c} + \sum_{a} q_{hj}^{ia} + q_{hj}^{s} = \overline{q}_{hj}^{\omega}. \qquad \forall\ h \in H, j = \text{family labor} \qquad (3.3^{*})$$

The implicit assumption is that family labor and hired labor are imperfect substitutes due to monitoring problems; no market for buying family labor exists. If labor can be hired it will be specified as a separate commodity belonging to set P, since hired labor will not be sold again. As can be seen from Equation 3.3* a market for selling family labor (off-farm employment) is assumed to exist in this case. Using a single commodity balance focuses the attention on the assumptions of tradability, instead of suggesting something to be inherently different about labor, setting it apart from the other commodities in the model. As an illustration consider two other sets of assumptions regarding labor: perfect markets and efficiency wages. First, assume perfect labor markets. Hired and family labor are then perfect substitutes, and q^{s}_{hj} in equation 3.3* can be replaced by q^{ht}_{hj} and the time constraint is no longer binding since additional labor can be purchased. Second, assume that (high quality) labor needs to be produced as done in efficiency wage models. This requires the addition of labor production, q^{o}_{hj} to Equation 3.3* and defining a production function for labor as in (3.2).

Another common restriction in household models is the land constraint, requiring total land used for production to not exceed land endowments of the household. The implicit assumption is that all land markets fail, including those for hiring land. In terms of equation 3.3:

$$\sum_{a\in A} q^{i}_{haj} \le \bar{q}^{\varpi}_{hj}\,. \qquad \forall\; h\in H, j=\text{land} \qquad (3.3^{\#})$$

Again, starting with a general specification of commodity balances focuses the attention on the assumption made instead of having a range of implicit assumptions regarding labor and land markets. As illustrated by the time and land constraints, the general specification of commodity balances in the village equilibrium model thus allows dealing with a range of topics (like imperfect substitution of labor or efficiency wages) in a consistent way, while enforcing explicit consideration of assumed market failures.

Next to production technologies and commodity balances, utility maximization is constrained by a cash constraint. This cash constraint only applies to traded and price band commodities:

$$\sum_{p\in P} p^{p}_{hj} q^{p}_{hj} \le \sum_{s\in S} p^{s}_{hj} q^{s}_{hj} + \sum_{ht\in HT} p^{ht}_{hj} q^{ht}_{hj} + \sum_{l\in L} \bar{y}^{l}_{h}\,, \qquad \forall\; h\in H \qquad (3.4)$$

where p_{hj} is the price of tradable commodities. Additional exogenous income may be received from different locations l ($\bar{y}^{l}_{h}$), for example transfers from other households in the village or remittances from outside the village. The exogenous income could also be negative, like for example tax payments.

The last part of the household model consists of nonnegativity constraints on variables and prices:

$$q^{c}_{hj}, q^{i}_{haj}, q^{s}_{hj}, q^{p}_{hj} \ge 0\,, \qquad \forall\; h\in H, j\in J \qquad (3.5a)$$

$$p^{p}_{hj} \ge p^{s}_{hj} \ge 0,\;\; p^{ht}_{hj} \ge 0 \qquad \forall\; h\in H, j\in J \qquad (3.5b)$$

The net marketed surplus can take a negative value (when the household is a net buyer) and thus is not included in (3.5a). Note that in addition to being nonnegative, purchase prices must be higher than selling prices. If purchase prices would be lower than selling prices unlimited amounts would be bought and resold, resulting in an infinite income. Although generally purchase prices will be strictly higher than selling prices, since commodities for which buying and selling prices are equal are included in the set HT, it is possible for these prices to become equal. The reason for allowing this is discussed in the next section on village transactions.

These five equations together describe household behavior and its necessary bounds. The remaining task is to specify the transactions between the households in the village, and interactions with the rest of the world, through trade balances and a balance of payments.

3.5.2 transactions within the village and with the rest of the world

Equivalent to the household part of the model, commodities may have different levels of tradability at the village level. Commodities can be tradable at household level but not at village level. For example, a village land rental market may exist in which only households from the village participate. This implies that land would be tradable at household level but nontradable at village level.

Household tradable commodities have been subdivided in traded commodities, with equal buying and selling prices, and price band commodities, with a wedge between buying and selling prices. A similar distinction can be made at the village level, but this requires some careful thought with respect to the character of the price wedge. If buying and selling prices for commodities traded within the village are not identical, a recipient of the price difference needs to be identified to satisfy the accounting requirements of the village equilibrium model. This could be done, for example by introducing an intermediary household that performs transactions. Viewing within-village transactions as people meeting face-to-face to conclude a transaction, however, it seems more logical to assume that buying and selling prices of transactions within the village are identical. *i.e.* that the amount paid by one household is received in full by another household.

Note that assuming identical buying and selling prices for within village transactions still allows introduction of transaction costs, using the 'iceberg' assumption: part of the purchased or sold commodity 'melts' away. This can be implemented by introducing appropriate coefficients in equation 3.3. Assume for example that the household produces a commodity k that can be consumed, sold and purchased,

$$q^c_{hk} + \alpha^s_{hk} q^s_{hk} \leq q^o_{hk} + \alpha^p_{hk} q^p_{hj} . \qquad \forall\ h \in H, 0 > \alpha^s_{hk}, \alpha^p_{hk} \geq 1 \qquad (3.3^{\$})$$

By introducing 'iceberg' coefficients (α) that are less than one, one unit of produced k yield less than one unit of k for sale. Similarly, one unit of purchased k yields less than one unit of k for consumption. On the other hand, one unit of household produced k yields one unit of household consumed k; there are thus no transaction costs for within household transactions. This thus effectively introduces a price wedge between sold and purchased commodities without having to specify the nature of the transaction costs. This example also illustrates the versatile character of the general village equilibrium model.

Assuming within village transactions to occur at identical buying and selling prices implies village nontradables to be household traded commodities. If household traded commodities can also be traded with the outside world without price wedges, they are classified as village traded commodities. Furthermore, household price band commodities are, by assumption village price band commodities. tradability at village level can thus be modeled with three sets: village traded VT commodities, imported commodities M and exported commodities E.

Since trade among households is assumed to occur at identical buying and selling prices, the implicit assumption is that price band commodities are not traded among households. As a result separate trade balances are needed for bought and sold price band commodities. This yields three different trade balances, where only one (equation 3.3) was needed at the household level:

$$q_j^{vt} \leq \sum_{h \in H} q_{hj}^{ht} \qquad \forall j \in VT \qquad (3.6a)$$

$$q_j^{e} \leq \sum_{h \in H} q_{hj}^{s} \qquad \forall j \in E \qquad (3.6b)$$

$$\sum_{h \in H} q_{hj}^{p} \leq q_j^{m} \,. \qquad \forall j \in P \qquad (3.6c)$$

The first equation (3.6a) specifies that the marketed surplus of the economy of village traded commodities (q_j^{vt}), cannot exceed the sum of the net marketed surplus by the households. Since the net marketed surplus of households can both be negative and positive this equation determines the village or export of the marketed surplus if the household demand does not balance. In case of a closed village market, q_j^{vt} is zero and total demand in the village needs to meet total supply. Equation 3.6 then determines the endogenous (and observable) village price. The other two trade balances are a straightforward summation of export of price band commodities from the village (q_j^{e}) and the import of price band commodities to the village (q_j^{m}). As with the household model tradable commodities are either traded or part of the price band set: *$M \cap VT = \emptyset$, $E \cap VT = \emptyset$.*

Separating the trade balances for bough and sold price band commodities is one way of dealing with price bands. An alternative approach is to allow for trade among households in price band commodities. If such intra-village trade occurs, the price band disappears with an effective village price in between selling and purchasing price of trade with the outside world. Instead of three different equations there combined trade balances can be defined, similar to the household commodity balances:

$$\sum_{h \in H} q_{hj}^{p} + q_j^{e} + q_j^{vt} \leq \sum_{h \in H} q_{hj}^{ht} + \sum_{h \in H} q_{hj}^{s} + q_j^{m} \,. \qquad \forall j \in J \qquad (3.6)$$

The price constraints (3.5b) allow for purchasing prices for households to become equal to the selling price, *i.e.* price band commodities then become identical to traded commodities.

Note that the model uses a trade-pool approach (Ginsburgh and Keyzer, 1997:150). Instead of modeling all bilateral trade flows (which would require indexing of all commodities by source and destination, greatly complicating the model structure) we assume a 'pool' of commodities at the village level to which households sell, and from which they purchase commodities. We thus only need data on how much households are selling and buying inside the village, and we do not need to know from which household they are buying or selling. Equation 3.6 assures that village markets balance, *i.e.* that total sales match total purchases at village level. Imports and exports to and from the outside world also take place from this pool and therefore are not household-specific. This implies that households face identical prices for their imports and exports. Due to this trade-pool approach the additional variables to identify imports, exports, and marketed surplus in do not have a household index.

The last equation of the village equilibrium model specifies a balance of payments for trade with the outside world,

$$\sum_{j\in M}\bar{p}_j^m q_j^m \le \sum_{j\in E}\bar{p}_j^e q_j^e + \sum_{j\in VT}\bar{p}_j^{vt} q_j^{vt} + \sum_{h\in H}\sum_{l\in L}\bar{y}_h^l\,, \tag{3.7}$$

where $\bar{p}_j$ are prices of the village tradables (traded and price-band), which are exogenous to the model. It can generally be assumed that trade by a village with the rest of the world will not affect prices, *i.e.* the 'small country' assumption can be made. The balance of payments follows from the household budget constraints (which can easily be seen by substituting equations 3.6a-c in 3.7), and does not allow the equivalent of a current account deficit at the village level.

Non-negativity restrictions, mimicking those imposed at the household level, complete the village equilibrium model:

$$q_j^m, q_j^e \ge 0 \qquad \forall\, j\in J \tag{3.8a}$$

$$\bar{p}_j^m > \bar{p}_j^e \ge 0,\ \bar{p}_j^{vt} \ge 0\,. \qquad \forall\, j\in J \tag{3.8b}$$

Note that import prices are required to be strictly higher than export prices, even if just by an arbitrary small amount, to avoid re-exporting and infinite income levels.

The above three equations specify transactions between households within the village and transactions with the rest of the world, as well as the necessary bounds on variables. Together with the equations describing household behavior these comprise the main set of equations of the general village equilibrium model. By using sets the model can easily be transferred to different uses, requiring only changes in the set elements to capture widely different economic settings.

3.5.3 placing the village equilibrium model in context

In summary the village equilibrium model developed in this study applies a macro-level general equilibrium model structure, but modified in such a way that the behavior of the households in the model is fully compatible with the rural household literature. The result is a hybrid village model that accounts for interactions among households within the village, while preserving individual rationality. Using a general equilibrium structure, even though there may only be a few local village markets, allows the use of powerful accounting and theoretical consistency checks.

The village equilibrium model contributes to the existing literature on village models by accounting for nonseparability of household decisions. The major adjustment to the Taylor and Adelman (1996) set-up is the specification of production decisions by households. This, at first sight minor, change has considerable implications for both the construction of the village SAM and the calibration of the general equilibrium model. In both cases other procedures than are standard for macro-level models have to be followed. These implications cannot be derived from the stylized application used by Löfgren and Robinson (1999), on which the introduction of nonseparability in the village equilibrium model builds.

The central role of nonseparability in the village equilibrium model means that the second 'shoulder' on which the village equilibrium model is standing are the rural (or farm) household models. Reduced-form and optimization household models indicate the importance of accounting for interactions between production and consumption decisions. The underlying theoretical household model as outlined in Singh, Squire and Strauss (1986a) is used to shape the behavior of the households in the village model.

The household component of the applied village equilibrium model developed in Chapter 5 does not seem like a household model at first sight. Production decisions are based on profit maximization while consumption decisions are based on utility maximization. This suggests a separation of consumption and production decision, but the devil is in the details. Since production is specified by household type and input prices may be household-specific if they are not traded, this specifies a household model as a system of non-linear equations. Although this is not a common way to describe household behavior in the rural household literature, it is completely in line with the underlying theoretical (nonseparable) household model. Moreover it allows a direct translation of macro-level general equilibrium models to the village level, while taking due notice of the impact of nonseparability of production and consumption decisions.

The next chapter provides the first step towards an applied village model by constructing a Chinese village SAM. As discussed in Chapter 2, a multitude of choices regarding conceptualization, interaction, aggregation and dynamics need to be made to arrive at an applied model. As illustrated by the variety of models derived from a single theoretical household model, the choices made in the process of developing an applied model strongly affect model structure and thus model outcomes. Appendix B therefore discusses the steps from a general model as defined in the current chapter to an applied village model. This discussion also motivates choices made in developing the applied Chinese village model of this study and indicates alternative choices. These alternatives may be appropriate if the general village model is used for an applied model in a different setting than the Chinese village economy analyzed in this study.

CHAPTER 4

constructing a chinese village SAM: separability and shadow prices

Constructing a Social Accounting Matrix (SAM) is a crucial step when developing an applied general equilibrium model. The SAM entries (household types, production activities, commodities and so on) determine the contents of the sets of the village equilibrium model, while commodity flows in the SAM provide information on tradability of commodities. This chapter describes the construction of the village SAM on which applied models in later chapters are based. The chapter starts with a short description of the case study village. The main topic of this first section is a grouping of surveyed households into representative household types, that will be used in both the SAM and in the village equilibrium model.

The second section addresses the issue of nonseparability of household decisions. The distinguishing feature of the village equilibrium model developed in this study is the incorporation of the impact of nonseparability on production decisions. Being such a fundamental feature of the model, the claim of nonseparability should be tested empirically.

Impressions of the case study village during the data collection and household survey data, suggested the labor market to be among the imperfect markets. Testing for a relationship between total farm labor and household labor endowment, shows that for the majority of surveyed households separability is rejected, backing the assumptions made in the village equilibrium model. The finding of nonseparability is in line with other studies of Chinese households (see for example Bowlus and Sicular, 2003), but complicates SAM construction. Given nonseparability, labor allocations are based on a household-specific *unobservable* shadow wage. Thus, although the quantities supplied to different activities can be readily derived from the survey data, the price needed to calculate the value flows in the SAM cannot be observed. According to economic theory, the value of labor (or any other input) is equal to the value of its marginal product. Section three therefore estimates an agricultural production function, from which shadow prices are derived. This estimation extends an existing method for estimating shadow wages, by also deriving shadow prices for land and household nontradable intermediate inputs. Apart from providing shadow prices, the estimation provides information on the functioning of the village markets that can be used in the village model.

Having established the main ingredients for constructing a SAM, the fourth section presents the Chinese village SAM. Four groups of households are constructed, grouping households on the basis of draught power and links outside the province. The SAM includes eleven household-specific activities: three crop activities (one-season rice, two-season rice, other crops); three livestock activities (cattle, pigs, other livestock); three off-farm activities (agricultural wage labor inside the village, nonagricultural employment inside and outside the village); and two migration activities (inside the province and outside the province). As the SAM shows, many interactions exist with the outside world, through external inputs, selling of output and outside employment. At the same time, there are a number of local village markets (for agricultural labor, irrigated land, oxen and tractor services), local business activities, and transfers among households in the village.

4.1 the case study village

The applied models in this study are based on household data collected in Jiangxi Province, China. This section will first provide a short general description of the case study village and the collected data. The main topic of this section is a grouping of the surveyed households into representative household types. The household grouping is the first step towards the SAM, that consists of the summed data of individual households constituting a group.

4.1.1 the case study village

Data collection in the case study village formed part of a research project[1] focusing on the impact of economic policy on soil degradation in Jiangxi Province, located in the South-East of China (see Figure 4.1). Jiangxi province is among the poorer provinces of China. It borders both booming coastal provinces and lagging inland provinces. Agriculture plays an important role in Jiangxi, while there is also considerable amount of (temporary) migration in search of employment in the coastal cities.

The research area is located in the North-East corner of Jiangxi Province (see Figure 4.1) where soil degradation (erosion, nutrient depletion, acidification, and soil blocking) is reported to be a problem. In the context of the overall research project, three villages were surveyed, reflecting different environmental issues, levels of market access and geographical circumstances. The villages were selected after an explorative survey of 24 villages in Jiangxi Province, and after consultation with local researchers and government officials.

The case study village used for this study is representative of the plain areas in Jiangxi Province, that are used for rice cultivation. The village has an intermediate level of market access (relative to the other two surveyed villages), located 20 km from the nearest city over sand and tarmac roads. Table 4.1 presents some key characteristics of the village obtained from interviewing the village leader. The roughly 3,000 villagers live in seven hamlets (groups of houses).

As elsewhere in China the land is not owned by the households, but allocated to them under the household responsibility system for periods up to 30 years. This allocation, however, is not completely fixed for this time period; adjustments take place to accommodate demographic

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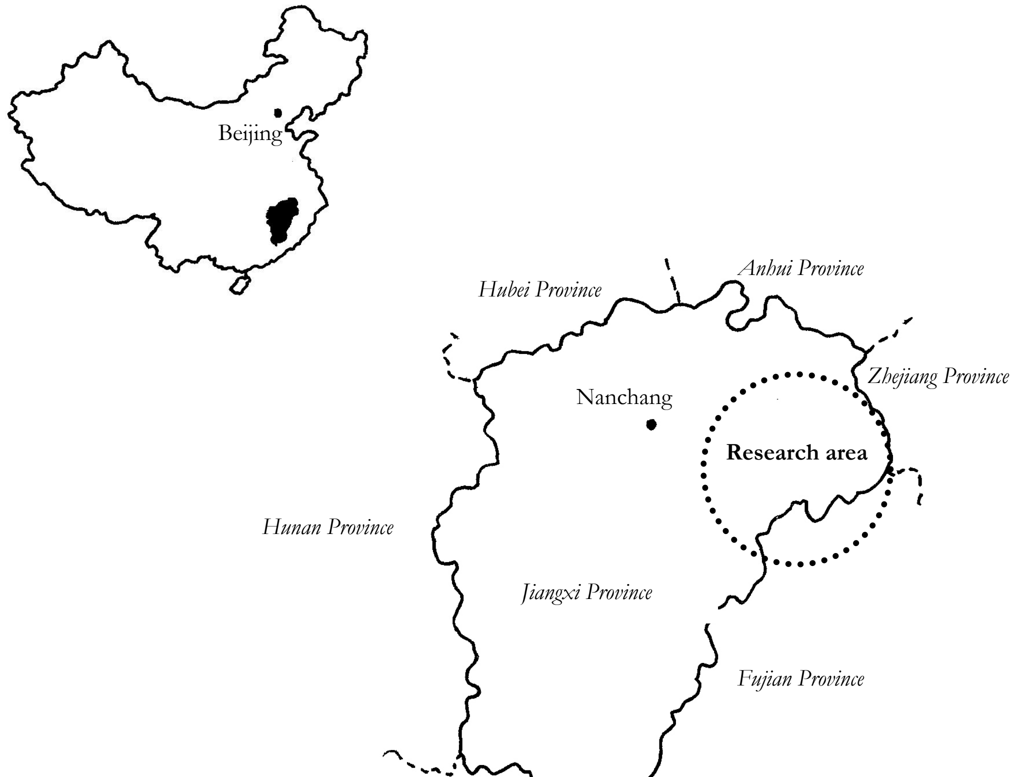
[1] The SERENA project (Strengthening Education and Research in Environmental and Resource Economics at Nanjing Agricultural University) is a cooperation between the College of Land Management at Nanjing Agricultural University, the Development Economics and Agrarian Law Groups of Wageningen University and the Institute of Social Studies in the Hague. The project consists of an education and a research component.

changes. The frequency at which these adjustments occur differ per hamlet. The occurrence of reallocations implies that households not cultivating their land, for example due to off-farm activities, risk loosing their land. Given the insecurity of off-farm employment (rural-urban migration being illegal until recently), most households want to maintain access to their land. As a result some households hiring in land do not pay any rent. This suggests that renting out land primarily serves the purpose of keeping the land cultivated to avoid reallocation, indicating distortions in the land rental market.

Figure 4.1: Location of the research area



Most agricultural land consist of paddy fields, the village being a typical rice-producing village. Some of the households in the village have (partially) switched to the use of tractors instead of draught animals for plowing. Vegetables are grown mostly for own consumption, but some crops (like watermelon, sweet potato and sugar cane) are sold on markets outside the village. The village is located along the bank of a river and is thus susceptible to flooding. Soil compaction (hardening of the soil due to inappropriate fertilizer use) is a common soil degradation issue in Jiangxi, and reported in this village as well.

Table 4.1: General village characteristics

Population	- persons	3200
	- households	730
Village structure	- hamlets	7
	- village groups	22
Land tenure	- allocation criteria	household size, quality, distance
	- frequency of adjustments	3-5 years for small adjustments; 5-10 years for large adjustments
Agriculture	- main crops	rice, vegetables
	- soil degradation issues	soil compaction, limited flooding

The villagers live in hamlets that are scattered around the village area. To account for differences across hamlets in land tenure, available land, and location (some hamlets are across the river, which increases the distance to the nearest town), random sampling was done at hamlet level using a list of registered households from the village administration. The sample size per hamlet reflects the relative size of the hamlet in the total village population. An extensive questionnaire was used to collect all data. To reduce the burden on the farmers and to increase the quality of recalled data, it was decided to conduct the survey in two rounds. Given time and money constraints, this yielded an initial sample of 174 households. The first part of the fieldwork (covering January - July 2000) was conducted in July and August of 2000, the second part (covering July – December 2000) was conducted in February 2001.

When conducting the first survey it became clear that part of the registered households had actually left the village in search for employment elsewhere in China. These households were replaced with other households from the same hamlet. There are no data available from the migrated households. This is most clearly reflected by the difference between land hired in and out for the village as a whole, as will be discussed when constructing the village SAM. From the initial sample of 174 households from the first round, six households had left the village at the time of the second survey. All remaining households participated in the second survey, yielding a sample of 168 households for which data over the year 2000 are collected.

The household questionnaire covered household activities and expenditures. For agricultural activities input and output data were recorded in detail, for off-farm employment the household member involved and the payment received were registered. Data on consumption expenditures, credit, transfers and so on were collected as well. The coverage of the household survey was similar to surveys used elsewhere, apart from explicitly registering source and destination of all commodities (inside hamlet, inside the village, inside the township, inside the province or outside the province). These source and destination data are needed to establish tradability and to construct trade flows in the SAM.

4.1.2 constructing representative households

Only a limited number of household groups are distinguished in the SAM, requiring a grouping of the surveyed households. Classifying households for modeling purposes aims at grouping household together that will respond similarly to policy changes. This grouping has to take place at the start of the modeling exercise when the response of the households is not yet known (Hazell and Norton, 1986:148). Household thus need to be classified on the basis of characteristics expected to strongly affect their policy response. These characteristics should be relatively stable, in the sense of not changing as a result of simulated policy changes. If households would move between groups when external conditions change, classification becomes meaningless. Criteria used for classification should thus be relevant for the behavior of the households, and based on stable features of the household.

General impressions from the village nor a first exploration of the data revealed an obvious criterion to group households. Ownership of a tractor, for example, represents a large capital investment and seemed a promising candidate for grouping. Only five households, however, own a tractor. The relative importance of agricultural activities and off-farm employment, however, differs considerably between households. Households are therefore grouped on their potential for obtaining agricultural and non-agricultural income.

About half of the households own either a tractor or a draught animal. Ownership of draught power is important for agricultural activities. Although there is a village market for draught services, timing of plowing can be crucial for agricultural production. Households owning draught power can be expected to first plow their own fields, before renting draught services to other households. Draught services can also allow households to cultivate larger tracks of land, thus increasing agricultural income. Ownership of draught power (animals or tractors) is thus taken as an indicator of potential for earning agricultural income. Given the large investment associated with the purchase of draught animals or tractors, this indicator can be assumed to be relatively stable when external conditions change.

The potential to earn income from off-farm employment is the second grouping criterion. The first survey revealed that a number of households had left the village in pursuit of employment elsewhere and thus could not be included in this study. Of the surveyed households, 70 percent have members that have left the village in search for outside employment as well (for part or for most of the year). The majority of these household members migrate outside the province; of the surveyed households 65 percent has at least one household member (temporary) migrating outside Jiangxi Province. The widespread involvement in migratory employment reflects findings from other studies on China. The urban jobs are very attractive in terms of earnings, resulting in large scale rural-urban migration (Rozelle *et al.*, 1999a estimate a number of 54 million permanent and 46 million temporary migrants).

Ignoring household preferences which may affect the decision to work off-farm, there are two main factors rationing access to well-paying off-farm employment: social networks and gender. Studies of migration in China indicate the importance of social networks as a source of information and of practical help (Rozelle *et al.*, 1999a; Zhang and Li, 2003; Zhao, 2001). The household survey does not include data on access to a social network outside the village, but has information on the location of off-farm employment and of relatives sending remittances. This information is used to construct a dummy variable measuring whether households have a link outside the province, either through off-farm employment or through relatives sending remittances.

Table 4.2: Characteristics of representative household groups

Link outside province:	*No link*		*Link*		*Total*
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*	
N=	*18*	*23*	*59*	*68*	*168*
Labor:					
Total household size (persons)	3.56 $^{---}$	3.87 $^{---}$	4.69	4.96 $^{+++}$	4.57
	(0.86)	(0.87)	(1.76)	(1.43)	(1.52)
Labor force (male equivalents)	2.32 $^{---}$	2.70 $^{---}$	3.43	3.81 $^{+++}$	3.36
	(0.67)	(0.68)	(1.32)	(1.01)	(1.18)
Fraction male adults	0.36 $^{-}$	0.38	0.40	0.45 $^{++}$	0.41
	(0.13)	(0.15)	(0.17)	(0.17)	(0.17)
Fraction of female adults	0.33	0.34	0.38	0.37	0.37
	(0.15)	(0.14)	(0.14)	(0.13)	(0.14)
Average male education level (years)	5.94	4.89 $^{-}$	5.95	5.69	5.70
	(2.78)	(1.99)	(2.20)	(2.01)	(2.17)
Average female education level (years)	4.76	3.02 $^{-}$	4.30	3.78	3.96
	(2.10)	(2.45)	(2.38)	(2.31)	(2.36)
Land:					
Total contracted land (mu)	6.96 $^{--}$	8.21	9.51	9.33	8.98
	(3.05)	(4.18)	(5.22)	(3.84)	(4.39)
Contracted land per person	2.06	2.06	2.09	1.95	2.03
	(1.05)	(0.87)	(1.12)	(0.81)	(0.96)
Contracted land per male equivalent	3.18	3.01	2.91	2.59 $^{+}$	2.83
	(1.66)	(1.41)	(1.70)	(1.39)	(1.54)
Cultivated land (mu)	7.83	10.53	7.36 $^{---}$	10.63 $^{++}$	9.17
	(4.73)	(5.79)	(6.41)	(6.14)	(6.21)
Cultivated land per male equivalent	3.63	3.89 $^{++}$	2.12 $^{---}$	2.87	2.83
	(2.44)	(2.19)	(1.27)	(1.80)	(1.87)
Off-farm:					
Male agricultural employment (days)	2.72	4.26	0.09 $^{--}$	0.81	1.24
	(6.24)	(12.22)	(0.53)	(4.92)	(5.95)
Female agricultural employment (days)	1.77	0.39	0.02	0.13	0.30
	(5.30)	(1.85)	(0.13)	(0.76)	(1.95)
Male nonagricultural employment,	10.12	3.96	4.45	4.80	5.13
inside village (days)	(15.13)	(12.88)	(13.65)	(12.29)	(13.18)
Female nonagricultural employment,	1.09	2.08	1.73	2.23	1.91
inside village (days)	(4.61)	(8.42)	(6.65)	(9.74)	(8.06)
Male nonagricultural employment,	7.41	7.92	4.15	4.90	5.32
outside village (days)	(12.62)	(11.71)	(11.37)	(13.21)	(12.30)
Female nonagricultural employment,	1.09	0.36	0.94	0.43	0.67
outside village (days)	(4.61)	(1.74)	(4.81)	(3.25)	(3.86)

Table 4.2: Characteristics of representative household groups (continued)

Migration:					
Number of males, inside province	0.06	0.00 $^{----}$	0.07	0.07	0.06
	(0.24)	(0.00)	(0.25)	(0.26)	(0.24)
Number of females, inside province	0.00	0.00	0.07	0.01	0.03
	(0.00)	(0.00)	(0.41)	(0.12)	(0.25)
Number of males, outside province	n.a.	n.a.	0.68	0.84	0.58
			(0.51)	(0.70)	(0.63)
Number of females, outside province	n.a.	n.a.	0.53	0.51	0.39
			(0.75)	(0.56)	(0.61)

Note: standard deviation in parentheses; significance of t-tests for difference with other households reported in terms group mean compared to mean other groups ($^{---}$ less than mean at 1 percent level; $^{--}$ less than mean at 5 percent level; $^{-}$ less than mean at 10 percent level; $^{+++}$ more than mean at 1 percent level; $^{++}$ more than mean at 5 percent level; $^{+}$ more than mean at 10 percent level); n.a. =not applicable.

The location of off-farm employment and of relatives sending remittances is used since it captures access to outside province employment, with high earnings and a loss of labor for farm production (distance does not allow a frequent return to the household to participate in farming). Furthermore, establishing a connection outside the province is more difficult than establishing one inside the province, and can thus assumed to be relatively stable over time.

The second factor limiting access to off-farm employment is gender. Due to a combination of physical requirements of jobs and cultural factors, young males are the most likely candidates for (temporary) migration. In this sense China is not different from other parts of the world. At the same time there are indications that off-farm employment opportunities for women are rapidly increasing (Rozelle *et al.*, 1999a), which would make the gender composition of the households less of an issue.

Since all households have at least one adult male that could engage in off-farm employment, gender composition of the household will therefore not prevent access to off-farm employment. Only the social network dummy is therefore used to group households in terms of off-farm employment opportunities. Since the gender composition of the households may affect the response of households to increases in off-farm employment opportunities, male and female labor endowments are separate entries in the SAM. This allows modeling of the impact of differential access to off-farm employment in the village equilibrium model.

Using the two criteria, owning draught power and presence of a link outside the province, we arrive at four types of households: no outside link and no draught power (18 households), no outside link and with draught power (23 households), outside link and no draught power (59 households), outside link and with draught power (68 households). A number of patterns emerge from the key characteristics of the household types, as presented in Table 4.2.

The available labor force per household is calculated by summing the number of males, the number of females weighed by 0.8 and the number of adolescents (male and female) by 0.5. The weights were taken from another study of Chinese households (Bowlus and Sicular, 2003), since insufficient data were available to estimate differences in agricultural productivity by gender.

Household characteristics in terms of labor endowment show that households with an outside link are larger, both in terms of household size as labor force[2]. These households also have a higher fraction male adults. In terms of education there is no clear pattern. It thus seems that the availability of more male labor has allowed these households to invest in establishing an outside link.

Household characteristics in terms of land endowment show, as expected, no differences between the households in land per person. The significantly smaller amount of contracted land of the household with no link and no draught power is due to its smaller household size. Similarly, the higher land endowment per labor force of the households with a link and draught power is due to its higher fraction of male adults.

The results in terms of contracted land are the direct result of the land tenure system in China, in which the collectively owned land is allocated based on household size. Whereas contracted land is determined by the allocation mechanism, amounts cultivated land[3] may differ because of hiring in and out of land, and because of double-cropping. Irrespective of having a link outside the province, households owning traction cultivate about 40 percent more land than households not owning traction. Grouping on traction ownership of traction thus succeeds in capturing differences in agricultural income of households.

Household characteristics in terms of local of-farm employment and (temporary) migration indicate different types of off-farm activities for households without and with an outside link. Grouping households on an outside link thus succeeds in capturing differences in off-farm employment. Households without access to outside province employment are much more active in local off-farm employment, both inside and outside the village. The high involvement in village agricultural labor by households without an outside link suggest that they area hired in by households which have migrated household members. The household with no link and no traction also has a high involvement in village nonagricultural employment. This household may substitute limited opportunities for earning agricultural income and migration by specializing in local production activities.

Table 4.2 provides a first impression of differences between household types, providing a background for the separability and shadow price estimations. Differences between the household types will be addressed in more detail when discussing the village SAM in Section 4.

4.2 testing nonseparability of household decisions

Nonseparability of household decisions is a crucial assumption in the village SAM and equilibrium model. If household decisions are separable, production can be analyzed at sector instead of household level, greatly simplifying both SAM and model. The first step in constructing the SAM is therefore to empirically assess nonseparability. We first motivate the hypothesis that household decisions in the village are nonseparable, drawing on other studies of Chinese households and on patterns in the household data. We then proceed by formally testing the separability hypothesis.

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[2] Unless indicated otherwise, throughout this study household size includes household members that have (temporary) migrated.

[3] Cultivated land in Table 5.2 is the simple sum of area cultivated with rice or other crops. It includes contracted and rented land, and may include double cropping.

4.2.1 hypothesizing nonseparability of household decisions

In the context of rural households in developing countries there are two prime candidates for causing nonseparable household decisions (Benjamin, 1992:293):

1) incomplete labor markets: constraints on hiring in or hiring out of labor
2) imperfect substitutability of household and non-household labor.

China is generally considered to have a rural labor surplus, estimated to be as large as 38 percent of the rural population in 1992 (Sabin (1995) cited in Cook, 1999:41). Rawski and Mead (1998), however, argue that the reforms in China have led to a development of labor markets, linking rural households to the national labor market. Part of their argument is based on deficiencies in official statistics, overestimating agricultural employment. Whatever position taken with respect to the size of the surplus, constraints in off-farm employment opportunities seem to be the most relevant for China, as opposed to constraints in hiring farm labor.

If the off-farm employment constraint is binding, the household would be willing to supply more labor to the market than it can supply (Benjamin, 1992:293):

$$L^s(\overline{w},Y;\gamma) > L^f(\overline{w},\overline{A}) + L^o, \tag{4.1}$$

where $L^s(\overline{w},Y;\gamma)$ is the labor supplied by the household, given the market wage ($\overline{w}$) exogenous to the household, the household's full income (*Y*) and a set of household characteristics (γ); $L^f(\overline{w},\overline{A})$ is the demand for farm labor *at the going market wage*, assuming (for simplicity) land ($\overline{A}$) to be fixed, L^o is the amount off-farm work the household may engage in. By assumption the household cannot expand its off-farm labor supply, but it can expand its supply of labor *beyond* the point where the marginal productivity equals the market wage, depending on production technology and household preferences.

A binding off-farm constraint has two implications in the context of constructing a village equilibrium model. First, with a binding off-farm labor constraint, the market wage does not equal the household shadow wage, *even* if the household engages in off-farm activity. Second, the market wage provides an upper bound on the household shadow wage.

A second cause of nonseparablity could be imperfect substitutability of household and non-household labor. Non-household labor, for example, could be less efficient due to incentive problems. According to the survey data a few households hire in labor, but most non-household labor consists of exchange labor. This exchange labor is primarily used for harvesting and transplanting that are peak periods in agricultural production. The very limited use of non-household labor (apart from peak periods), resonates with assuming a surplus of rural labor and restricted access to off-farm employment.

Another clue pointing towards surplus labor is large difference between demand and supply of irrigated land[4]. Renting of irrigated land recorded by the survey primarily consists of hiring in land. Summing over all households a total area of 469 mu is hired in, while only 42 mu is hired out. There could be an incentive to not report the hiring out of land, because of the risk loosing the land during the next allocation of land. Questions on land tenure and cultivated areas were asked in two different survey rounds, half a year apart. Cross-checking these two sets of answers on cultivated

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[4] Since irrigated land accounts for 95 percent of all land transactions discussions of the land market refer to irrigated land, unless indicated otherwise.

irrigated area were found to be matching. Furthermore, input per unit of land does not indicate any households over-reporting their cultivated area.

Excluding underreporting of hired out land, the unbalanced land market can only be explained by the bias in the household sample that excludes migrated households[5]. These households are likely to rent out their land to assure cultivation[6], reducing the risk of loosing the land during a next round of reallocations. Land tenure policies have changed considerably in the past two decades. According to formal policies land is contracted for 30 years without reallocations. Although use rights can be rented in and out within this 30 year period, the law is not clear about the type of transactions that are permitted. Furthermore, unclear ownership rights of the land and lack of implementation of state policies, result in a very ambiguous land tenure system (Ho, 2001; Ho and Lin, 2003). According to the survey data land reallocations are still occurring in the village (see Table 4.1), and migrating households thus still have an incentive in keeping their land cultivated to avoid loosing it in a next round of reallocations.

The unbalanced land market and the high number of households renting in land (46 percent of the surveyed households do so) signals a strong demand for land. This again points towards a labor surplus in the village. Based on these considerations the hypothesis is formulated that household decisions are nonseparable, with as a main motivation limited off-farm employment possibilities.

4.2.2 testing separability of household labor decisions

Although assumptions regarding separability of household decisions are made frequently, formal testing of this assumption is less common. Here we follow the approach for testing separability developed by Benjamin (1992). This test hinges on the distinction between supply and demand in the neoclassical model. If decisions are separable, households allocate factors to maximize profits separately from their own factor endowment. Excess factors are sold on the market, while factors short in supply are purchased. Controlling for the off-farm wage (representing the opportunity cost of farm labor), supply side variables (like household size) should thus not influence the demand for labor. This provides an operational test of separability, consisting of testing whether the coefficients of supply side variables are equal to zero (separability) or not (nonseparability) in farm labor demand.

The empirical model used here combines elements of the models estimated by Benjamin (1992) for Javanese farmers, and by Bowlus and Sicular (2003) for Chinese households:

$$\ln L^f = \alpha + \omega \ln W + \alpha \ln A + \delta_0 \ln N + \sum_{i=1}^{C} \delta_i \frac{n_i}{N} + \sum_{i=1}^{Q} \phi_i X_i + \sum_{i=1}^{P} \varphi_i T_i + \varepsilon \, , \tag{4.2}$$

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[5] This bias is expected to be considerable given the number of households that needed to be dropped from the second survey round. Of the 174 households included in the first survey round, just half a year later 6 households were already found to have left the village (3.4 percent of the initial sample). The difference between the official village administration and number of households actually present in the village at the time of the survey, is the cumulative sum of migration over a number of years. This will represent a considerable share of the registered number of households and thus accounts for the large gap between demand and supply of irrigated land.

[6] Land could also be hired in from the village. Although the village may keep some land to facilitate land reallocations, the excess amount of land rented in is too high (28 percent of contracted land) to be accounted for by renting from the village.

where L^f is total on-farm labor demand, W is wage, A is cultivated area, N is household size, n_i household composition structure variables (*e.g.* number of adult females), X_i additional variables to control for human capital quality differences, T_i additional variables to control for technology and land characteristics, and ε is an error term.

The δ capture the effect of supply side variables on labor demand; δ_0 is the elasticity of labor demand with respect to household size; δ_i is the elasticity of labor demand with respect to household composition. The null hypothesis is that household decisions are separable. This implies that supply side variables do not affect labor demand: $\delta_0 = \delta_i = 0$. Rejection of this null hypothesis implies nonseparability of household labor decisions.

Table 4.3: Data used for testing separability (descriptive statistics)

Symbol	*Description*	*Mean*	*Standard deviation*
L^f	Total farm labor demand (person days)	208.41	112.03
W	Average wage (yuan/hour)	11.25	16.40
A	Total cultivated area (mu)	9.21	6.23
N	Household size (persons)	4.57	1.53
n_i/N	Household composition:		
	- fraction female adults (16-66)	0.37	0.14
	- fraction children (0-11)	0.09	0.14
	- fraction adolescents (12-15)	0.09	0.15
	- fraction elderly (67 and up)	0.04	0.10
X_i	Quality human capital :		
	- average age adults	36.33	6.08
	- average education adults (years)	5.00	1.78
T_i	Technology and land characteristics:		
	- fertilizer price (yuan/jin)	0.65	0.11
	- herbicide price (yuan/bag)	1.57	0.32
	- fraction irrigated land in total area	0.86	0.10

Descriptive statistics of the data used in the estimation are presented in Table 4.3. The boundaries of the age categories are based on detailed survey information on the main occupation of household members. An average wage is calculated by dividing all income from off-farm employment (excluding migration, for which no wage data are available) by the number of hours worked off-farm. The average wage covers income earned by self-employment. The survey did not register data on other inputs than labor, all income derived from self-employment is therefore assumed to accrue to labor. This causes the high average wage in Table 4.3 which overestimates the return from off-farm employment.

Even with separability, farm management (including labor use) can be affected by the quality of human capital. Since adults take the major share of labor supply, the average age and education of adults are used as human capital indicators. Both fertilizers and herbicides can substitute for labor in farm production. Within the bounds of the production technology, this substitution depends on the relative prices of labor and the external inputs. Fertilizer and herbicide prices are therefore included as technology characteristics. Total cultivated area aggregates irrigated area cultivated with rice, and non-irrigated area cultivated with other crops. These are likely to have different labor requirements, and therefore the fraction irrigated area (*i.e.* area cultivated with rice) is included as well.

Table 4.4: Results of estimating separability (dependent: log farm labor)

		Wage included (N=79)	*No wage included (N=162)*
W	Log wage	-0.088 **	
		(0.036)	
A	Log area	0.711 ***	0.648 ***
		(0.095)	(0.064)
N	Log household size	0.177	0.295 **
		(0.183)	(0.137)
n_i/N	Fraction adult females	0.328	0.186
		(0.424)	(0.297)
	Fraction children	-0.120	-0.492 *
		(0.380)	(0.283)
	Fraction adolescents	0.246	0.018
		(0.359)	(0.006)
	Fraction elderly	0.016	0.009
		(0.756)	(0.392)
X_i	Average adult age	0.016 *	0.018 ***
		(0.009)	(0.006)
	Average adult education	-0.068 **	-0.053 **
		(0.027)	(0.020)
T_i	Log fertilizer price	-0.119	-0.103
		(0.273)	(0.179)
	Log herbicide price	-0.117	-0.065
		(0.236)	(0.167)
	Fraction irrigated area	-0.735	-0.393
		(0.554)	(0.355)
	R^2	0.586	0.523
	Test of null hypothesis of separability	F(5,66)=0.47	F(5,150)=1.89 *

Note: all estimations include a constant; standard errors are in parentheses; * indicates significance at 10% level, ** at 5% level, *** at 1% level.

Table 4.4 presents the results of estimating separability. The first estimated model includes all variables discussed above. Less than halve of the sample is involved in (non-migratory) local off-farm employment and has wage data, thus reducing the sample to 79 observations. There is a significant (at the 5 percent level) negative wage elasticity of –0.09. More importantly in the present context, none of the household size and composition variables are significant. Consequently, the null hypothesis of separability is not rejected, as reported in the last line of the table. For households involved in local off-farm employment, the hypothesis that restricted off-farm employment causes nonseparability is thus rejected.

The aggregation of own business activities and non-agricultural wage labor may cause the rejection of nonseparability. Households with own businesses can most likely increase their off-farm labor time, which could absorb excess labor. Testing separability for households with and without own businesses (not reported), however, did not yield differences between these two groups.

The first model only refers to the subset of households engaged in off-farm employment. Since this accounts for only halve of the surveyed households, we need to assess whether the result from the first model holds for the other households as well. A second model is estimated, identical to the first model except for dropping the wage variable, increasing the sample size to 162 observations[7] (second column in Table 4.4).

For the sample as a whole separability is rejected: coefficients of household size and composition variables are no longer jointly zero. In particular, household size and the fraction of children are significant: larger households use more farm labor, while a higher proportion of children reduces the use of farm labor. These results comply with restricted off-farm labor opportunities and an adult labor surplus.

Results for variables other than household size and composition are consistent across the two equations. Cultivated area is the prime determinant of labor used in farming; whether this is irrigated land does not significantly affect labor use. The two technology indicators, fertilizer and herbicide prices, are not significant in any estimation. Substitution of external inputs for labor thus does not seem to play a role of importance.

Human capital indicators are significant in all equations. Increased education reduces the use of household labor. One explanation is that educated household members could be more efficient, requiring less time. Alternatively, educated household members may be more likely to obtain off-farm employment. This would reduce the household labor surplus and thus farm labor use, compared to households with a less educated labor force. The positive sign for age suggests older household members to be less efficient that younger ones. Alternatively, older household members are less likely to find off farm employment, increasing the surplus of labor compared to younger households.

The difference in separability tests for the two models corresponds to the findings of Carter and Yao (2002). Using village- and household-level data for China they find that market imperfections affect households differently. Some households may be constrained, while others are not. A global test for separability obscures differences among households, and may lead to wrong conclusions for subsets of households.

The main conclusion at this point is a rejection of the separability for the sample as whole. The finding that for the subset of households engaged in off-farm employment separability is not rejected, can be taken as a confirmation of this hypothesis that nonseparability is mainly due to limited off-farm employment possibilities.

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[7] Missing observations for fertilizer and herbicide prices leads to six households being dropped from the sample.

4.2.3 testing separability of household labor decisions by representative household groups

Separability was tested to serve as an input in SAM and village equilibrium model construction. Finding separability to differ across groups of households raises an important question: are labor decisions separable for the four representative household types?

Households are grouped on the presence of a link outside the province and on the ownership of draught power (animals or tractors). Both of these indicators are interacting with the amount of surplus labor that may be employed at the farm. Contacts outside the province increase the opportunities for migration, reduce the surplus labor force, and increase the likelihood of separability. Draught power, on the one hand, can substitute for labor. Ownership of draught power could thus increase the labor surplus, and increase the likelihood of nonseparability. On the other hand, households may invest in draught power because they are having a labor shortage, in which case owning draught power increases the likelihood of separability. The net impact of the grouping on separability therefore seems ambiguous.

To test for separability by household group we follow the approach of Bowlus and Sicular (2003), defining household size and composition variables group-specific. The number of households in each group varies from considerably, from 18 to 68. As a result there are a limited number of observations, especially for the two household types with no link outside the province (18 and 23). To reduce the number of variables to be estimated by group, the fractions children, adolescents and elderly are aggregated into a new variable, dependents. Furthermore, the technology indicators were consistently insignificant in the estimated models above, and are therefore dropped from the group-specific models.

To check consistency of the results after reducing the number of variables, the model is first estimated without distinguishing household groups. Results are reported in the first column of Table 4.5. The results are similar to the results of the estimation without wages (second column in Table 4.4). Coefficients differ slightly, but the signs are identical as is the pattern of significance of variables. Most important, the simplified model reaches the same conclusion as the model in Table 4.4, rejecting separability for the sample as a whole.

Using the simplified equation as a starting point, household size and composition variables are made household group specific. Subsequent testing for separability by household group yields the following results:

a) no draught power, no link outside the province: separable
b) draught power, no link outside the province: separable
c) no draught power, link outside the province: nonseparable
d) draught power, link outside the province: nonseparable.

From these results we can first of all conclude that owning draught power does not affect separability. Second, having a link outside the province yields nonseparability of farm labor, while separability was expected.

Bowlus and Sicular (2003) explain a similar unexpected result (nonseparability in land abundant villages) by assuming that relative labor shortage induces nonseparability. Such an argument could be invoked here as well, arguing that migration of household members reduces the available labor force to such an extent that the household becomes nonseparable because of a shortage of labor.

The results from the first test of separability (Table 4.4), combined with the household characteristics (Table 4.2) suggest an alternative explanation. The first test of separability was restricted to households involved in off-farm employment, and did not reject separability. Engagement in off-farm employment thus seems to provide an outlet for surplus labor, resulting in separability. The household characteristics in Table 4.2 show that household without an outside link are much more active in local off-farm employment. Not rejecting separability for households without an outside link could thus be explained by their involvement in local off-farm employment.

The two alternative explanations of nonseparability of households with an outside link, and separability of households without such a link are tested by re-estimating the first model reported in Table 4.4. The sample of households is again restricted to the households with local off-farm employment for which an outside wage is observed. Different to the reported estimation in Table 4.4 the households are subdivided in two groups, with and without an outside link. The results (not reported) indicate separability for both groups. This confirms that it is the involvement in local off-farm employment that drives the result of separability for households without an outside link, and thus not the presence of the link.

Households that have an outside link, and are involved in local off-farm employment, are found to be separable as well. These form about a third of the households with an outside link (as opposed to being about two-thirds of the households with no link) and therefore the group with an outside link as whole is found to be nonseparable. Note that this finding illustrates the loss of individual detail when working with aggregate groups.

The investigation of the driving force for the unexpected pattern in separability also shows that labor surplus causes the nonseparability. If migration would reduce the available labor to such an extent that a shortage occurs (the first explanation of the separability results given above), the households with an outside link and local off-farm labor would have been nonseparable. The off-farm employment would have aggravated the labor shortage resulting from migration. The finding that households with an outside link and local employment are separable indicates that involvement in migration does not exhaust the labor surplus.

In summary, the study of the separability of household decisions has yielded three important findings. First, household decisions for the sample as a whole are nonseparable. This corresponds to the findings of Bowlus and Sicular (2003), also rejecting overall separability. We thus share their conclusion that, despite considerable reforms, Chinese factor markets remain underdeveloped. As a result households are restricted in their off-farm employment possibilities, resulting in the use of household labor beyond the point where the marginal return equals the off-farm wage.

Second, testing for separability by representative household groups indicates different approaches in dealing with the labor surplus. Households without a link outside the province are more involved in non-migration off-farm employment. These employment opportunities are in or relatively close to the village, and the off-farm employment can apparently be increased relatively easy if necessary. Households with a link outside the province seem to have all their cards on migration, being much less involved in local employment. Since migration cannot be as easily be expanded as nearby employment, the net effect is that labor decision of these households are nonseparable. These households are the largest group in the village, and as a result decisions of 66 percent of the surveyed households are nonseparable.

Table 4.5: Estimation results of testing separability by household group (dependent: log farm labor)

		Simplified equation (N=166)	*Group specific variables (N=166)*
A	Log area	0.645 ***	0.639 ***
		(0.061)	(0.068)
N	Log household size	0.340 **	
		(0.133)	
	- no draught power, no link outside province		0.337
			(0.422)
	- draught power, no link outside province		-0.084
			(0.359)
	- no draught power, link outside province		0.388 **
			(0.190)
	- draught power, link outside province		0.314 *
			(0.182)
n_i/N	Fraction females	0.081	
		(0.293)	
	- no draught power, no link outside province		-0.668
			(0.866)
	- draught power, no link outside province		0.968
			(0.811)
	- no draught power, link outside province		0.314
			(0.182)
	- draught power, link outside province		0.343
			(0.424)
n_i/N	Fraction dependents (children, adolescents, elderly)	-0.367 *	
		(0.221)	
	- no draught power, no link outside province		0.274
			(0.909)
	- draught power, no link outside province		0.797
			(0.709)
	- no draught power, link outside province		-0.643 *
			(0.365)
	- draught power, link outside province		-0.563
			(0.373)
X_i	Average adult age	0.019 ***	0.024 ***
		(0.006)	(0.006)
	Average adult education	-0.064 ***	-0.061 ***
		(0.020)	(0.022)

Note: all estimations include a constant; standard errors are in parentheses; * indicates significance at 10% level, ** at 5% level, *** at 1% level.

Table 4.5: Estimation results of testing separability by household group (continued)

R^2	0.531	0.534
Test of null hypothesis of separability	F(3, 159)=3.22 **	
- no draught power, no link outside province		F(3, 150)=1.62
- draught power, no link outside province		F(3, 150)=1.32
- no draught power, link outside province		F(3, 150)=2.69 **
- draught power, link outside province		F(3, 150)=2.66 **

Third, the importance of a labor surplus implies that there is a potential demand for land. At the same time, the separability found for households with off-farm employment suggest that they could be willing to supply land to the village market, having alternative options for employing labor. Based on this one would expect a renting of land by households with local employment to households without such employment. The data however show that it is mainly the households with a link but without draught power that are renting out land[8]. For this group of households separability is not rejected and it is the group with the least amount of off-farm employment. This suggests that the institutional framework, especially fees that need to be paid for formal rental arrangements and for reallocations of land, hamper the supply of land. The land market seems therefore constrained from the supply side.

4.3 estimating shadow prices for SAM construction

Nonseparability of household decisions implies presence of shadow prices that cannot be observed. The village SAM, however, is constructed in value terms and thus requires estimation of shadow prices. In this section we derive shadow prices for household nontradables (non-irrigated land, manure and crop residues used as animal feed) and for household tradables with market imperfections (household labor, irrigated land).

4.3.1 an empirical approach to deriving shadow prices

The approach to estimating shadow prices builds on the work by Jacoby (1993) and Skoufias (1994) on estimating shadow wages. This approach is founded upon the standard result from economic theory that, in equilibrium, the wage equals the marginal product of labor. The first step in the analysis is to estimate an agricultural production function. This production function is then used to estimate marginal products for the individual households. Equality of price and marginal product is a general result from economic theory, not limited to labor. The estimation in this study extends earlier work on shadow wages, by estimating shadow prices for all agricultural inputs with an

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[8] These households are clearly over-represented in the group of households renting out land: representing only 35 percent of the households in the village, they account for 65 percent of the households renting out land.

unobservable shadow price. Furthermore, use of different technologies by different household groups is tested.

Production functions can be estimated in dual or primal form. The dual approach looks at production in terms of demands, prices, costs and profits, which seems more natural to economics than analyzing technical production functions. It has been the dominant approach in production economics since the late 1960s (Chambers, 1997:1-5). The primal approach looks at production in terms of a technical relation, irrespective of the economic (price) environment. A main reason for the shift towards the dual approach is the possible endogeneity of quantities of inputs (while their prices can generally be considered exogenous), rendering a primal estimation inconsistent. Mundlak (1996), however, argues that the dual estimator does not use all available information by only considering prices, which may lead to sizeable losses in statistical efficiency. As a result he argues that in general the primal estimator is superior to the dual estimator. Comparing primal and dual estimators, Coelli and Cuesta (2001) arrive at the same conclusion.

The focus of this section is on obtaining shadow prices that cannot be observed. Since the dual approach relies on prices, we have no choice but to employ a primal approach. Given the findings of Mundlak (*ibid.*) and Coelli and Cuesta (*ibid.*) we neglect possible endogeneity of inputs and proceed by estimating a technical relation between agricultural inputs and outputs.

The households in the sample are involved in a number of diverse agricultural activities. In the SAM these are aggregated into three crop activities (one-season rice, two-season rice, other crops) and three livestock activities (cattle, pigs, other livestock). Assuming that households equalize the marginal products across commodities, we estimate an aggregated agricultural production function. This is the same approach as taken by other empirical studies of shadow wage (Cook, 1999; Jacoby, 1993; Skoufias, 1994). In the present context it has the additional advantage of yielding a single price for each commodity on the 'household market', facilitating the incorporation of the results in a general equilibrium framework[9].

The next issue that needs to be resolved is choosing a functional form from a wide range of possible specifications (see Griffin *et al.*, 1987 for an excellent overview of the characteristics of different functional specifications). A flexible functional form, like the translog function, can be interpreted as a second order approximation to an unknown production function (Denny and Fuss, 1977). To exploit this flexibility, however, a large number of parameters needs to be estimated, even with a limited number of explanatory variables. In the present context we are not only interested in estimating the average shadow prices over the whole sample, but also in testing whether there are significant differences in production technology (and thus marginal product) between households groups. Since the smallest household group only has 18 observations, we therefore opt for a Cobb-Douglas specification[10].

The objective of the estimation is to obtain unobservable shadow prices. In contrast to other studies (like Cook, 1999; Jacoby, 1993; Skoufias, 1994) we are not only after the shadow wage of household labor. The estimation of separability pointed towards a supply-constrained market for irrigated land. A similar argument as with labor can then be used to argue for a shadow price of land, even if households hire in land. If households are constrained by the supply of irrigated land,

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[9] With different prices, an explanation for the differences needs to be modeled in order to satisfy the general equilibrium constraints.

[10] The Cobb-Douglas specification was tested for omitted variables using the Ramsey regression specification error test. The results did not reject the Cobb-Douglas as the appropriate form. A one was added to zero entries. This did not bias the results (checked through dummies, as described in Battese, 1997).

there is no reason to expect equalization of the returns of own and hired in land. Since the constraint now occurs at the supply side (as opposed to the demand side, as with labor), the household shadow price of land is expected to be higher than the market price, and may vary across households.

Next to household labor and irrigated land, the household survey data indicate presence of three household nontradables: non-irrigated land, manure applied to crops, and crop residues fed to animals. These three commodities are not traded by the households, and thus no prices are observed.

Next to the tradables with imperfect markets (household labor, irrigated land) and household nontradables (non-irrigated land, manure, crop residues), the marginal productivity of exchange labor is estimated. Exchange labor is not exchanged on a one-on-one basis, *i.e.* exchanging exact amounts of labor, but involves a mixture of payments in food, crop output and labor. Exchange labor could also have a different productivity than household labor, because of monitoring issues, or because it is used for specific activities. These specific activities (transplanting and harvesting) are likely to have a different productivity than the average productivity of household labor used for all production activities.

Apart from nontradable or imperfectly tradable commodities, the households use tradable inputs like seeds, fertilizer, herbicides, pesticides and so on. Because of the limited number of observations in some of the household groups, all tradable inputs are lumped together using their monetary values[11] to reduce the number of variables in the model. The cross-section character of the data does not allow to control for fixed effects, like differences in human capital across households. As when testing separability, average adult age and average education of adults are therefore used as proxies for human capital.

The above discussion can be summarized in the following empirical model:

$$\ln Y = \alpha_h + \sum_{h\in H}\sum_{i\in I}\beta_{hi}\ln N_{hi} + \sum_{h\in H}\gamma_h \ln T_h + \sum_{i\in I}\eta_i M_i + \varepsilon, \tag{4.3}$$

where Y is the gross value of agricultural output, N_{hi} are quantities of nontradable inputs, T_h is the total input of tradables in monetary terms, M_i are the proxies of management ability and ε is an error term. Inputs are defined by representative household type (h) to allow for different technologies across household types. Households with a link outside the province, for example, may have access to information not available to the other households. Making inputs household-specific allows for testing whether the coefficients are equal across groups.

Since output is expressed in monetary terms, shadow prices can be directly derived from the first order derivative of (4.3):

$$\hat{P}_{khi} = \beta_{hi}\frac{\hat{Y}_{kh}}{N_{khi}}, \tag{4.4}$$

where $\hat{P}_{khi}$ is the estimated shadow price for commodity i for household k belonging to group h and $\hat{Y}_{kh}$ is the fitted value of output. Note that the production function specified in (4.3) assumes

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[11] An estimation for the sample as a whole with disaggregated tradable inputs (not reported) yielded similar results as the aggregated estimation.

that households within a group of representative households use the same production technology. Even when employing an identical production technology, differences in relative prices (for example due to different endowments) may lead to households choosing different points along this production function. Therefore for each individual household k the shadow price of nontradable inputs is calculated, based on their actual input levels. The shadow price for each representative household group is then calculated as the average of the shadow prices of the individual households in each group.

Table 4.6: Data used for estimating shadow prices (descriptive statistics)

Link outside province:	*No link*		*Link*		*Total*
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*	
Gross agricultural income[1] (1,000 yuan)	6.83	9.01	7.35	10.34	8.74
	(3.05)	(4.61)	(4.70)	(5.06)	(4.88)
Cultivated irrigated land (mu)	6.76	9.21	6.44	9.53	8.13
	(3.98)	(4.99)	(6.08)	(5.67)	(5.71)
Cultivated non-irrigated land (mu)	1.07	1.32	1.20	1.19	1.20
	(1.50)	(1.18)	(1.06)	(0.97)	(1.09)
Household labor use (days)	152.89	216.94	177.01	238.74	205.18
	(70.69)	(121.13)	(105.43)	(114.69)	(112.41)
Exchange labor use (days)	3.43	3.00	3.94	4.40	3.94
	(4.52)	(4.82)	(5.75)	(9.17)	(7.12)
Hired labor use (days)	2.79	0.34	2.77	1.22	1.80
	(4.74)	(1.22)	(7.83)	(6.52)	(6.43)
Manure (1,000 jin)	1.92	1.54	1.2	2.42	1.84
	(3.48)	(2.64)	(2.85)	(4.03)	(3.43)
Crop residues fed to animals (1,000 jin)	5.06	14.556	3.41	9.32	7.57
	(5.70)	(15.43)	(6.98)	(9.54)	(10.18)
Tradable inputs (1,000 yuan)	4.62	4.34	5.34	4.48	4.77
	(4.81)	(3.47)	(6.10)	(3.79)	(4.75)
Average age adults (years)	38.57	34.04	36.32	36.08	36.15
	(9.71)	(5.23)	(5.50)	(5.09)	(5.96)
Average education adults (years)	5.25	4.19	5.35	5.04	5.05
	(2.22)	(1.65)	(1.85)	(1.49)	(1.75)

Note: a mu is 1/15 hectare, a jin is 500 gram; standard deviation in parentheses.

[1] Sum of output value of crop and livestock activities. Output of livestock is the value of produce in a single year, plus 20% of the value of the animal stock (Jacoby, 1993:910). Estimation results are not sensitive to assuming a different appreciation rate for livestock.

4.3.2 estimating shadow prices

Table 4.6 presents descriptives of the data used for the shadow price estimation. The distinction between irrigated and non-irrigated land corresponds to the distinction between rice (one-season and two-season) and other crops. The labor use has been disaggregated into household labor, exchange labor and hired labor. Hired labor is a tradable with an observed price. Given the assumed surplus of labor, households that are hiring in labor could be using a different technology. To control for this possibility hired labor has been separated from other tradable inputs.

First a model allowing for different technologies across households was estimated (not reported). Testing did not reject identical coefficients for all households. Households can thus be assumed to use the same production technology. Table 4.7 presents the results of estimating a production function for the sample as a whole assuming a single technology for all households.

Table 4.7: Estimation results shadow prices (dependent: log value of agricultural output)

	Single technology
Intercept	6.027 ***
	(0.376)
Log cultivated irrigated land (mu)	0.510 ***
	(0.057)
Log cultivated non-irrigated land (mu)	0.157 **
	(0.071)
Log household labor use (days)	0.115 *
	(0.060)
Log exchange labor use (days)	-0.026
	(0.023)
Log hired labor use (days)	-0.047
	(0.034)
Log manure (jin)	0.017 *
	(0.010)
Log crop residues fed to animals (jin)	0.012
	(0.007)
Log tradable inputs (yuan)	0.084 **
	(0.033)
Average age adults (years)	0.010 **
	(0.005)
Average education adults (years)	0.005
	(0.016)
R^2	0.68
N	164

Note: standard errors in parentheses; * indicates significance at 10% level, ** at 5% level, *** at 1% level.

Coefficients have the expected positive signs, except for hired labor and exchange labor (for which the coefficients are not significant). Since it is unlikely that hiring in labor will actually reduce output, the negative coefficient is taken to indicate that households hiring in labor are less involved in agriculture than households not hiring in labor. To explore this possibility different specifications involving interaction terms with hired labor have been tested (not reported), which did not yield any significant interaction effects. Since hired labor has an observable price, the negative coefficient does not affect SAM construction.

Apart from signaling less-involvement in agriculture, the negative sign of exchange labor could also be due to the fact that it is mainly used for transplanting and harvesting in rice. Rice has a lower gross income per mu than vegetables, which could be picked up by the coefficient one exchange labor. Different specifications of the production function were estimated (not reported), including one for rice only, but the negative coefficient on exchange labor turned out to be a robust result. This yields a problem for SAM construction, since we need a price to value the flows of exchange labor.

The robustness of the estimation results do indicate a lower marginal productivity for exchange labor, compared to household labor. Apart from being used to different activities, this finding fits the presence of monitoring costs. Estimates of monitoring costs, or differences in efficiency of household and non-household labor, are scarce. A study from the Philippines finds an average 0.23 hour of supervision for one hour of hired work (Evenson *et al.*, 2000), while a study of Chinese agricultural teams estimates supervision to absorb 10 to 20 percent of total labor time (Dong and Dow, 1993). Based on these numbers, the productivity of exchange labor is assumed to be 85 percent of the productivity of household labor. This amounts to a 15 percent loss in productivity when using exchange labor, which in light of the mentioned studies seems a conservative estimate. Since the amount of exchange labor is low compared to the amount of household labor (see Table 4.6), SAM and village equilibrium model results are not expected to be sensitive to this specific assumption.

The other inputs for which shadow prices need to be calculated all have positive coefficients, and (with the exception of crop residues) are significant at at least the 1% level. Of the two indictors of management ability only age is significant, suggesting a positive impact of experience on production.

With the estimated coefficients and the predicted output value, Equation (4.4) is used to calculate shadow prices for each household. Table 4.8 presents the average shadow prices by household group, and for the sample as a whole. The shadow prices by group will be used in the SAM calculation. An interesting result is that the relative standard deviations for the household nontradables (non-irrigated land, manure and residues) are much larger than the standard deviations of the imperfectly tradables (household labor and irrigated land). These results support the tradability classification that will be used for the village equilibrium model.

Comparing the shadow wage (on average 0.60 yuan per hour) to the agricultural wage (averaging 3.33 yuan per hour) indicates that the household wage is far below the lowest paid type of off-farm employment for all households. All other types of off-farm employment, especially those outside the village, have a much higher wage. One explanation would be that the shadow wages are underestimated. Another explanation would be that off-farm employment involves transaction costs, like time spent searching for employment. The data do not allow a further analysis of transaction costs of off-farm employment.

The pattern in the household wage confirms the hypothesis of surplus labor causing the nonseparability of household groups with an outside link. The shadow wages of household groups with a link are lower than those without a link and for which separability was not rejected. For the latter groups the estimated shadow wage would be expected to equal the off-farm wage, while for nonseparable households (due to a labor surplus) the shadow wage would be lower than the off-farm wage.

Table 4.8: Estimated shadow prices (average by household group)

Link outside province:	*No link*		*Link*		*Total*
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*	
Household labor (yuan/day)	6.53	5.41	5.35	5.20	5.43
	(3.81)	(1.31)	(2.68)	(1.90)	(2.41)
Irrigated land (yuan/mu)	606.47	576.89	634.22	576.15	599.90
	(180.82)	(159.11)	(188.18)	(145.86)	(167.99)
Non-irrigated land (yuan/mu)	1506.79	1487.00	1788.58	1791.66	1721.19
	(904.41)	(1028.51)	(1617.66)	(1092.51)	(1275.88)
Manure applied to crops (yuan/jin)	0.08	0.06	0.11	0.07	0.08
	(0.08)	(0.04)	(0.15)	(0.07)	(0.11)
Residues fed to animals (yuan/jin)	0.04	0.04	0.10	0.05	0.06
	(0.07)	(0.08)	(0.13)	(0.09)	(0.10)
Exchange labor (yuan/day)[1]	5.55	4.60	4.55	4.42	4.61
	(3.24)	(1.12)	(2.28)	(1.61)	(2.05)

Note: standard deviation in parentheses.

[1] Exchange labor calculated as 85% of household labor wage.

Although having slightly higher shadow wages, households without a link still have an estimated shadow wage that is a fraction of the lowest paid type of off-farm employment. This raises the question which wage to use in the SAM and village equilibrium model. First of all, the households are involved in a variety of different activities with widely varying wages. There is thus no single off-farm wage that can be used to value labor. Second, using an off-farm wage to value the labor of the household groups without a link, while using the shadow wage for the other two groups with an outside link would create large differences between the groups which will drive all model simulation results. One way to reduce this impact would be to increase all wages to a level similar to off-farm wages. This would imply that the estimation is assumed to underestimate the prices. Results for other shadow price, however, do not support such an assumption. For irrigated land, for example, shadow prices are higher than observed prices (see below).

Since the pattern in shadow wages reflects a larger labor surplus for households with a link, as was assumed to be the driving force behind nonseparability, labor is valued against the estimated household-specific shadow wage. This implies the assumption of a type II error in the separability estimation: not rejecting the null-hypothesis when it is false (Greene, 2000:147). Given the small sizes of the household groups without a link a Type II error seems a possibility. Furthermore, proceeding in this way maintains the relative wages in line with a labor surplus assumption, while not completely determining the simulation results. Valuing the labor in off-farm employment against the low shadow wage implies that households earn additional income above the opportunity costs of their labor. Implications of this feature for SAM and village equilibrium model construction will be discussed in when discussing the SAM and the village equilibrium model in Chapter 5.

The estimated average price of irrigated land (600 yuan/mu) is higher than the observed prices for rented in land (365 yuan/mu). This confirms the hypothesis that the market for irrigated land is constrained from the supply side due to institutional factors, as discussed before. The much higher estimated value of non-irrigated land than of irrigated land is due to the higher return to cultivating vegetables and fruits. Prices of vegetables and fruits are well above the price of rice, yielding a higher return even with higher external input use, which is reflected in the higher value of the land. This suggests that expansion of vegetable and fruits would be an interesting option. Such an expansion is likely to be hampered by transportation issues, that are of prime importance for these perishable products.

The estimated shadow price of manure (0.08 yuan per jin[12]) is well below the average price of chemical fertilizer (0.65 yuan per jin). Such a difference is to be expected, given the much higher amounts of nutrients per jin in chemical fertilizers. Expenses on purchased feed (2500 yuan on average) can be used as a reference point to judge the estimated price for crop residues fed to animals. Estimated expenses on crop residues (529 yuan on average) are well below the costs of feed. This seems reasonable, given that crops residues are a lower quality type of feed.

4.4 a chinese village SAM

After examining nonseparability and estimating shadow prices, we have all the ingredients for constructing a village SAM. This requires calculating total value flows by households type and putting these in the SAM, after which the SAM has to be balanced (match row and column totals). Different approaches to establish a balanced SAM are available. The main choice is between manual balancing, or use of a balancing technique, like RAS or entropy methods.

RAS has been developed to update a SAM from an (older) existing and balanced SAM. It takes the column and row totals as given, and updates SAM entries iteratively until the SAM balances (Francois and Reinert, 1997:117-119). When constructing a (unbalanced) SAM some entries are generally considered more reliable than others. Tax payments, for example, can be assumed to be more precise than the amount of crop residues consumed by grazing cattle. The RAS method cannot incorporate additional information on the reliability of specific entries, being based on a proportional allocation of row and column differences. Recently entropy methods have been applied to reconcile data from different sources (Harris, 2002; Robilliard and Robinson, 2001). These studies match a macro SAM to a more disaggregated micro SAM, based on different data sources. The entropy methods used by these studies allow identification of more reliable entries. Entries considered more reliable are used as a starting points for the estimation, thus allowing the use of all available information.

The survey used for this study was the first survey of the village. Official statistical data are not detailed enough to allow construction of a village SAM. Furthermore, all data in the SAM are derived from the same survey. There is thus no clear reference point that could be used to use one of the balancing techniques described above. Some data from the survey, however, seem more precise than other entries (tax data versus crop residues, for example). It would therefore be possible to take either a row or column total as given, as well as using certain entries as a starting point for an entropy procedure.

Lacking a clear reference point, entropy estimation of the village SAM would be based on subjective judgments of reliability of specific entries. Furthermore, all balancing techniques eventually achieve a balance in a mechanical way, making it hard to trace why entries have been

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[12] A jin is 500 gram.

changed. Since subjective judgments would be the basis of any balancing in the current situation, the manual approach was chosen. Processing the raw survey data for use in the SAM resulted in a good feel for the 'soft spots' in the dataset. Furthermore, adjustments were made such that relative positions as observed in the raw data were maintained. The adjustment process was done in a structured and transparent way, tracing all adjustments made and their motivation.

The SAM is built with the data from the 168 households for which data from the two surveys are available. Since the SAM represents the whole village of 730 households, the data for the four household groups are scaled to the village level by assuming the surveyed households to be representative for the village population. All entries as calculated from the household data are thus multiplied with 730/168. This also holds for the number of households in each household group, increasing their numbers to 78 (no link, no draught power), 100 (no link, draught power), 256 (link, no draught power) and 295 (link, draught power). The balanced SAM is rather sparse and will therefore be discussed in parts. Table 4.9 summarizes where the different tables used in the discussion fit into the SAM. These tables cover most of the SAM; some straightforward entries are indicated in the text but not included in the tables[13].

Table 4.9: Location of tables in the village SAM (numbers refer to table numbers)

		Activities			**Commodities**					**F.**	**Instit.**		**C.**	**O**
		A	B	C	D	E	F	G	H	I	J	K	L	M
Activities:														
· Crops	A													
· Livestock	B							4.12						
· Off-farm	C													
Commodities:														
· Pools	C													
· Output	E													
· Intermediates	F	4.10	4.11									4.15		
· External inputs	G													
· Consumption	H													
Factors	I													
Institutions:														
· Households	J			4.13				4.14						
· Government	K													
Capital	L													
Outside village	M													

4.4.1 agricultural production activities

Six different agricultural activities are distinguished in the SAM, three crop activities (one-season rice, two-season rice, other crops), and three livestock activities (cattle, pigs, other livestock). Two-

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[13] The complete SAM can be downloaded from the website of Development Economics Group, Wageningen University: www.sls.wageningen-ur.nl/dec.

season rice consists of the sequential cultivation of early and late rice, whereas one-season rice is grown during a full season. The systems differ in terms of input use and output prices (compared to two-season rice, prices of one-season rice are higher, while yields are lower), and are therefore treated as separate activities in the SAM. Other crops is an aggregation of vegetable and fruit production. There is a tremendous variety across households in types of vegetables and fruits produced, that cannot be dealt with in the SAM. These are therefore aggregated into a single activity, other crops.

Table 4.10 presents input use in crop production. Inputs are grouped under the four headings: pool commodities, intermediate inputs, external inputs and factors. The village equilibrium model uses a trade-pool approach to model trade flows in the village (see the discussion of the village model in Section 4.1). This avoids tracing bilateral trade flows, on which no data are available. The pool commodities in the SAM are the implementation of this trade pool approach. The entries in Table 4.10 indicate how much each activity takes out of the village pools of exchange labor, agricultural labor, irrigated land, oxen and tractors. The accounting rules of the SAM assure that these totals balance with the amounts supplied to the pools, which will be encountered in other tables.

The use of pool commodities also allows the SAM to distinguish between hired and own factors. Use of own factors is recorded by direct payments to the factors, except for animal traction services. Cattle are a factor, but require labor and feed to be maintained. Animal traction services are thus produced by the cattle activity, which makes the factor payments to the cattle. Use of own cattle is recorded as an intermediate input, while hired animal traction services are recorded by a pool of animal traction services. The households with no draught power need to hire in all animal traction services, while the households owning cattle use only own draught power.

The raw data show that some households within the households types owning cattle hire in animal traction services, while other households hire out cattle. The net flow is used in the SAM, assuming that hiring in of animal traction services by households with draught power is done within the own household group. Similar adjustments are made for other accounts with two-way flows in the SAM.

Payments to household labor are distributed over male and female labor. The distinction between male and female labor is introduced for off-farm activities that are primarily a male activity (see Table 4.13). This distinction makes the male labor endowment available for off-farm employment explicit, which could become a binding constraint in the model simulations. The household survey data do not distinguish male and female labor by cropping type. Use of on-farm household labor is therefore allocated to male and female labor using the ratio of males to females in the household, and applying an identical shadow wage (estimated in Section 5.3) to both types of labor. After correcting for the productivity difference through the calculation of a labor force in terms of male equivalents (as discussed in Section 5.1 with the grouping of households), male and female labor are assumed to be perfect substitutes in production. This assumption may overestimate the substitution of male by female labor, once males get more involved in off-farm employment or migration. Research in areas with large scale (male) migration indicates, however, that women indeed take over the farm work previously done by men (Rawski and Mead, 1998:770). This supports the assumption of perfect substitutability (after accounting for the productivity differences) between male and female labor in this study.

Table 4.10: Inputs in crop production activities (yuan)

	One-season rice				Two-season rice				Other crops			
	hh1	*hh2*	*hh3*	*hh4*	*hh1*	*hh2*	*hh3*	*hh4*	*hh1*	*hh2*	*hh3*	*hh4*
Pool commodities												
Exchange labor	1443	3207	8504	15552	9420	9221	31277	37443	261		660	239
Agricultural labor			5010				17329				382	
Irrigated land	16938	37743	28296	100040	46290	84037	57414	223736				
Animal traction services	2268		11519		11432		28918		4089		8795	
Tractor services	682		5623		8608		25754					
Intermediate inputs												
Seed	391	1043	4528	1508	5757	6926	11393	18745	2833	4345	11671	9190
Manure	213	135	634	1247	843	830	3611	10329	8086	15499	39468	105807
Animal traction services		5545		22574		23981		89742		4176		13644
External inputs												
Fertilizer	6822	14031	27836	46564	35900	61846	118834	185876	7517	5384	24950	14487
Herbicides	243	513	1186	1460	1269	2129	3806	6852	43	56	117	96
Pesticides	1412	3472	7496	10029	6926	11884	21461	37882	1556	1990	6053	7708
Purchased seed	1065	1612	3103	6357	2920	8873	11771	21383	1330	5127	8130	9251
Other external inputs	587	1881	2472	3116	4158	5849	13622	24572			74	122
Factors												
Male labor	7135	5892	10754	21418	24264	27523	44613	91745	14483	24624	57531	68542
Female labor	4176	5805	11610	21943	20792	26906	48367	86353	13831	24829	63532	70145
Irrigated land	34605	60981	171911	198430	94574	135776	348836	443766				
Non-irrigated land									75620	117469	315317	374064
Tractor services				504		5388		23343				
Total	*77980*	*141859*	*300482*	*450740*	*273155*	*411168*	*787005*	*1301768*	*129649*	*203501*	*536680*	*673295*

Notes: for readability zero entries are omitted; household types are coded: hh1= no draught power, no outside link; hh2= draught power, no outside link; hh3= no draught power, outside link; hh4= draught power, outside link.

Table 4.11: Inputs in livestock production activities (yuan)

	Cattle				Pigs				Other livestock			
	hh1	*hh2*	*hh3*	*hh4*	*hh1*	*hh2*	*hh3*	*hh4*	*hh1*	*hh2*	*hh3*	*hh4*
Pool commodities												
Local business activities					665	1895	17207					
Intermediate inputs												
Crop residues		24173		61615	95495	60690	305887	271725	7856	2464	46081	19249
External inputs												
Purchased feed					82112	37560	162112	26767	9586	9177	25250	22986
Other external inputs		291		1004	587	2038	2386	6679	2859	5306	708	1669
Factors												
Male labor		786		4675	348	413	2481	4254	165	265	374	252
Female labor		795		4793	343	413	2742	4358	161	265	413	256
Cattle		49388		177294								
Rest of the world												
Outside village					1881	4719	11289	21996	8034	14969	16616	26197
Total		*75433*		*249382*	*181431*	*107727*	*504104*	*335778*	*28661*	*32446*	*89442*	*70610*

Notes: for readability zero entries are omitted; household types are coded: hh1= no draught power, no outside link; hh2= draught power, no outside link; hh3= no draught power, outside link; hh4= draught power, outside link.

Apart from animal traction services the households use manure and seed produced on their own farm. Manure is valued against the household-specific shadow price estimated in Section 5.3. Seed is valued against the observed market price. Next to intermediate inputs the SAM distinguishes a set of external inputs. Some of these are bought from traders visiting the village, but there were no clear price differences between different sources of external inputs. Since money paid to a visiting trader does not enter the village economy, all external inputs are imported from outside the village.

When constructing the SAM with the estimated shadow prices of irrigated and non-irrigated land, expenditures greatly exceeded the receipts for all crops. The cost of land dwarfed all other costs, which seemed unrealistic and prohibited balancing the SAM. Land prices were therefore reduced with 40 percent. Through this reduction expenditures and receipts were in each other's neighborhood, with both positive and negative gaps across the activities. At the same time, the reduced prices in the SAM for irrigated land preserved the finding that household prices exceed the market price, indicating a supply constrained market. By reducing the non-irrigated land price with the same amount, the relative price ratio between the two types of land was maintained.

Table 4.11 presents the inputs in livestock activities. The households without draught power do not have any cattle activity. Little external inputs are used for cattle, these are limited to veterinary costs captured as other inputs. The cattle activities distribute payments for animal traction services, by the own households and household hiring in cattle, to the factor account for cattle.

The pig and other livestock activities use young animals bought outside the village, which is recorded as direct payments to the rest of the world. The SAM includes an account for produced animals, where these purchases could have been recorded. Such an approach would suggest that similar animals are bought and sold, which is not the case. The approach used in the SAM separates purchases of young animals from sales of adult animals. One of the households sells young animals to the other households in the village. This is one of a variety of local business activities. The village activities are modeled through a single account for local business activities. In the case of pigs, the buying of locally produced pigs by the first three household groups, matches the local selling of pigs by the last household group.

Table 4.12 and 4.13 present the destination of output produced by cropping and livestock activities. The supply to the pool of animal traction services, mentioned before is recorded in the first column of Table 4.13. The supply of piglets by the fourth household (link and draught power) is recorded as a local business activity, similar to the selling of other crops inside the village by three of the households.

The columns with the header 'produced commodities' record sales of produced commodities outside the village. It indicates that some of the cattle is sold by the households owning cattle. Since no cattle are bough there is a reduction in the cattle owned by the households.

The column intermediate inputs records the production of inputs that are used on the own farm. The two cropping activities produce crop residues used by the livestock activities. Cattle and pig activities produce manure, used by the cropping activities. No data were available on the production of seed. It has therefore been assumed that seed used for production consists of newly produced seed.

Table 4.12: Output of crop activities (yuan)

	Pools	Produced goods			Intermediates		Household	Government		Total
	Local business	*One-season rice*	*Two-season rice*	*Other crops*	*Seed*	*Crop residue*		*Above quota*	*Public grain*	
One-season rice										
hh1		16060			391	23438	27983	9082	1025	*77980*
hh2		83707			1043	21048	35622		439	*141859*
hh3		83220			4528	74086	110643	23212	4793	*300482*
hh4		190834			1508	109535	108766	26932	13166	*450740*
Two-season rice										
hh1			57857		5757	54967	128271	10572	15730	*273155*
hh2			84958		6926	36378	239853	20627	22426	*411168*
hh3			116222		11393	170164	399010	60229	29986	*787005*
hh4			240496		18745	216163	716921	70123	39320	*1301768*
Other crops										
hh1				1981	2833	24950	99884			*129649*
hh2	521			31729	4345	29895	137010			*203501*
hh3	8803			95826	11671	107714	312666			*536680*
hh4	7626			114675	9190	26897	514906			*673295*

Notes: for readability zero entries are omitted; household types are coded: hh1= no draught power, no outside link; hh2= draught power, no outside link; hh3= no draught power, outside link; hh4= draught power, outside link.

Table 4.13: Output of livestock activities (yuan)

	Pools		Produced goods			Intermediates		Household	Total
	Animal traction	*Local business*	*Cattle*	*Pigs*	*Other livestock*	*Manure*	*Animal traction*		
Cattle									
hh1									
hh2	15686		14174			11871	33702		*75433*
hh3									
hh4	51335		11558			60529	125960		*249382*
Pigs									
hh1				163333		9142		8956	*181431*
hh2				86535		4597		16594	*107727*
hh3				408709		43713		51682	*504104*
hh4		19766		165875		56849		93288	*335778*
Other livestock									
hh1					13053			15608	*28661*
hh2					15330			17116	*32446*
hh3					24472			64970	*89442*
hh4					21731			48880	*70610*

Notes: for readability zero entries are omitted; household types are coded: hh1= no draught power, no outside link; hh2= draught power, no outside link; hh3= no draught power, outside link; hh4= draught power, outside link.

The columns for household consumption record the consumption of farm-produced output. As the structure of the table indicates, households can only directly consume their own output. Household consumed output is valued against the market price. No household buys rice for consumption, so it is not possible to assess a potential price difference between buying and selling rice. Households do buy vegetables on the market. It has been assumed that these are different from the household produced vegetables, since all households sell vegetables on the market as well. Purchased vegetables are assumed to be either entirely different goods (not produced in the village), or they could be the similar crops purchased from the market outside of the own production season. The households do not consume any cattle output, like milk. Cattle thus only serves as draught power, and produces manure.

The rice market is still regulated. Households are required to deliver rice to the government as a tax, for which they do not receive a payment. After fulfilling this tax requirement and own consumption, they can sell surplus rice to the government or on the market. The price of sales to the government differs from the market price, and are therefore recorded separately in the government column. The rice delivered as tax is valued against the market price, since all households sell to the market as well.

4.4.2 off-farm labor and migration activities

Next to farm production, households can engage in off-farm employment. Table 4.13 presents the allocation of male and female labor over the five off-farm activities distinguished in the SAM. Note that exchange labor is not explicitly included as an off-farm activity. There are no data on the supply of exchange labor. The amount supplied is therefore set equal to the amount used, and is dealt with by direct payments from the pool of exchange labor to the households.

All off-farm activities have higher returns to labor than the shadow wage. The difference between the opportunity cost of household labor (hours valued against the shadow wage) and the actual income received is captured in the SAM as profit.

Off-farm agricultural labor occurs only within the village. Table 4.14 records the supply by the different households to the pool of agricultural labor. The third household (link and no draught power) is the only one using hired agricultural labor (see Table 4.10), the other households supply agricultural labor. The household with no draught power and no link outside the village supplies relatively the most labor (the SAM records total supply of all households in a group, and this group consists of only 18 households). This corresponds with the high involvement of households with no outside link in off-farm employment as discussed before.

Nonagricultural labor aggregates self-employed and wage labor. A distinction is made between nonagricultural employment inside and outside the village. Nonagricultural labor consists of a wide variety of activities, and includes occupations like carpenter, blacksmith, doctors, and cooks. There are no data on which households rent in nonagricultural labor. There is information, however, on the consumption of village produced goods, like processed food or furniture. To link the supply of nonagricultural labor to the consumption of goods the local business account is used. This account receives payments from households consuming locally produced goods. These payments are distributed to the households through by payments to labor supplied to nonagricultural activities inside the village. Note that this account is not netted out. All households supply nonagricultural labor inside the village and consume locally produced goods. The implicit assumption is that the households are involved in different activities, not captured by the aggregate entries used in the SAM. By using the local business account there is no need to specify the activities since only the total value of nonagricultural labor supplied inside the village is required to match the total value of village produced consumption goods.

The other three off-farm employment activities are straightforwardly incorporated in the SAM. These labor services are exported from the village economy, resulting in an inflow of money. For the two migration activities (inside and outside the province), these inflows of money are equal to the money send back as remittances. This amount received as remittances is used to value the labor spent on migration. Actual wages earned by the migrants are higher than the implicit wage used in the SAM, since not all earned money is send back and some migrants do not send any money at all.

Table 4.14: Off-farm employment activities (yuan)

		Male labor	*Female labor*	*Profit*	**Total**
Agricultural labor, inside village	hh1	834	539	4806	*6179*
	hh2	2864	261	11728	*14852*
	hh3				
	hh4	200	30	1460	*1690*
Nonagricultural labor, inside village	hh1	5171	556	89130	*94857*
	hh2	2138	1125	88161	*91424*
	hh3	6105	2373	48315	*56792*
	hh4	7378	3428	50196	*61003*
Nonagricultural labor, outside village	hh1	3785		84380	*88165*
	hh2	4284	196	82642	*87122*
	hh3	5692	1291	209010	*215993*
	hh4	7526		117330	*124856*
Migratory employment, inside province	hh1	6809		3620	*10429*
	hh2				
	hh3	19541	20240	60160	*99940*
	hh4	19897		1829	*21726*
Migratory employment, outside province	hh1				
	hh2				
	hh3	156711	133295	631185	*921190*
	hh4	204552	141394	166357	*512304*

Notes: for readability zero entries are omitted; household types are coded: hh1= no draught power, no outside link; hh2= draught power, no outside link; hh3= no draught power, outside link; hh4= draught power, outside link.

4.4.3 household income and expenditures

Households receive income from agricultural production, off-farm employment, hiring out factors, and transfers. Table 4.15 presents the sources of income recorded by the SAM. The pool accounts distribute income from hiring out factors: exchange labor, irrigated land and tractor services. The irrigated land market is unbalanced since none of the household groups rents out irrigated land, while all hire in land. This is attributed to the biased sample, lacking data on households that have left the village. To obtain a balanced SAM a fifth household group is introduced, renting out irrigated land. The income it receives is assumed to leave the village, since no data are available on the expenditures of these migrated households inside the village (most migrants return to the village at least once a year, mostly during for the New Year celebrations). Irrigated land rented in by activities is valued against the household-specific shadow price of irrigated land, representing the value of the land for production. Due to the institutional structure this is a higher price than actually paid by the households, all pay less than the estimated value of land and some households can cultivate the land for free. To account for this feature of the village land market, the value of the land above the amount paid to the migrated household accrues to the households.

Table 4.15: Household income (yuan)

Link outside province:	*No link*		*Link*		*Migrated household*
Owning draught power:	*No*	*Yes*	*No*	*Yes*	
	hh1	hh2	hh3	hh4	hh5
Pools					
Exchange labor	11124	12427	40441	53234	
Irrigated land	50140	96104	56618	255113	136519
Tractor		18072		22595	
Village assistance	6131			24533	
Village lending		10250		4093	
Local business		2607			
Factors					
Male labor	282706	357965	1013579	1863912	
Female labor	303080	411133	1088730	1595658	
Irrigated land	129180	196757	520746	642196	
Non-irrigated land	75620	117469	315317	374064	
Cattle/oxen		49388		177294	
Tractor		5388		23847	
Off-farm employment					
Profit	181935	182530	948670	337173	
Transfers					
Assistance				66039	
Lending	2850	30955	71066	181683	
Outside village	3476	3302	69654	34023	
Total	*1046242*	*1491742*	*4124822*	*5655458*	*136519*

Notes: for readability zero entries are omitted, the table is a transposed version of the SAM entries.

Two pool accounts appear in Table 4.15 that have not been discussed yet: village assistance and lending. The survey data indicate money flows among households in the village, either as assistance (with no interest or other obligations attached) or as loans. The lending consists of the net receipts during 2000, *i.e.* the receipts of money minus repayments made during the survey year. Rather surprising is the receipts of village assistance and loans by the household with draught power and outside links. In addition this household is the only one receiving a net inflow of assistance from outside the village. All households receive loans from outside the village, again the household with draught power and links has the highest amount (while not being the largest group of households). The last line in Table 4.15 captures remittances received from household members outside the village. These household members are not part of the household and thus do not involve a loss of labor, as the migration activities do.

Income from agricultural production and off-farm employment is received through factor payments. All household labor is valued against the household shadow wage. In case of off-farm employment, receipts exceed the opportunity cost of labor valued in shadow wages. This difference is recorded in a separate account: profit from off-farm employment.

In the accounting framework of the SAM the receipts of income need to be balance by expenditures, presented in Table 4.16. The first rows repeat household consumption of agricultural output, discussed in Table 4.12. The pool accounts record the households supplying village assistance and village lending. Interestingly all household, except the fourth one, have a net outflow of assistance to household and friends outside the village.

In addition to consumption of own farm production, all households purchase food (vegetables, fruit, meat, etc.) and processed foods (noodles, oil, salt etc.). Nonfood includes items like cleaning products and cigarettes. Durable consumption goods mainly involve expenditures on furniture and clothing. Part of these expenditures are made within the village, which is accounted for through the local business account. The remainder of the purchases is done outside the village.

Next to consumption goods there are other expenses, on education, social events (weddings, funerals, New Year celebrations) and transport. Education costs are made outside the village, while part of the costs for social activities are made inside the village (again, recorded in the local business account). The transport costs consist of two components, payments (for transport and so on) and time spend on transport. This breakdown is captured in the SAM by the transport account paying to household labor and to the outside village account.

The consumption of male and female labor is leisure, a usual consumption good in household models. Leisure is defined as consisting of the time spent on taking care of the household (collecting firewood, house cleaning, child care etc.), social activities and village labor requirements[14]. After deducting the use of labor (by all activities, leisure and for transport) from the total availability (assuming 365 days and 16 hours per day), a negative balance remained. This is due to the fact that the SAM only accounts for adults and adolescents as available labor force, while all household members may participate in activities summarized as leisure. The data only record the total time spend by the household, and thus cannot be disaggregated into dependents and labor force. The leisure account was therefore used to balance the labor accounts, assuming that the remainder not included in the SAM is done by non-labor force household members. This approach results in a higher share of female hours spent on leisure, which seems reasonable since a major part of the household chores is done by women.

Table 4.16: Household expenditures (yuan)

Link outside province:	*No link*		*Link*	
Owning draught power:	*No*	*Yes*	*No*	*Yes*
	hh1	hh2	hh3	hh4
Own production				
One-season rice	27983	35622	110643	108766
Two-season rice	128271	239853	399010	716921
Other crops	99884	137010	312666	514906
Pigs	8956	16594	51682	93288
Other livestock	15608	17116	64970	48880
Pools				
Assistance		6587	24077	
Lending	96		14248	
Consumption goods				
Food	29448	33059	121363	76550
Processed food	22039	32233	114380	144245
Nonfood	60881	78458	398949	446999
Durable consumption goods	8929	15834	109900	45760
Other expenses				
Education	14261	31746	161569	108353
Social events	63471	78071	377327	304984
Transport	88886	228294	365061	394960
Factors				
Male labor	175291	185937	582166	1269609
Female labor	222381	237202	673951	1076415
Institutions				
Government	57140	89634	158332	252337
Public grain tax	16755	22860	34784	52486
Transfers				
Assistance	5962	5631	49744	
Total	*1046242*	*1491742*	*4124822*	*5655458*

Note: for readability zero entries are omitted.

The payments to institutions are tax payments to the government and the public grain tax. The latter is a tricky account. Recall from Table 4.12 that the public grain tax is recorded explicitly as a destination of rice output. This captures the feature of this tax being paid in kind from the rice yield. By including it as a destination, however, it becomes a payment to the household. By including the public grain as an expenditure in Table 4.16 this receipt of money for the public grain is balanced by an identical expenditure. The net result is that the household has not paid the tax yet. Therefore the other tax payments to the government are increased with the value of the public grain

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[14] Strictly speaking only the social activities are leisure since the other activities are productive activities to maintain the household. Lacking data on the allocation of labor between the different components, however, we refer to the total time not spend on working on- or off-farm as leisure, as is common practice in agricultural household models.

tax. Although being a bit cumbersome, this construction makes the share of output that has to be reserved in kind for tax payment explicit. This information would be lost if the public grain account was deleted and the tax was included as a monetary payment only.

4.5 concluding remarks

This chapter provided the first step to developing an applied village equilibrium model. After a short discussion of the case study village, representative household groups were constructed. The next step was to formally test the assumption of nonseparability, a crucial element of the village equilibrium model developed in this study.

The test indicated that for the major part of the households separability could be rejected. Despite a global rejection of separability, test for subgroups of households revealed unexpected differences across groups of households. Households without a link outside the province turned out to be more involved in nearby off-farm employment, rendering their farm labor decisions separable. Household with a link outside the province turned out to focus more on migration, which is more difficult to increase in the short run. As a result, for this (large) group of households separability could be rejected. Testing for separability also provided additional information on different income strategies followed by the households in the village. Next to information on labor allocation, the tests indicated that the irrigated land market is constrained from the supply side. This finding matches casual observations of a highly distorted land market during the household survey.

Nonseparability implies unobservable household shadow prices, complicating SAM construction. A agricultural production function was estimated to estimate a shadow wage of labor. Given the observation of a distorted land market, a shadow price for irrigated land was estimated as well. Next to these two imperfectly household tradables, the survey data indicated a number of household nontradables (manure, crops residues used as feed and non-irrigated land). For these nontradables no prices are observed and shadow prices were therefore estimated from the production function.

Having information on prices and quantity flows a village SAM was constructed, using the information on the limited tradability of household labor and irrigated land. The resulting SAM is very detailed. Households engage in eleven different production activities, external inputs are disaggregated by type, transport costs are made explicit, as are different types of money flows among households and with the outside world. This detailed SAM forms the basis of applied models in later chapters, but in most cases an aggregated version of the SAM presented here will be used. Once having constructed a detailed SAM, more aggregated versions can be easily derived by combining accounts (while the opposite is not possible without returning to the survey data).

Based on the SAM, and on the additional information on market structure obtained when testing nonseparabiliy and estimating of shadow prices, the following chapter will develop a basic village equilibrium model. This model will make a number of simplifying assumptions, both in terms of the village SAM, and of the behavioral equations of the model. Subsequent chapters will study the effect of dropping the simplifying assumptions, using the basic model as a reference point.

CHAPTER 5

capturing interactions among households: a basic chinese village model

Chapter 4 set the first strides towards an applied village equilibrium model by constructing a village SAM. Next to describing the structure of the village economy, testing of separability and estimating shadow prices, it also provided information on the functioning of (village) markets. This chapter develops an applied village model, building on the SAM and insights gained during its construction.

In terms of the matrix of key issues from Chapter 2, this chapter focuses on conceptualization, with an emphasis on modeling interactions among households. Modeling of consumption and production decisions is therefore kept very basic using easy to calibrate but restrictive functional forms. Apart from focusing attention on modeling village interactions, the simple functional forms reduce the complexity of the model, making it easier to trace the impact of shocks. This basic model is used in Chapter 6 and 7 as a reference point to assess the robustness of model results when introducing more realistic but complex specifications of consumption and production decisions.

The first objective of this chapter is to develop an applied village model based on the general model of Chapter 3. This involves a conceptualization process, translating the generic village model to an application fitting the case study data. Although the SAM provides an indispensable source of data, it only provides a single snap-shot of the village economy. Additional information from the household survey data and observations made during the fieldwork were used to model village markets.

The second objective of this chapter is to assess the significance of village interactions on household response. The response to an exogenous shock is therefore compared for two versions of the model. The first version of the model applies a partial equilibrium closure to the village model, breaking it apart in separate household models. The second version of the model applies a general equilibrium closure, thus including interactions among households. Comparison of household response in these two model versions yields the impact of interactions within the village economy on household response.

The chapter starts with describing the way in which the applied model is derived from the general village model of Chapter 3. The second section describes the SAM used for the basic village model. Main features of the activities and sets to which commodities belong are identified, summarizing key assumptions of the applied model. The third section describes the functional forms used to model household production and consumption decisions. Section four summarizes the model structure and shortly describes calibration and consistency checks. Section five then presents and discusses simulation results, comparing separate household models to household response in the basic village model. Section six concludes.

5.1 structure of the applied village model

The general model in Chapter 3 describes household behavior in terms of a maximization problem (primal formulation). In the applied village equilibrium model household behavior is cast in terms of demand and supply equations (dual formulation). These are derived by solving the first-order conditions of the household maximization problem (see Appendix C). In this section we restrict our attention to describing the resulting equations that compose the applied village equilibrium model.

Household decisions can be described in four blocks of equations: prices, production, consumption and commodity balances. The *price block* describe the relevant decision-making prices for the households, which depend on the type of commodity considered (see Appendix A for a list of variables, parameters and sets used in this study):

$$\tilde{p}^{p}_{hj} \geq p^{*}_{hj}; \quad q^{p}_{hj} \geq 0; \quad q^{p}_{hj}(\tilde{p}^{p}_{hj} - p^{*}_{hj}) = 0, \qquad \forall\ h \in H, j \in P \tag{5.1}$$

$$p^{*}_{hj} \geq \tilde{p}^{s}_{hj}; \quad q^{s}_{hj} \geq 0; \quad q^{s}_{hj}(p^{*}_{hj} - \tilde{p}^{s}_{hj}) = 0, \qquad \forall\ h \in H, j \in S \tag{5.2}$$

$$\tilde{p}^{ht}_{hj} = p^{*}_{hj}, \qquad \forall\ h \in H, j \in HT \tag{5.3}$$

where a tilde (~) indicates prices that are perceived as exogenous by the household. We assume households not to take their impact on local price formation into account. Prices of commodities traded in the village are thus perceived as exogenous by the household, despite being endogenous to the village model. The effective household shadow price is indicated with an asterisk (*). This price can be exogenous or endogenous for the household, depending on the tradability of the commodity concerned.

Equations (5.1) and (5.2) together define the price band within which the shadow price of price-band commodities moves. The complementarity constraints allow the household to choose its position in the market as a net buyer, net seller or autarkic. Tradable commodities can thus become non-traded with a household shadow price that differs from the market price. For household tradables the price band is effectively zero, as defined by (5.3).

Apart from the equations defining the relevant decision-making prices, the nonnegativity constraints defined in Chapter 3 still apply,

$$\tilde{p}^{p}_{hj} \geq \tilde{p}^{s}_{hj} \geq 0, \ \tilde{p}^{ht}_{hj} \geq 0. \qquad \forall\ h \in H, j \in J \tag{5.4}$$

The *production block* describes production decisions of the household and consists of two types of equations: input demand and production functions. The input demand functions relate input demand to input and output prices,

$$q^{i}_{haj} = f_{a}(p^{*}_{hj}). \qquad \forall\ h \in H, a \in A, j \in J \tag{5.5}$$

The input demand functions are derived from the first-order conditions of profit maximization under a given production technology,

$$q^o_{haj} = g^o_{ha}(q^i_{haj}), \qquad \forall\ h \in H, j \in O, a \in A \qquad (5.6)$$

that determines the output produced with the demanded inputs.

The *consumption block* describes consumption decisions. As with production, these consist of two types of equations: full income and consumption demand. Full income (w_h) determines the available resources for consumption:

$$w_h = \sum_{j \in J} p^*_{hj} \bar{q}^{\omega}_{hj} + \sum_{l \in L} \bar{y}^l_h + \sum_{a \in A} \pi_{ha}, \qquad \forall\ h \in H \qquad (5.7)$$

where profit π_{ha} is defined as,

$$\pi_{ha} = \sum_{o \in O} p^*_{hj} q^o_{haj} - \sum_{i \in I} p^*_{hj} q^i_{haj}. \qquad \forall\ h \in H, a \in A$$

Profits are introduced in the village equilibrium model to bridge the gap between household shadow prices and off-farm wages. Section 3 discusses the rationale for introducing profits and the implications for modeling markets and production decisions.

Having defined full income, consumption decisions are determined by income and prices of consumption goods,

$$q^c_{hj} = f(p^*_{hj}, w_h), \qquad \forall\ h \in H, j \in C \qquad (5.8)$$

in a manner described by the utility function. Note that in a model in dual form the utility function is not explicit in the equations of the applied model. The applied model in dual form does not have an objective function but consists of a system of equations that implicitly maximize utility.

The *commodity block* completes the household component in the village model. It consists of a set of household commodity balances,

$$q^c_{hj} + \sum_{a \in A} q^i_{haj} + q^s_{hj} + q^{ht}_{hj} = \sum_{a \in A} q^o_{haj} + \bar{q}^{\omega}_{hj} + q^p_{hj}. \qquad \forall\ h \in H, j \in J \qquad (5.9)$$

The household model defined in Chapter 3 also included a cash constraint. As described in the derivation of the model (see Appendix C) this constraint is incorporated in the full income constraint (5.7), and thus does not appear in the applied model.

The *village constraints* complete the village equilibrium model by adding a layer of interactions among households. As discussed in Chapter 3 there are different ways of dealing with village trade in price band commodities. The applied village equilibrium model assumes the absence of price bands in village trade, specifying separate trade balances for commodities traded within the village but not outside the village (*VNT*),

$$\sum_{h \in H} q^{ht}_{hj} = q^{vt}_j = 0, \qquad \forall\ j \in VNT \qquad (5.10)$$

exports,

$$q^e_j = \sum_{h \in H} q^s_{hj}, \qquad \forall\ j \in E \qquad (5.11)$$

and imports

$$\sum_{h \in H} q_{hj}^{p} = q_{j}^{m} \,. \qquad \forall\, j \in M \qquad (5.12)$$

Next to trade balances the village model in Chapter 3 also includes a village balance of payments. This equation is not included in the applied village model, but instead used to check whether Walras' Law holds for the applied model. Given Walras' Law any of the equations can be left out of the model and used for checking the results. We use the village balance of payments because of the introduction of profits that make the full income equations more complex. To reduce the risk of inappropriate specifications of full income, like for example double-counting of labor endowments, the village balance of payments is calculated after solving the model. The cash constraint does not allow households to run a deficit and the village balance of payments should therefore be zero.

5.2 activities and commodities in the applied model

Activities and commodities play a central role in defining the applied model. For the applied model we use a slightly modified version of the SAM described in Chapter 4. Several accounts on which this study does not focus are aggregated to reduce the model size. Lending and assistance accounts have been aggregated to a single account called assistance. Expenditures on social activities, education and the monetary component of transportation costs have been aggregated into an account called other expenses, while the labor component of transportation has been added to the leisure account.

Two additional modifications to the SAM are made in the destination of rice production. As described in Chapter 4 rice can be sold on the market, consumed by the household, sold to the government or used for tax payments in kind. According to the survey data, prices for above-quota sales to the government match market prices. Since we lack data on factors affecting the choice between selling on the market or to the government, sales to the government have been aggregated with market sales. At the time of the survey households still paid taxes in kind. This system has since then been replaced by payments of taxes in money. To simplify the model and reflect the current tax system, the value of the taxes in kind has been converted to a monetary tax in the applied village model.

The number of activities in the village equilibrium model exceed the number of activities explicitly distinguished in the SAM of Chapter 4 (see Table 5.1). The village equilibrium model treats renting of factors (draught animals and tractors) and exchange labor as activities, although these are not being defined as such in the SAM. Modeling the rental of factors as activities facilitates the introduction of wages differences and of fixed inputs and outputs. Furthermore, the village nonagricultural employment activity has been subdivided in four local business activities producing village consumption goods. This was implicit in the use of the pool account for local businesses activities in the SAM, but needed more explicit treatment in the village equilibrium model.

Table 5.1 summarizes main features of the way in which activities are modeled. Agricultural production activities are modeled through constant returns to scale Cobb-Douglas production functions, following standard general equilibrium practices. Although referred to as Cobb-Douglas, the production functions have in fact a nested structure, as discussed below. The SAM in Chapter 4 has cattle as an agricultural activity as well. Animal traction services, or factor rental, is the main output of this activity. The maintenance of the cattle requires some fixed inputs and apart from animal traction also calves are produced. To deal with this mixture of fixed and variable inputs and outputs, cattle is modeled as a markup activity. Tractor rental uses one input and is therefore modeled as a Leontief activity.

Table 5.1: Activities in the basic village equilibrium model

	Cobb-Douglas	*Leontief*	*Markup*	*Profit*[1]	*Bounds on supply*
Farm production					
One-season rice	x			no	no
Two-season rice	x			no	no
Other crops	x			no	no
Pigs	x			no	no
Other livestock	x			no	no
Factor rental					
Draught animals			x	no	(village) demand
Tractor		x		no	village market share
Inside village employment					
Exchange labor		x		no	household demand
Agricultural labor		x		yes	village market share
Village processed food		x		yes	village market share
Village nonfood		x		yes	village market share
Village durables		x		yes	village market share
Village other goods		x		yes	village market share
Outside village employment					
Non-agricultural labor		x		yes	fixed supply
Migration inside province		x		yes	fixed supply
Migration outside province		x		yes	fixed supply

[1] Profits are introduced to bridge the gap between market and household shadow prices, see Section 3 for a discussion.

Off-farm employment activities are modeled as Leontief activities due to a lack of data on substitution possibilities between the two inputs, male and female labor. The last column in Table 5.1 indicates the way in which markets are assumed to function. This will be discussed in more detail when deriving the production decisions.

Activities combined with commodities form the backbone of an applied village equilibrium model. Table 5.2 presents the commodities distinguished in the village equilibrium model and specifies set-membership. Assigning set membership is a crucial step in the development of the applied model since it imposes a specific market structure on the model.

Table 5.2: Commodities and set-membership in the basic village equilibrium model

	Type of use			**Household tradability**				**Village tradability**		
	I	*O*	*C*	*HT*	*S*	*P*	*HNT*	*VNT*	*E*	*M*
Output of agricultural production										
One-season rice		x	x		x				x	
Two-season rice		x	x		x				x	
Other crops		x	x		x				x	
Cattle		x			x				x	
Pigs		x	x		x				x	
Other livestock		x	x		x				x	
Outside village employment										
Non-agricultural labor		x			x				x	
Migrant labor inside province		x			x				x	
Migrant labor outside province		x			x				x	
Farm produced inputs										
Manure	x	x					x	x		
Feed	x	x					x	x		
Animal traction services	x	x		x				x		
Tractor services	x	x		x				x		
Exchange labor	x	x					x	x		
Agricultural labor	x	x		x				x		
External inputs										
Fertilizer	x					x				x
Herbicides	x					x				x
Pesticides	x					x				x
Seed	x					x				x
Purchased feed	x					x				x
Other external inputs	x					x				x
Consumption goods										
Food			x			x				x
Processed food			x			x				x
Nonfood			x			x				x
Durables			x			x				x
Other expenses			x			x				x
Village processed food		x	x	x				x		
Village nonfood		x	x	x				x		
Village durables		x	x	x				x		
Village other expenses		x	x	x				x		
Factors										
Male labor	x		x				x	x		
Female labor	x		x				x	x		
Irrigated land	x						x	x		
Non-irrigated land	x						x	x		
Cattle	x						x	x		
Tractor	x						x	x		

Note: *I* = inputs; *O* = outputs; *C* = consumed; *HT* = household tradable; *S* = sold; *P* = purchased; *HNT* = household nontradable; *VNT* = village nontradable; *E* = exported; *M* = imported.

Outputs of agricultural production activities are the first set of commodities in Table 5.2. These are all produced (*O*) and consumed (*C*), except for the output produced by the cattle activity (consisting of calves sold outside the village). All sold agricultural output (*S*) is exported (*E*) from the village. Since output is not part of purchased commodities (***P***), this specification assumes that households do not trade output within the village. This assumption reflects the trade flows represented in the SAM. It could be relaxed by moving the outputs from the set of sold commodities (*S*) to the set of household tradables (***HT***), thus allowing village trade.

Outside village employment forms the second set of commodities. In the SAM these are represented by activities. To deal with the additional income earned above the shadow wage, commodities are introduced representing the different types of employment. These commodities do not directly affect the village economy; after production they are exported from the village.

Farm produced inputs form the third group of commodities. They are produced by the households and used as inputs as well. Similar to outside village employment, animal traction and tractor rental services are modeled as commodities. In case of animal traction services, these are produced by the cattle activity, requiring inputs like labor and feed. Tractor services are directly linked to tractor endowments. Traction services and agricultural labor are households tradables (***HT***) but only traded within the village (***VNT***). This represents presence of a local village market without price bands. The other three intermediate inputs (manure, feed and exchange labor) are household nontradables (***HNT***), requiring household demand and supply to match. Exchange labor is dealt with as a household nontradable because of lack of data on the organization of labor exchanges. This suggest that exchange labor could be aggregated with family labor used in production, for which demand needs to meet supply as well. However, because of the presence of monitoring costs discussed with the estimation of shadow prices in Chapter 4, exchange labor is treated as a separate commodity.

External inputs are the next set of inputs for production. These are all imported from outside the village and only used as an input in production. The disaggregation of external inputs used in the SAM in Chapter 4 is maintained to capture differences in substitution possibilities across external inputs in Chapter 7.

Consumption goods are defined in terms of broad categories (food, processed food, nonfood, durable consumption goods and other expenditures). These five types of consumption goods can be imported from outside the village, or they can be produced inside the village. Village consumption goods are produced by the village nonagricultural labor activity (this is included through the local business account in the SAM). It is assumed that these goods differ from the imported goods and are not sold outside the village. They are traded within the village without transaction costs creating price band, and thus part of the set ***HT***.

Factors are all inputs into production. Male and female labor is consumed as well (leisure). All factors are household nontradables. For labor this implies that family and hired labor are considered imperfect substitutes. Family members can engage in off-farm employment, but this is modeled through the off-farm employment activities. In a similar fashion cattle and tractors are a household nontradable, while their services are sold through the rental activities.

Finally, irrigated land is considered a household nontradable, thus assuming that all households continue renting the land they are renting in the SAM. This is a rather bold assumption regarding the functioning of the land market, made to avoid modeling the institutional features of the land market which is beyond the scope of this study.

5.3 production and consumption behavior

Having outlined the activities and commodities included in the applied village equilibrium model, we now turn to specifying the behavioral equations of the model. As any general equilibrium model, the village model consists of accounting relations (like the commodity balances), and equations governing the behavior of the agents (production and utility functions). The accounting relations described in Section 1 can be directly included in the model. To include the behavioral equations, functional forms and their parameters have to be specified.

5.3.1 agricultural production activities

Agricultural production activities (except for the cattle activity) are modeled through a constant returns to scale Cobb-Douglas production technology. This a pragmatic choice since these production functions can calibrated on the SAM without requiring additional data on elasticities. A more elaborate calibration of the production decisions, exploiting the availability of detailed household data is discussed in Chapter 7.

Activities denoted as Cobb-Douglas are actually described by nesting Leontief production functions in a Cobb-Douglas production function (Figure 5.1). Commonly general equilibrium models only include factors in the production function. Intermediate and external inputs are assumed to be fixed shares of the output level (Leontief). In the present context such an approach seems less suitable, since it excludes the possibility of substitution between factors and other inputs. Herbicides can substitute for labor, for example, by reducing time needed for weeding.

At the top-level a Cobb-Douglas production technology therefore combines five types of composite inputs into a composite activity output. To allow for the production of multiple goods, activity output is linked to produced goods through using a Leontief production function (upper part of Figure 5.1). In a similar way composite inputs are linked to commodities used as inputs through Leontief production functions. Such a nested structure partly overcomes an important limitation of the Cobb-Douglas production function, a constant unitary elasticity of substitution. The generic structure in Figure 5.1 can be used for all agricultural production activities. Inputs not used by an activity, like for example non-irrigated land in rice production, will simply have a Leontief input coefficient of zero.

Input demand functions are defined separately for the two levels of the production function. At the top level the demand for composite inputs is determined by solving a cost minimization problem,

$$\min_{QI_{hak}} \sum_{k \in CI} PI_{hak} QI_{hak} , \qquad \forall\ h \in H,\ a \in CA \qquad (5.13a)$$

subject to

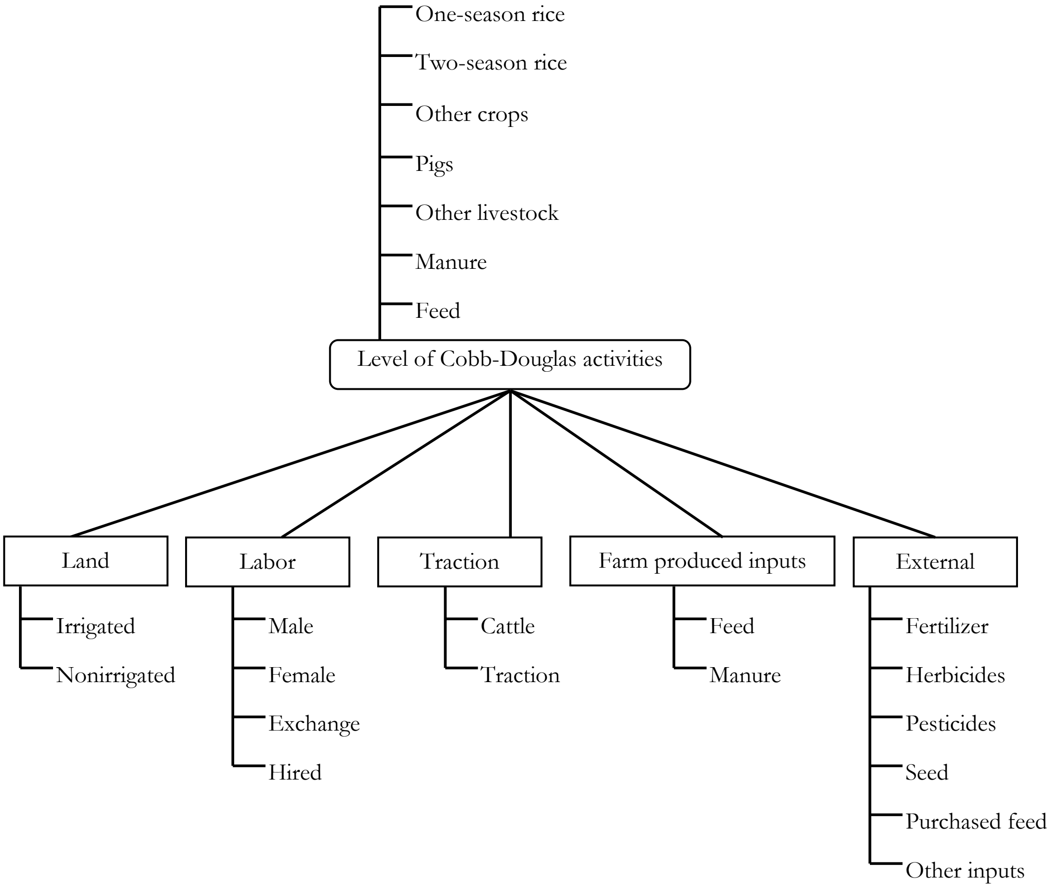
$$QA_{ha} = 1 , \qquad \forall\ h \in H,\ a \in CA \qquad (5.13b)$$

with

$$QA_{ha} = \delta_{ha} \prod_{k \in CI} QI_{hak}{}^{\alpha_{hak}} \text{ , and } \sum_{k \in CI} \alpha_{hak} = 1, \qquad \forall\ h \in H,\ a \in CA \qquad (5.13)$$

where variables in uppercase denote composite variables. QA_{ha} is the composite output produced by the activity; QI_{hak} is the composite input used in production. Their respective (composite) prices are denoted by PA_{ha} and PI_{hak}. The restriction on the cost shares (α_{hak}) indicates that a constant returns to scale Cobb-Douglas is used. Two new sets are introduced in (5.13). The equations refer to Cobb-Douglas activities (*CA*), which is a subset of the activity set (*A*). A new set of composite inputs for Cobb-Douglas activities (*CI*) is also introduced, in addition to the already defined set of inputs (*I*).

Figure 5.1: Structure of agricultural production activities



Note: rectangles indicate composite commodities.

Prices in (5.13a) are household-specific shadow prices, thus allowing derivation of input demand functions separately from other household decisions. Note that the parameters in the production function have a household index, indicating that production functions differ among household groups. Using a Cobb-Douglas specification that differs across household groups allows direct calibration of the production function for each household on the SAM, but may imply the unrealistic assumption that households use different production technologies.

The cost minimization problem defined above results in standard input demand functions for a Cobb-Douglas production function,

$$PI_{hak}QI_{hak} = \alpha_{hak}PA_{ha}QA_{ha} \,. \qquad \forall\ h\in H,\ a\in CA,\ k\in CI \tag{5.14}$$

Total expenditures on the composite input are thus a fixed share (α_{hak}) of the value of output. Note that the price of the composite input is activity-specific. Determination of these prices is specified below. The production function (5.13) and the input demand functions (5.14) together define input demand at the top-level of the Cobb-Douglas production activities.

The next step is defining demand for inputs at the lower level of the production function. These are described by Leontief production functions and thus independent of prices,

$$q^{i}_{haj} = \sum_{k\in CI}\iota_{hakj}QI_{hak} \text{ with } \sum_{j\in I}\iota_{hakj} = 1, \qquad \forall\ h\in H,\ a\in CA, j\in I \tag{5.15}$$

where ι_{hakj} are the Leontief input-coefficients.

In a similar way the output produced by the activities is linked to the activity level,

$$q^{o}_{haj} = \theta_{haj}QA_{ha} \text{ with } \sum_{j\in O}\theta_{haj} = 1, \qquad \forall\ h\in H,\ a\in CA, j\in O \tag{5.16}$$

where θ_{haj} are the Leontief output-coefficients. The input demand and output supply of Cobb-Douglas activities are defined by (5.13-5.16). In these equations two composite prices are used that need to be defined to complete the description of the Cobb-Douglas production activities.

The definition of the composite prices follows directly from the Leontief production functions. Since the composite input represents the inputs used in production, we require the total value of the inputs used to produce the composite input to equal the total value of the composite input,

$$PI_{hak}QI_{hak} = \sum_{j\in I} p_{hj}q^{ia}_{hj} \,. \qquad \forall\ h\in H,\ a\in CA,\ k\in CI \tag{5.17a}$$

Divide by QI_{hak} and substituting a rearranged expression of (5.15) yields the definition of the composite input price,

$$PI_{hak} = \sum_{j\in I}\iota_{hakj}\,p_{hj} \,. \qquad \forall\ h\in H,\ a\in CA,\ k\in CI \tag{5.17}$$

The composite input price is thus a weighed sum of input prices. The activity-specific input coefficients serve as weights, resulting in an activity-specific composite input price.

The definition of the composite activity price is derived in an identical manner,

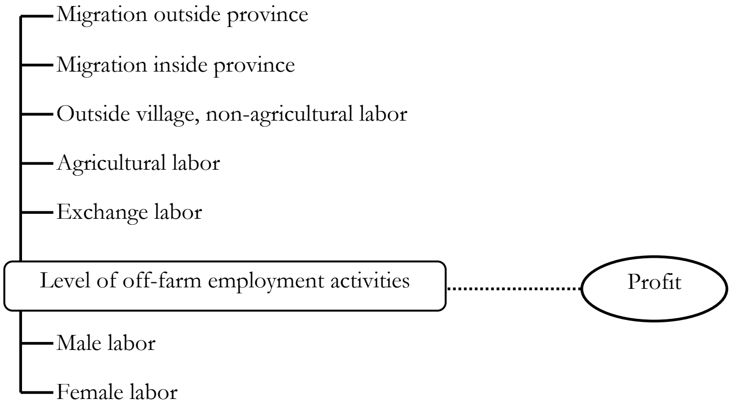
$$PA_{ha} = \sum_{j\in O}\theta_{haj}\,p_{hj} \,, \qquad \forall\ h\in H,\ a\in CA \tag{5.18}$$

again resulting in an activity-specific activity price, without output prices being activity specific. The price equations (5.17) and (5.18) complete the description of Cobb-Douglas production activities.

5.3.2 off-farm employment outside and inside the village

Off-farm employment activities are described by Leontief production functions using male and female labor as inputs. The model treats off-farm employment as a commodity, with the Leontief production function serving as a way of aggregating male and female labor in a single commodity representing each type of off-farm employment (Figure 5.2).

Figure 5.2: Structure of off-farm employment activities



From the analysis of the household survey data in Chapter 4 we know that off-farm wages differ substantially across types of employment and from the shadow wage. This implies different prices for male and female labor, depending on the type of employment being analyzed. To be able to deal with these price differences, a commodity is introduced for each off-farm employment activity, as depicted in the upper part of Figure 5.2. The price or wage can now differ across off-farm employment activities while shadow wages for household male and female labor are the same across all activities. Each employment activity has a single output, through an appropriate choice of output-coefficients the general structure for outside village employment of Figure 5.2 can be used.

Similar to the Leontief parts of the agricultural production decisions discussed above, we can define input demand and output supply as

$$q^{i}_{haj} = \beta_{haj} QA_{ha} \text{ with } \sum_{j \in I} \beta_{haj} = 1 \qquad \forall\ h \in H,\ a \in LA,\ j \in I \qquad (5.19)$$

$$q^{o}_{haj} = \gamma_{haj} QA_{ha} \text{ with } \sum_{j \in O} \gamma_{haj} = 1 \qquad \forall\ h \in H,\ a \in LA,\ j \in O \qquad (5.20)$$

where β_{haj} are the input-coefficients and γ_{haj} the output-coefficients, and LA denotes the set of Leontief activities.

Input demand and output supply are defined in terms of the activity level by (5.19) and (5.20). As stated above, the main reason for introducing commodities for each type of off-farm employment is to deal with the difference between shadow wages and off-farm wages. This difference flows into household full income through profit π_{ha} (see also 5.7), defined as

$$\pi_{ha} = \sum_{j \in O} p_{hj} q^{o}_{haj} - \sum_{j \in I} p_{hj} q^{i}_{haj} . \qquad \forall\ h \in H,\ a \in LA \qquad (5.21)$$

Total profit earned by each Leontief activity is thus the difference between the value of output produced minus the costs of inputs needed for production.

Introducing profits into the model implies that a market mechanism needs to be defined as well. In the case of outside village employment the price of the output (the value of outside employment) will be higher than the costs of inputs (labor valued at the shadow wage). Given that utility is directly linked to full income, the household would like to expand the outside village employment into the highest paying type of employment, while refraining from all other activities earning less than this off-farm wage. This would continue until the shadow wage equals the off-farm wage, returning to a zero profit situation.

Given the findings in Chapter 4 we assume that households cannot freely choose the amount of outside village employment they engage in. To reflect such a constrained access to outside village employment, the amount of outside employment produced is constrained,

$$q^{o}_{haj} = \varepsilon_{haj} . \qquad \forall\ h \in H,\ a \in OUT,\ j \in O \qquad (5.22)$$

where OUT is the set of outside village employment activities and ε_{haj} is the fixed level of employment, set at the level observed in the SAM[1].

The equality constraint used in (5.22) implies that the household is forced to maintain the level of outside employment even if its shadow wage rises above the outside wage. This seems reasonable since the wages used in the SAM represents the net income send back to the household. In case of migrants this is only part of their actual wage and they will not return in case the household shadow wages rises (returns from migration activities are the lowest of all off-farm employment, reflecting that remittances only cover part of the actual wage received by the migrant). In fact the profit equation (5.21) captures the costs for the household of having members working off-farm. In case these activities earn negative profits, from the household's perspective the absent household members cost more than they yield. This interpretation, however, ignores other motives for migration, like income diversification to reduce income fluctuations. Furthermore, a return of migrated household members would have implications for consumption as well, an implication not accounted for in the current specification.

In the case of agricultural labor, the wage also exceeds household's shadow wage. Again, following the same logic as above households would like to increase their agricultural wage labor in order to maximize their income. Hiring in of agricultural labor in a labor surplus situation reflects the seasonal character of agricultural production; labor is hired for specific tasks during peak seasons when all households face a labor constraint. This is reflected by a high agricultural labor wage compared with the shadow wages. To account for this seasonality, the agricultural wage is fixed at the observed level. Apart from seasonality this assumption reflects observations during the fieldwork that the agricultural wage is common knowledge in the village. This suggests that the wage is institutionally fixed instead of being negotiated at every transaction.

Fixing the agricultural wage implies that quantities demanded and supplied need to make all adjustments to maintain equilibrium in the village market for agricultural labor. Based on the

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[1] We thus model outside village employment as being demand-driven, which is consistent with findings of demand driving migration by other studies (Hare, 1999; Wu and Yao, 2003).

seasonality considerations we assume the agricultural labor market to be demand-driven. Agricultural production choices thus determine the demand for agricultural labor, and supply follows.

Three household groups are supplying agricultural labor, while one household group demands agricultural labor. Total demand for agricultural labor is found by summing the demand for agricultural labor by the Cobb-Douglas agricultural production activities. Given a fixed agricultural labor wage, households supplying agricultural labor cannot compete with each other through prices. We therefore assume that households have a fixed market share ξ_{haj}, yielding the following demand equation for agricultural labor,

$$q^{o}_{haj} = \xi_{haj} \sum_{h \in H} \sum_{a \in CA} q^{i}_{haj} \,, \qquad \forall\ h \in H,\ a \in AL,\ j \in LL \qquad (5.23)$$

where *AL* is an activity set with hiring out of agricultural labor as its only member, and *LL* is a set of commodities with agricultural labor as its only member. Again, as with outside employment, an equality sign is used to simplify the model. In the SAM agricultural wages are more than five times higher than the highest shadow wage, and it is thus unlikely that this activity will start earning negative profits[2].

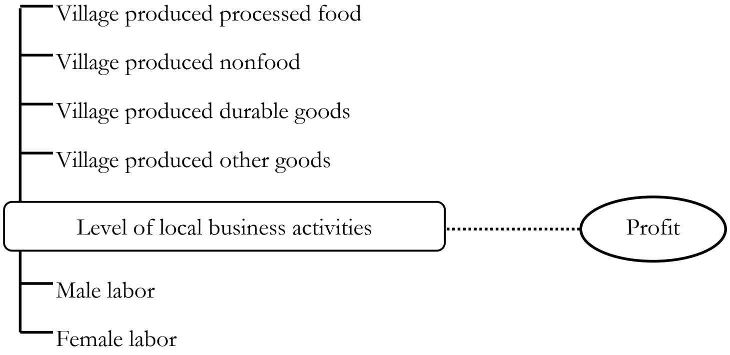
In the case of exchange labor the value of the output will be lower than the input costs (exchange labor is valued at 85 percent of the shadow wage, as discussed in Chapter 4). Incurring negative profits on exchange labor, households would thus like to reduce the amount of exchange labor to zero. Again, to capture seasonality of agricultural production we assume that all households continue using exchange labor. Given the notion of exchange we assume that households supply as much exchange labor as they use. This implies that production decisions determine the amount of exchange labor used, and supply adjusts. This constraint is imposed by assigning the commodity exchange labor to the set of household nontradables (see Table 5.2). Given the household commodity balance (5.9) household demand and supply then balance. The agricultural production activities will always demand the composite input labor and thus exchange labor, forcing households to incur the monitoring costs associated with exchange labor.

5.3.3 local business activities

Apart from the off-farm activities discussed above, households can engage in non-agricultural employment activities inside the village. These are linked to the consumption of village-produced commodities in the SAM through the local business account. As discussed in Chapter 4, this nonagricultural employment account aggregates a diversity of activities, like local shops, blacksmiths, doctors and so on. The household survey lacks data on non-labor inputs in these activities, but as with the off-farm employment discussed above, returns to labor are higher than the shadow wages. This is again dealt with by introducing profits (Figure 5.3), thus requiring the definition of a market mechanism.

As with agricultural labor we assume fixed village prices. A village doctor, for example, can be expected to charge the same amount for the same treatment with the price being common knowledge in the village. While prices of village-produced goods are observable and common knowledge, shadow wages are an analytical construct that cannot be directly observed. Given the gap between observed output prices and estimated shadow wages, we assume that changes in shadow wages are not translated into the village price of consumption goods. Shadow wages being unobservable, adjustment of the village price will be hard to justify. A second reason for fixing prices of local business activities is the absence of a peak season for non-agricultural production activities. Production can therefore be shifted to times when little labor is needed in agriculture, limiting the need to increase the output prices when the shadow wages increase.

Figure 5.3: Structure of local business activities



All households consume locally produced goods and engage in village nonagricultural employment, reflecting a heterogeneity in goods not captured by the aggregates used in the SAM and village model. Such two-way flows are a common feature in macro-level trade models, and generally dealt with through the Armington approach, which consists of defining a function aggregating domestic and imported commodities into a single composite good. Such an approach, however, requires data on bilateral trade flows which we lack in case of the village model.

We therefore again assume fixed market shares, which seems reasonable given the underlying diversity of produced goods. We lack information to directly link nonagricultural village labor to village-produced goods (which was the reason for linking them through the pool account of local business in the SAM). We therefore assume that all households have a share in the production of each village good equal to their share in the total amount of village nonagricultural labor. We furthermore use the household-specific ratio of male to female labor from the village nonagricultural activity for the household's production of village goods.

Being Leontief activities with only male and female labor as inputs, equations (5.19), (5.20) and (5.21) apply to model input demand, output supplied and profits. What remains is defining demand for households' output. With the assumptions made above this can be modeled as,

$$q_{haj}^{o} = \kappa_{haj} \sum_{h \in H} q_{hj}^{c} , \qquad \forall\ h \in H,\ a \in VA,\ j \in J \tag{5.24}$$

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[2] This should be checked after solving the model, and appropriate adjustments made in case profits become negative.

where κ_{haj} is the market share of a household for a village produced good, and *VA* are village production activities. As with agricultural labor, profits on village production need to be positive after solving the model to justify the equality sign in (5.24).

The above set of equations defines the production of each household and assures that all consumed village goods are produced (market shares sum to one). The household commodity balances determine whether a household group is a net buyer or net seller of a commodity.

5.3.4 renting of tractor services

Two of the household groups earn income by renting out tractor and animal traction services. Use of tractors is still limited, the majority of the households use draught animals. Therefore tractors are modeled as not being fully utilized, supply of tractor services can be expanded beyond the levels observed in the SAM. This implies that the price of tractor services is assumed fixed at current levels. Again (5.19) and (5.20) are used to model the link between the tractor (input) and tractor services (output). There are no data on the operating cost of tractors. It is therefore not possible to establish whether profits are made when renting tractor services, and profits are set to zero. Payments for tractor services are thus assumed to cover operating and other costs associated with the use of tractors.

Assuming tractors not being fully utilized implies that demand for tractor services determines the total supply. All four household groups use tractor services, while two household groups own tractors. These households can rent out tractor services, but may also rent them in if circumstances change. This implies that tractor services are a household tradable, represented in the household commodity balances by a net marketed surplus that is negative for net buyers. By summing over the absolute value of the net marketed surplus of each household and dividing by two, we get the total amount of tractor services rented within the village. As with the other activities without price competition the total traded amount is allocated to the two household groups owning a tractor on the basis of their initial market share,

$$q^{o}_{haj} = \sum_{a\in CA} q^{i}_{haj} + \tau_{hj}\left[\tfrac{1}{2}\sum_{h\in H}\left|q^{ht}_{hj}\right|\right] \qquad \forall\ h\in HD,\ a\in TA,\ j\in TS \qquad (5.25)$$

where *TA* is an activity set with tractor rentals as a single element, and *TS* is a set of commodities with tractor services as its only element, and *HD* is a subset of household groups owning draught power. The total amount of tractor services produced by a household group depends on its own tractor use (determined by the Cobb-Douglas agricultural production activities), and its market share (τ_{hj}) of the amount of village traded tractor services.

To model tractors not being fully utilized, the endowment of tractors is not fixed but determined by the amount of tractor services the household produces. The amount of produced tractor services determines the amount of tractor used as input (by 5.19 and 5.20), which on its turn determines the endowment of tractors,

$$q^{\omega}_{hj} = q^{i}_{hj}, \qquad \forall\ h\in HD,\ j\in T \qquad (5.26)$$

where *T* is a set of commodities with tractors as its only element.

5.3.5 renting of animal traction services

Animal traction services are linked to the cattle livestock activity. As depicted in the SAM, the main output of the cattle activity is the supply of animal traction services. In addition, the cattle activity produces manure (used for crop production) and calves (sold outside the village). Maintenance of the animals requires labor, feed and other (external) inputs.

The model abstracts from saving and investments, hence the stock of cattle is assumed fixed. This implies that the inputs needed to maintain the animals (labor, feed and other inputs) are fixed, as are the production of manure and calves. The cattle activity thus has a number of fixed inputs and outputs that are independent of the amount of animal traction services supplied.

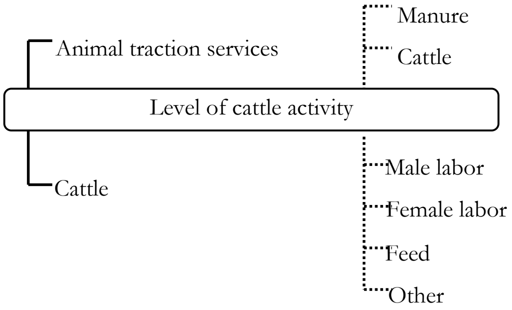
The production of animal traction services and use of cattle can be described by (5.19) and (5.20), as with the other Leontief activities. In addition we need to specify the fixed inputs and outputs,

$$q^{i}_{haj} = \bar{q}^{i}_{haj}, \qquad \forall\ h \in H, a \in MA, j \in FI \qquad (5.27)$$

$$q^{o}_{haj} = \bar{q}^{o}_{hoj}, \qquad \forall\ h \in H, a \in MA, j \in FO \qquad (5.28)$$

where *FI* is the set of fixed inputs, *FO* the set of fixed outputs, and *MA* is a set of markup activities (see below) which has cattle as a single element.

Figure 5.4: Structure of cattle activity



Note: dashed lines indicate fixed inputs and outputs.

The presence of fixed costs suggests increasing returns to scale, since the amount of fixed costs per unit of animal traction services decreases when more services are produced. This is not the case, however, since the other input (cattle) is a fixed stock with a household-specific shadow price (services can be traded, but cattle are a household nontradable). Marginal costs are thus not fixed but increasing.

In contrast to tractors, draught animals are fully utilized during the peak season. This is reflected in the description of the representative household groups in Chapter 4; households owning draught animals cultivate larger areas than those without traction. Observations during the fieldwork also indicate that supply during agricultural peak periods constrains production decisions. With draught animals fully employed we thus cannot assume their price to be fixed and endowments adjusting as with tractors, and we need to define a market mechanism.

If animal traction services were priced according to marginal costs, households owning cattle could incur a loss since the value of their fixed output may not cover their fixed input costs. We therefore assume that households use an average pricing rule, in which a markup above the marginal costs serves to recover fixed costs. In the presence of fixed inputs and outputs this boils down to requiring the value of total output to equal total inputs costs,

$$p_{hj} = \frac{\sum_{j \in I} p_{hj} q^{ia}_{haj}}{q^{oa}_{haj}}. \qquad \forall\ h \in HD,\ a \in MA,\ j \in J. \qquad (5.29)$$

The average pricing rule is used in general equilibrium models with imperfect competition in case of free entry and exit. The threat of new entrants then serves to deter producers from earning profits. Animal traction services are the only good for which a village market with endogenous prices exists. We need to address the issue of market power since the model does not include investment in cattle by the two household groups not owning them, nor are there new households that could enter and erode market power.

It would be possible to introduce imperfect competition for animal traction services, with the two households owning cattle manipulating prices or quantities to earn a profit. In contrast to macro-level general equilibrium models, however, we are not dealing with agents that interact anonymously in markets. The households interact with each other in village markets but have social relations as well. Since cattle ownership, use and prices can easily be observed, it seems unlikely that households have much room for influencing the price without incurring social sanctions. Having draught animals standing idle next to your house when the whole village has a peak demand for animal traction services, for example, seems a rather unrealistic assumption. We therefore adopt an average pricing rule, with social repercussions serving as the disciplining force normally provided by the threat of new entrants to the market.

Replacing the free entry and exit assumption by social sanctions we can thus proceed with modeling cattle as a zero profit activity. Animal traction services are the only village nontradable for which village prices are endogenous. The village price is determined by the village trade balance (5.10) requiring the sum of the net marketed surplus over all households to be zero. For the other village nontradables the equations linking demand to supply replace the village trade balance. These equations also result in a supply matching demand, but realized through quantity instead of price adjustments as in the case of animal traction services.

5.3.6 consumption decisions and welfare measurement

Consumption decisions are the last set of behavioral equations that remain to be defined. Focusing on modeling village interactions, consumption decisions are kept simple in this chapter. A Cobb-Douglas utility function that can be calibrated directly on the SAM is used. As with production, using household shadow prices allows us to look at consumption decisions in isolation from the other household decisions, resulting in a straightforward utility maximization problem.

The utility maximization problem can be formulated as,

$$\max_{q^c_{hj}} \prod_{c\in C} q^{c\ \mu_{hc}}_{hj} \,, \qquad \forall\ h\in H, j\in C \qquad (5.30a)$$

subject to

$$p^*_{hj} q^c_{hj} \leq w_h \,, \qquad \forall\ h\in H, j\in C \qquad (5.30)$$

where μ_{hc} are the budget shares of the consumed goods. Since the utility function is non-satiated (5.30) will hold as an equality. Solving this maximization problem yields the following standard consumption decisions,

$$p^*_{hj} q^c_{hj} = \mu_{hc} w_h \,. \qquad \forall\ h\in H, j\in C \qquad (5.31)$$

The Cobb-Douglas utility function results in households spending a fixed share of their income on each consumption good. This specification hence ignores possible shifts in spending patterns towards luxury goods when income increases. In Chapter 5 we will relax this relax this restrictive assumption by introducing Stone-Geary utility functions.

The description of consumption decision (5.31) completes the applied model. Since general equilibrium models are generally build to assess different policies we need to define a measure for assessing the welfare of the households, which will serve as a summary statistic of the simulation results later on.

Given that we have fully specified utility functions we can use compensating variation (CV) or equivalent variation (EV) to measure welfare impacts. The CV measures the willingness to pay for a change, while the EV measures the willingness to accept a change. Willingness to accept and willingness to pay may differ from each other if the change involves an income change. A change in income affects the value of additional money, and thus the measurement of utility in monetary terms. Wealth effects will thus cause a divergence between the CV and EV measurements of utility (Mas-Colell *et al.*, 1995:83).

When analyzing scenarios we will be using the base run reproducing the SAM as a point of reference. In making such pair wise comparisons the EV is easier to use than the CV since the EV is based on income and prices from the base run. By using the same reference point across pair wise scenario analyses, the EV allows a direct comparison of the welfare implications of different scenarios (Shoven and Whalley, 1984), making EV the standard measure of welfare changes in general equilibrium models.

With a linearly homogenous utility function, like the Cobb-Douglas, the EV can be computed as (Shoven and Whalley, 1984),

$$EV_h = \left(\frac{u^a_h - u^b_h}{u^b_h} \right) w^b_h \,, \qquad \forall\ h\in H \qquad (5.32)$$

where superscripts d denotes current levels (after simulation levels of variables) and b denotes base levels. Calibration of the demand function (5.31) defines the parameters of the utility functions. With the utility function fully specified, the EV defined by (5.32) can straightforwardly be computed from the model solution.

5.4 closure, calibration and consistency checks

In previous sections all ingredients for an applied village equilibrium model have been collected. Section 1 described the equations to be included in the model, Section 2 described data and the sets to which commodities belong, while Section 3 specified production and consumption decisions. The model is programmed in GAMS and solved as a mixed complementarity problem[3].

5.4.1 model summary and closure

The way in which the model is closed, *i.e.* the number of equations is made to match the number of variables, has been implicitly discussed by describing the way in which markets for all commodities are balanced. Since the closure drives model outcomes, we recapture the main elements of the model including the closure.

The model distinguishes three types of production activities, Cobb-Douglas agricultural production activities, Leontief activities and mark-up activities. Prices of exported and imported goods are fixed at SAM levels. In case agricultural output is not exported its price becomes endogenously determined by household demand and supply. The position of households in agricultural output markets as net sellers or autarkic is endogenously determined by solving the model as a mixed complementarity problem.

Prices of Leontief activities are fixed, while their levels are fixed (outside village employment) or determined by the household market share in total village demand (village produced goods and tractor services).

Endowments of tractors, measured in terms of supplied services, are endogenously determined. Tractors are thus assumed to be underutilized. Endowments of other factors (labor, land and cattle) are fixed. Their prices adjust to match demand and supply. Households land endowments include the amount of land rented in in the SAM. Village land markets are thus excluded from the model.

Households are restricted to satisfy their budget constraint that does not allow them to run a deficit. The households are thus not allowed to borrow money apart from the transfers observed in the SAM. These transfers from households in the village or from relatives outside the village are fixed at levels observed in the SAM and captured through the exogenous income, $\overline{y}_h^l$. Transfers among households in the village are fixed because of lack of data on the conditions on which these transfers are provided, as well as a lack of data on the decisions between transferring money to other households or spending it on own consumption. This fixing of cash transfers among households eliminates a pathway through which additional income from migration may be dispersed through the village economy, thus potentially underestimating the village-wide impact of migration. In the absence of other agents, requiring household budgets to balance implies that the village balance of payments needs to balance as well.

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[3] More information on the GAMS software, applications and so on can be found on www.gams.com. The model with a windows-based user interface (GAMS Simulation Environment) can be downloaded from the Development Economics Group site ate www.sls.wageningen-ur.nl/dec. Note when comparing the equations described above to the GAMS model that demand functions for the different Leontief activities have been combined in a single function. Also note that the specification of complementarity constraints in the price block result in a mixed complementarity problem with matching equations and variables.

5.4.2 model calibration

Model parameters are specified such that the base run of the model reproduces the initial SAM. This means that the SAM plays a central role in the applied model. It first of all provides the information needed for calculating parameters of all behavioral equations, like market shares for Leontief activities and budget shares for consumption. Macro general equilibrium models are normally calibrated with a SAM by normalizing all prices to one. This implies that all values of the SAM can be interpreted as quantities, allowing calibration without price information.

For calibration of the village model additional information on prices is needed, since normalizing all prices to one is inconsistent with the presence of household-specific shadow prices. In the calibration of the village model the prices of composite goods (like nonfood consumption goods or prices of composite inputs) are normalized to one. For the composite goods no meaningful quantity measures exists since their constituent parts are measured in different ways. The composite goods should thus be thought of as an index summarizing the contribution to production of their constituent inputs with a price that could be set at any level (Keller, 1979:118). For all other commodities prices used in the construction of the SAM are used for calibration as well. Combining values from the SAM with the price data allows calculation of all model parameters (due to the use Cobb-Douglas functional forms), and determination of base levels of all variables.

5.4.3 consistency checks

The second role of the SAM is to provide initial levels of all variables. Good starting values for variables can be crucial for solving nonlinear models, since without appropriate starting values the solution algorithm may get stuck in an infeasible solution.

Initializing variables at the levels in the SAM does not only provide good starting values for solving the model, it also provides a first consistency check on the model. Since we are calibrating the model such that it reproduces the base situation depicted in the SAM, using SAM-based starting values implies that all equations of the model should balance. GAMS will flag equations that are not balanced using initial variable levels, which provides a fast way of identifying problems in model equations and calibration procedures.

Apart from reproducing the SAM, the village equilibrium model should satisfy two more consistency checks related to its general equilibrium properties: Walras' Law and homogeneity. Walras' Law is checked by calculating the village balance of payments after solving the model. If the inflow does not equal the outflow of money there is an inconsistency in the model. Walras' Law will hold for the base run if the model passes the first consistency check, *i.e.* replication of the SAM, and should therefore be checked after applying an exogenous shock to the model.

The third consistency check is homogeneity in prices. As discussed in Chapter 3 only relative prices matter in general equilibrium models. This may not be immediately obvious from the applied village equilibrium model since it lacks a price normalization equation. Anchoring of the price level is provided by the fixed prices of import and exports, providing an implicit price normalization. To check whether the model is homogenous in prices, all price and monetary variables are multiplied with a constant after which the model is solved. In terms of quantity variables this solution should replicate the base solution. Again, flagging of initially infeasible constraints by GAMS helps detecting equations that are not homogenous in prices.

With the applied model passing all three consistency checks we are finally ready to analyze the impact of village interactions on household response.

5.5 assessing the effect of village interactions on household response

Before turning to the basic village model we first assess the impact of interactions among households in the village on household response. To this end results of separate household models for each of the four household groups are compared with results from the basic village model. To get a clear view on the impact of interactions among households we analyze a shock that initially affects only two household groups.

After a short discussion of the construction of separate household models from the village model and a motivation of the shock to outside province employment used throughout this study, we start by discussing the results from separate household models. The absence of interactions among households reduces the complexity of the analysis and shows the direct impact of the shock on the households. We then proceed with comparing these findings to the results of the basic village model, to assess the impact of indirect effects of the shock.

5.5.1 creating separate household models from the village model

With a few modifications the village model can be used for a standard household level analysis. The village model consists of a set of household models linked through village markets. Hence, by removing the village interactions the model falls apart in separate household models. Households interact through trade in commodities that earn a profit (local business activities and agricultural labor) and commodities that do not earn a profit (tractor and animal traction services).

In case of activities earning a profit, households want to expand production until a zero profit situation is achieved. In the village model, village demand serves as a bound on the supply of these commodities. To generate separate household models we need to break this link between households, and therefore fix production at the levels observed in the SAM.

In case of animal traction and tractor services no profits are made. For animal traction, equilibrium is attained in the village model by having prices adjust until supply meets demand. To break the link between the households, prices of animal traction are assumed fixed. Households can thus rent in unlimited amounts of animal traction services, while households owning cattle can rent out services against a fixed price until they exhaust their endowment.

For tractor services prices are fixed in the village model to capture that fact that tractors are not fully utilized. Equilibrium is achieved by having endowments match demand for tractor services. To break the link between households we fix the amount of services sold by the households owning tractors. For households renting in tractors nothing changes, they can rent in unlimited amounts against a fixed price. For households owning tractors, fixing the sold amounts maintains the feature that tractors are underemployed. Endowments, however, now only respond to changes in the households' own use of tractor services.

5.5.2 increased outside province income: motivation

Since both the separate household models and the village model reproduce the SAM, we need to perform a simulation to assess the impact of interactions among households on household response. In this study we focus on an increase in income obtained from outside province employment. Migrants from the case study village move to the coastal provinces in search of employment, reflecting the transition from an agricultural to an industrialized economy as described in Chapter 1. This rural-urban flow of migrants is expected to continue in the future with the increasing openness of the Chinese economy.

Analyses of the impact of China's WTO accession (Diao *et al.*, 2003; Huang *et al.*, 2003) and the Doha round find changes in China's production structure reflecting its comparative advantage in labor-intensive activities. A main source of the Chinese gains from multilateral trade liberalization is improved market access of its labor-intensive manufacturing sectors. The result is an expansion of manufacturing and an increase in real factor prices. Household members that have migrated to the coastal provinces can be expected to share in this gain through a wage increase. Part of an increase in payments could be transmitted to the village through increased flows of money from the migrants to the household remaining in the village. An analysis of the impact of an expanding labor-intensive manufacturing sector on levels of migration is postponed to Chapter 6, since this requires a different specification of household consumption demand than used in the basic of model of the current chapter.

Comparing the results of separate household models with results from a village model is highly relevant in the Chinese context. The rapid economic development of the past decades has mainly concentrated in the coastal provinces, leading to an increasing dichotomy between regions in China. This dichotomy is reflected in the case-study village by differential access to outside province employment across household groups. Given the social tensions arising from the growing income differences, distribution of the benefits of an increase in manufacturing in the coastal provinces is important for assessing the need for complementary policies.

In the case of separate household models the increase in income from outside province migrants only affects the two household groups with a link outside the province. Standard household-level analysis does not allow the analysis of indirect effects through interactions in the village. In the village model, in contrast, the increased income of the two household groups affects the households initially untouched by the shock. Depending on the way in which the households interact, the households without an outside province link may benefit or loose from the inflow of money, which will affect the income distribution within the village.

5.5.3 increased outside province income: household analysis

The increase in income from outside province migrants is modeled as a 10 percent increase in remittances of outside province employment[4]. When analyzing model results a base run replicating the SAM is used as the reference point. Analyzing a shock to a nonlinear (general equilibrium)

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[4] Analysis of the impact of the Doha round already finds between 7 and 9 percent increase in employment in the manufacturing sector with further trade liberalization (Kuiper and Tongeren, 2004). The proposed changes in the Doha are less far-reaching than China's WTO accession. Combined with the continuing high growth rates in China, a 10 percent increase in employment opportunities seems a reasonable indication of the changes in coastal employment.

model is easiest by following the shock throughout the model. In the current case this implies we start with the change in profits and its impact on household full income (Table 5.3).

Table 5.3: Profit, income and EV with separate household models with a 10% increase in outside province remittances (%)

	Household with a link and no draught power	*Household with a link and draught power*
Profit from outside province employment	13.1	30.4
Total profits	7.9	14.0
Household full income	3.7	0.9
Equivalent variation (10^3 yuan)	91.5	45.1

Note: % change with respect to base; shock does not affect the two household groups without a link outside the province.

The increased remittances of outside province employment increases the profits earned on this activity. Since the increase is modeled as a price change of the good produced by the outside province migration activity, the change in profit depends on the total (fixed) amount of outside province employment. The net result (after changes in shadow wages, discussed below) is an increase in profit from outside province employment exceeding the initial shock, especially for the household owning draught power.

Increase in total profits depends on the share of outside province employment in total profits and on the decrease in profits of other activities. The initial shock to profits from outside province employment is watered down further when reaching household full income. Not surprisingly, the income increase translates into an increased welfare for both households. The larger gain for the household with no draught power is due to the relative greater importance of outside province income for this household. For the household with no draught power profits account for about a quarter of full income, while being only about 6 percent of full income for the household with draught power.

The increase in household full income in first instance only affects household consumption. Given the Cobb-Douglas utility function, the income increase is allocated in fixed shares over consumption goods. For most consumption goods prices are exogenous to the household, implying consumption increases with the same percentage as full income. Leisure consumption is the only exception since shadow wages are endogenous. The increased demand for leisure results in an increased shadow wage, tempering the increase in leisure consumption. This effect is most pronounced for the household lacking draught power, with leisure increasing with 0.3 percent while its full income increases with 3.7 percent. The increase in leisure for the household owning draught power is only 0.2 percent lower than its increase in full income.

Apart from tempering the increase in leisure, the rising shadow wage also affects production decisions. Table 5.4 presents changes in production and marketed output. The changed production pattern represents a shift away from activities with high labor input (two-season rice) to activities with less labor use (one-season rice) and high external input use (other livestock activities). The shift towards less labor-intensive production corresponds to differences across villages observed during the fieldwork. In villages with little off-farm employment activities, two-season rice using labor-intensive green manure was still observed, while in the village used for this study two-season rice is still grown but without green manure.

Table 5.4: Produced and marketed output with separate household models with a 10% increase in outside province remittances (%)

	Household with a link and no draught power	*Household with a link and draught power*
Produced agricultural output		
One-season rice	2.9	62.7
Two-season rice	-1.3	-27.7
Other crops	-1.2	-0.1
Pigs	-1.2	-3.8
Other livestock	4.5	99.7
Outside village marketed output		
One-season rice	2.1	91.6
Two-season rice	-10.4	-83.2
Other crops	-14.5	-4.0
Pigs	-1.8	-6.2
Other livestock	6.7	321.7

Note: % changes with respect to base; shock does not affect the two household groups without a link outside the province.

Table 5.5: Activity composition by household group and village average (percentage of value-added)

Link outside province:	*No link*		*Link*		*Village*
Owning draught power:	*No*	*Yes*	*No*	*Yes*	
Agriculture					
One-season rice	9.4	10.8	8.2	10.5	9.5
Two-season rice	28.5	28.2	18.6	27.1	23.9
Other crops	21.2	24.7	18.4	22.4	20.9
Cattle	-	7.5	-	8.1	4.1
Pigs	0.1	0.1	0.2	0.4	0.3
Other livestock	0.1	0.1	0.0	0.0	0.0
Village employment					
Agricultural labor	1.3	2.2	-	0.1	0.4
Local business	19.4	13.5	2.4	2.7	5.2
Outside village					
Outside employment	18.0	12.9	9.1	5.4	8.9
Migration					
Inside province	2.1	-	4.2	0.9	2.3
Outside province	-	-	38.8	22.3	24.6
	100	*100*	*100*	*100*	*100*

Note: '-' indicates that the household is not involved in this activity.

The model has been constructed such that households cannot purchase agricultural output (see the set assignments in Table 5.2). This introduces a subsistence demand for agricultural production that will maintain production even when it is no longer profitable to grow the crop for the market. In the case of two-season rice the household with draught power is getting close to the subsistence level production, with marketed output dropping by 83 percent. It should be noted that the introduction of household demand for commodities is not as restrictive as it seems at first sight. In case the crop is no longer sold its price will rise above the market price (due to the complementarity constraints on prices of sold and purchased commodities). Given the fixed budget shares consumption levels will drop when the shadow price of the crop increases, thus reducing subsistence production levels.

Comparing the production response, the household group owning draught power shows a much stronger response due to a difference in production technology. This household group has a more capital intensive other livestock production. The increased availability of cash from the remittances releases its cash constraint, allowing it to expand other livestock production. Although other livestock production increases more than three-fold, the initial share of other livestock in production is very small (Table 5.5). In absolute terms the increase in other livestock is therefore much more modest than the percentages suggest.

5.5.4 increased outside province income: village analysis

With separate household models the impact of an outside province income shock is limited to the two household groups having access to outside province employment. Through interactions within the village their increase in income affects the other two household groups as well, which can be analyzed with a village model. Table 5.6 presents results of the village model in terms of profits, income and welfare for all four household groups.

Table 5.6: Household profit, income and EV with the village model with a 10% increase in outside province remittances (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Profit from outside province employment	n.a.	n.a.	13.0	28.5
Total profits	1.0	1.2	8.0	13.5
Household full income	0.4	0.4	3.8	1.5
Equivalent variation (10^3 yuan)	2.1	2.1	93.4	49.2

Note: % with respect to base.

The increase in profit from outside province employment is slightly less than with the separate household models. Since this profit is defined as the difference between income received by the households and costs of labor inputs, this indicates that shadow wages increase more in the village model. The two households without a link outside the province do not directly benefit from the increase in income, their increase in profit is due to an increase in local business activities. Their increase in income is modest, less than a half percent. In terms of equivalent variation this still amounts to an increase in welfare of a little over 2,000 yuan (about 120 US dollar) per year.

Comparing the results in terms of EV for the two households with a link outside the province, we find that interactions within the village further increase their welfare. In case of the household with no draught power with 2 percent, for the household with draught power with 9 percent. To get an insight in the effect of the interactions, Table 5.7 presents the changes in production of the four households, while Table 5.8 presents changes in village trade and sales outside the village.

Table 5.7: Produced agricultural output with the village model with a 10% increase in outside province remittances (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Agricultural output				
One-season rice	-2.8	-15.6	2.3	25.5
Two-season rice	1.0	6.9	-0.9	-11.0
Other crops	0.0	-0.1	-1.2	-0.3
Pigs	0.1	0.6	-1.2	-2.1
Other livestock	-3.3	-47.0	4.9	50.8
Tractor services	n.a.	2.7	n.a.	-4.1

Note: % with respect to base.

The household groups without and with a link outside the province show opposite change in production pattern. As with the separate household models, household groups with a link move towards less intensive use of irrigated land (one-season rice) and an increased use of capital for external inputs (other livestock). Compared to the separate household models, the response of households with a link is more modest. This is most pronounced for the household owning draught power, which halves its response from compared to the analysis with separate household models: other livestock production now increases with 50.8 instead of 99.7 percent and one-season rice production increases with 25.5 as opposed to 62.7 percent with the separate household models. This more moderate response of both households involved in outside province migration is due to a decrease in the price of animal traction (for reasons discussed below), which compared to the analysis above increases the relative attractiveness of rice with regard to other livestock.

The two household groups without a link outside the province show an opposite movement towards more intensive use of land (two-season rice) and reducing other livestock. Shadow wages for all household groups increase in the village model, the key factor in the opposing shifts in production is therefore not the price of labor, but the availability of cash from outside the province and from the renting out of animal traction services. The increase in cash income allows the two household groups with an outside link to expand other livestock activities. As before, their increase in shadow wages (which is higher than for the other two household groups because of their increased demand for leisure) also makes them shift to less labor-intensive rice production. This less intensive use of the land releases animal traction services, that are sold on the village market by the household group owning cattle. In contrast to the separate household models, in the village model the increased supply decreases the price of animal traction, thus reducing the inflow of cash from cattle renting.

The drop in the price of animal traction increases the attractiveness of two-season rice for the households without an outside link, both lacking additional money from remittances for expanding other livestock production. Moving from one to two-season rice, however, also requires more external inputs. Reducing other livestock production releases the required cash. Two-season rice being a double cropping system requires more draught power than one-season rice. The household owning draught power thus needs more animal traction services for its own cultivation, implying a reduction in its cattle rental. This reduction in rental activities amplifies the reduced inflow of cash from the decrease in animal traction services price. As a result the household with draught power and no outside link reduces production of other livestock to its own consumption needs. There is only a very minor difference between the market price and household shadow price (0.007 percent) above the, indicating that the household has just passed the switching point towards subsistence production.

Table 5.8: Village trade and village marketed surplus with the village model with a 10% increase in outside province remittances (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Village trade				
Animal traction services[1]	1.6	-8.6	1.0	4.2
Tractor services[1]	1.8	1.0	0.8	1.0
Consumption goods[2]	2.5	3.0	6.8	1.2
Outside village marketed output				
One-season rice	-6.2	-22.3	0.9	36.8
Two-season rice	1.8	18.4	-9.4	-35.3
Other crops	-9.0	-2.1	-14.7	-7.5
Pigs	0.1	0.6	-1.8	-4.0
Other livestock	-7.6	-100.0	7.7	161.7

Note: % with respect to base; [1] refers to change in purchases by household not owning draught power and change in sales by households owning draught power; [2] refers to changes sales by households lacking an outside link and change in purchases by households with an outside link.

The village analysis thus shows opposing changes in agricultural production. Households obtaining additional income through their link outside the province shift towards the production of less labor- intensive and more capital-intensive production systems. The households without an outside link move in a more labor- and land-intensive direction, driven by decreasing prices for animal traction services and an increasingly limiting cash constraint.

Apart from the village market in animal traction services, the households interact through local business activities. Households with an outside link are net buyers of locally produced goods. Their increased consumption allows the other two groups of households to expand their within-village sales of local consumption goods (see Table 5.8).

In terms of aggregate village marketed surplus results are mixed: changes in production move in opposite direction some goods, while moving in the same direction for others. Depending on whether households have a link outside the province, production shifts towards two-season rice (no link) or one-season rice (link). The change in surplus of other livestock also shows an opposite movement along the dividing line of a link outside the province. For other crops the marketed surplus decreases, mainly because of increased household consumption.

5.5.5 comparing household and village-level analyses

Above the impact of the increased income has been analyzed for each of the household groups. Accounting for village interactions resulted in indirect effects on all households, including those initially unaffected by the income shock, causing changes in production patterns dependent upon access to outside province income. Having focused the discussion above on household-level impacts, we now turn to the overall impact on the village. In terms of policy analysis a number of indicators are relevant: change in welfare, income distribution and village marketed surplus. Table 5.9 presents the village-level outcomes of separate household models and the village model.

Table 5.9: Village-level impact with household and village models following a 10% increase in outside province remittances (%)

	Separate household models	*Village equilibrium model*
Equivalent variation* (10^3 yuan)	136.6	146.8
Increase in full income*	1.7	2.0
Income per adult equivalent		
Household with no link, no draught power	0.0	0.4
Household with no link, draught power	0.0	0.4
Household with link, no draught power	3.7	3.8
Household with link, draught power	0.9	1.5
Village marketed surplus		
One-season rice	46.8	14.3
Two-season rice	-40.6	-15.3
Rice	*-12.4*	*-5.8*
Other crops	-7.7	-9.7
Pigs	-2.2	-1.6
Other livestock	95.9	27.7

Note: % with respect to base; * Computed as the sum over all households.

Not surprising given a shock involving an increase in income, both the separate household models and the village model result in an increase in total welfare. Comparing household and village models, the interactions within the village are found to have a positive impact on aggregated welfare, which increases to 146,800 yuan in the village model (representing a 7 percent increase compared to the separate household models). This does, however, not say anything about the income distribution within the village.

To asses the distributional impact of the shock, the income per adult equivalent[5] for each household group is calculated. Although the two household groups without a link outside the province share some of the benefits, the main beneficiaries are the households with an outside link. These two household groups already have more income per adult equivalent in the base run than households without a link. The increase in outside income thus reinforces initial income differences[6].

Apart from income and welfare indicators, marketed surplus is also important for policy-makers. Where differences between household and village models are marginal in terms of welfare and income, differences in terms of marketed surplus are pronounced. Because of the opposing changes in production, the village model shows a much more moderate change in marketed surplus than resulting from an analysis with separate household models.

For Chinese policy-makers guaranteeing the supply of rice to the urban areas has been a major issue in the past. Aggregating one and two-season rice, simulations with the separate household models result in a 12.4 percent decrease in exports of rice from the village, whereas the village model results in a 5.8 percent decrease in rice exports. Given the rising incomes, supply of meat can be expected to become more of a concern in the future than production of staple crops like rice. Household and village models have the same result in terms of pigs sold outside the village; a small decrease in production coupled with an increased consumption results in a reduction in exports. Results for other livestock, however, are far apart. An analysis with separate household models result in almost a doubling of exports of other livestock, which contrasts with only a 27 percent increase in the village model. This is mainly due to the sharp production decrease by the household owning draught power and no outside link, which faces a tightened cash constraint. An analysis with separate households models thus overestimates the impact on village exports in terms of reduced rice exports, and especially in terms of supply of other livestock.

5.6 concluding remarks

Interactions among households are the main theme of this chapter. The first part of this chapter conceptualizes the applied village model. Production and demand are described using easy to calibrate but restrictive functional forms, leaving the focus of attention on interactions among households. The SAM provides important information on these interactions, but only offers a single observation. Observations during the fieldwork therefore provided additional guidance in modeling village markets.

The resulting village model does not have a market structure as typically used in macro-level models. Village prices are assumed to be fixed for most village nontradables, resulting in demand driven markets and non-zero profits. A first reason for assuming fixed prices in local business

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[5] See Chapter 6 for a description of the calculation of the adult equivalents per household group and a more detailed discussion of the income distribution across households.

[6] Recall that transfers among households are fixed at levels observed in the SAM. Direct redistributions of the additional income from the outside province remittances through household transfers are thus excluded from the analysis.

activities is that prices are common knowledge in the village, making it difficult to start increasing them if a household's (unobservable) shadow wage increases. A second reason for fixing the prices of local business activities is the absence of a peak season for nonagricultural production. Production can therefore be shifted to times when little labor is needed in agriculture, limiting the need to increase the price when the shadow wages increase.

The only exception to the fixed village prices is the market for animal traction services. Supply of animal traction services during peak periods for agricultural production limits production possibilities. The fact that a household has to forego using cattle on its own land if the cattle are rented justifies a price increase if demand for animal traction services increases. A limitation of the current model specification is that shifts from animal traction to tractor services are not allowed by the Leontief component of the production function, although tractors are not yet fully utilized (which provides the rationale for having their prices fixed and endowments adjust to demand). Introducing a more realistic production function in Chapter 7, we find a high amount of substitutability between the two types of traction, underlining the restrictive character of the production specification in the current chapter.

The second part of this chapter focuses on the impact of village interactions on household response. Applying a partial equilibrium closure to the village model results in separate household models. Comparison of the simulation results of the separate household models with the village model highlights the impact of village interactions on household response to an increase in income from outside province migrants. Such an increase is a likely scenario in the light of the trade liberalization pursued by the Chinese government. For the present purpose it also has the attractive feature of initially affecting only two of the four household groups, thus highlighting the difference between separate household models and a village analysis.

The simulation results show little difference between household and village models in terms of welfare and income indicators. The village interactions lead to some reinforcements of patterns found by the analysis with separate household models. In the village model households initially unaffected by the shock are able to increase their income through an increased demand for locally produced consumption goods, thus spreading some of the benefits from increased remittances through the village economy.

When analyzing agricultural exports from the village, differences between the two approaches become pronounced, with results from separate household models showing roughly twice the response of a village analysis. The increase in outside province income induces the two household groups with an outside link to shift towards a more labor-extensive and capital-intensive production pattern. The result is a decrease in rice exports and an increases in other livestock exports. In contrast to the separate household models, the village model also accounts for the impact on the other two household groups not directly affected by the increase in remittances. The shift towards more labor-extensive production also lowers demand for animal traction services and therefore its price, with as main impacts a decrease in available cash for households owning cattle but having no outside link and a reduction in production costs of two-season rice. By accounting for interactions among households in village factor markets, the village model finds a more moderate household response than a separate household analysis suggests.

The small differences between the household and village models in terms of welfare and income indicators thus obscure the differential adjustments generated by village interactions. By shifting production all households manage to benefit from the increased flow of income in the village economy, overcoming the initially adverse impact of a decreased demand for animal traction on the household with draught power and no link outside the province. The pronounced differences in total village exports between the separate household models and the village models is testimony to these adjustments.

CHAPTER 6

analyzing migration: production, consumption and village-level effects

Chapter 5 analyzed household response to an increase in remittances from household members employed outside the province. This analysis was motivated by an expectation of a continuing expansion of the labor-intensive Chinese manufacturing industry. Apart from an increase in income, this expansion is also likely to attract more (transitory) migrants. The rural-urban flow of people that featured prominently in the recent past of China can therefore be expected to continue in the future. Apart from an increase in income, analyzed in the previous chapter, a continuation of the rural-urban migration flows will also affect the size of the labor force remaining in the rural areas.

The first objective of this chapter is to analyze the total impact of migration on both production and consumption decisions of the household involved in migration, as well as the impact on other households in the village that are not involved in outside province migration. In Chapter 5 we analyzed the impact of an increase in remittances, while keeping the level of migration fixed. In this chapter we account for the impact of a reduction in the household size, both on the available agricultural labor force as well as on consumption. Household members that leave in search of employment in the cities not only reduce the available labor for production, they also reduce the consumption demand of the household. Migration thus has a three-fold impact on households: increasing remittances, reducing available labor and reducing subsistence consumption needs.

Studies of migration tend to focus on the factors affecting migration decisions (see for example Hare, 1999; Wu and Yao, 2003; Zhao, 1999), while our focus is on the impact on household members remaining in the village. Two existing studies of migration in China focus on the impact of migration on the source communities. Rozelle *et al.* (1999b) assess the impact of migration on maize yields. They find the reduction in labor to reduce yields, while the availability of remittances allows a substitution of labor with external inputs. Labor is only partially substituted, resulting in a negative impact of migration on maize yields. A second study on the impact of migration on sending households by Taylor *et al.* (2003), finds that the loss of labor is fully compensated by an increased use of external inputs, resulting in a positive impact of migration on crop yields. The estimated effect of migration on household income was not significantly different from zero, migration thus does not affect aggregate rural household income. When computed in income per capita, however, households do experience an income increase between 16 and 43 percent.

Both studies of the impact on sending communities focus at the household-level impact of migration, focusing on the reduction in the labor force and the impact of remittances in releasing households' cash constraint. These studies do not account for the impact of migration on consumption demand, nor for interactions among households in a village community. The models developed in Taylor and Adelman (1996) do focus on the impact of migration on a village economy. Despite this migration focus, however, these village models only incorporate the reduced labor force and receipt of remittances. To our knowledge, our study thus provides the first assessment of the three-way impact of migration on Chinese households, while also accounting for interactions among households. We furthermore account for the possibility that households shift between different agricultural production activities, following the reduction in available labor and increased availability of cash.

The second objective of this chapter is to replace the Cobb-Douglas utility function used in Chapter 5 with a more realistic specification. The Cobb-Douglas utility function results in demand functions with fixed expenditure shares. These demand functions are unable to capture shifts in expenditure patterns that are observed when incomes increase. In this chapter we therefore replace the Cobb-Douglas utility function with a Stone-Geary utility function, allowing shifts in expenditure patterns. Furthermore, to capture the impact of migration on household consumption, demand is no longer specified at household level but per household member.

The third objective of this chapter is to develop a calibration procedure for the demand functions that makes optimal use of the available data. The Stone-Geary utility function is a common functional form in applied general equilibrium models. Calibration of this functional form requires specification of elasticities, which cannot be derived from the SAM. Macro-level models generally resort to elasticities from the literature that may not be consistent with the model specification. Village equilibrium models can rely on the household survey data on which they are built. As a result, elasticities can be used that are consistent with the assumptions made in the village equilibrium model[1].

This chapter starts with describing the demand functions derived from a Stone-Geary utility function. The second section discusses the calibration used to incorporate the new demand functions in the applied village model. To assess the impact of changing the demand system on modeling results, the third section repeats the simulation of a 10 percent increase in outside province remittances. Comparison with the findings of Chapter 5 highlights the impact of changing the demand functions on model results. This simulation also provides a reference point for analyzing the impact of simulating an increase in migration in the fourth section. Outside province migration is assumed to increase with 10 percent. In addition to a 10 percent increase in remittances (analyzed in Chapter 5), this results in a decrease in size of migration households, reducing their available labor and subsistence consumption. Comparison with the results of simulating an increase in remittances highlights the impact of the change in household size on household and village-level response. The last section concludes.

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[1] The same approach could be used in macro level models in case household expenditure data are available.

6.1 per adult equivalent linear expenditure system

The Cobb-Douglas utility function used in Chapter 5 implies fixed expenditure shares. If income increases, *ceteris paribus* expenditures on all commodities thus increase proportionally. The demand functions therefore do not reflect the shift from basic necessities to luxury goods observed with increasing incomes. A variety of alternative functional forms are available for modeling expenditure functions. Common forms are the Constant Elasticity of Substitution (CES), Linear Expenditure System (LES), Constant Difference of Elasticity (CDE) or Almost Ideal Demand System (AIDS) (Martin, 1997).

The CDE and AIDS are more flexible functional forms. These have the advantage of being better capable of capturing observed behavior than the more restrictive CES-family or LES specifications. A drawback of the flexible specifications is the larger amount of parameters needed for calibration. Furthermore, flexible functional forms may lack global regularity required for solving a general equilibrium model (Perroni and Rutherford, 1998).

In the present context we selected a LES specification. It has the advantage of being more flexible than functions from the CES-family, allowing expenditure shares to vary with income levels. At the same time it can be calibrated with income elasticities (see next section), whereas the CDE and AIDS require price elasticities as well. The household survey data used in this study allow estimation of income elasticities, but do not display enough variation in prices to allow estimation of price elasticities. A second advantage of using a LES is that it allows recovering of the utility function from the demand functions, which is needed for welfare analysis of the modeling results. Using a LES specification thus captures shifts in spending patterns with rising incomes, permits welfare analyses, and allows calibration with the available household data. A drawbacks of using a LES is the assumption of linear Engel curves, which holds over a short income interval at best. Furthermore, all consumed commodities are assumed to be gross complements and inferior goods are not allowed.

6.1.1 deriving demand functions

The Linear Expenditure System (LES) developed by Stone (1954) is derived from the Stone-Geary utility function (Sadoulet and de Janvry, 1995:42),

$$u_h = \prod_{j \in C} (q_{hj}^c - \sigma_{hj}^c)^{\nu_{hj}^c}, \qquad \forall\ h \in H \qquad (6.1)$$

with

$$q_{hj}^c - \sigma_{hj}^c > 0, \qquad \forall\ h \in H, j \in C \qquad (6.1a)$$

$$0 < \nu_{hj}^c < 1 \text{ and } \sum_{j \in C} \nu_{hj}^c = 1, \qquad \forall\ h \in H, j \in C \qquad (6.1b)$$

where σ^c_{hj} are the subsistence or committed quantities, and ν^c_{hj} are marginal budget shares. As shown by (6.1a), consumption cannot fall below the subsistence levels. Marginal budget shares (ν^c_{hj}) are required to be positive (6.1b), hence inferior goods are not allowed.

Maximizing a Stone-Geary utility function subject to a full-income constraint (w_h) yields demand functions that constitute the LES (Sadoulet and de Janvry, 1995:42),

$$p_{hj}q^c_{hj} = p_{hj}\sigma^c_{hj} + \nu^c_{hj}\left(w_h - \sum_{j\in C} p_{hj}\sigma^c_{hj} \right). \qquad \forall\, h\in H, j\in C \qquad (6.2)$$

The first term at the right-hand side covers expenditures on subsistence consumption. The second term allocates income after subsistence expenditures in fixed proportions (ν^c_{hj}) to consumption. Since the marginal budget shares sum to one, all available income will be spent. Goods with low subsistence quantities and high marginal budget shares (luxury goods) will get a larger share of total expenditures when income increases. The opposite holds for goods with large subsistence shares and small marginal budget shares (necessities). A LES thus combines a simple specification that can easily be implemented in a general equilibrium model with a pattern of spending reflecting observed changes with increased incomes.

6.1.2 demand per adult equivalent and elasticities

Demand equations defined by (6.2) refer to total household consumption. There are three reasons for modeling demand at a per adult equivalent instead of household-level: subsistence expenditures, different consumption needs, and migration. Larger households will spend more on subsistence goods like food than smaller households at the same income level. When modeling and calibrating demand functions, these differences need to be accounted for. This can be done by modeling consumption at a per capita basis, but this ignores differences in consumption needs of household members of different age and sex. These differences can be accounted for by computing the household size in terms of adult equivalent consumer units.

Migration provides a second reason for modeling demand on a adult equivalent basis. When household members migrate, household expenditures on subsistence goods decrease. In terms of the household-level demand function (6.2), this implies a change in the parameters allocating income to subsistence and above subsistence expenditures. Defining demand on an adult equivalent basis avoids changes in demand parameters. Migration then affects available income per adult equivalent, but not the allocation parameters. The household consumption pattern is still affected by migration, but this can easily be calculated from the per adult equivalent consumption.

The per adult equivalent demand functions are obtained by dividing total household demand (6.2) by the number of adult equivalent consumers in the household:

$$p_{hj}q^{ae}_{hj} = p_{hj}\sigma^{ae}_{hj} + \nu^c_{hj}\left(w^{ae}_h - \sum_{j\in C} p_{hj}\sigma^{ae}_{hj} \right), \qquad \forall\, h\in H, j\in C \qquad (6.3)$$

where the superscript ae indicates variables expressed in adult equivalent variables (consumption, subsistence consumption and income). This demand function in adult equivalent terms replaces the fixed expenditures shares used in Chapter 5 (Equation 5.29). Additional modifications to the model are needed, since all other equations are expressed at the household level. We therefore need to specify the links between the household-level equations and consumption in adult equivalent terms.

To arrive at the consumption per adult equivalent we need to define the number of migration corrected adult equivalent consumers per household (c_h):

$$c_h = \varpi_h - \sum_{a \in PA} \phi_{ha} \varepsilon_{ha} , \qquad \forall\ h \in H \tag{6.4}$$

where ϖ_h is the household size in adult consumer equivalents and ϕ_{ha} is the number of adult consumer equivalents for each level of outside village employment activity (ε_{ha}) involving migration (denoted by the set PA, a subset of the activity set A). All elements at the right hand side of (6.4) are exogenous, hence the number of adult equivalent consumers is exogenous as well. Note that the number of consumers per household corrects for differences in age and gender by being defined in terms of adult equivalents, as well as for the absence of migrants.

This approach is consistent with modeling off-farm employment as a constraint activity. As before, households are thus not free to choose their level of outside village employment, including migration. Apart from being consistent with the situation in the case-study village, this approach reduces the complexity of the model. If migration is modeled as an activity with a level to be chosen by the household (as is the case in the models developed in Taylor (1996)), the number of consumers would become endogenous. Migration decisions then would have to account for their impact on both production and consumption sides of the household.

The fixed level of outside village employment (ε_{ha}) from the production side of the household model is used to calculate the number of consumers present in the household, to assure that shocks involving a change in the fixed demand for outside village employment are accounted for at the consumption side of the household. The parameter transforming the amount of off-farm employment to consumers (ϕ_{ha}) accounts for the gender composition of the migrants, as well as the length of their absence from the household for each type of migratory employment. Consumption demand functions are thus defined in terms of consumption per migration corrected adult equivalent.

After defining the number of consumer equivalents, defining per adult equivalent income and consumption is straightforward,

$$w_h^{ae} = \frac{w_h}{c_h} , \qquad \forall\ h \in H \tag{6.5}$$

$$q_{hj}^{ae} = \frac{q_{hj}^{c}}{c_h} . \qquad \forall\ h \in H, j \in C \tag{6.6}$$

Thus by replacing fixed expenditures shares (5.29) with (6.3) and adding equations in terms of adult equivalent (6.4-6.6), the household-level fixed expenditure shares are replaced with a linear expenditures system defined in terms of migration corrected adult equivalents.

6.1.3 equivalent variation with a stone-geary utility function

The Stone-Geary utility function is not linearly homogeneous, hence the calculation of the equivalent variation (EV) as used in Chapter 5 needs to be adapted. EV is defined as (Sadoulet and de Janvry, 1995:14):

$$EV_h = w_h^a - w_h^b - [e_h(p_h^a, u_h^a) - e_h(p_h^b, u_h^a)]. \qquad \forall\ h \in H \qquad (6.7a)$$

Expenditures at current prices and with current utility $(e_h(p_h^a, u_h^a))$ equal total current income (w_h^a), thus simplifying the expression for EV to,

$$EV_h = e_h(p_h^b, u_h^a) - w_h^b. \qquad \forall\ h \in H \qquad (6.7)$$

We thus need to calculate expenditures at base prices needed to attain the current utility level, and subtract the base income level to calculate the EV.

In case of a Stone-Geary utility function, the expenditure function is defined by (Sadoulet and de Janvry, 1995:16)

$$e_h = \sum_{j \in C} p_{hj} \sigma_{hj}^c + u_h^c v_h \prod_{j \in C} p_{hj}^{\ v_{hj}^c}, \qquad \forall\ h \in H \qquad (6.8)$$

with,

$$\sigma_{hj}^c = c_h \sigma_{hj}^{ac}, \qquad \forall\ h \in H, j \in C \qquad (6.8a)$$

$$v_h = \left[\prod_{j \in C} v_{hj}^{c\ v_{hj}^c} \right]^{-1}. \qquad \forall\ h \in H \qquad (6.8b)$$

After solving the model, substitution of the results in (6.7) and (6.8) gives a quantification of the changes in welfare. Note that by multiplying the consumption per adult equivalent with the number of consumers in (6.8a) changes in welfare are calculated for the household as a whole.

6.2 calibrating the linear expenditure system

In the SAM we only observe total consumption expenditures. We thus need additional information to split total expenditures in subsistence and above subsistence expenditures, in order to calibrate the demand functions. In this section we calibrate a LES by exploiting the household survey data on which the SAM is based. We first discuss the calibration method, after which calibration results are presented.

6.2.1 calibrating a LES with household survey data

A LES is a popular form of specifying demand functions in general equilibrium models. The tricky part when using this functional form is the choice of parameters, *i.e.* specifying subsistence consumption and marginal budget shares. One option is to use consumption levels from an earlier time period as subsistence consumption levels, a rather ad hoc approach. A second option is to use income elasticities to calibrate subsistence consumption levels. As with other elasticities used in applied general equilibrium modeling, income elasticities are generally taken from the literature or other secondary sources and may not be consistent with other parameters in the general equilibrium model.

The approach taken in this study is to use the household survey data on which the SAM is based for calibration. Since the data refer to a single year and a single village there is not enough price variation to allow direct estimation of the LES. Variation in income between households, however, does allow estimation of income elasticities. Income elasticities are needed for a calibration procedure proposed by Keller (1979):

$$\sigma_{hj}^{ae} = (1-\eta_{hj})q_{hj}^{ae}, \qquad \forall\ h\in H, j\in C \tag{6.9}$$

where η_{hj} is the income elasticity. With this procedure demand functions will reproduce the income elasticities, if these satisfy the properties of the LES. Once subsistence quantities are calibrated, marginal budget shares can be calculated as well.

The restriction on the income elasticities can be derived from the restriction that marginal budget shares sum to one (6.1b), yielding the following relation between income elasticities and marginal budget shares,

$$\eta_{hj} = \frac{v_{hj}^{c}}{\beta_{hj}^{c}}, \qquad \forall\ h\in H, j\in C \tag{6.10}$$

where β_{hj}^{c} is the budget share of commodity *j*. Rearranging, summing over all *j* and applying the restriction on the marginal budget shares we get a restriction on income elasticities:

$$\sum_{j\in C} \beta_{hj}^{c}\eta_{hj} = 1. \qquad \forall\ h\in H \tag{6.11}$$

Using the properties of the LES we thus obtain a restriction on the income elasticities which is imposed during estimation. Using these restricted income elasticities in (6.9) for calibrating demand functions reproduces the income elasticities. A drawback of the Keller calibration procedure, however, is that commodities with an elasticity larger than one will have negative subsistence quantities. In the current setting negative subsistence quantities do not have a meaningful interpretation.

Dellink (2003) shows that any transformation with an arbitrary constant will maintain the reproduction of the income elasticities. Choosing the maximum income elasticity to normalize the elasticities assures that all commodities will have positive subsistence quantities,

$$\sigma_{hj}^{ae} = \left(1-\frac{\eta_{hj}}{\max\limits_{j}(\eta_{hj})}\right)q_{hj}^{ae}. \qquad \forall\ h\in H, j\in C \tag{6.9'}$$

This normalized calibration procedure will reproduce the initial elasticities, if these satisfy restriction (6.11) (see Appendix D). If the elasticities do not satisfy this restriction (as is the case in the application of Dellink (2003)), implied elasticities after calibration will differ from elasticities used for calibration.

Estimating income elasticities satisfying (6.11), in combination with observed consumption levels, thus provides sufficient information to calibrate the LES consistent with the assumptions underlying the village equilibrium model.

6.2.2 estimating income elasticities

In order to calibrate the LES for the village equilibrium model we need to estimate income elasticities for each group of households that satisfy (6.11). Income elasticities can be derived by estimating Engel curves. Different specifications of Engel curves are possible, most of which have an income elasticity that varies with the consumption level. In the current context we need to impose a restriction on the estimated income elasticity. Therefore a double logarithmic specification is chosen (Sadoulet and de Janvry, 1995:38),

$$\ln q_{hj}^{c} = m_{hj} + n_{hj} \ln w_{h} . \qquad \forall\ h \in H, j \in C \qquad (6.12a)$$

This specification gives a constant income elasticity equal to the income coefficient,

$$n_{hj} = \eta_{hj} \ . \qquad \forall\ h \in H, j \in C \qquad (6.12b)$$

This feature of the double logarithmic Engel curve allows us to impose the restriction on income elasticities through a restriction on the income coefficient,

$$\sum_{j \in C} \beta_{hj}^{c} n_{hj} = 1 \cdot \qquad \forall\ h \in H \qquad (6.13)$$

Estimating a system of equations defined by (6.12a) subject to the restriction (6.13) yields income household-specific elasticities that are consistent with the assumptions made in the village equilibrium model.

A limitation of the Stone-Geary utility function is that inferior goods are not allowed. To avoid negative income elasticities, estimation is done for aggregated groups of commodities: own produced food, purchased food, nonfood, durables and other expenses, and leisure. These commodity group aggregate consumed commodities in the SAM and the village model, implying for example that all types of own produced food are assumed to have the same income elasticities. Table 6.1 presents descriptives of variables taken from the household survey data, while Table 6.2 presents budget shares computed from the SAM. Note that full income as defined in the village equilibrium model is used to obtain consistency between the estimated income elasticities and the demand functions used in the village equilibrium model.

Comparing budget shares across households, we find only the household group lacking draught power and having a link outside the province to have a different spending pattern. The other three household groups have a very similar allocation of income over the different categories, with own produced food and leisure taking the bulk of the expenditures. The household survey data only contain data on total household consumption, not on consumption of individuals within a household. We therefore rely on data from a detailed study of consumption patterns by age and gender (Zeller *et al.*, 2001) to obtain conversion factors for different categories of household members (Table 6.3). Combining the conversion factors with data on household composition, the number of consumers in adult equivalent units can be calculated for each household. Summing over all households in a group and scaling to village level yields the household size for each household group (ϖ_h) needed for Equation (6.4).

Table 6.1: Descriptives of variables used for income elasticity estimation per household group (yuan)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
	N=16	*N=18*	*N=57*	*N=68*
Full income per a.e.	3359	2852	3085	3399
	(1430)	(807)	(1140)	(1077)
Own produced food per a.e.	590	769	690	894
	(198)	(879)	(529)	(731)
Purchased food per a.e.	513	489	396	434
	(737)	(445)	(369)	(727)
Nonfood per a.e.	528	474	576	801
	(340)	(241)	(447)	(1273)
Durables and other expenses per a.e.	776	741	961	825
	(526)	(350)	(1179)	(736)
Leisure per a.e.	484	788	613	670
	(324)	(845)	(431)	(384)

Note: a.e.= migration corrected adult equivalent consumers; standard deviations in parentheses.

Table 6.2: Budget shares from SAM used as weights in income elasticity estimation per household group

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Own produced food	0.29	0.33	0.24	0.28
Purchased food	0.05	0.05	0.06	0.04
Nonfood	0.06	0.06	0.10	0.08
Durables and other expenses	0.09	0.10	0.20	0.09
Leisure	0.50	0.47	0.39	0.50

Table 6.3: Consumption conversion factors by gender and age group

	Male	*Female*
Children (0-11 years)	0.52	0.47
Adolescents (12-15 years)	0.79	0.69
Adults (16-60 years)	1.00	0.81
Elderly (60+ years)	0.68	0.61

Source: Zeller et al.(2001).

For each household group income elasticities are then estimated using an iterated version of Zellner's seemingly unrelated regression procedure, imposing the restriction on the income coefficients across equations. Table 6.4 presents estimation results by household groups. Due to the aggregation of individual consumption categories, all income elasticities are positive.

By (6.9') low income elasticities correspond with high subsistence shares. As expected, total consumption of own produced food thus to a large extent consists of subsistence consumption, while leisure and purchased food are more of a luxury good. Less expected are the rather low income elasticities for nonfood and durables and other expenses, which one would expect to have a more than unitary income elasticity. The lack of data on saving and investment decisions in the household surveys provides an explanation for the limited income elasticity of these commodity groups. The expenditures on nonfood, durables and other expenses (which includes expenditures on education) may partly consist of investments and therefore less responsive to income changes than luxury consumption expenditures.

Although all household groups have a similar per adult equivalent expenditure pattern in terms of budget shares, estimated income elasticities show more variation across groups. This is due to the household group-specific constraint (6.11) that is imposed on the system of equations, which spreads the effects of the categories which do show differences in budget shares (durables, other expenses and leisure) across all consumed goods.

Table 6.4: Estimated income elasticities by household group

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
N=	16	18	57	68
Own produced food per a.e.	0.636 ***	0.585	0.237	0.560 ***
	(0.173)	(0.515)	(0.160)	(0.183)
Purchased food per a.e.	1.471 ***	0.985	1.192 ***	1.010 ***
	(0.398)	(0.629)	(0.232)	(0.267)
Nonfood per a.e.	0.767	0.355	0.539 ***	0.582 **
	(0.290)	(0.427)	(0.198)	(0.273)
Durables and other expenses per a.e.	0.824 **	0.492	1.465 ***	0.341
	(0.381)	(0.492)	(0.246)	(0.271)
Leisure per a.e.	1.224 ***	1.479 ***	1.333 ***	1.433 ***
	(0.140)	(0.343)	(0.154)	(0.128)

Note: a.e.= migration corrected adult equivalent; estimated by a constrained system of equations, see text for details; standard error in parentheses; * indicates significance at 10%level, ** at 5% level, *** at 1% level.

Having estimated household specific income elasticities we can compute the subsistence shares of total consumption expenditures (Table 6.5). Due to the normalization in (6.9'), the subsistence shares of the commodity group with the highest income elasticity are set to zero. For the two household groups owning draught power this is leisure, while for household groups lacking draught power this is purchased food (no outside link) or durables (outside link).

Table 6.5: Subsistence consumption shares by consumption good (% of total expenditures by category)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Own produced food	57	60	84	61
Purchased food	0	33	19	30
Nonfood	48	76	63	59
Durables and other expenses	44	67	0	76
Leisure	17	0	9	0

In the village equilibrium model, consumption is not defined in terms of the aggregate consumption categories used for the estimation, but in terms of more detailed consumption categories. In the calibration we assume that commodities within a category have the same income elasticity, implying by (6.9') the same subsistence quantities. Having calibrated subsistence quantities, we can divide total consumption expenditures in a subsistence and an above subsistence component, allowing calibration of all parameters in the demand function (6.3). Note that although all commodities composing the aggregate groups in Table 6.5 have the same subsistence quantities, marginal budget shares differ across the consumption goods distinguished in the village model since total expenditures differ across commodities.

6.3 increased remittances: the impact of changing demand functions

Having calibrated the new demand functions we can now analyze household response using a Stone-Geary utility function. Furthermore, by defining consumption per adult equivalent instead of per household we can assess the impact of migration, both on the availability of labor for production as on household consumption. Before analyzing the impact of migration (Section 4) we first repeat the 10 percent increase in income from outside province migrants analyzed in Chapter 5. A comparison with the results from Chapter 5 indicates the robustness of the findings to the functional form chosen for the utility function.

6.3.1 increased outside province remittances: simulation results

Table 6.6 summarizes the results of a 10 percent increase in outside province remittances, in terms of profits, income and equivalent variation. In qualitative terms results are similar to the findings in Chapter 5, in quantitative terms effects are slightly stronger. Profits increase less for the two households with an outside link. Since the applied shock is identical, the shadow wage thus has risen more with the current model. Profits for the two households without a link outside the province increase more than in Chapter 5, indicating a stronger increase in demand for local business activities which generated the positive impact on the households initially unaffected by the shock.

Table 6.6: Profit, income and EV with a 10% increase in outside province remittances (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Profit from outside province employment	n.a.	n.a.	11.8	26.5
			(13.0)	(28.5)
Total profits	1.0	1.1	6.5	11.2
	(1.0)	(1.2)	(8.0)	(13.5)
Household full income	0.6	0.7	4.9	1.9
	(0.4)	(0.4)	(3.8)	(1.5)
Equivalent variation (10^3 yuan)	5.9	10.2	187.5	103.0
	(2.1)	(2.1)	(93.4)	(49.2)

Note: results from the village model of Chapter 5 in parentheses.

With the Cobb-Douglas utility function in Chapter 5 all consumption increased with the same percentage as income increased. Exception was the increase in consumption of leisure, which was tempered by an increase in the shadow wage. With a Stone-Geary utility function, income available after satisfying subsistence consumption demand (hereafter referred to as surplus income) is also allocated in fixed shares. Combining subsistence and surplus expenditures, however, results in different rates of change across commodities, as can be seen in Table 6.7. Note that since prices of most consumption goods do not change, the rise in surplus income exceeds the change in full income.

Table 6.7: Increase in income and consumption with a 10% increase in outside province remittances

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Income				
Full income	0.6	0.7	4.9	1.9
Surplus income	0.8	1.1	6.8	2.8
Consumption				
Own produced food	0.4	0.4	1.1	1.1
Purchased food	0.8	0.7	5.6	1.9
Nonfood	0.4	0.3	2.5	1.1
Durables and other expenses	0.5	0.4	6.8	0.7
Leisure	0.1	-0.1	0.6	0.7

The increase in consumption of own produced food is less than the increase in full income. This reflects a commonly observed shift in consumption away from staples when income increases. The pattern in terms of imported and locally produced consumption goods is less clear-cut. Preferences for food, nonfood and durables vary across household groups, resulting in different expenditures shifts.

Household groups with no draught power have a subsistence quantity of leisure. Due to shadow wage increases, their surplus income increases slightly less (0.1 and 0.3 percent) than in the absence of wage changes. The household group with no outside link and owning draught power is the only one reducing its consumption of leisure; its increase in surplus income is less than the increase in shadow wages. Allocating a fixed share of surplus income to leisure thus results in a reduction of leisure. For the household group with draught power and an outside link, rising shadow wages also tempers the increase in leisure consumption, but for this group a net increase remains.

The LES allows households to increase the consumption of highly valued goods more than the consumption of other goods. Goods with the highest income elasticity will have zero subsistence quantities due to the calibration procedure. Consumption of these commodities will increase most when income increases, and given the utility function this will have a high contribution to utility. As a result the welfare increase measured in terms of EV (see Table 6.6) is much higher than found in Chapter 5. Despite the quantitative changes, relative positions in terms of EV are preserved: the household with a link and no draught power gains most from the increased remittances.

Table 6.8: Produced agricultural output with a 10% increase in outside province remittances

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
One-season rice	-5.3	-22.6	4.1	46.1
	(-2.8)	(-15.6)	(2.3)	(25.5)
Two-season rice	1.9	10.1	-1.5	-19.9
	(1.0)	(6.9)	(-0.9)	(-11.0)
Other crops	-0.1	-0.4	-2.1	-0.6
	(0.0)	(-0.1)	(-1.2)	(-0.3)
Pigs	0.3	-0.1	-2.0	-3.9
	(0.1)	(0.6)	(-1.2)	(-2.1)
Other livestock	-6.2	-47.0	8.6	92.0
	(-3.3)	(-47.0)	(4.9)	(50.8)
Tractor services	n.a.	4.6	n.a.	-7.3
		(2.7)		(-4.1)

Note: results from the village model of Chapter 5 in parentheses.

Turning to production (Table 6.8) we see a similar pattern as in Chapter 5. Again the two household groups with draught power show the strongest response, which is stronger than the response in Chapter 5. For the household with draught power and an outside link, the increased demand for leisure combined with the inflow of cash magnifies the previously found move towards one-season rice and other livestock. This further move to one-season rice reduces the demand for cattle services and thus its price. As a result, the price of cattle service drops another 1.7 percent compared with the price drop in Chapter 5.

The additional drop in price of cattle services further tightens the cash constraint for the household with draught power but no outside link. This household reduces its production of other livestock to subsistence levels. Unlike in Chapter 5, production cannot drop below subsistence levels even if the shadow price of other livestock rises above the market price. This more stringent constraint doubles the shadow price increase compared to the findings of Chapter 5. In response to this constraint, a stronger shift from one to two-season rice occurs, releasing cash while increasing the demand for labor. This household group does not have a subsistence consumption of leisure, thus having more flexibility in adjusting its consumption of leisure than its consumption of other livestock.

The partitioning in subsistence and surplus consumption leads to an increased demand for village produced goods, sparking a further increase in local business activities. This accounts for the larger increase in income for all household groups, including the household group with no outside link and owning draught power that faces a tighter cash constraint than in Chapter 5.

6.3.2 analyzing the impact of a change in utility function: village-level results

To summarize the impact of changing the utility function, Table 6.9 presents the village-level results of the current model alongside the findings of Chapter 5. Apart from the difference in EV, discussed above, differences in terms of income are minimal. As with the comparison of household and village models, this similarity in terms of income obscures differences in production response between the two model versions.

The total exports from the village summarize the differences in production and consumption. Differences in terms of other crops and pigs are minimal. There are no major changes in production for these two activities, whereas consumption increases in both model versions. The differences in terms of rice exports and other livestock reflect the differences in behavior of the two household groups with draught power.

Total rice exports from the village now decrease with 7 percent, slightly more than the 6 percent decrease in the case of Cobb-Douglas utility functions. Exports of other livestock, on the other hand, increase much more with the current model version. The shift away from rice towards other livestock by the household with a link outside the province thus outweighs the opposite movement of the household with no outside link.

Summarizing, the change in utility function does not affect model result in terms of household income. While having a strong impact on the quantification of the welfare impacts of the shock, the change in utility function does not change the relative positions of the household groups in terms of welfare changes. In terms of exports of rice and other livestock from the village, the change in utility function does have a large impact on the model results: changes in exports are much large in the case of a Stone-Geary utility function. The rise in income now results in a shift in expenditure patterns away from farm produced output, which is more realistic than the fixed expenditure shares with a Cobb-Douglas utility function, and translates to a stronger village supply response.

Table 6.9: Comparing results with Cobb-Douglas and Stone-Geary utility functions with a 10% increase in remittances (%)

	Cobb-Douglas utility	*Stone-Geary utility*
Equivalent variation* (10^3 yuan)	146.8	306.6
Increase in full income*	2.0	2.7
Income per adult equivalent		
Household with no link, no draught power	0.4	0.6
Household with no link, draught power	0.4	0.7
Household with link, no draught power	3.8	4.9
Household with link, draught power	1.5	1.9
Village exports		
One-season rice	14.3	29.1
Two-season rice	-15.3	-24.3
Rice	*-5.8*	*-7.1*
Other crops	-9.7	-8.3
Pigs	-1.6	-2.5
Other livestock	27.7	72.7

Note: * Computed as the sum over all households.

6.4 increased migration: production and consumption effects

The scenario analyzed thus far involved an increase in income received from outside province remittances. The underlying assumption is that an expected increase in wages with ongoing trade liberalization would be (partly) transferred to the village. Apart from raising incomes, a further expansion of the Chinese manufacturing sector and the rising wages can be expected to increase the flow of migrants from the rural to the urban areas.

An increase in migrants does not only imply more income for the household members remaining in the village, it also reduces labor available for production. These two effects of migration are commonly part of analyses of the impact of migration, as for example in the models presented in Taylor and Adelman (1996). Apart from these impacts on production, migration of household members also reduces household consumption needs, leaving more income for remaining household members. Murphy (2000) in a descriptive study of migration from a county in Jiangxi province, for example, mentions that remaining household members can sell subsistence consumption quantities of migrated members.

This section analyzes the impact of migration on both production and consumption decisions. To be able to use the analysis of the previous section as a reference point, a 10 percent increase in outside province migration is assumed. The increase in outside province remittances will therefore be the same as in the scenario analyzed in Section 3. Reinterpreting the results from Section 3 as the income effect of an increase in migration, this section focuses on the impact of the reduced household size on production and consumption.

6.4.1 increased migration: profits, income and welfare

Once again we start our analysis by tracing how the shock enters the model. As before the point of entry is the profit earned on outside migration (Table 6.10). With the current shock there are two opposing forces at work that affect the total profits earned with outside province employment. The increase in employment increases profits since every unit of outside employment earns a profit over the costs of the labor. At the same time, however, the increase in employment reduces the availability of labor, thus raising shadow wages. This erodes profit and could eventually lead to a negative profit.

Table 6.10: Profit, income and welfare with a 10% increase in outside province migration (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Profit from outside province employment	n.a.	n.a.	5.1	-1.6
Total profits	1.0	1.2	1.2	-5.3
Household full income	0.7	1.1	5.5	2.7
Equivalent variation (10^3 yuan)	6.5	14.7	243.8	187.2

The two opposing pressures on the profit earned with outside province employment have a different net result for the two households with an outside link. For the household group without draught power a net increase in profits remains after the shadow price increases, while for the household group with draught power a net decrease in profits compared to the base run results. Despite this erosion of profits compared with the base situation, both household groups still earn a net profit on outside province employment.

The difference in behavior between the two household types is due to their initial profit margin on outside province employment. The household with no draught power receives more than twice the income from its migrated households members than the household with draught power (see Table 4.13), with similar levels of off-farm employment (see Table 4.1) and initially having similar shadow wages. This larger profit margin allows the household without draught power to increase its profits with 5 percent, despite a 10 percent rise in shadow wages which reflects the increased scarcity of labor. The household with draught power, on the other hand, has a net reduction of 1.6 percent in profit, with only a 5 percent increase in shadow wages.

The increased scarcity of labor erodes profits from all Leontief activities, as reflected by the change in total profit for the two household groups with an outside link. The other two household groups neither have access to the extra income (as in previous simulations), nor do they face an increased scarcity of labor. For them the net impact in terms of an increase in profit and full income is about 1 percent, which is similar to the findings with increasing remittances.

Despite the reduced increase or even decrease in profits, full income increases beyond the results obtained before for both household groups with an outside link. This is due to the increasing shadow wages, increasing the value of the labor endowments and thus household income. Results for full income and profits thus move in opposing directions compared to earlier findings, indicating that the impact of shadow wages on full income outweighs its tempering effect on profits.

In terms of welfare all household gain more than before, while again maintaining the ranking of households in terms of relative gains. This also holds for the households without an outside link. The household lacking draught power experiences a 0.1 percent points more of an increase in full income, while the household owning draught power increases its full income with 0.4 percent points more than in Section 3. These differences are translated into an additional welfare increases, of 600 yuan for the household lacking draught power and 4,500 yuan for the household owning draught power.

6.4.2 increased migration: effects on production

One impact of the increase in migration is through the change in profit, the first effects of which have been analyzed above. The increase in cash for the two households with an outside link will have the same impact as in the case of increased income. An additional impact of the increase in migration is to reduce available labor for other activities. This could magnify or temper the impact of the additional income.

The reduction in available labor increases the shadow price of labor for the two household groups with an outside link. More males than females are involved in migration. This is reflected in the ration of male to female labor used for outside migration, and therefore male labor becomes more scarce than female labor after the increase in migration. This is reflected in their respective shadow prices (Table 6.11).

Table 6.11: Household price changes with a 10% increase in outside province migration (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Male labor	0.7	1.9	10.0	5.2
Female labor	0.8	1.8	9.3	4.9
Cattle traction services	-5.9	-5.9	-5.9	-5.9
Two-season rice	0.0	0.0	0.0	0.1

The increased scarcity of labor magnifies the shift towards more labor-extensive and capital-intensive agricultural production for the two households with a link outside the province. Compared to earlier findings, the result is a stronger increase in one-season rice production and other livestock (Table 6.12). Focusing on rice, which is the major agricultural activity for all households, we find that total rice yields decrease when households increase their migration activities. The migration household owning draught power shows the strongest response, reducing two-season rice production to its own consumption needs. As a result, this household group has a household price of two-season rice which is 0.1 percent higher than (exogenous) market price (Table 6.11).

Table 6.12: Agricultural output with a 10% increase in outside province migration (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
One-season rice	-7.5	-41.4	6.6	78.1
Two-season rice	2.7	18.4	-2.4	-33.8
Rice	*1.0*	*5.7*	*-0.3*	*-10.4*
Other crops	0.1	-0.6	-3.3	-1.6
Pigs	0.4	-1.7	-3.1	-7.7
Other livestock	-8.2	-46.9	13.3	168.9
Tractor services	n.a.	8.1	n.a.	-12.8

Of the two household groups without an outside link, again the one with draught power is affected most. The stronger response of migration households further decreases demand for animal traction, reducing renting of cattle by the household with no link with 26 percent (instead of 14 percent found in Section 3). Since other livestock production cannot be decreased below subsistence needs, other activities using external inputs and thus cash are reduced (other crops and pigs).

In terms of production, the decreased availability of labor due to migration magnifies the response already observed with an increase in remittances. As a result, households with an outside link move even more towards one-season rice and other livestock, while the households without an outside link move even stronger in the opposite direction.

Increases in local business activities are the same as before, except for production of durables which now increases with 2 percent points more than with an increase in remittances. It seems likely that this is due to the reduction in household size of the two households with an outside link. This frees income previously needed for subsistence consumption of the migrated household members. To see whether this hypothesis holds we will now turn to analyzing changes in consumption.

6.4.3 increased migration: effects on consumption

The 10 percent increase in migration translates to a decrease in subsistence expenditures for the two households with an outside link (Table 6.13). The decrease in subsistence expenditures is determined by initial levels of outside province migration to which the shock is applied, the length of absence of migrants, and shadow wages changes for the households with a subsistence consumption of leisure. Due to the calibration of the demand function, only household groups lacking draught power have a subsistence consumption of leisure. This tempers the decrease in subsistence expenditures for the household involved in migration, which with 1.6 percent is 1 percent point lower than for the other migration household. For the household lacking both draught power and an outside link, subsistence expenditures increase with 0.2 percent point due to the rising shadow wage

Table 6.13: Changes in income and consumption with a 10% increase in outside province migration (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Income				
Full income	0.7	1.1	5.5	2.7
Subsistence expenditures	0.2	0.0	-1.6	-2.6
Surplus income	0.9	1.6	8.8	5.0
Consumption				
Own produced food	0.4	0.6	-0.8	0.3
Purchased food	0.9	1.1	6.7	2.7
Nonfood	0.5	0.4	1.6	0.5
Durables and other expenses	0.5	0.5	8.8	-0.8
Leisure				
Male	0.1	-0.3	-1.2	-0.2
Female	0.1	-0.2	-0.7	0.1

Compared to the findings in Section 3, the increase in migration increases the surplus income with about 2 percent for the two household groups with a link outside the province. We hypothesized above that this causes an increased demand for village produced durables. Table 6.13 shows that this hypothesis only holds for the household lacking draught power, which increases its demand for durables with 8.8 percent. The effect on village demand is, however, tempered by a 0.8 percent decrease in consumption of durables by the household with draught power. This household group has a low income elasticity for durables (see Table 6.3), and as a result its decrease in subsistence consumption outweighs the increase in surplus demand. As a result of different consumption preferences, the decrease in subsistence consumption following migration thus has mixed effects.

6.4.4 increased remittances versus an increase in migration: village-level effects

Because of the opposing movements in terms of production and the mixed results in terms of consumption, we again turn to assessing the village-level impacts of the increase in migration. As a point of reference we use the results of increasing remittances from outside province migration analyzed in Section 3. Comparing these two scenarios provides the net impact of the decrease in household size on production and consumption decisions.

The increased scarcity of labor raises the shadow wage, which is reflected by a 0.6 percent point higher increase in total full income with migration. The impact of a reduction in household size on available income per adult equivalent is clearly visible for the migration households, for the household group owning draught power the income more than almost triples if the impact of migration on household size is accounted for.

In terms of total exports from the village, the change in production by the household with a link outside the province and draught power dominates the opposite movement of the household with draught power and no outside link. The shift towards one-season rice decreases total rice exports by about 10 percent, 2.6 percent points more than with an increase in remittances. The clearest difference between the two scenarios is observed in other livestock exports. As opposed to rice, changes in production of the household with no link but owning draught power do not temper changes of the migration households. Because of the set assignments this household cannot start purchasing other livestock, and therefore its sales cannot drop below zero. This point was already reached with only the change in remittances, and thus the additional increase in production by households with a link are translated completely into an increase in exports from the village.

Table 6.14: Village-level impact of a 10% increase in remittances and a 10% increase in outside province migration (%)

	Remittance	*Migration*
Equivalent variation* (10^3 yuan)	306.6	452.2
Increase in full income*	2.7	3.3
Income per migration corrected adult equivalent		
Household with no link, no draught power	0.6	0.7
Household with no link, draught power	0.7	1.1
Household with link, no draught power	4.9	8.4
Household with link, draught power	1.9	5.5
Village exports		
One-season rice	29.1	49.5
Two-season rice	-24.3	-37.9
Rice	*-7.1*	*-9.7*
Other crops	-8.3	-9.0
Pigs	-2.5	-4.4
Other livestock	72.7	152.6

Note: * Computed as the sum over all households.

Comparing the two scenarios we find that from a welfare perspective and for the agricultural supply response it matters whether only incomes increase, or whether additional people migrate to urban areas. Interestingly, the increase in migration also magnifies the shift from grains to livestock. The impact of migration on agricultural production thus seems to support the change in production that will be needed with the increasing incomes that are drawing migrants to the cities.

Of the two studies of the impact of migration on source communities discussed in the introduction to this chapter, Rozelle *et al.* (1999b) also found a negative impact on grain production. Their analysis, however, was limited to a single crop (maize) and therefore did not account for possible shifts in activity patterns. The study by Taylor *et al.* (2003) found a positive impact of migration on crop production, due to a substitution of external inputs for labor. Our finding of a shift towards more capital-intensive activities, is in line with the substitution of external inputs for labor. Using Cobb-Douglas production functions seem to limit substitution possibilities within activities, and the shift towards external inputs is therefore expressed by a shift in activities which is not accounted for in the study of Taylor *et al.* (2003).

6.5 concluding remarks

This chapter focused on modeling the impact of migration on production and on consumption decisions. To allow an analysis of the impact on consumption, the household-level demand functions of Chapter 5 were replaced by consumption demand in terms of adult equivalents. Apart from this switch in demand functions, the underlying utility function was changed as well. Restrictive assumptions of the Cobb-Douglas utility function resulted in fixed expenditure shares which do not reflect the shifts in spending patterns observed when income increases. A linear expenditure system was introduced in the model, replacing the demand functions used in Chapter 5 with demand functions that allow shifting spending patterns.

Demand functions were calibrated using income elasticities estimated with the household survey data used for building the village SAM. This allowed an estimation of model parameters that fully consistent with the assumptions made in the village equilibrium model. This consistency contrasts with the common use of elasticities from the literature in macro-level general equilibrium models.

Comparing village-level results with a Cobb-Douglas and a Stone-Geary utility function, we find results in terms of income and welfare ranking to be robust. Results in terms of marketed surplus from the village, however, are sensitive to the functional form chosen for the utility function. With rising incomes consumption now shifts away from farm produced output, magnifying shifts in agricultural exports. As a result, drops in rice exports and increases in other livestock exports are larger than found in Chapter 5.

In terms of full income, results are robust to whether only income or migration increases. Accounting for the reduced subsistence consumption needs due to migration leads to larger welfare increases. The combination of an increase in income with a reduction in consumers results in higher income increases for the remaining household members. Apart from affecting the welfare assessment, accounting for changes in household size also affects production decisions (a reduced demand for leisure reduces pressure on the shadow prices) and the dispersion of the income through the village economy (the increase in surplus income increases demand for village produced durables). As a result, households without access to outside province migration also experience larger welfare increases when more migrants leave the village.

Apart from relaxing the strict assumptions on demand functions, this chapter focused in analyzing the three-fold impact of migration on the source village. In addition to the impact on income and production that are commonly analyzed when studying migration, the impact on consumption decisions was accounted for as well.

Our findings are consistent with the two studies of the impact of migration on source communities discussed at the beginning of this chapter. We also find a substitution of external inputs for labor. Accounting for different agricultural activities, however, we find this substitution mainly to occur by changing from two-season to one-season rice and increasing capital-intensive other livestock production. The changes induced by a reduction in labor force and an increase in cash income are amplified by the shifts in consumption decisions of migration households. In contrast to the existing studies of migration on sending communities, we also account for the impact on households lacking access to migration. As in Chapter 5, we find households moving in an opposite direction, responding to a decreased price of animal traction by intensifying rice production. This opposite movement tempers the aggregate village supply response to migration, qualifying conclusions drawn from analyzing migration households only.

For village agricultural supply response not only within village-interactions matter, but also whether expansion of urban employment is transmitted only through income, or whether it will increase the flow of migrants. An increasing flow of migrants will magnify the shift away from rice and towards other livestock production. This shift in production pattern is not accounted for in the existing studies of the impact of migration on agricultural production but is important from a policy perspective. The rising urban incomes that are drawing rural migrants also result in a shift from grain to meat consumption. A rising flow of migrants is found to support the required shifts in agricultural production decisions to meet changes in demand with rising incomes.

CHAPTER 7

finding better grounds for nesting: testing separability and calibrating production functions

In Chapter 6 we simulated an increase in outside province migration, finding a substitution of labor by external inputs through a shift in agricultural activities by migration household. The less labor-intensive production pattern affected households not involved in migration through the village market for animal traction. The household production response to a change in relative prices depends on the substitution possibilities within a specific activity, as well as differences in substitution possibilities between production activities. Substitution possibilities are determined by the choice of functional form and parameters of the production function. The way in which production is modeled thus plays a prime role in simulation results obtained with the village model.

In this chapter we therefore shift our attention from consumption decisions to modeling agricultural production activities. Two aspects of modeling production are recurring topics in the applied general equilibrium literature: functional form (restrictive versus flexible functions) and parameters (elasticities). Although choice of a functional form and parameters play an important role, the structure of the production function takes center stage in this chapter. A common approach for introducing more flexibility in production decisions is by nesting restrictive functions, resulting in a layered structure of the production function. When introducing nested production functions in applied general equilibrium models, decisions on factors and intermediate inputs are assumed to be separable (for an illustration of this standard approach see Löfgren *et al.*, 2002). We find this assumption inappropriate in the context of a village equilibrium model and focus this chapter on calibrating production functions that reflect household production decisions. To our knowledge, this aspect of modeling production is not addressed in the literature on general equilibrium modeling.

The focus of this chapter is on modeling agricultural activities. We find each activity requiring a specific functional form, introducing variety in substitution possibilities across activities and across household groups. To assess the impact of these changes on the model results, last part of this chapter returns to simulating an increase in migration and compares the findings to the results of Chapter 6.

This chapter is divided in three parts. Section 1 motivates and describes the approach used for calibrating agricultural production activities. Section 2 discusses calibration results, focusing on differences in substitution elasticities across households and across activities. Section 3 assesses the impact of the change in production functions on household- and village-level response to an increase in migration opportunities.

7.1 calibrating nested CES production functions

General equilibrium models generally use nested CES production functions to allow variability in substitution elasticities, while maintaining a functional form that can be easily implemented in an applied model. We start this section by introducing the concept of nested production functions. We then proceed by motivating the choice for a nested CES function instead of using a flexible functional form. The remainder of this section is devoted to presenting the approach that will be used in this study to calibrate structure and elasticities of the agricultural production activities.

7.1.1 nested production functions

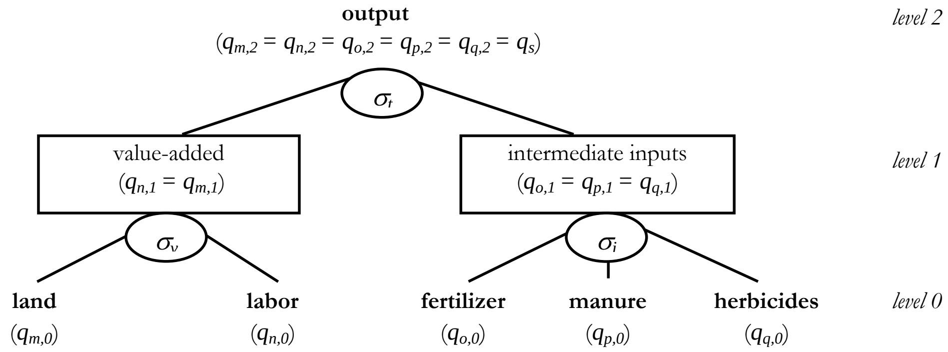
The discussion of nested production functions will be illustrated with the production structure depicted in Figure 7.1. The salient feature of this nested structure is a separation of factors and intermediate inputs in two different branches, as is standard in applied general equilibrium modeling. The example includes two factors (land and labor) and three intermediate inputs (fertilizer, manure and herbicides).

As illustrated in Figure 7.1, a nested production structure defines output as a function of aggregated inputs. These aggregated inputs, in turn, are functions of lower level inputs. The example consists of three levels, but can of course be generalized to more levels and branches, as we will see in the applications in Section 2. Quantities of different inputs cannot be added and there is thus no physical measurement for aggregate inputs. Instead aggregate inputs, like value added composed of labor and capital, should be interpreted as an index representing the value contribution of individual inputs to production.

It will be useful to introduce the notion of 'association', which can be defined in the following way (Keller, 1979:118): "[..] we say that two production components are associated if the higher level component is a function of the lower level. This means that two components are associated if one component is an aggregate that includes the other.". We furthermore define the levels or layers of the production function by the subscript l, with $l = 0,1,\ldots L$. Using the notion of association and levels we can now identify a production component associated with an input n with $q_{n,l}$. Figure 7.1 illustrates the use of these symbols to identify different components of the production function. The top level of the production function, representing produced output, is identified by q_s. Since all inputs are used to produce the output, output is associated with all inputs. More specifically, output corresponds to the highest level (L) production component of each input.

Use of nested production functions in general equilibrium modeling implies that production decisions can be modeled as if decisions are taken in stages. More specifically, each nest is treated as a production function, where decisions taken to produce the aggregate are made separately from decisions on inputs not associated with this nest. This step-wise approach to production decisions implies weak separability, defined as "[..] marginal rates of substitution between pairs of factors in the separated group are independent of the levels of factors outside that group" (Denny and Fuss, 1977:404). Note that this definition assumes only factors to enter the production function, as is the common assumption in applied general equilibrium modeling. In Figure 7.1, this assumption could be implemented by having a substitution elasticity of zero at both the top level (σ_t) and for the intermediate input nest (σ_i). Intermediate inputs are then a fixed proportion of output, and production decisions focus on determining an optimal combination of land and labor.

Figure 7.1: A general nested production structure



Note: rectangles indicate composite inputs; ovals contain substitution elasticities; see text for explanation of symbols.

Choosing a specific nesting structure thus implies assumptions on the separability of different inputs. In case of Figure 7.1, the marginal rate of substitution between land and labor is independent of the levels of intermediate inputs. Similarly, a choice among intermediate inputs is made independently of the amount of factors used in production. One may question this separation of factors and intermediate inputs in case of a detailed micro-level model like a village equilibrium model. There are likely to be differences in substitution possibilities with factors across intermediate inputs. In Figure 7.1., for example, herbicides can substitute for weeding labor and it is therefore likely to have a different substitution elasticity with labor than fertilizer. Furthermore, a single intermediate input is likely to have different substitution elasticities with different factors. Herbicides, for example, are likely to have a different substitution elasticity with land than with labor. Given these considerations substitution possibilities between inputs should be calibrated using the available production data, without imposing *ex ante* a structure on the production function.

One way to relax the strong assumption of equality of substitution elasticities between different production components is by a type of separability which has recently been coined 'latent separability' (Blundell and Robin, 2000). This approach assumes weak separability of latent goods, *i.e.* in the aggregates of the function. With latent separability, commodities may enter in multiple nests, while still allowing modeling of decisions in a stage-wise fashion. The difficulty with implementing this approach is that we only observe total input use, not the latent commodities that are analytical constructs.

7.1.2 CES versus flexible production functions

Apart from designing the structure of the production function, we have to specify the form of each aggregation function in the nested production function. If functional form would have a negligible impact on model results, we could opt for an easy to calibrate form like the Cobb-Douglas.

Given the impact of the change in demand functions on model results in Chapter 6, we expect specification of production functions to matter. This expectation is confirmed by a study comparing two versions of a general equilibrium model, with CES and normalized quadratic functions, finding an impact of functional form specification even for small policy changes (McKitrick, 1998). This finding gains more weight by the fact that both versions of the model were estimated using a 29-year time-series database, standing in sharp contrast with the common approach of calibrating a general equilibrium model on a single SAM, using elasticities from the literature. Furthermore, this is the only other study we are aware of, which calibrates a nesting structure on the data. No details are provided on the method used, but given the elaborate data available this approach will probably be based on cost functions. Given the thorough empirical basis of these findings, we can safely conclude that choice of functional form requires attention. Unfortunately, general equilibrium theory provides little guidance on the proper specification of production technologies. The flexibility of general equilibrium theory, which accounts for its popularity, comes with a lack of testable implications to guide a choice between functional forms (Hansen and Heckman, 1996).

Although the omnipresence of nested CES functions in applied general equilibrium models suggests otherwise, there have been studies addressing the issue of functional form of the production function as early as the 1980s (see for example Hertel, 1985; Pollak and Wales, 1987). One reason for the limited use of flexible functions, like the translog or normalized quadratic function, is lack of global regularity, *i.e.* being nondecreasing and concave in prices. The algorithms used for solving general equilibrium models may move far away from the benchmark used to define the function. Even when a function is concave around the benchmark, lack of global regularity may thus prevent a solution to the model (Perroni and Rutherford, 1998).

Perroni and Rutherford (1995) propose a flexible functional form which satisfies the requirements for incorporation in a general equilibrium model, the nonseparable N-stage CES function (NNCES). Although referred to as nonseparable, this function is latent separable as defined above. It allows staged decision-making, but inputs can enter in multiple nests. Apart from showing that the NNCES can be used in an applied general equilibrium model, Perroni and Rutherford (1998) also provide a way of calibrating a NNCES function without the need of prior imposition of the number of aggregates to be used, based in on cross-price elasticities at the benchmark[1].

Given the objections against separability of factors and intermediate inputs in the context of a village equilibrium model, calibrating a flexible function without *ex ante* imposing the nesting structure as possible with the NNCES seems an attractive option. The calibration of a NNCES, however, requires cross-price elasticities which we do not have in case of the village model. We not only lack elasticities, our cross-section data also lack price variation needed for estimating cost functions, on which current calibration approaches for macro general equilibrium models are based.

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[1] GAMS code for calibrating a NNCES can be downloaded from www.gams.com/solvers/mpsge/cesfun.htm (accessed March 26, 2004).

Because of the limitations of our data we opt for calibrating a nested CES production function. Flexible production functions obtain their flexibility at the cost of an increasing number of parameters that need to be estimated. Being less flexible, data requirements of a nested CES function are also more limited. In addition to input and output data derived from the SAM we need to obtain substitution elasticities of each nest, in order to calibrate nested CES functions. These substitution elasticities can be calibrated using the household survey data, after specifying the production structure, as discussed below.

Despite following the standard approach of using nested CES functions, the structure of the production functions is not standard. Instead of assuming separability of factors and intermediate inputs, we empirically establish the appropriate nesting for each agricultural production activity. When implementing this approach, we find that by introducing several layers we can introduce sufficient flexibility in the production function to capture the specifics of the economy being studied.

7.1.3 calibrating the structure of a nested CES production function

Choosing a specific nesting structure implies assumptions on separability of inputs. We can thus test whether a specific nesting structure is in accordance with the survey data by testing the implicit separability assumptions. Formally, we need to test for weak homothetic separability, which is a sufficient condition for a staged optimization procedure (Denny and Fuss, 1977).

We test for separability by using the approximate testing procedure of Denny and Fuss (1977). In this procedure a translog production function is estimated, with symmetry and adding up conditions imposed. This translog function can then be interpreted as a quadratic approximation to an arbitrary linear homogenous production function. Weak separability of a linear homogenous function is equivalent to weak homothetic separability, hence we can establish separability by testing for weak separability using the estimated translog production function.

The testing procedure employs a primal approach to estimating production decisions. Given the lack of price variation in our cross-sectional data of a single village, we are unable to estimate cost functions (as already discussed in Chapter 4, where a primal approach was used for estimating shadow prices). The approximation approach of Denny and Fuss (1977) is not generally used for testing separability, after the associated cost functions were shown to be inflexible (Diewert and Wales, 1995). In the current context, however, we are not after the 'true' (possibly flexible) production function, but we aim at formulating a production function by nesting (inflexible) CES functions. In this context, use of the approximate testing procedure is considered valid and feasible with the available data.

The approximate testing procedure estimates a translog production function,

$$\ln Y = \alpha_0 + \sum_{i \in I} \alpha_i \ln X_i + \tfrac{1}{2} \sum_{i \in I} \sum_{j \in J} \gamma_{ij} \ln X_i \ln X_j \, , \tag{7.1}$$

imposing symmetry,

$$\gamma_{ij} = \gamma_{ji} \, , \tag{7.1a}$$

and adding up constraints,

$$\sum_{i\in I}\alpha_i = 1, \quad \sum_{j\in J}\gamma_{ji} = 0, \tag{7.1b}$$

where Y is output and X_i are inputs. Decisions on inputs i and j are then approximately weakly separable from decisions on input k if,

$$\frac{\alpha_i}{\alpha_j} = \frac{\gamma_{ik}}{\gamma_{jk}}, \tag{7.2}$$

which can be tested after estimating (7.1). Restriction (7.2) implies that inputs i and j have an identical substitution elasticity with input k, therefore decisions on inputs i and j can be taken separately from decisions on input k.

Testing establishes weak separability for pairs of inputs. In the current context we have additional requirements on separability that follow from using a nested CES production function. The property which provides the CES with its name, constant elasticity of substitution, has implications for the elasticities of substitution when using nested CES functions. The elasticity of substitution (σ) between inputs associated with an aggregate and inputs not associated with this aggregate is equal for all inputs,

$$\sigma_{im} = \sigma_{jm}, \tag{7.3a}$$

where inputs i and j are associated with aggregate G, and m is not associated with G. Furthermore, the substitution elasticities between inputs associated with an aggregate are equal,

$$\sigma_{ij} = \sigma_{ik} = \sigma_{jk}, \tag{7.3b}$$

where inputs i, j and k are all associated with aggregate G at level l.

Weak separability implies the Allen-Uzawa elasticities of substitution (AUES) to be equal. Restriction (7.3a) will thus be satisfied when inputs associated with the aggregate are weakly separable from inputs not associated with the aggregate. This can be established by testing for weak separability using the approximate testing procedure. Weak separability does not, however, impose an equality constraint on the AUES among inputs associated with the aggregate at level l (restriction 7.3b). In case of two inputs, there is only one cross-price elasticity of substitution, always allowing the use of a CES function. With three or more inputs, equality of substitution is no longer trivial but requires strong separability of the associated inputs (Berndt and Christensen, 1973).

Strong separability requires the weak separability conditions as defined by (7.2) to hold simultaneously. In case of three inputs composing an aggregate, this implies (Denny and Fuss, 1977:410)

$$\frac{\alpha_i}{\alpha_j} = \frac{\gamma_{ik}}{\gamma_{jk}} \qquad (\sigma_{ik} = \sigma_{jk}) \tag{7.4a}$$

$$\frac{\alpha_i}{\alpha_k} = \frac{\gamma_{ij}}{\gamma_{jk}} \qquad (\sigma_{ij} = \sigma_{jk}) \tag{7.4b}$$

to hold simultaneously. Note that in case of three inputs, the two constraints (7.4a) and (7.4b) imply the third constraint ($\sigma_{ij} = \sigma_{ik}$). In case of three inputs, satisfying the two constraints simultaneously is therefore sufficient to establish appropriateness of using a CES function to aggregate the inputs.

We calibrate a nested CES function for each agricultural activity in the village equilibrium model. We thus do not assume *a priori* that all activities can be modeled by a similar structure. We start by estimating a restricted translog function as defined by Equation (7.1). This estimation is done for the sample as a whole (containing 168 observations) and not by household group, since activities may use up to eight different inputs, requiring up to 45 parameters to be estimated. Although using the whole sample assumes households to have access to similar production technologies, it does not impose identical technologies. With a nested production structure, substitution elasticities depend on the cost shares of the different aggregates, which may differ across households. Furthermore, calibration of the parameters of the production functions is done using the household-specific data from the SAM, also allowing differences across households groups.

We start by testing if production can be modeled using a single level CES production function. This amounts to testing for strong separability of all inputs. If a single level CES is rejected, we test for separate factor and intermediate input branches. Separability of factors and intermediate inputs requires testing for weak separability of all combinations of factors and intermediate inputs, without imposing any restrictions on the substitution elasticity among factors or among intermediate inputs. With a large number of inputs, pair wise testing can be a daunting task. To reduce the number of tests we therefore simultaneously test for a limited number of weak separability constraints, which is sufficient to establish weak separability. This can be illustrated for the production structure of Figure 7.1 which distinguishes five inputs. In this case it is sufficient to simultaneously impose five weak separability constraints (indicated by the = in Figure 7.2) to establish that all substitution elasticities between factor (land and labor) and intermediate inputs (fertilizer, manure and herbicides) are equal. These five constraints replace testing for all combinations, which would involve 13 pair wise tests.

Figure 7.2: Illustration of testing for separability of factors and intermediate inputs

	Fertilizer		*Manure*		*Herbicides*	
Land:	$\sigma_{land,fertilizer}$	=	$\sigma_{land,manure}$	=	$\sigma_{land,herbicides}$	] =
Labor:	$\sigma_{labor,fertilizer}$	=	$\sigma_{labor,manure}$	=	$\sigma_{labor,herbicides}$	

If separability of factors and intermediate inputs is rejected, we proceed by testing for separability of as many intermediate inputs from the factors and remaining intermediate inputs. We thus aim at staying as close as possible to the separation of factors and intermediate inputs. At this point we have two groups of inputs, a group of only intermediate inputs and a group of factors and remaining intermediate inputs. In case the three or more intermediate inputs can be separated from the rest of the inputs, we test whether we can model the nest with only intermediate inputs as a CES, *i.e.* if the intermediate inputs have identical substitution elasticities among each other. If such strong separability among intermediate inputs is rejected, we test which intermediates can be put in a nest separately from the other intermediate inputs, *i.e.* we add an extra layer to the branch of intermediate inputs to accommodate differences in substitution elasticities among intermediate inputs. In a similar fashion we proceed the with the group of factors and remaining intermediate inputs, adding layers until the structure is consistent with the data.

These steps can be illustrated with the structure of Figure 7.1. To test whether the nested production structure in this figure holds, a translog function would have been estimated with five inputs. Testing for a single level CES would have led to rejection, separation in factors and intermediate inputs would have been accepted. The last step would be to test for strong separability among intermediate inputs, a three-input nest, which would have been accepted. The factor nest has only two inputs and thus only one cross-substitution elasticity, therefore always satisfying a CES specification. With three tests the production structure of Figure 7.1 could thus have been established.

7.1.4 calibrating substitution elasticities

Having established the structure of the production function we need to obtain the substitution elasticities of each of the nest. Although elasticities play a prime role in determining the result of an applied general equilibrium model, use of appropriate elasticities is hampered by a lack of effort on developing econometric methods for estimating technology and preference parameters in general equilibrium models (Francois and Reinert, 1997:17). As a result general equilibrium models are often criticized for a lack of empirical validity of the elasticities used in the model. This criticism is aptly summarized by McKitrick (1998:544):

> '[these elasticities are] estimated for commodity and/or industry classifications which are inconsistent with those maintained in the model, and/or for countries other than the one(s) represented by the model, and/or obsolete estimates from past literature, not to mention outright guesses when no published figures are available'.

Where appropriate elasticities are hard to find in the context of macro-level general equilibrium models, information on appropriate elasticities for a village equilibrium model can safely be assumed to be non-existent. We therefore proceed by calibrating substitution elasticities for each nest using the household survey data, assuring substitution elasticities to be consistent with the village equilibrium model.

The calibration of the production structure establishes separability of production decisions. Since separability implies that decisions on inputs in a nest can be taken separately from decision on inputs not associated with this nest, we can model production by staged decision-making. We thus treat each nest as a single level production function for which we calibrate substitution elasticities. The method used for calibrating substitution elasticities depends on the number of inputs in a nest: in case of two inputs the elasticities are computed from a translog function, with three or more inputs a CES function is calibrated.

In case of two inputs, production functions for the aggregates are estimated using translog production functions with symmetry and adding up constraints imposed, *i.e.* using the function defined in (7.1) with two inputs. From the estimated parameters Allen-Uzawa elasticities of substitution (AUES) can be computed,

$$AUES = \frac{\sum_{i\in I} X_i f_i}{X_i X_j} \frac{F_{ij}}{F}, \tag{7.5}$$

where f_i is the logarithmic marginal production of input i; F is the determinant of the bordered Hessian matrix; and F_{ij} is the cofactor of f_{ij} and F. In general, the AUES does not provide an appropriate measure of the curvature of the isoquants, and therefore the Morishima elasticity is generally used in production function analysis (Blackorby and Russell, 1989). In the current context, however, we are determining nested CES production functions, and for CES functions the AUES serves as an appropriate measure of substitution (Valle *et al.*, 2003).

In order to calculate the AUES we need to define[2] the production elasticities (ε_i)

$$\varepsilon_i = \alpha_i + \sum_{j\in J} \gamma_{ij} \ln X_j, \tag{7.6}$$

the marginal product of input i (f_i),

$$f_i = \frac{\partial \ln Y}{\partial \ln X_i} = \varepsilon_i \frac{Y}{X_i}, \tag{7.7}$$

the second direct partial derivative of input i (f_{ii}),

$$f_{ii} = [\gamma_{ii} + (\varepsilon_i - 1)\varepsilon_i] \frac{Y}{X_i^2} \tag{7.8}$$

and the second cross-partial derivative for input i with respect to input j,

$$f_{ij} = [\gamma_{ij} + \varepsilon_i \varepsilon_j] \frac{Y}{X_i X_j} \quad . \tag{7.9}$$

Evaluating the derivatives at the mean of the sample we can construct the bordered Hessian matrix,

$$\begin{bmatrix} 0 & f_i & f_j & \cdots f_n \\ f_i & f_{ii} & f_{ij} & \cdots f_{in} \\ f_j & f_{ji} & f_{jj} & \cdots f_{jn} \\ \vdots & \vdots & \vdots & \ddots \vdots \\ f_n & f_{ni} & f_{nj} & \cdots f_{nn} \end{bmatrix} \tag{7.10}$$

to compute the determinant and cofactors needed for computing the AUES.

The above formulae provide a general procedure for computing AUES, and can be used to compute the substitution elasticities in case of three or more inputs. In order to assure the constant elasticity of substitution characteristic of a CES, however, we need to impose all weak separability constraints as defined in Equation (7.2) during estimation. These constraints are nonlinear, requiring use of nonlinear estimation techniques. Nonlinear estimation methods are beyond the scope of most statistical software packages, but can easily be implemented with GAMS. GAMS, however, can also be used for directly calibrating a CES function (Kalvelagen, 2003). In case of three or more inputs we therefore avoid the calculations as described above, which become rather tedious with

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[2] All following definitions are taken from de Valle (2003:67-69).

three or more inputs, and directly calibrate a CES function for the sample as a whole. From this calibrated CES function we only use the substitution elasticity in the village equilibrium model. The remaining CES parameters are calibrated for each household group using data from the SAM.

The substitution elasticities described above refer to elasticities within a specific nest of the production structure. Individual inputs interact with inputs associated with different levels of the production structure. The resulting overall substitution elasticities (σ) between individual inputs n and m in a nested CES function are defined by Keller (1979:121),

$$\sigma_{nm} = \sigma_{n,K} C_{n,K}^{-1} - \sum_{l=K+1}^{L} \sigma_{n,l} (C_{n,l-1}^{-1} - C_{n,l}^{-1}) \qquad \forall\, n \neq m \tag{7.11}$$

$$\sigma_{nn} = -\sum_{l=1}^{L} \sigma_{n,l} (C_{n,l-1}^{-1} - C_{n,l}^{-1}), \tag{7.12}$$

where the level K is the lowest common level (*i.e.* the lowest level where two inputs 'meet'); $C_{n,l}$ is the cost share of component $q_{n,l}$ in total costs; $\sigma_{n,K}$ is the substitution elasticity in at level K and $\sigma_{n,l}$ the substitution elasticity at all levels above K.

The estimation of the substitution elasticities uses the whole village sample, resulting in identical substitution elasticities for each type of household. This does not impose identical household response since households may have different cost shares. As shown in (7.11) and (7.12), different costs shares imply different substitution elasticities between individual inputs. With this calibration procedure we thus impose similar, but not identical production technologies across households.

7.1.5 incorporating nested production structures in the village equilibrium model

To incorporate the nested production structures in the village equilibrium model, we need to replace the Cobb-Douglas production function and input demand functions defined in Chapter 5 (Section 5.3.1). Since nesting allows one to treat each of the branches in the nested production structure separately from the remainder of production decisions, each nest will be modeled as a separate production function, linked with other nests through the use of aggregates produced by other layers in the production structure.

Calibration results in different production structures for each activity (see next section). As a result we can no longer define a general production structure for the set of agricultural activities as used in previous chapters, but we need to define production and input demand functions separately for each activity. Despite the variation in the number of layers and the composition of aggregates, there are only three options for modeling a specific nest: Leontief, Cobb-Douglas or CES. The calibrated substitution elasticity determines which functional form needs to be used for a specific nest. Given the calibration methodology, all production and input demand functions are household-, activity- and nest-specific. To increase readability, these three sets are suppressed in the following presentation of production and input demand functions.

Modeling Leontief production functions is rather straightforward. The demand for individual inputs is a fixed ratio of the aggregate,

$$q_j^i = \sum_{k \in K} \beta_{jk} \cdot QL_k \,, \qquad \forall\, j \in J \tag{7.13}$$

where q_j^i is the demand for an individual input, β_{jk} is the Leontief coefficient of individual input j relating it to the aggregate Leontief input, QL_k; and K is the set of composite inputs. As in Chapter 5 we use uppercase to denote composite inputs, while lower case letters are reserved for individual inputs and outputs as distinguished in the SAM and village equilibrium model.

The price of the Leontief input is then a weighed sum of the price of the constituting inputs,

$$PQL_k = \sum_{j \in J} \beta_{jk} p_j \,, \qquad \forall\ k \in K \tag{7.14}$$

where PQL_k is the price of the Leontief composite input.

In case of a Cobb-Douglas production function, we obtain the same functions as derived in Chapter 5,

$$QAD = \delta \prod_{k \in K} QD_k^{\alpha_k} \,, \qquad (\sum_{k \in K} \alpha_k = 1) \tag{7.15}$$

$$PQD_k \cdot QD_k = \alpha_k \cdot PQAD \cdot QAD \,, \qquad \forall\ k \in K \tag{7.16}$$

where QAD is the output of the Cobb-Douglas nest and $PQAD$ its price; QD_k are the inputs used (which can be individual or aggregate inputs of lower branches) and PQD_k the corresponding price; δ is the shift parameter; and α_k is the cost share of an input, summing to one by assuming a constant returns to scale technology.

Solving a cost-minimization with a CES production function yields the CES function itself (7.17) and the associated input demand functions,

$$QAC = \delta \, (\sum_{k \in K} \psi_k \cdot QC_k^{\rho})^{\frac{1}{\rho}} \qquad (\sum_{k \in K} \psi_k = 1) \tag{7.17}$$

$$PQC_k \cdot (\sum_{k} \psi_k QC_k^{\rho}) = PQAC \cdot QAC \ \cdot QC_k^{(\rho-1)} \,, \qquad \forall\ k \in K \tag{7.18}$$

where QAC is the CES output and $PQAC$ its price; QC_k are the inputs used and PQC_k their prices; ρ is the substitution parameter, ψ_k is the distribution parameter, and δ is the shift parameter. The substitution parameter is defined by the calibrated substitution elasticity (σ):

$$\rho = 1 - \frac{1}{\sigma} \qquad . \tag{7.19}$$

Knowing the substitution parameter, we can calibrate the other CES parameters using data from the SAM.

7.2 calibrated production structures

In this section we describe the results of calibrating production functions for each of the agricultural activities. We first discuss calibrated structures by activity, focusing on differences in cross-substitution elasticities across household groups. The last part of this section focuses on differences in substitution elasticities across cropping activities.

7.2.1 one-season rice production

We start with the first agricultural activity in the SAM, one-season rice. This is one of two rice activities distinguished in the village equilibrium model. The SAM distinguishes eleven different inputs used in one-season rice production. When calibrating the production function these inputs are aggregated to eight inputs: labor, animal traction, tractor, land, fertilizer, manure, herbicides and pesticides, other inputs (descriptives of the variables used in calibration can be found in Appendix E). After estimating a restricted translog production function (Equation 7.1), different nesting possibilities were tested, resulting in the structure of Figure 7.3.

For one-season rice testing led to rejection of the common distinction between factors and intermediate inputs. To accommodate a variety of substitution elasticities, a five-layer production structure was needed. The relatively low substitution elasticity of manure with all other inputs used in one-season rice production reflects that manure is used in relatively fixed amounts, depending on the availability of manure from livestock production.

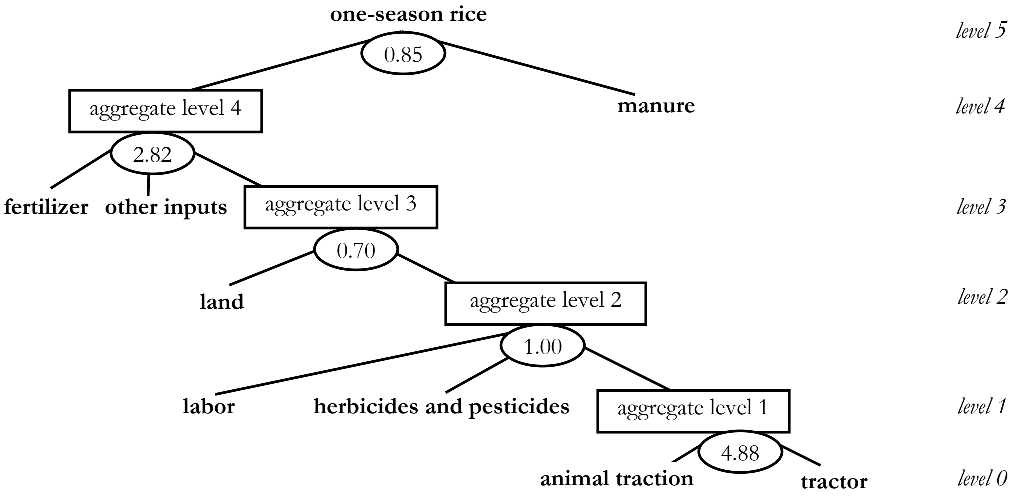
The impact of household-specific cost shares on implied substitution elasticities becomes clear when comparing the substitution elasticity for land with all inputs associated with the second level aggregate (Table 7.1). The household with no outside link and no draught power has a relatively high substitution elasticity between land and the inputs associated with the second level aggregate. This is due to a relatively higher share in total costs of the third level aggregate. In other words, this household type uses relatively more factors and herbicides and pesticides, making it more responsive to changes in relative factor prices.

The calibrated structure also confirms the hypothesized differences in substitution possibilities for intermediate inputs, which are not allowed in standard nested structures. Herbicides and pesticides, for example, have a different substitution elasticity with labor than with land. These substitution elasticities differ again for those of fertilizer with labor and land.

The last line in Table 7.1 shows unrealistic high substitution elasticities between animal traction and tractors. Of the 80 households producing one-season rice, 11 use tractors and none of these 11 households uses animal traction. This suggests that animal traction and tractors are perfect substitutes, driven by relative prices households uses a single type of traction. We could have modeled this by setting the substitution parameter in the CES function to 1, implying an infinite substitution elasticity (see Equation 7.19).

The SAM and the village equilibrium model, however, do not use individual households but representative household groups, constructed by summing over households. As a result, all household groups, except the one with no outside link and owning draught power, use both animal traction and tractors in one-season rice production. Given this aggregate character of the household groups, use of an infinite substitution elasticity does not seem appropriate. The data prohibited estimation of the substitution elasticity between animal traction and tractors, and we therefore used the substitution elasticity of 4.88 estimated for a similar crop, two-season rice. The result is a high, but not infinite, substitution elasticity between the two types of traction. We do not expect the high substitution elasticity to cause unrealistic production response in the village equilibrium model. First of all, traction amounts for only a small share of total costs (causing the high substitution elasticity in Table 7.1). Secondly, the price of animal traction is endogenous in the model. Any sharp increases in demand will thus be counterweighed by a higher price, and vice versa.

Figure 7.3: Calibrated production structure for one-season rice



Note: rectangles indicate composite inputs; ovals contain substitution elasticities of a specific nest.

Table 7.1: Household-specific substitution elasticities in one-season rice

	Link outside province	*No link*		*Link*	
	Owning draught power:	*No*	*Yes*	*No*	*Yes*
Input:	*All inputs associated with:*				
Manure	Aggregate level 4	0.85	0.85	0.85	0.85
Fertilizer, other inputs	Aggregate level 3	2.83	2.82	2.82	2.83
Land	Aggregate level 2	0.43	0.38	0.39	0.39
Labor, herbicides and pesticides	Aggregate level 1	1.77	2.12	1.85	1.83
Animal traction	Tractor	104.32	101.39	69.87	77.62

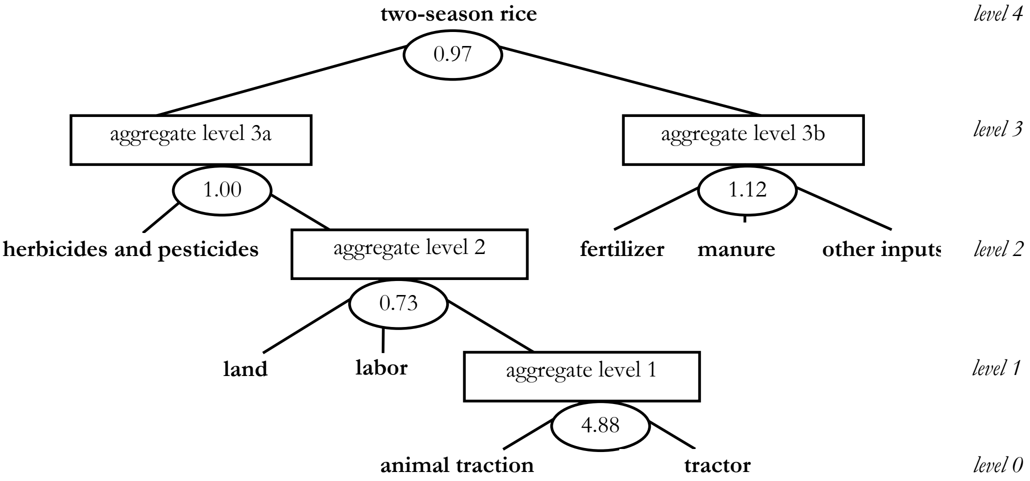
Note: substitution elasticities between inputs from the first column with all inputs associated with the aggregates mentioned in the second column; elasticities are calculated according to Equation 7.11.

7.2.2 two-season rice production

Two-season rice is the second agricultural activity in the SAM. It consists of sequential growing of early and late rice. Two-season rice uses the same eight inputs as one-season rice. Similar inputs and similar crops suggests that two-season rice may have the same structure as found for one-season rice. Testing, however, rejected this hypothesis, as well as a single-level CES in all inputs, or a separation of factors and intermediate input in different branches of the production structure. Again we thus find that the standard approach used in general equilibrium modeling does not fit with the household survey data on which the village equilibrium model is based. Stepwise testing of nesting combinations results in the structure of Figure 7.4.

Despite rejecting separability of factors and intermediate inputs, the calibrated production structure remains close to the standard approach of general equilibrium modeling. Only the substitution elasticity between factors and herbicides and inputs differs from the substitution elasticity of factors an the other inputs. Differences are not very pronounced though, with a substitution elasticity with factors of 1.01 for herbicides, and 0.97 for all other intermediate inputs. Comparing these findings to the results of one-season rice, and acknowledging that two-season rice consists of an aggregation of two different crops, suggests that aggregating over different crops makes the standard macro-level approach more appropriate. Results for other crops, which aggregates a wide variety of fruit and vegetable crops, however, contradicts this suggestion.

Figure 7.4: Calibrated production structure for two-season rice



Note: rectangles indicate composite inputs; ovals contain substitution elasticities of a specific nest.

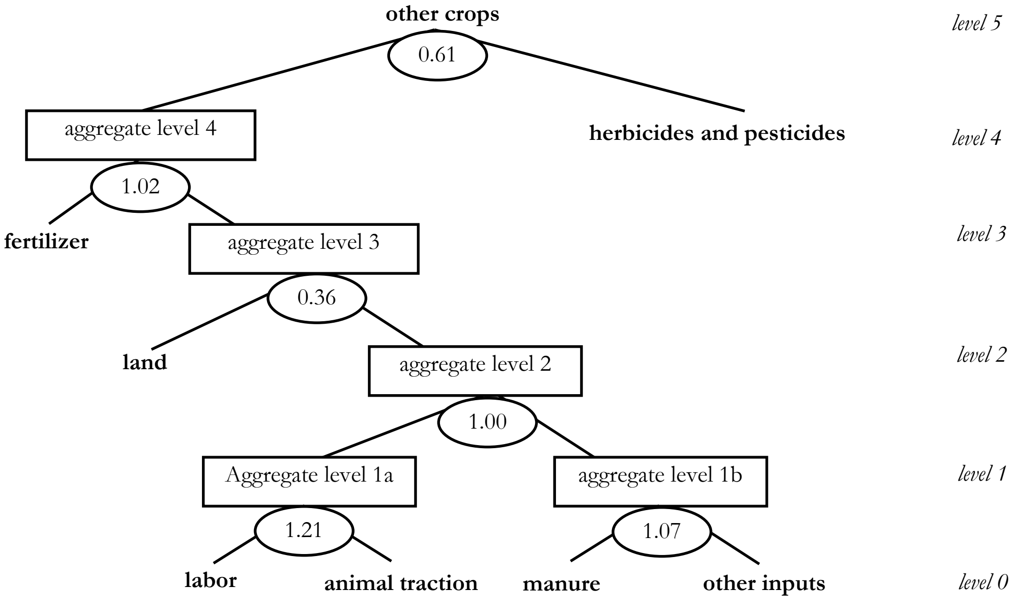
Table 7.2: Household-specific substitution elasticities in two-season rice

	Link outside province	*No link*		*Link*	
	Owning draught power:	*No*	*Yes*	*No*	*Yes*
All inputs associated with:	*All inputs associated with:*				
Aggregate 3a	Aggregate level 3b	0.97	0.97	0.97	0.97
Aggregate 3b	Aggregate level 3b	1.80	1.70	1.71	1.72
Herbicides and pesticides	Aggregate level 2	1.01	1.01	1.01	1.01
Aggregate 2	Aggregate level 1	0.66	0.65	0.65	0.65
Animal traction	Tractor	57.23	58.75	60.39	48.43

Note: elasticities are calculated according to Equation 7.11; data refer to cross-substitution elasticities only.

Most substitution elasticities are remarkably similar across households. The one exception, apart from varying traction substitution elasticities, is the relatively high substitution elasticity among fertilizer, manure and other inputs for the household lacking an outside link and not owning draught power. As with one-season rice, this household relies more on factors than on intermediate inputs.

Figure 7.5: Calibrated production structure for other crops



Note: rectangles indicate composite inputs; ovals contain substitution elasticities of a specific nest.

Table 7.3: Household-specific substitution elasticities in other crop production

	Link outside province	*No link*		*Link*	
	Owning draught power:	*No*	*Yes*	*No*	*Yes*
All inputs associated with:	*All inputs associated with:*				
Herbicides and pesticides	Aggregate level 4	0.61	0.61	0.61	0.61
Fertilizer	Aggregate level 3	1.03	1.02	1.02	1.02
Land	Aggregate level 2	0.32	0.34	0.32	0.34
Aggregate level 1a	Aggregate level 1b	2.16	2.00	2.13	1.90
Labor	Animal traction	3.00	2.79	2.99	2.82
Manure	Other inputs	2.90	2.57	2.76	2.28

Note: elasticities are calculated according to Equation 7.11; data refer to cross-substitution elasticities only.

7.2.3 other crop production

Other crop production aggregates a wide variety of vegetable and fruit crops. The same type of inputs are used as in rice production, except for tractors due to the small plot size and inclusion of perennial crops. We thus calibrate a production structure with seven inputs, resulting in the structure depicted in Figure 7.5. As with the two rice activities, separability of factors and intermediate inputs is rejected.

Herbicides and pesticides enter at the top-level of the production structure, with a substitution elasticity of 0.61 with all other inputs. This indicates relatively fixed amounts of herbicides and pesticides to be used in vegetable production. Comparing substitution elasticities across household groups we find higher substitution elasticities for households not owning draught power at the lower levels of the production function (Table 7.3).

Households not owning draught animals have a relatively high substitution elasticity between labor and traction. Since they need to rent in draught animals, this is not surprising. With the rice activities such a clear difference between households with and without draught power was not found. This suggests that substitution between labor and draught power is easier in fruit and vegetable production than in rice production.

The difference in substitution elasticity between manure and other inputs is also due to ownership of draught animals. Not surprising, households owning cattle use more manure, reflected in the lower substitution elasticity. Such a clear pattern was not observed with rice, suggesting manure to be mostly used for fruit and vegetables. This is confirmed by the data in the SAM, indicating that households use about 90 percent of available manure for other crops.

7.2.4 pig production

Next to the three crop activities, the village equilibrium model includes two livestock activities so far modeled with a Cobb-Douglas production function: pigs and other livestock. Both activities use only family labor and three intermediate inputs (crop residues, purchased feed and other inputs).

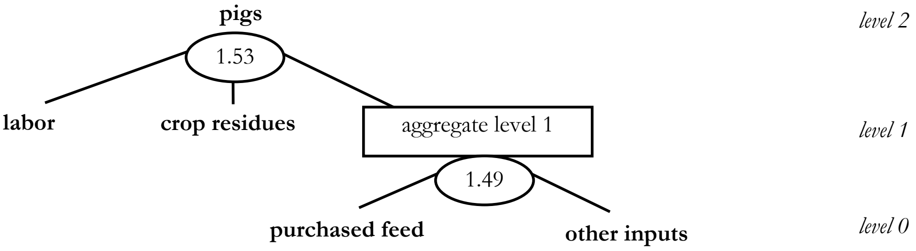
Testing led to rejection of a single-level CES function with all inputs. Nesting of crop residues and purchased feed was also rejected, because of differing substitution elasticities with labor. We could, however, separate external inputs (purchased feed and other inputs) from labor and crop residues, resulting in the production structure of Figure 7.6. Note that the production structure for pig production is the first one which implies an equal substitution elasticity between factors (labor) and intermediate inputs.

Calibrated substitution elasticities are identical across household types, with exception of the household with an outside link and owning draught power. This household uses a relatively large amount of external inputs, resulting in a lower substitution elasticity among external inputs.

7.2.5 other livestock production

In case of other livestock production three inputs are used, labor, crop residues and external inputs. Testing did not led to rejection of a single-level CES with all inputs (Figure 7.7). We calibrated a substitution elasticity of 0.87 for other livestock, which is lower than the substitution elasticity found with pig production. This difference may have less to do with technical possibilities for substituting types of feed, than with the way in which animals are kept. Pigs are generally kept in stables next to the house, whereas other livestock mainly consist of poultry roaming around the village. Switching between crop residues and external inputs can be interpreted as a switch to more intensive production, which is more likely in case of animals kept in confinements, allowing the external inputs to benefit only the own animals.

Figure 7.6: Calibrated production structure for pig production



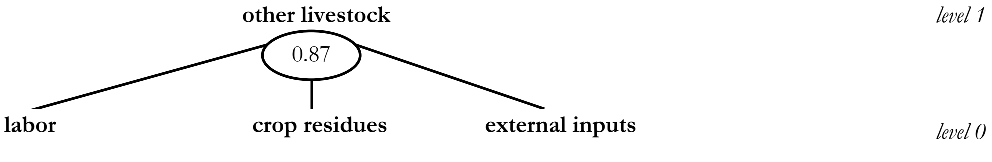
Note: rectangles indicate composite inputs; ovals contain substitution elasticities of a specific nest.

Table 7.4: Household-specific substitution elasticities in pig production

	Link outside province	*No link*		*Link*	
	Owning draught power:	*No*	*Yes*	*No*	*Yes*
All inputs associated with:	*All inputs associated with:*				
Labor, crop residues	Aggregate level 1	1.53	1.53	1.53	1.53
Purchased feed	Other inputs	1.44	1.44	1.43	1.29

Note: elasticities are calculated according to Equation 7.11; data refer to cross-substitution elasticities only.

Figure 7.7: Calibrated production structure for other livestock



Note: rectangles indicate composite inputs; ovals contain substitution elasticities of a specific nest.

7.2.6 comparing substitution elasticities across cropping activities

The discussion of substitution elasticities so far has focused on differences across households. The computed substitution elasticities were presented in terms of aggregates, allowing a focus on differences across household types. Since aggregates differ in composition across production activities, the discussion so far did not shed much light on differences in substitution elasticities across production activities. To compare differences in substitution elasticities across cropping activities, Table 7.5 through 7.7 present average substitution elasticities by activity, thus ignoring differences across households.

Table 7.5: Calibrated substitution elasticities in one-season rice production (village average)

	Land	*Labor*	*Animal traction*	*Tractor*	*Herbicides*	*Fertilizer*	*Manure*
Labor	0.39						
Animal traction	0.39	1.87					
Tractor	0.39	1.87	79.21				
Herbicides and pesticides	0.39	1.87	1.87	1.87			
Fertilizer	2.82	2.82	2.82	2.82	2.82		
Manure	0.85	0.85	0.85	0.85	0.85	0.85	
Other inputs	2.82	2.82	2.82	2.82	2.82	2.82	0.85

Table 7.6: Calibrated substitution elasticities in two-season rice production (village average)

	Land	*Labor*	*Animal traction*	*Tractor*	*Herbicides*	*Fertilizer*	*Manure*
Labor	0.66						
Animal traction	0.66	0.66					
Tractor	0.66	0.66	53.65				
Herbicides and pesticides	1.01	1.01	1.01	1.01			
Fertilizer	0.97	0.97	0.97	0.97	0.97		
Manure	0.97	0.97	0.97	0.97	0.97	1.72	
Other inputs	0.97	0.97	0.97	0.97	0.97	1.72	1.72

Table 7.7: Calibrated substitution elasticities in other crop production (village average)

	Land	*Labor*	*Animal traction*	*Tractor*	*Herbicides*	*Fertilizer*	*Manure*
Labor	0.33						
Animal traction	0.33	2.88					
Tractor	-	-	-				
Herbicides and pesticides	0.61	0.61	0.61	-			
Fertilizer	1.02	1.02	1.02	-	0.61		
Manure	0.33	2.01	2.01	-	0.61	1.02	
Other inputs	0.33	2.01	2.01	-	0.61	1.02	2.49

Note: a '-'denotes that the input is not used.

When interpreting the calibration results, it is important to keep in mind that the substitution elasticities are derived from observed behavior of households, not from agronomic experiments. Within the limits of technical possibilities, households choose the combinations of inputs according to relative prices and access to inputs. An example is manure in other crop production. As discussed above, households owning draught animals use more manure, resulting in a lower substitution elasticity for manure. This finding reflects differences in access to manure, which is a household nontradable, not technical differences in substitution possibilities.

Keeping the influence of household decisions on calibrated substitution elasticities in mind, the differences between one and two-season rice are in line with findings in earlier chapters. Both activities involve production of rice on irrigated (paddy) fields with the same inputs. Although there are some technical differences between the three types of rice involved (recall that two-season rice is a combination of early and late rice), these do not account for the large differences in substitution elasticities found when comparing Table 7.5 and 7.6.

Overall the substitution possibilities in two-season rice are more limited than in one-season rice. Recall from the simulation results in Chapter 5 and 6 that households involved in migration shifted from two to one-season rice. The changes were summarized as a shift towards more labor-extensive and capital-intensive agricultural production. This summary fits the differences in substitution elasticities between one and two-season rice.

Focusing first on substitution elasticities between factors, we find less substitution possibilities for land and more for labor and traction in one-season rice production. The household survey data thus indicate more differences in combinations of labor and traction in one-season rice than in two-season rice. This is in line with replacing labor with traction when shadow wages increase.

The lower substitution elasticity for land indicates less diversity in the ratio of land to labor and traction in one-season rice. When the amounts of labor of traction change, the amount of land thus changes in a similar manner, keeping land-labor and land-traction ratios relatively close compared with two-season rice. This finding may be explained by the labor surplus situation, which provided an important reason for modeling household decisions as nonseparable. Households were found to shift to one-season rice when their labor force reduced due to increased migration. Turning the migration findings around, we can argue that the choice for two-season rice is to a large part due to a labor surplus, *i.e.* a lack of alternative employment opportunities. In case of labor surplus, households will employ labor as long as it has a positive marginal product. Following this line of thinking, labor use in two-season rice will to a larger extent be determined by labor availability which shows more variability across households than off-farm wages. This variability shows up as a larger substitution elasticity between land and labor, compared with one-season rice.

Considering differences in alternative employment opportunities as the driving force behind the choice between one and two-season rice also provides a rationale for the differences in substitution elasticity between fertilizer and manure. Both of these provide nutrients and are technically speaking imperfect substitutes, since fertilizer satisfies only part of the nutritional needs of the crop. This fits with the less than unitary substitution elasticity found in one-season rice, making the high substitution elasticity in two-season rice puzzling. It becomes less puzzling when accounting for differences in cash and labor demands, with manure requiring more labor, but no cash outlays as a household nontradable. Being nontradable, manure will have a wider variation in (shadow) prices across households than the external input fertilizer. Taking cultivation of two-season rice as a sign of limited alternative employment opportunities, the households cultivating two-season rice will have more labor and less cash available. Manure is thus more frequently used in two-season rice (by 50 percent of the households, while 38 percent of households use manure when cultivating one-season rice). And as a result of the variation in shadow prices, more differences in manure-fertilizer ratios across households are observed, showing as a high substitution elasticity between fertilizer and manure in two-season rice production.

The discussion so far focused on differences between one and two-season rice, since these were *a priori* assumed to have similar production functions. Next to rice, households can also cultivate a variety of vegetable and fruit crops, aggregated as a single cropping activity. Comparison with rice indicates three salient differences: a relatively high substitution elasticity between labor and animal traction, a low substitution elasticity of herbicides and pesticides with all other inputs, and a high substitution elasticity between manure and other inputs.

The high substitution elasticity of labor and animal traction and of manure and other inputs most likely reflect the variety in crops aggregated under the heading of other crops. Other crops, for example, includes perennial fruit trees which do not require plowing but may involve a lot of labor. The combination of crops cultivated by a household will thus determine choices between total amount of labor and animal traction. Similarly, the type of crop will determine the mixture of manure and expenditures on other inputs which includes seed. This diversity of crops is also reflected in the larger variety in substitution elasticities by household type in Table 7.3.

The relatively limited substitution possibilities of herbicides and pesticides with other inputs are the last interesting finding of calibrating other crop production. Excessive herbicide and pesticide use is a problem in China (see for example Widawsky *et al.*, 1998). In case of vegetables and fruits this also poses a risk for consumers, next to farmer's health and environmental concerns, because of high residues in consumed products. Compared with rice, farmers use relatively fixed amounts of herbicides and pesticides in other crops, having a substitution elasticity of 0.6 with all other inputs. This despite the variety of crops being aggregated in the other crop activity. Changes in relative prices will thus have a limited impact on herbicide and pesticide use, suggesting that price incentives alone will not suffice to reduce the use of herbicides and pesticides in vegetable and fruit production.

7.3 increased migration: the impact of nesting production functions

To assess the impact of the nested production structure we return to simulating the 10 percent increase in migration. To explore the robustness of the model results, we compare the results with nested CES production functions to the findings of Chapter 6 when we employed a Cobb-Douglas production function.

7.3.1 increased migration: profits, income and welfare

As before, the point of entry for our analysis is the change in profits, income and welfare by household type (Table 7.8). The increase in migration has a qualitatively similar effect on profits from outside province employment as in Chapter 6. In quantitative terms, the two household groups involved in migration face a stronger erosion of their profits, due to a larger increase in shadow wages. The larger increase in shadow wages also implies that household full income increases more than in Chapter 6.

By eliminating land and village credit markets from the model, renting of animal traction is the most important link in transmitting the effect of migration through the village economy. A second link was through an increase demand for village produced goods, linked to the increased income. Table 7.8 includes changes in subsistence and above subsistence income by household group. The two household groups involved in migration experience comparable changes in income as in Chapter 6. This implies no major changes in terms of transmitting the additional remittances through the consumption of village goods. We therefore focus the remainder of this discussion on changes in agricultural production.

Table 7.8: Profit, income and welfare with a 10% increase in outside province migration (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Profit from outside province employment	n.a.	n.a.	4.6	-2.3
	(n.a.)	(n.a.)	(5.1)	(-1.6)
Total profits	0.9	1.3	0.6	-6.6
	(1.0)	(1.2)	(1.2)	(-5.3)
Household full income	0.6	0.4	5.8	2.8
	(0.7)	(1.1)	(5.5)	(2.7)
Subsistence expenditures	0.2	0.0	-1.5	-2.6
	(0.2)	(0.0)	(-1.6)	(-2.6)
Surplus expenditures[1]	0.8	0.5	9.2	5.2
	(0.9)	(1.6)	(8.8)	(5.0)
Equivalent variation (1,000 yuan)	5.8	5.1	256.7	193.5
	(6.5)	(14.7)	(243.8)	(187.2)

Note: results from Chapter 6 in parentheses; [1] As in Chapter 6, above subsistence expenditures are referred to as surplus expenditures.

7.3.2 increased migration: agricultural production decisions

The change in substitution elasticities, as implied by the change in production structure, changes the production response to the increased migration opportunities (Table 7.9). In qualitative terms the production response does not show major differences from the findings in earlier chapters: household involved in migration shift to two-season rice and livestock production, while households not involved in migration shift to two-season rice while reducing livestock production. In qualitative terms model results are thus robust to the way production is modeled. In quantitative terms response is more moderate than before, and reversed for some activities.

Table 7.9: Produced agricultural output with a 10% increase in outside province migration (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
One-season rice	-4.2	-23.4	6.0	77.3
	(-7.5)	(-41.4)	(6.6)	(78.1)
Two-season rice	1.5	10.4	-2.5	-33.8
	(2.7)	(18.4)	(-2.4)	(-33.8)
Other crops	0.0	-0.1	-0.9	-0.4
	(0.1)	(-0.6)	(-3.3)	(-1.6)
Pigs	0.4	0.0	3.6	-1.8
	(0.4)	(-1.7)	(-3.1)	(-7.7)
Other livestock	-7.2	-47.1	-27.0	82.1
	(-8.2)	(-46.9)	(13.3)	(168.9)
Tractor services	n.a.	-6.0	n.a	-23.2
	(n.a.)	(8.1)	(n.a.)	(-12.8)

Note: results from Chapter 6 in parentheses; [1] this household group hires agricultural labor from the other household groups.

Table 7.10: Changes agricultural input use with a 10% increase in outside province migration (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Labor	-0.4	1.2	-2.7	-6.7
	(-0.6)	(1.3)	(-4.8)	(-8.1)
Animal traction	7.1	8.1	8.2	-6.4
	(5.1)	(11.9)	(3.5)	(-5.3)
Tractor	-6.3	-0.6	-7.9	-38.1
	(5.6)	(24.4)	(2.5)	(-27.9)
Manure	0.4	0.0	3.6	-0.9
	(0.4)	(-0.5)	(-3.1)	(-3.7)
Fertilizer	0.5	3.9	-0.9	-10.8
	(0.9)	(6.8)	(-1.1)	(-10.8)
Herbicides and pesticides	0.4	2.6	-0.5	-10.0
	(0.9)	(4.6)	(-0.6)	(-9.7)
Other inputs	-2.0	-12.8	-2.7	6.2
	(-2.1)	(-11.7)	(0.4)	(20.6)
Feed	-0.2	-1.3	-0.2	3.3
	(-0.2)	(-2.5)	(-0.8)	(3.4)
Purchased feed	-0.4	-9.2	-0.6	37.0
	(-8.8)	(-10.6)	(-0.9)	(73.9)

Note: results from Chapter 6 in parentheses.

Before delving into household production response, we first need to check whether the high substitution elasticity between animal traction and tractors results in unrealistic strong shifts in type of traction. Changes in types of traction do not appear out of line, except for the household involved in migration and owning draught power. Analyzing the input use by activity (Table 7.10), the drop in tractor use is not due to a high elasticity, but due to a shift from two-season to one-season rice for which this household uses less tractors. Not the nested structure, but the assumption that households use the same technology as in the SAM, thus causes the drop in tractor use in Table 7.10.

Comparing production response with nested CES functions to the results of Chapter 6, we find that the general impact of migration on the village economy is robust to the introduction of nested production functions. As in earlier chapters, households involved in migration shift to one-season rice and livestock, while households not involved in migration shift to two-season rice. Despite a similar pattern in response, examining input use reveals three differences in input use that are due to the nested structure: (i) a more moderate shift to one-season rice by households involved in migration; (ii) a more moderate shift to two-season rice by households not having access to migration; (iii) the migration household lacking draught power increases pig instead of other livestock production.

The more moderate shift to one-season rice by households involved in migration is due to more limited substitution possibilities for labor in one-season rice. The Cobb-Douglas specification of earlier chapters implied a unitary substitution elasticity of labor with all other inputs. With nesting, substitution possibilities for labor are more limited, with an own price substitution elasticity of 0.4 in one-season and 0.7 in two-season rice. There are thus less possibilities for reducing the use of labor in response to increased scarcity of labor. Also note that the substitution elasticity for labor in one-season rice is less than in two-season rice. This accounts for the more modest shift towards one-season rice. Finally, the more limited substitution possibilities of labor also cause a stronger increase shadow wages, following the increase in migration.

Table 7.11: Price changes with a 10% increase in outside province migration (%)

Link outside province:	*No link*		*Link*	
Owning draught power (animals or tractor):	*No*	*Yes*	*No*	*Yes*
Factors: Male labor	0.7	0.8	11.0	5.5
	(0.7)	(1.9)	(10.0)	(5.2)
Female labor	0.7	0.8	10.3	5.2
	(0.8)	(1.8)	(9.3)	(4.9)
Animal traction services	-3.0	-3.0	-3.0	-3.0
	(-5.9)	(-5.9)	(-5.9)	(-5.9)
Goods: Two-season rice	0.0	0.0	0.0	0.2
	(0.0)	(0.0)	(0.0)	(0.1)

Note: results from Chapter 6 in parentheses.

While substitution possibilities for labor are more limited, the nested production function allows more substitution possibilities between animal traction and tractors. This causes the more moderate shift to two-season rice by households not having access to migration. When prices of animal traction decrease due to the decreased demand for traction by migration households, animal traction is substituted for tractors, tempering the decrease in demand. As a result the price of animal traction drops less than in earlier simulations (Table 7.11), resulting in a more moderate shift to two-season rice by households not involved in migration.

The third difference in production response with the nested production structure is the increase in pig instead of other livestock production by the migration household lacking draught power. This change in response is due to the ability of the nested production function to capture differences in production technology across household groups, that the single-level Cobb-Douglas specification failed to capture. The nested production structure captures the relatively high returns to external inputs in pig production for the migration household lacking draught power, causing the shift towards pig production when remittances release the cash constraint.

As a conclusion of the discussion of the impact of specification of production functions on household response, we find the nested production structure more in line with existing studies of the impact of migration on source communities than the Cobb-Douglas specification of Chapter 6. Both the study by Rozelle *et al.* (1999b) and by Taylor *et al.* (2003) find negative impact of the reduction in labor on crop yields (see the discussion in Chapter 6). The less than unitary own substitution elasticities with a nested production structure are more in line with these findings than the assumption of a unitary substitution elasticity of the Cobb-Douglas production function.

7.3.3 increased migration: village-level impact and employment

The analysis of the simulation results thus far has focused on the household-level impact of the increase in migration opportunities. The differences observed at the household level, result in a different aggregate village-level response compared to the findings of Chapter 6 (Table 7.12). As with changing the utility function in Chapter 6, differences in aggregate full income are small when changing the production function. This aggregate measure, however, obscures considerable differences in income by household. When changing the production function, the two households involved in migration obtain a small additional increase in income per adult equivalent. At the same time, however, the increase in income of the household lacking an outside link and owning draught power drops with 0.7 percent points lower than with a Cobb-Douglas production function. The change in substitution possibilities introduced through the nested production thus result in an increase in aggregate village income and welfare, but the increase in incomes becomes more concentrated with the households involved in migration. In terms of equivalent variation, the share of the two household groups lacking access to migration in village welfare increase drops from 4.8 percent to 2.4 percent.

This difference is most pronounced for the household owning draught power, with its welfare dropping to a third of its equivalent variation in Chapter 6. This household is negatively affected by the drop demand for animal traction, which tightens its cash constraint. With the nested production functions, the possibilities for substituting its limited amount of labor by traction are less than with the Cobb-Douglas production function. As a result, this household group's options for increasing income by more increased rice production are limited, resulting in the sharp drop in full income compared to Chapter 6.

Moving to the lower part of Table 7.12, we find the changes in exports from the village. When discussing production decisions by household we found a more moderate change in one and two-season rice for three of the four household group. Only the household with an outside link and draught power maintained the same response as in Chapter 6, increasing one-season rice and decreasing two-season rice production. Since the opposite movement of the two households lacking access to migration is more moderate, total exports of one-season rice increase more, while exports of two-season rice drop more than in Chapter 6. The net impact is a slightly larger drop of rice exports of 11.1 percent, compared with a 9.7 percent drop in rice export from the village in Chapter 6.

Table 7.12: Village-level impact of a 10% increase in outside province migration with Cobb-Douglas and nested production functions (%)

	Cobb-Douglas production functions	*Nested production functions*
Equivalent variation* (10^3 yuan)	452.2	461.1
Increase in full income*	3.3	3.3
Income per adult equivalent:		
Household with no link, no draught power	0.7	0.6
Household with no link, draught power	1.1	0.4
Household with link, no draught power	8.4	8.7
Household with link, draught power	5.5	5.6
Village exports		
One-season rice	49.5	53.7
Two-season rice	-37.9	-41.9
Rice	*-9.7*	*-11.1*
Other crops	-9.0	-2.4
Pigs	-4.4	1.4
Other livestock	152.6	22.4

Note: shock is a 10% increase in migration outside the province. * Computed as the sum over all households.

The most notable change in exports is the much more moderate increase in export of other livestock. The reduction in other livestock production is about similar for the two household groups lacking access to migration, but major changes occur for the two households with access to migration. The household owning draught power has a much lower increases in production (82 percent, against 169 in Chapter 6), while the household not owning draught power reduces other livestock production and increases pig production. The net effect is increase in exports of pigs, as opposed to a decrease with a Cobb-Douglas function, and a more limited increase in other livestock exports.

Summarizing, we find substantial differences in income distribution across households and in exports from the village when introducing nested production functions in the village model. The difference in incomes is most notable for the household not involved in migration and owning draught power, while for village exports a more moderate increase in other livestock exports is found. Despite these differences, the overall pattern of response is robust to the change in production function.

7.4 concluding remarks

This chapter has shown that even within the limitations of cross-section data, calibrated elasticities that are consistent with the economy being modeled as well as the chosen commodity classification can be used in a general equilibrium model. This is especially relevant in the context of applied village equilibrium modeling. Where appropriate elasticities are already hard to find in the context of macro-level general equilibrium models, appropriate elasticities for a village equilibrium model can safely be assumed to be non-existent.

For the five agricultural activities included in the village equilibrium model of this study, we found around unitary substitution elasticities only for the substitution between factors and intermediate inputs in one-season rice production. Substitution elasticities among factors and among intermediate inputs in two-season rice production, as well substitution elasticities in all other agricultural activities differed from the unitary substitution elasticity implied by a Cobb-Douglas specification. There was no consistent pattern in these differences, implying that we cannot conclude *a priori* whether a Cobb-Douglas specification overestimates or underestimates substitution possibilities.

Apart from calibrating substitution elasticities, which play a crucial role in the results of general equilibrium models, we questioned the separation of factors and intermediate inputs as is common in applied general equilibrium models. General equilibrium models separate factors and intermediate inputs at the top level of the production function, implying that the substitution elasticity is identical for all combinations of factors and intermediate inputs. This strong assumption may be warranted in macro-level general equilibrium models, but in the context of a micro-level village equilibrium model this assumption is considered inappropriate. This is confirmed in this study by empirical testing of the separability assumption.

Calibration of production structures for each agricultural activity instead of using a generic production function was found to capture both differences in technology, as well as differences across households in access to resources like labor and capital. The patterns found were consistent with conclusions in previous chapters regarding a labor surplus situation and the importance of remittances in releasing the cash constraint of households. Based on these findings we conclude that the approach for calibrating both structure and substitution elasticities used in this chapter captures more of the characteristics of the village economy than existing modeling approaches.

The final point we need to address is whether all the (tedious) work matters for the conclusions derived from the village equilibrium model. To this end we repeated the increased migration experiment of Chapter 6, allowing a comparison between a Cobb-Douglas and a nested CES production structure. General conclusions did not change qualitatively. As in Chapter 6, when we explored the consumption side of the model, general findings are thus found to be robust to model specification.

Despite a general robust result, introducing nested production functions does generate differences, both qualitatively and quantitatively. With nested production functions, benefits from migration are higher for households involved in migration, while households lacking access to migration benefit less. This difference is as large as a 63 percent lower increase in full income for the household lacking access to migration and owning draught power.

The variation in substitution elasticities introduced by nesting result in different responses, also makes differences across household more pronounced. Parameters of each nest are household-specific, allowing the model to better capture differences across households. The nested production structure also has a less than unitary own-price substitution elasticity of labor. This corresponds better to findings of a negative impact of migration on crop yields in other studies of the impact of migration on sending households than the unitary elasticity assumed in the Cobb-Douglas specification. In addition to better capturing household-specific production structure and resonating with existing studies, the nested production structure also leads to a more moderate household production response. Since in practice household generally do not radically change their production pattern if a single element of their socio-economic environment changes, this further warrants the efforts of calibrating nested production functions.

Although the eventual outcome is a more moderate response of village exports to the increase in migration than found in earlier chapters, the increase in income is concentrated more with the households involved in migration. In terms of policy implications the use of nested production functions thus generates more concern for the rising income inequalities due to asymmetric access to migration.

CHAPTER 8

the chinese village model: taking stock and identifying directions for future research

In this concluding chapter we take stock of the contributions of this study to the existing literature and of the insights gained in the Chinese case study village. Based on these results we identify directions for future research. In Chapter 1 we argued that village modeling can contribute to understanding the impact of the economic transformation of China in the rural areas. Based on a review of existing models, we concluded that blending household and general equilibrium modeling would be the most consistent way of capturing household decisions and interactions among households in a village economy. The remainder of this study developed applied village equilibrium models for a Chinese case study.

Similar to the review of existing models in Chapter 3, we employ the matrix of key modeling issues to identify the contributions of the village equilibrium model developed in this study. After reviewing the structure of the applied village model, the second part of this chapter addresses the insights gained in the Chinese case study village, looking back at the arguments used to build a case for developing a Chinese village model in Chapter 1. The last part of this chapter combines the assessment of the village equilibrium model with the insights gained in the case-study village to identify promising directions for future research.

8.1 the chinese village equilibrium model: achievements

The discussion of the Chinese village equilibrium model is cast in terms of the key issues defined in Chapter 2. Using the matrix of key choices as defined in Table 2.2, we obtain a consistent view on the model developed in this study. Table 8.1 summarizes key choices made in the three chapters developing the village model, each one building on the model of the previous chapter. In this assessment we use the model of Chapter 7, *i.e.* with Stone-Geary utility functions and nested-CES production functions.

Since we developed a static model, the column referring to modeling dynamics is left out of Table 8.1. Furthermore, in the absence of non-market institutions from the model, the row referring to non-market institutions is also omitted. Hence, we discuss the village equilibrium model in terms of the choices made with respect to modeling natural resources, technology, households and markets.

8.1.1 natural resources

The modeling of natural resources has not received much attention in the discussion of the village equilibrium model in previous chapters. Choices made are standard for economic models of household decisions. The only natural resource explicit in the model is land, with a distinction made between irrigated paddy fields and non-irrigated land used for fruit and vegetable production. Within these subcategories, land is assumed to be of uniform quality, and soil quality is thus not considered an explicit input in production.

Despite the standard economic approach taken to modeling the use of natural resources for agricultural production, the village SAM and the production functions use a detailed specification of inputs, distinguishing herbicides and pesticides, fertilizer and manure. This detailed distinction is used to capture differences in substitution possibilities between factors and intermediate inputs. Although not pursued in this study, this detailed specification of inputs may provide a crude indication of the sustainability of production decisions. Fruit and vegetables, for example, are notorious for herbicide and pesticide residues which may affect consumers' health. Distinguishing herbicides and pesticides as separate inputs would allow a crude assessment of the impact of changes in relative prices on their use, providing a very preliminary indication of the need for supplementary health policies. Only crude assessments can be made, however, since different types of herbicides and pesticides are aggregated into single inputs and we lack data on thresholds levels for residues to assess the impact on consumers' health. Similar crude assessments of the impact on substitution of fertilizer and manure could be made with the current model specification.

The static character of the model developed in this study, however, limits any assessment of the sustainability of natural resource use to an *ex post* computing of the impact of household decisions on natural resources.

8.1.2 technology

The modeling of technology received ample attention, with Chapter 7 devoted to capturing differences in technology across households and across activities by calibrating nested-CES functions. The use of CES functions implies that features like thresholds or synergy among inputs are not accounted for. Furthermore, all inputs are assumed to be substitutable, an unrealistic assumption from an agronomic perspective. Despite using a primal approach in calibrating the production functions, calibration did not use agronomic data, but was based on household input decisions. The calibrated structures therefore reflect both technical production possibilities and access of households to various inputs. An illustration of this combination of technology and household decisions are the differences found in input substitution elasticities between one- and two-season rice. In technical terms these are very similar crops, calibration however resulted in different production structures and substitution elasticities. These differences reflect the shift from two- to one-season rice when labor becomes more scarce.

Table 8.1: Key choices made in the village equilibrium model

Key issues: **Key elements:**	*Conceptualization*	*Interaction*	*Aggregation*
Natural resources	▪ irrigated and non-irrigated land ▪ detailed input distinction (herbicides, pesticides, manure, chemical fertilizer)	▪ no spatial interactions between land units	▪ land is assumed to be of uniform quality ▪ inputs are aggregated by type (e.g. no distinction between types of herbicides)
Technology	▪ nested CES production functions	▪ crop and livestock activities interact through manure and crop residues used as feed ▪ inputs can be substituted with varying substitution elasticities	▪ constant returns to scale in all activities, except for cattle which has partly fixed inputs and outputs ▪ 11 activities, agricultural or off-farm, that are household-specific
Household	▪ maximize Stone-Geary utility derived from consumption of farm output, purchased consumption goods and leisure ▪ household decisions are nonseparable ▪ risk is not included in the model	▪ parameters of utility function calibrated on observed household consumption patterns ▪ households treated as a single decision-making unit	▪ four representative household groups constructed based on agricultural income earning opportunities (draught power) and access to migration ▪ nonlinear response of households within a group not accounted for
Markets	▪ limited village agricultural labor market (fixed market shares) ▪ distorted village land market (fixed amounts of rented land) ▪ village market for animal traction and tractor services ▪ limited village credit market with one household focused on migration providing net transfer to the other households (transfers fixed at base level) ▪ village market of local consumption goods (fixed market shares)	▪ households interact through village markets	▪ most village markets have fixed prices and equilibrium attained through fixed market shares ▪ animal traction services have an endogenous price ▪ tractors are under-utilized and have a fixed price with endowments adjusting ▪ household position (buyer, seller, autarkic) in external markets and market for animal traction services is endogenously determined; position in other markets is fixed through market shares

Note: Chapter 2 of this study discusses the matrix of key choices applied here to the village equilibrium model.

Agricultural activities interact through the usual competition for factors of production. In addition, cropping activities use manure produced by the livestock activities, whereas livestock activities use crop residues as feed.

Agricultural activities are modeled by CES functions, implying constant returns to scale. The only exception is the cattle activity, which produces animal traction services. The extent to which cattle are used for traction is assumed not to affect their feeding requirements or their production of manure nor calves. As a result, cattle is modeled as a mark-up activity, with the mark-up used to recover fixed production costs. All off-farm activities are modeled as Leontief activities, using male and female labor as inputs.

The household perspective on general equilibrium modeling is reflected by modeling activities as being household-specific. This contrasts with the approach in macro-level general equilibrium and in existing village-level models, which model production at sector level. By modeling activities as household-specific, we are able to capture opposite production responses to an increase in migration opportunities. Driven by differences in household-specific shadow prices, households with access to migration shift to one-season rice, while households lacking access to migration move towards two-season rice.

8.1.3 household

Differences between households play a key role in the village equilibrium model. The surveyed households are aggregated into four groups of households, based on agricultural income earning opportunities and access to outside province migration. These two criteria capture the two main sources of income in the case study village. This grouping allows an analysis of the impact of the transformation of the Chinese economy described in Chapter 1 on rural households, of which the shift from an agricultural to an industrial based economy is a main feature. The four groups of households are treated as uniform groups, no assessment is made of the distribution of different households within a representative group.

Households are treated as a single decision-making unit, maximizing utility from consumption of farm output and of consumption goods that are either produced in the village or imported from outside. Consumption decisions cannot be separated from production decisions, because of imperfections in irrigated land and labor markets as well as missing markets for non-irrigated land, manure and crop residues. As a result prices of these commodities are household-specific, resulting in idiosyncratic household production and consumption responses.

Utility is modeled using Stone-Geary utility functions, with parameters derived from income elasticities calibrated on household expenditure data. The resulting consumption demand functions include fixed subsistence consumption levels, allowing the assessment of the impact of migration on household subsistence consumption demand.

8.1.4 markets

Markets are the last main ingredient of the village equilibrium model. In line with the findings of Huang and Rozelle (2004), the case study village is well integrated in markets for agricultural output and external inputs. Presence of village nontradables, however, necessitates the use of a village model. Households interact through factor markets (land, labor and draught power) and through markets for locally produced goods and services.

In contrast to most general equilibrium models that rely on prices to obtain equilibrium, equilibrium in most village markets is achieved through quantity adjustments with fixed prices. Households have a fixed share in these village markets, resulting in demand-driven markets. This mechanism is used to deal with a lack of data on trade flows between household groups and on inputs besides labor used for producing local consumption goods.

Two exceptions to this market structure are the village market for irrigated land and for animal traction services. There is an extensive village market for irrigated land, but the land is mainly supplied by households that have migrated from the village. As a result all household groups distinguished in the village equilibrium model rent in land. This confirms the notion of China having a labor surplus, a finding which is further supported by household shadow prices of land exceeding rent payments. Modeling of migration of whole households is beyond the scope of this study, and therefore the amounts of rented irrigated land by each household group are fixed at the levels observed in the SAM, effectively removing the irrigated land market from the model.

Animal traction services are the only village market with endogenous prices. Two of the household groups own draught power, which suggests that they may use their market power to earn excess profits on renting out animal traction services. In order to earn such excess profits, households need to manipulate prices or quantities. With similar technologies and prices being common knowledge, raising prices above the input costs is likely to incur social sanctions. Manipulating prices through reducing quantities, implies that cattle will be standing idle when other villagers have a peak demand for traction services, and can also safely be assumed to generate social sanctions. Therefore, the village market for animal traction is modeled as being perfectly competitive. The threat of social sanctions prevents excess profits, thus taking the role of free entry and exit used in macro-level models to prevent excess profits.

The position of households in markets where prices determine equilibrium (external inputs, agricultural output which is marketed outside of the village and animal traction services) is endogenous. If households withdraw from the market, for example by reducing agricultural production to household consumption needs, production and consumption decisions are determined by a household-specific shadow price which differs from the exogenous market price.

8.1.5 main differences with existing models

The key choices made when developing the village equilibrium model are driven by a household perspective on general equilibrium modeling and by capturing essential features of the Chinese case study village. The result is a hybrid model which blends features standard in household optimization models, like nonseparability, with features standard in applied general equilibrium modeling, like demand and supply functions. Where possible, the household survey data are used to determine the structure of the model and the functional forms. In case insufficient data were available, for example regarding trade flows among household groups, the most simple solution like fixing market shares is chosen to make model results as tractable as possible.

Compared with existing village equilibrium models, taking a household perspective on general equilibrium modeling results in fundamental changes in the way in which the model is developed. To account for nonseparability of household production and consumption decisions, production activities in the SAM are household-specific. For household nontradables shadow prices are estimated, which are then used to construct the value flows in the SAM. This contrasts with the convention of normalizing all prices to one, used in macro general equilibrium models and existing village equilibrium models. By using household-specific prices in the SAM and calibration of model parameters, both the SAM and the village equilibrium model are fully consistent with nonseparability of household decisions.

In all steps of developing the village model, standard conventions in general equilibrium and household modeling were questioned, and replaced by alternative approaches wherever necessary and possible. One example is the use of fixed prices and market shares to model village markets, which was necessary because of lack of data on bilateral trade flows between household groups. Although the available data were limiting in terms of trade flows, they offered possibilities in terms of calibrating elasticities. Elasticities of both consumption and production decisions were calibrated on the household survey data, resulting in a general equilibrium model that is fully consistent with the underlying data. This contrasts with the reliance on elasticities from the literature in macro-level general equilibrium models, and on Cobb-Douglas functions with unitary elasticities in existing village equilibrium models.

Apart from calibrating substitution elasticities, the approach taken to modeling production decisions, also reflects the questioning of standard modeling conventions. Existing macro and village equilibrium models assume separability of factors and intermediate inputs. Testing led us to reject this assumption, and it was therefore dropped when modeling the production decisions. The result is a modeling of household production decisions that captures differences in resource endowments and access to inputs, that are absent from existing models.

8.2 the chinese village equilibrium model: findings

The village equilibrium model is built through an interactive process of matching model structure and data collected in the case study village. Although the resulting model is tailor-made for the Chinese case study, the approach used for determining model structure and parameters can be applied elsewhere. Apart from resulting in a tailor-made model structure, the approach used for developing the applied model yielded valuable insights in the workings of the village economy. In this section we first discuss the insights gained in Chapter 4, when constructing the village SAM. The second part discusses the findings from the model simulations in Chapters 5 through 7.

8.2.1 findings from constructing a chinese village SAM

When building a case for village modeling in Chapter 1, we argued that missing land, labor and credit markets were expected to give rise to within-village interactions. In Chapter 3 we argued that missing markets may also give rise to nonseparability of household decisions. Examining the data we found village markets for irrigated land, animal traction, tractors, agricultural labor, and locally produced consumption goods. Despite extensive involvement in off-farm employment households still have a labor surplus, indicating restricted access to off-farm employment. Combined with missing markets for non-irrigated land, manure and crop residues indicated by the data, this restricted access to off-farm employment results in nonseparability of household decisions.

Given the nonseparability of household decisions, we estimated shadow prices of commodities with imperfect markets. In this estimation we included irrigated land, because of the distortions present in this market. The estimated shadow prices are consistent with a labor surplus: estimated prices of land exceed observed rental payments. Distortions in the land market are also confirmed by the finding that all household groups are renting in land, mainly supplied by households that have migrated from the village.

Relying on friends and family for credit, because of lack of access to formal lending was also used in Chapter 1 to argue for a village model. The SAM indicates a local credit market, in which the household most involved in migration is a net supplier of cash to the other households. Although the majority of credit is obtained from outside the village[1], the importance of the availability of cash for production decisions in the model simulations suggests that increased local availability of cash could be an important avenue through which households influence each other. The informal character of cash flows within the village is reflected by the conditions on which money is provided, on which the household survey data unfortunately only provided a very limited perspective.

Apart from the insights gained in the village economy, the approach used for constructing the SAM provided important information on the workings of the village economy used in designing the village equilibrium model. The household survey data lack sufficient information to model interactions in the irrigated land market and cash transfers within the village. We therefore assumed that households maintained the amount of land they rented in the SAM. Similarly, we assumed that the cash flows within the village are fixed at the levels in the SAM. Both assumptions reduce the amount of interactions among households in the village, thus limiting the introduction of indirect effects in the village model.

To reflect a labor surplus situation with restricted access to off-farm employment, wages are fixed and demand determines the level of off-farm employment. In case of outside village employment this results in fixed levels of employment, while levels of within-village employment are determined by demand. In this case initial market shares determine the off-farm labor supply of each household group.

8.2.2 household versus village analysis

In Chapters 5 through 7 we develop different versions of the applied village equilibrium model and used it to analyze an increase in migration opportunities outside the province. In Chapter 5 we develop a basic village model, using Cobb-Douglas utility and production functions, to analyze the impact of interactions among households on household response to an increase in remittances. Since the Cobb-Douglas utility functions do not facilitate an analysis of the subsistence consumption impact of migration, we simulate an increase in outside province remittances while leaving the amount of labor involved in migration, and hence the number of consumers in the household, fixed.

When using separate household models, an increase in outside province remittances only affects the two household groups having a link outside the province. For these household groups

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[1] Computations with data in the SAM show that of total assistance and lending, 83 percent originates outside the village.

the increase in remittances provides extra cash and raises the shadow wage of family labor. The rising wages result in a less intensive rice production, and the 'migration households' (*i.e.* the households involved in migration outside the province) switch from two- to one-season rice production. The increased availability of cash induces a shift to capital-intensive livestock production. Ignoring village interactions, the other two household groups are not affected.

Applying the same increase in remittances to the village equilibrium model, interactions within the village economy result in a transmission of the shock to the two household groups not directly affected. By disregarding land and credit markets from the model, the village market for animal traction services provides the main mechanism for transmitting the shock through the economy. The change to less intensive rice production by migration households reduces demand and thus the price of animal traction services. Lower animal traction prices reduces production costs, while the two household groups lacking access to migration outside the province do not face an increased shadow wage. They switch to more intensive rice production, increasing two-season rice production, thus moving in the opposite direction of the migration households. The net result at village level is a drop in rice exports and an increase in exports of other livestock.

Opposite response conditional on access to migration thus results in a more moderate aggregate supply response when household interactions are accounted for. Interactions in village markets result in a welfare increase for all household groups. Overall, however, the diffusion of welfare derived from the increase in remittances is limited. The two migration household groups retain most of the welfare increase. This finding can be partly explained from the absence of village markets for land and credit from the model. If households with access to migration would make part of their increase in cash income available to the other households, the rise in welfare of households lacking access to migration can be expected to be higher. Similarly, if following a rise in outside-village employment households would migrate from the village, the increase in available land for the remaining households would increase the welfare of households lacking access to migration.

8.2.3 accounting for the impact of migration on remittances, consumption and labor availability

Migration does not only affect remittances, as analyzed in Chapter 5, but also available production labor and subsistence consumption demand. In Chapter 6 we therefore modify the specification of household consumption decisions by replacing a household-level Cobb-Douglas utility function with a Stone-Geary utility function defined per migration corrected adult consumer equivalent. The Stone-Geary utility function captures shifts in the spending patterns when income rises, while defining consumption per adult consumer equivalent captures decreases in household consumption needs with increasing migration.

Comparing village-level results of an increase in remittances with a Cobb-Douglas and a Stone-Geary utility function, we find results in terms of income and welfare ranking to be robust. Results in terms of marketed surplus from the village, however, are sensitive to the functional form chosen for the utility function. Different consumption patterns magnify production shifts found in Chapter 5 using a Cobb-Douglas utility function. As a result the drop in rice exports and increase in other livestock exports are larger than found in Chapter 5.

Introducing a Stone-Geary utility function allows us to link subsistence consumption demand to the number of migrants. In this way we can assess the three-fold impact of an increase in migration: reduced consumption demand, reduced availability of on-farm labor, and increased remittances.

The impact of migration on available labor magnifies production shifts observed when only remittances increase. Households with access to migration display a stronger shift to one-season rice, which in turn induces a stronger shift to two-season rice by households lacking access to migration. For the aggregate village supply response it thus matters whether the expansion of employment outside the province is transmitted only through income, or whether it will increase the flow of migrants. An increasing flow of migrants will magnify the shift away from rice and towards other livestock production.

An increase in remittances or migration has the same impact on household full income. In case of an increase in migration, however, the household size is reduced, thus more income is available for remaining household members than when remittances increase. An increase in migration thus raises welfare more than an increase in remittances. The welfare impact of reduced consumption with migration only raises the welfare of the two migration household groups. The reduced labor force of migration households induces a stronger production response, however, resulting in a stronger welfare increase for the two non-migration households as well. As a result, all household groups experience a larger welfare increases with an increase in migration than when only remittances increase.

8.2.4 capturing differences in production response

In Chapter 7 we shift from consumption to production by replacing the Cobb-Douglas production function with less restrictive nested-CES functions. Both the structure of the nested functions and the substitution elasticities are calibrated on the household survey data. No *a priori* structure is assumed, but calibration starts by testing the standard assumption in general equilibrium modeling, which separates factors and intermediate inputs. This assumption is rejected for all activities, underscoring the need to match the model structure to the case study data.

Calibrating production structures by agricultural activity instead of using a generic production function is found to capture both differences in technology and differences across households in access to resources. The calibrated production functions are consistent with findings of a labor surplus situation and the importance of remittances in releasing the cash constraint of households in earlier chapters. The calibration of both structure and substitution elasticities used in this study thus captures more of the characteristics of the village economy than existing modeling approaches.

Although we assumed similar technologies across households, multi-level production functions allowed us to elicit differences across households in access to production inputs and endowments. These differences resulted in a different production response when analyzing the impact of migration. Migration households still increase livestock production, but, differences in household endowments now result in a focus on different types of livestock. As a result, village supply response is more moderate than when using Cobb-Douglas production functions.

In terms of welfare, using nested production functions limits the diffusion of additional income to households lacking access to migration. More limited substitution possibilities for labor in one-season rice, combined with increased substitution possibilities between tractors and animal traction, temper the shift to less intensive rice production by migration households. The impact on the household groups lacking access to migration depends on household endowments. For the household group not owning draught power, the tempered reduction in animal traction prices slightly reduces the income increase compared to earlier chapters. The household group owning draught power is more strongly affected, since the increased substitution possibilities between types of traction reduces the demand for tractors when the price of animal traction decreases. Furthermore, a reduction in substitution possibilities between traction and labor compared to earlier chapters hampers the shift to other livestock production for this household with a small labor endowment. For this household group the income increase is less than half the income increase found with Cobb-Douglas production functions. Accounting for differences in household endowments and the choice of production function thus has a significant impact on the estimated diffusion of welfare within the village economy.

As in previous chapters, aggregate village supply response is sensitive to the change in functional form. Although the response in qualitative terms remains the same, the quantitative response is more moderate than in earlier chapters.

8.2.5 insights gained from a household perspective on general equilibrium modeling

Standard approaches to general equilibrium and household modeling were found unsatisfactory when developing the Chinese village equilibrium model. As a result this study focused on modeling the essential features of a general equilibrium model (markets, consumption and production decisions) in line with household survey data. The result of this household-level perspective on general equilibrium modeling is a hybrid household-village equilibrium model, which differs in fundamental ways from existing general equilibrium and village models.

The first difference with existing general equilibrium and village models is the attention for nonseparability of household production and consumption decisions when constructing the SAM and developing the applied model. This nonseparability is reflected in modeling production at household level, allowing us to capture opposing household production responses, linked to whether or not households have access to outside province migration. This shows that not only do village interactions matter when assessing the impact of rural-urban migration, but also that a household-level perspective to village modeling is needed. The differences in household production response are missed by existing village models with sector-level production. Also note that we found significant changes in production response of all household groups, even though the model only includes a limited number of village markets, and can be expected to underestimate the indirect impact of the simulated increase in migration by disregarding interactions in village land and credit markets.

The second difference with existing village-level studies of migration is the inclusion of the impact of migration on household consumption. Existing village models used to analyze migration only account for the impact of migration on the size of the labor force and available cash. Apart from the impact on labor availability and cash we also account for reduced household consumption by introducing a Stone-Geary utility function, resulting in a significantly larger increase in welfare due to an increase in available income per adult equivalent. By introducing a Stone-Geary utility function we can also account for shifts in consumption when income increases, which results in a stronger aggregate supply response than found with Cobb-Douglas utility functions due to the nonseparability of household decisions. The village model in this thus study provides an assessment of all three pathways through which migration affects household decisions, resulting in a more complete view on the impact of migration on household response and welfare.

The third difference with existing general equilibrium and village models is the calibration of the structure of agricultural production activities on household survey data, without imposing *a priori* assumptions on separability of inputs. After testing we reject the commonly assumed separability of factors and intermediate inputs, and we proceed with calibrating nested CES production functions in which substitution possibilities differ across pairs of factors and intermediate inputs. These nested CES functions capture both technical differences across activities and differences in access to inputs across households. Replacing Cobb-Douglas production functions with nested CES functions reduces the diffusion of benefits from an increase in migration though the village economy, due to more moderate household production response. In terms of income and welfare, the migration households retain most of the benefits from an increase in migration. In terms of aggregate village supply response, an increase in migration leads to a more moderate response with nested CES functions, although a shift to less intensive rice production and an increase in livestock production is consistently found in all simulations.

Applying a household-level perspective to general equilibrium modeling thus results in significant changes to all aspects of developing an applied model. It changes the structure of the SAM by making prices and activities household-specific, changes which carry through to the village model. Apart from adapting the structure of the model we also calibrated all elasticities on the available household survey data, thus addressing one of the most common points of criticism on applied general equilibrium models. By placing household models in a general equilibrium framework, theoretical consistency of the modeling work was imposed which is easily lost in an applied model.

The findings of this study suggest that farm household models can benefit from applying general equilibrium consistency checks, which proved invaluable in developing the applied village model. Making the general equilibrium nature of applied farm household models explicit is expected to improve the quality of these models, for example by revealing weak parts of the data on which the models are build. The rejection of the separability of factors and intermediate inputs suggests that macro-level general equilibrium models may need to check the assumptions made when applying the standard specifications of production. Especially in models with a detailed specification of agriculture, the standard separability assumptions may not be valid.

Applying a general equilibrium model with a household perspective provided a fruitful way of analyzing changes in a rural village. Analyzing an increase in outside-province migration with different versions of the applied village model, findings in qualitatively terms consistently pointed towards a decrease in the village supply of rice and an increase in the supply of livestock. In quantitative terms the aggregated supply response varied across different model versions, showing a stronger response when introducing Stone-Geary utility function and a more moderate response when introducing nested CES production functions. The aggregate supply response thus depends on the functional form of both utility and production functions. When assessing the welfare impacts of an increase in migration we also account for the reduced consumption needs to the households, implying an increase in the available income for remaining household members. Accounting for this aspect of migration that is absent in existing studies, we found a stronger supply response as well as a larger increase in welfare.

In terms of policy implications, the opposing supply response of different household groups points to the need to account for the impact of imperfect markets on household decisions. This opposing production response is also important in terms of assessing different income earning opportunities of households. The increase in off-farm employment opportunities for the migration households increases the agricultural income-earning opportunities for the two household groups lacking access to migration by reducing production costs. Interactions in village factor markets thus redistribute some of benefits of asymmetric access to off-farm employment opportunities. Existing village models assuming a uniform production response across households cannot account for this diffusion of benefits. Accounting for the impact of migration on consumption increases both the aggregate supply response as well as the increase in household welfare.

Summarizing, the village model developed in this study modifies existing model approaches to capture the three different ways through which migration affects household decisions as well as heterogeneous household response. Accounting for heterogeneous household response changes the impact of an increase in migration opportunities in terms of aggregate supply response and in the diffusion of benefits to household lacking access to migration.

8.3 directions for future research

Finding existing village models unsatisfactory, this study focused on developing an applied village model that captures heterogeneity across households. Having firmly established the foundations of a village equilibrium model that accounts for heterogeneity in household production and consumption decisions, several promising directions of future research can be identified.

8.3.1 non-market institutions

Two obvious directions for future research are related to non-market institutions and dynamics which are missing in the current model. A non-market institution which immediately comes to mind is the allocation of land. The collectively owned land is allocated to households, based on demographic characteristics. Despite 30-year user contracts, reallocations still occur to accommodate changes in household size. The administrative allocation of land and the unclear land tenure situation affect the land rental market, in some cases households renting in land even receive a payment to keep the land cultivated. Providing a subsistence income to all rural households is the main reason for maintaining the administrative allocation of land. Capturing the administrative allocation of land and its relation with the village land market could provide a useful tool for analyzing which set of rules would achieve an efficient allocation of land, while assuring a subsistence income to rural households.

The framework of Adelman and Head (1986) for analyzing institutions in terms of their objectives, as summarized in Chapter 2, offers a potential avenue for finding an institutional structure that maximizes rural households' welfare. Administrative and market allocations of land serve household objectives, like maximizing agricultural income and security. It may be possible to model this as a demand for characteristics of land allocation by households, with different institutional structures offering different characteristics. This approach is used in economic models to deal with new goods, and could be used to determine the mixture of institutional characteristics that maximizes households' utility. Since institutions are the result of interactions among households, a village equilibrium model seems a natural setting for such an approach to comparing institutional arrangements.

A second non-market institution that could be analyzed along similar lines as sketched for land allocation, is the use of exchange labor in agricultural production. With the continuing transformation to an industrialized society, the migration to the coastal cities can be expected to continue. When labor is becoming more scare, one can expect the use of exchange labor to change as well, affecting production decisions and household welfare.

8.3.2 dynamics

The discussion of land allocation and exchange labor already hinted at changes over time, leading to a second direction for future research, dynamics. Institutional changes, do not occur overnight and necessitate the use of a dynamic model to analyze them. The main reason for developing a static model in this study is the availability of data for a single year only. For a well-founded dynamic analysis, being it forward looking or recursive, observations for different periods are needed.

In a dynamic general equilibrium model, periods are linked through investments. Being static in nature the current model lacks saving and investment decisions[2]. The fact that the household most involved in outside-province migration provides a net transfer of cash to the other three household groups, suggests that to fully capture the impact of migration, saving and investment decisions need to be included in the model. Investments in human capital, for example, may allow more households to benefit from the expansion of the Chinese economy.

Technological changes are another area warranting a longer time-perspective than used so far. Technological developments have been the engine of the agricultural growth after the impact of the household responsibility system had worn out (Huang and Rozelle, 1996). Ongoing transformations of the Chinese economy will result in changing relative prices, most likely inducing technological change. A first step in such an analysis would be to introduce alternative technologies in the current model. So far each household group is assumed to employ a single technology for each activity calibrated on the SAM. It would be interesting to introduce alternative technologies, like for example genetically modified crops, and study their attractiveness for different household types, as well as the implications for household and village welfare.

When analyzing adoption of new technologies in a dynamic model, sustainability of natural resource use can also be addressed. The intensification of Chinese agriculture during the past decades has raised questions regarding the depletion of soil quality and overuse of external inputs. Following the definition of sustainability in Chapter 2, this would imply a search for development paths that utilize natural resources while accounting for the presence of thresholds beyond which damage becomes irreversible. Introducing different technologies in the model, one can analyze which technologies are compatible with a sustainable development path, as well as with the individual rationality of utility maximizing households. A possible disparity of sustainable and utility maximizing development paths could result in the identification of complementary policies required for adoption of sustainable technologies.

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[2] Although one may impose a fixed propensity to save in a static model, for example by following the extended linear expenditure system of Howe (1975), including savings in a single-period model remains uncomfortable since households lack a future period to enjoy the fruits of their savings. Lacking household survey data on savings and investment we therefore omitted savings from the village model.

The applied village model developed in this study provides a firm foundation for the future research directions sketched above. By questioning standard assumptions and making full use of the available household survey data, the model captures specifics of the studied village that affect household response. The steps taken in developing the applied model can be applied to other villages in China as well as in other countries, yielding case-specific village models that can be used to gain (policy) insights that cannot be obtained from other types of models. Following the approach developed in this study results in an applied village model firmly anchored in farm household theory, thus bridging the currently existing gap between household- and village-level models.

APPENDICES

APPENDIX A

model variables, parameters and sets

This appendix describes all variables, parameters and sets used in this study. The number in parentheses indicates in which chapter each element of the model is defined for the first time.

A.1 Variables

Prices:

p_{hj}^{*}	Effective household (shadow) price	(5)
p_{hj}^{ht}	Price of household tradables (perceived as exogenous by households)	(3)
$\overline{p}_{j}^{m}$	Exogenous price of imports of price-band commodity	(3)
$\overline{p}_{j}^{mt}$	Exogenous price of imports of village tradable	(3)
$\overline{p}_{j}^{e}$	Exogenous price of exports of price-band commodity	(3)
p_{hj}^{p}	Price of purchased commodity (perceived as exogenous by households)	(3)
p_{hj}^{s}	Price of sold commodity (perceived as exogenous by households)	(3)
PA_{ha}	Cobb-Douglas activity price	(5)
PI_{hak}	Price Composite input in Cobb-Douglas activity	(5)

Quantities:

q_{j}^{e}	Export of price-band commodities from village	(3)
q_{j}^{m}	Import of price-band commodities to village	(3)
q_{hj}^{c}	Quantity consumed	(3)
q_{hj}^{ht}	Net marketed surplus of household tradables	(3)

q^{i}_{haj}	Inputs by activity	(3)
q^{o}_{hj}	Output	(3)
q^{o}_{haj}	Output by activity	(5)
q^{s}_{hj}	Quantity sold of price-band commodities	(3)
q^{p}_{hj}	Quantity purchased of price-band commodities	(3)
q^{vt}_{hj}	Net marketed surplus of village tradables	(3)
$\bar{q}^{\omega}_{hj}$	Endowments	(3)
q^{ae}_{hj}	Household consumption per migration corrected adult consumer equivalent	(6)

Other variables

u_h	Utility	(3)
π_{ha}	Profits by activity	(5)
w_h	Household full income	(5)
$\bar{y}^{l}_{h}$	Exogenous income or payments	(3)
w^{ae}_{h}	Full income per migration corrected adult consumer equivalent	(6)

Composite quantities:

QA_{ha}	Composite activity output	(5)
QI_{hak}	Composite activity input	(5)
QL_{hak}	Aggregate Leontief input	(7)
QAD_{ha}	Aggregate Cobb-Douglas activity output	(7)
QD_{hak}	Aggregate Cobb-Douglas input	(7)
QAC_{ha}	Aggregate CES activity output	(7)
QC_{hak}	Aggregate CES input	(7)

Composite prices:

PA_{ha}	Composite activity price	(5)
PI_{hak}	Composite activity price	(5)
PQL_{hak}	Aggregate Leontief input price	(7)
$PQAD_{ha}$	Aggregate Cobb-Douglas activity output price	(7)
PQD_{hak}	Aggregate Cobb-Douglas input price	(7)
$PQAC_{ha}$	Aggregate CES activity output price	(7)
PQC_{hak}	Aggregate CES input price	(7)

A.2 Parameters

Leontief production functions:

β_{haj}	Input coefficient of Leontief activities	(5)
γ_{haj}	Output coefficient of Leontief activities	(5)
ε_{haj}	Level of outside village employment	(5)

Cobb-Douglas production functions:

δ_{ha}	Shift parameter	(5)
α_{hak}	Cost shares Cobb-Douglas production function	(5)
ι_{hakj}	Leontief input coefficients composite input of Cobb-Douglas production function	(5)
θ_{haj}	Leontief output coefficients of Cobb-Douglas activities	(5)

CES production functions:

δ_{ha}	Shift parameter	(7)
ψ_{hak}	Distribution parameter	(7)
ρ_{a}	Substitution parameter	(7)

Market shares:

ξ_{haj}	Household share of village demand for agricultural labor	(5)
κ_{haj}	Household market share of village produced goods	(5)
τ_{hj}	Household market share of village traded tractor services	(5)

Cobb-Douglas utility function:

μ_{hc}	Household budget shares of consumed goods	(5)

Stone-Geary utility function:

σ_{hj}^{ae}	Subsistence or committed quantities of consumed goods per adult equivalent	(6)
ν_{hj}^{ae}	Marginal budget shares of consumed goods per adult equivalent	(6)
ϖ_{h}	Household size measured in adult consumer equivalents	(6)
ϕ_{ha}	Consumer equivalents of outside employment activities involving migration	(6)
c_{h}	Household size measured in migration corrected adult consumer equivalents	(6)

A.3 Sets

A	Activities	(3)
AL	Hiring of labor (agricultural labor is only element)	(5)
C	Consumed commodities	(3)
CA	Cobb-Douglas activities	(5)
CI	Composite inputs of Cobb-Douglas activities	(5)
E	Commodities exported from the village	(3)
FI	Fixed inputs	(5)
FO	Fixed outputs	(5)
H	Households	(3)
HD	Households owning draught power	(5)
HT	Household tradables without price band	(3)
I	Inputs	(3)
J	Commodities	(3)
K	Composite inputs	(5)
L	Location from which exogenous income is received	(3)
LA	Leontief activities	(5)
LL	Hired labor (agricultural labor is only element)	(5)
M	Commodities imported in the village	(3)
MA	Markup activities (cattle is the only element)	(5)
O	Outputs	(3)
OUT	Outside village employment activities	(5)
P	Purchased price band commodities	(3)
S	Sold price band commodities	(3)
VA	Village production activities	(5)
VNT	Village nontradables	(5)
VT	Village tradables	(3)

APPENDIX B

steps from a theoretical to an applied model

This appendix describes the steps one needs to take to move from a general theoretical model as defined in Chapter 3 to an applied model as in Chapter 5. The aim of this appendix is to provide a concise overview of issues one needs to deal with when developing an applied general equilibrium model, and to indicate alternative for the choices made in developing the applied Chinese village equilibrium model. As with the key issues in Chapter 1 the discussion is largely non-technical and specifically aims at readers interested in developing their own applied village model.

The first section discusses the construction of a village SAM. Section 2 discusses and compares primal and dual specifications of a general equilibrium model. This section also discusses the issue of closure, which is an important driver of general equilibrium models in dual form. Section 3 discusses choice of functional forms for the behavioral equations and parameterization. Section 4 concludes by discussing the analysis of model results.

B.1 taking a snapshot of the economy: the village SAM

At this stage we have defined a general theoretical model of a village economy. In order to arrive at an applied model a large number of choices need to be made. These choices can be broken down in three parts: defining the building blocks of the economy (specifying agents, commodities and so on), selecting a primal or a dual formulation for the model, and defining behavior (defining and parameterize functional forms). This section focuses on defining the building blocks of the model. Discussion primal and dual formulations if postponed to Section 3, while Section 4 treats the specification of behavior.

In terms of the key issues of Chapter 2, the current section mainly deals with aggregation and interaction issues. The key point of developing an applied model is to translate the detailed and complex reality of a village into a limited number of actors (*e.g.* households, government) and commodities (inputs, outputs, consumption goods). This implies an aggregation of heterogeneous individual units into representative aggregate units. Furthermore, in order to define the behavioral relations we need to understand the interactions within the village economy (which commodities are traded in the village economy, which with the outside world and which are household nontradables).

The tool of choice for this exercise is a social accounting matrix. It provides a snapshot of the economy, defining aggregate units as well as interactions among them. This section first discusses the structure of a village SAM matching the village equilibrium model. The remainder of the section discusses implications of aggregating households and commodities, and how tradability affects the way in which the SAM is constructed.

B.1.1 general structure of a village SAM

Village equilibrium models require detailed data at household and village level. They are more akin to household than to macro general equilibrium models. Macro models tend to use aggregate data from secondary sources (like national accounts). Village equilibrium models generally use primary data, often collected specifically to address the policy questions for which the model is build. This has the advantage that collected data can be adjusted to research issues of interest. Compared to surveys used for household models, village equilibrium models require additional data on interactions between households and with the outside world, as well as data on non-household institutions, like local shops.

Table B.1: General structure of a village social accounting matrix

	Expenditures			
Receipts	*Activities*	*Pool accounts*	*Commodities*	*Factors*
Activities by household - agricultural activities - non-agricultural activities		Village sold commodities	Outside marketed output	
Pool accounts - village traded commodities - intra-village transfers	Village purchased commodities			
Commodities - agricultural output - nonagricultural output - purchased inputs - consumption goods	Intermediate inputs			
Factors - family labor - land - capital	Value added			
Households - household types		Intra-village transfers		Factor payments
Government	Activity taxes			Factor taxes
Capital				
Rest of world			Imports of commodities	Factor service imports
Total	*Total costs*		*Aggregate supply*	*Factor expenditures*

Table B.1: General structure of a village social accounting matrix (continued)

	Expenditures				
Receipts	*Households*	*Government*	*Capital*	*Rest of world*	*Total*
Activities by household - agricultural activities - non-agricultural activities	Home consumed output	Government purchased output			*Gross output*
Pool accounts - village traded commodities - intra-village transfers	Intra-village transfers				
Commodities - agricultural output - nonagricultural output - purchased inputs - consumption goods	Households consumption	Government consumption	Investment	Exports	*Aggregate demand*
Factors - family labor - land - capital	Consumption of factors			Factor income from rest of world	*Factor income*
Households - household types		Government-household transfers		Remittances	*Household income*
Government	Household taxes			Transfers from outside	*Government income*
Capital	Household savings	Government savings			*Total savings*
Rest of world	Transfers to outside	Transfers to outside			*Payments to outside*
Total	*Household expenditure*	*Government expenditure*	*Total investment*	*Receipts from outside*	

Source: adapted from Taylor and Adelman (1996), Reinert and Roland-Holst (1997) and Löfgren *et al.* (2002).

Construction of a social accounting matrix (SAM) is an important step in constructing an applied general equilibrium model. Constructing a SAM requires identification of all agents and commodities to be included in the model. These determine the contents of the SAM: for all agents and commodities all transactions should be recorded. The accounting system of the SAM requires row and column totals to match, providing a check that all (major) flows of the economy are covered by the model. This check assures that the applied model covers all (major) flows of the economy and is thus indeed a general equilibrium, as opposed to a partial equilibrium model. Apart from assuring that all flows in the economy are covered by the model, the SAM assures that the data are consistent with each other, and thus that the accounting relationships of the general equilibrium model are satisfied by the data. A final role of the SAM in developing an applied general equilibrium model is to detect programming errors. The first check when developing a model is whether or not it reproduces the SAM. Accounting identities not mimicking the SAM provide pointers to programming errors.

It should be noted that basing a general equilibrium model on a SAM is the ideal approach, however, it is not necessary for developing an applied model. General equilibrium models can also be constructed without reference to a SAM (just as most household optimization models are developed without checking consistency of the data). However, this makes it difficult to verify that the model is a general equilibrium model, in the sense that all transactions in the economy are covered, and to verify that there are no programming errors in the applied model.

SAMs combine stringent accounting rules with a large flexibility in structure. The same framework can thus be used for a wide variety of applications. Taylor and Adelman (1996) describe a general framework for constructing village SAMs (Chapter 2) and present a number of examples of village SAMs (Chapter 3 through 7) that illustrate the flexibility with village SAMs can reflect different economic structures.. More specific guidelines on sample selection, data collection and SAM construction can be found in Yúnez-Naude and Taylor (1999).

Table B.1 presents a village SAM that corresponds with the requirements of the village equilibrium model defined in Section 1. The columns register expenditures, while the rows register receipts. The column households, for example, registers on which items a household spends its income. The row households registers from which sources the household obtains its income. Total expenditures (column total) needs to match total income (row total), due to the double entry system of the SAM.

The majority of the entries in the SAM are similar to the entries used in other village SAMs, and to the ones used in macro level SAMs. Different from the SAMs in Taylor and Adelman (1996) it includes household-specific activities to allow for nonseparable household decisions. The structure of the SAM also shows that it is sufficient to make household activities household-specific. Commodities and factors do not require a household index, since household specific flows can be traced through the activities.

Apart from defining household-specific activities, the SAM in Table B.1 has a number of specific features designed to provide the necessary information for the village equilibrium model: pooling accounts, separation of destinations of output, and consumption of factors. The pool accounts deal with intra-village trade in commodities and intra-village transfers. Tracing bilateral trade flows, *i.e.* which household trades with which household, is cumbersome when collecting the data and greatly complicates the model structure. A trade pool approach is therefore taken, which only registers the amounts purchased and sold inside the village. The pool accounts collect these sales and distributes the purchases, assuring that the village trade balances are satisfied. Transfers of money among households within the village are dealt with in the same way.

Different destinations of produced output are traced in the SAM. The activity row distributes output to sales inside the village, sales outside the village, home consumption and government purchases. This separation of output by destination provides an indication of the tradability of output, since household nontradables will all be home consumed, village nontradables will be home consumed or sold inside the village. Another advantage of separating different destinations is that price differences between various destinations can be accounted for. In the case of China, for example, rice can be sold at the market or to the government, and prices between these two outlets may differ.

Consumption of factors is registered at the intersection of the factor row and household column. This entry is used to register use of family time as leisure, a prominent feature of the household model. If no unemployment is assumed the total family time endowment is thus registered in the SAM, which is allocated to production activities (that may include off-farm employment) and leisure. The SAM structure presented in Table B.1 is used to develop a SAM of Chinese village in Chapter 5. The discussion of this Chinese village SAM will illustrate the other (standard) features of the SAM, as well as illustrating how the SAM may be adjusted to capture the features of a specific economy.

B.1.2 representative households

To arrive at a limited number of households in the SAM, households from which data have been are collected need to be aggregated to a few representative households. Modeling each individual household is possible in theory. Besides practical implications of data requirements and solvability of the model, such an exercise is not required to meet the objectives of an applied village model. Policy analyses are the main reason for building applied models. Generally the interest in policy analysis is not on the impact on each individual household, easily resulting in an information overload, but on the impact of policy changes on relevant (vulnerable) groups in society. Therefore household are grouped in a limited number of classes and their behavior is modeled through a representative household for each group.

There are two major considerations for grouping agents: policy-susceptibility and homogeneity. Given the objective of policy analysis, expected differential policy responses is a first criterion for classifying households. Differential access to resources can be expected to play a major role in household response. For example, distinguishing landless laborers, small and large farm households may be relevant for many agricultural policies. The type of policy analysis for which the model is build may also be used to guide classification. For example, distinguishing households on the basis of engagement in off-farm employment when focusing on effects of off-farm employment on agricultural production.

The second criterion for grouping households is homogeneity. Since households within a group are represented by a single representative household, they should be as homogenous as possible. The requirement of homogeneity applies to all aspects of their decision-making, *i.e.* requiring similar and utility functions (or expenditure patterns), endowments and production technologies.

All general equilibrium models are affected by problems of using representative agents. As a result of income effects (expenditure patterns change as income changes), aggregation over consumers (with varying income levels) does not preserve the microeconomic characteristics of individual behavior; only continuity, homogeneity and adding up are maintained (Ginsburgh and Keyzer, 1997:117). This means that, when aggregating over utility maximizing consumers, aggregate behavior generally cannot be represented as utility maximization of total utility of the group, subject to a group budget constraint, *i.e.* no representative consumer can be constructed. Essential conditions for using such a representative consumer is that marginal budget shares of commodities do not vary between consumers (*i.e.* all consumers have a common expenditure function) and that the marginal budget shares do not depend on total income. CES and Cobb-Douglas functions satisfy these aggregation conditions. For a more extensive and formal treatment of these points see Ginsburgh and Keyzer (1997:79) and Mas-Colell *et al.* (1995: Chapter 4).

The key point is that an applied model can never satisfy all requirements of microeconomics. Compromises are needed to arrive at a feasible model (Fischer *et al.*, 1988:11). At the same time it is important to realize the limitations and consequences of using a representative household concept. For example, when assessing the impact of policy measures on vulnerable groups it can be worthwhile to explore in more detail the impact on the households the representative household is representing. Even if a representative household is not made worse off in a certain simulation, part of the households it is representing could still be worse off. If these households operate close to minimum subsistence levels even a slight worsening of their situation could have severe implications. One way to link the average outcome of the representative household to individual households is to correct for aggregation bias as discussed in the section on aggregation in Chapter 2.

A second point to note is that aggregation bias occurs because of the wealth effect at the consumer side of the model. The absence of wealth effects at the production side imply that decisions of profit maximizing producers can be aggregated without introducing a bias in the model: if firms take prices as given their aggregate supply is identical to the one obtained by joint profit maximization (Mas-Colell *et al.*, 1995:148). This feature allows models with separate consumers and firms to model the production at sector level, without having to identify the production of different firms (similar as in the SAMs in Taylor and Adelman (1996)).

The village equilibrium model defined in the first part of this chapter specifically allows for nonseparability of household decisions. As has been discussed in Chapter 3, in the case of nonseparability production decisions can still be modeled as profit maximization but with *endogenous* prices. Prices can thus differ across households and aggregate supply can no longer be represented by a single joint profit maximizing production decision. Production thus needs to be household-specific, which is dealt in the village equilibrium model and the SAM by introducing household-specific production activities.

B.1.3 classifying commodities and implications of household nontradability for SAM construction

Classification of commodities serves two goals: identifying all commodities and identifying their role in the economy. As with agents, classification of commodities should cover the entire economy. Distinguishing each individual commodity is possible in theory, but unworkable in practice. Commodities are thus grouped and each group is treated as a single commodity. This assumes that commodities within a group are perfect substitutes or perfect complements. If different levels of detail are required in different places of the model, different commodity classifications can be employed, connected through transformation matrices. An example of constructing such composite goods is the Armington approach frequently used in international trade models (Ginsburgh and Keyzer, 1997:116). In this case, a composite intermediate input is used in production, composed of a domestic produced input and an imported input. An Armington elasticity determines the ease of substitution between the imported and domestic produced good. A disadvantage of the Armington approach is that the composite good is an analytical construct for which no trade data area to validate the model findings.

After identifying all commodities, their role in the economy has to be established. In terms of the village equilibrium model, each commodity has to be assigned to specific sets. The SAM plays an important role in this set assignment. The SAM entries will indicate whether intermediate goods are used in production, which factors are employed, which commodities are consumed by which households, and which commodities are traded with the outside world.

Apart from determining what roles a commodity plays in production and/or consumption, the SAM provides important clues to the level of tradability of commodities. A household nontradable output will be consumed in full by the household. In terms of the SAM structure in Table B.1 such a commodity will only have an entry 'household consumed output'. A village nontradable, land for example, would have entries under the pool account (households renting land in and out), but there would be no factor income to land from the rest of the world. Although the SAM is designed to capture as much as possible the level of tradability of commodities, it only provides a snapshot of the economy. It might just so happen that in this snapshot demand and supply are such that trade of a commodity does not occur, while if circumstances change there would be trade within the village or with the outside world. The data in the SAM therefore need to be combined with knowledge of the case study area to properly classify commodities.

Presence of household nontradables creates a problem when constructing the SAM. The quantities of these commodities can be taken from the survey data, but the SAM is constructed in value, not in quantity terms. Household nontradables need to be valued against an unobservable household shadow price. In case of a produced commodity we could use the accounting properties of the SAM and value it against the total costs of the inputs (row and columns of this activity would then match). This approach, however, only works in case all inputs are household traded and thus have an observed price. Depending on the structure of the SAM it could be possible to deduce in a stepwise fashion, one by one the values of household nontradables. Apart from being dependent on the structure of the SAM, this approach also concentrates all inconsistencies between row and column accounts into a single cell of the SAM.

An alternative approach, employed in Chapter 5 for the Chinese SAM, is to directly estimate shadow prices for land, labor and intermediate inputs. This estimation is based on the standard result from economic theory that in equilibrium the price of inputs equals the value of their marginal product.

In Chapter 5 a SAM for a Chinese village is constructed. This SAM serves as the foundation for the applied models in the remainder of this study. It also serves to illustrate the different steps that need to be taken to develop an actual SAM, including formal testing nonseparability and estimating shadow prices, and the wealth of information contained in a village SAM.

B.2 primal versus dual formulations of a general equilibrium model

Having a balanced SAM with a limited number of representative households and all commodities classified in terms of their role in the village economy, we have in fact dealt with the accounting relations of the village equilibrium model. Before continuing with defining behavioral equations a choice has to be made between a primal or a dual formulation of the model.

The village equilibrium model as described in the first section of this chapter is a theoretical model of the a village economy. In order to develop this model into an applied model it has to be translated into a form that can be solved numerically. Like the household models in Chapter 2, there are two main ways of formulating an applied general equilibrium model: a primal formulation (maximizing an objective function subject to constraints), or a dual formulation (solving a system of nonlinear equations derived from the first order conditions of utility and profit maximization). The form chosen for the model affects the type of behavioral equations that needs to be specified for the applied model.

This section introduces three ways of formulating a general equilibrium model (hereafter referred to as formats): computable general equilibrium format, mixed complementarity problem format, and the Negishi format. The last part of this section compares the advantages and disadvantages of the different formats for developing an applied village equilibrium model, and motivates the choice for a dual format in this study.

B.2.1 the CGE format

The computable general equilibrium (CGE) format is the most common way of specifying a general equilibrium model. Applied general equilibrium models in this format are referred to as CGE models, or as AGE (Applied General Equilibrium) models in the literature. This study reserves AGE for applied general equilibrium models in general, while CGE is used for a specific format that does not allow inequality constraints, infinite numbers (of commodities, agents or periods), or increasing returns to scale (Ginsburgh and Keyzer, 1997:110).

Recall from Chapter 2 that a neo-classical Arrow-Debreu model of competitive equilibrium. can be described by three conditions: (1) producers maximize profits; (2) consumers maximize utility; (3) there is no excess demand in any market. To simplify the exposition we assume separability of household decisions. Producer and consumer behavior can then be separated, allowing use of the standard description of a general equilibrium model in the discussion of the formats. The way this translates to the village equilibrium model is discussed in detail in Chapter 6, when developing an applied village model. A different notation is used to stress the difference with the village equilibrium model.

The CGE format uses a dual specification, requiring restrictions on functional forms to be able to derive the first order conditions. A basic general equilibrium model in CGE format can be build on the following assumptions (Ginsburgh and Keyzer, 1997:108):

1. **Commodities**
   The set of commodities is split into a set of goods and a set of factors. Consumers have endowments of factors, but not of goods; one consumer has positive endowments of all factors.
2. **Producers**
   Each producers produces a single good with a constant returns to scale, continuous, production function. Factors are not produced.
3. **Consumers**
   Utility functions are continuous, strictly quasi-concave, and nonsatiated. One consumer's utility is increasing in all factors, or in goods that together use all factors.

Based on these assumptions, a basic general equilibrium model in CGE format can be defined as (Gunning and Keyzer, 1995:2030-2031):

$$\sum_h \mathbf{c}_{hg}(\mathbf{p}_g, \mathbf{p}_f, y_h) + A_g(\mathbf{p}_g, \mathbf{p}_f)\mathbf{q}_g = \mathbf{q}_g \qquad \text{(b.1)}$$

$$\sum_h \mathbf{c}_{hf}(\mathbf{p}_g,\mathbf{p}_f,y_h) + A_f(\mathbf{p}_f,\mathbf{p}_g)\mathbf{q}_g = \sum_h \boldsymbol{\omega}_{hf} \tag{b.2}$$

$$\mathbf{p}_g A_g(\mathbf{p}_g,\mathbf{p}_f) + \mathbf{p}_f A_f(\mathbf{p}_g,\mathbf{p}_f) = \mathbf{p}_g \tag{b.3}$$

$$y_h = \mathbf{p}_f \boldsymbol{\omega}_{hf}\ , \tag{b.4}$$

where subscripts g and f refer to goods and factors; $\mathbf{c}_h(\cdot)$ is the (Marshallian) demand function of household *h*; $\mathbf{p}$ are prices, y_h household income, ω_{hf} household factor endowments and $\mathbf{q}_g$ is gross output. Input demand is modeled through matrices of input coefficients for intermediate inputs $A_g(\cdot)$ and factors $A_f(\cdot)$.

Production of a single good by each producer implies that production decisions can be described as a cost minimization problem. Constant returns to scale leave producers indifferent with respect to the level of production, costs can thus be expressed in terms of producing a single unit. Input demand for a good or factor can then be described as a price dependent input coefficient a (derivative of the cost function with respect to each good's or factor's price), times the level of output. The CGE model as defined above thus includes the technology constraint through price-dependent matrices of input coefficients for intermediate inputs $A^g(\cdot)$ and factors $A^f(\cdot)$.

The model in CGE format then consist of four equations. Equation (b.1) and (b.2) specify good and factor balances. These allow for the use of intermediate goods as inputs and the consumption of factors. Characteristic for a model in CGE format are equality constraints on these balances; indeterminacy at the production side, resulting from a constant returns to scale technology, is solved by equating supply to demand. Equation (b.3) specifies a zero profit condition resulting from the constant returns to scale technology: prices of goods are set equal to cost of inputs (both intermediate goods and factors) used in their production. With the household budget equation (b.4) these equations constitute the core of a model in CGE format. For an applied models additional closure equations, and a price normalization may be added.

Comparison with the standard Arrow-Debreu formulation shows that the market clearance condition is detailed into good and factor balances, both holding as equalities. Utility and profit maximization are included through their first-order conditions (demand function and input-output coefficients). The zero profit condition of a constant returns to scale technology completes the set of equations, while simplifying the income constraint of households to factor incomes only.

B.2.2 the MCP format

The strict equalities of the CGE format may be overly restrictive and introduction of inequality constraints may be needed for a more realistic modeling of the economy, for example to include price bands or shifts in technology (Gunning and Keyzer, 1995:2031). Introducing inequality constraints implies a shift from a CGE to a mixed complementarity problem (MCP) format. The MCP format consists of a mixture of equalities and inequalities. The term complementarity refers to the complementary slackness conditions associated with inequality constraints. Mathiesen (1985a) initiated the use of a MCP structure for solving general equilibrium models. Since then the MCP format has become a common way to solve AGE models. For example, the MPSGE interface used for writing applied general equilibrium models in GAMS uses a MCP formulation (Rutherford, 1995).

The basic CGE model presented above can be transformed in MCP format as[1]:

$$\sum_h \mathbf{c}_{hg}(\mathbf{p}_g,\mathbf{p}_f,y_h) + A_g(\mathbf{p}_g,\mathbf{p}_f)\mathbf{q}_g \le \mathbf{q}_g \qquad \perp\ \mathbf{p}_g \ge 0 \tag{b.1'}$$

$$\sum_h \mathbf{c}_{hf}(\mathbf{p}_g,\mathbf{p}_f,y_h) + A_f(\mathbf{p}_f,\mathbf{p}_g)\mathbf{q}_g \le \sum_h \boldsymbol{\omega}_{hf} \qquad \perp\ \mathbf{p}_f \ge 0 \tag{b.2'}$$

$$\mathbf{p}_g A_g(\mathbf{p}_g,\mathbf{p}_f) + \mathbf{p}_f A_f(\mathbf{p}_g,\mathbf{p}_f) \ge \mathbf{p}_g \qquad \perp\ \mathbf{q}_g \ge 0 \tag{b.3'}$$

$$y_h = \mathbf{p}_f \boldsymbol{\omega}_{hf}\ , \tag{b.4'}$$

Maintaining the assumption of nonsatiated utility functions, budget constraints (b.4') will hold as equalities. Complementary slackness conditions on good (b.1') and factor balances (b.2') imply that commodities in excess supply will have a zero price. Equation (b.3') specifies cost pricing of produced goods, while also allowing goods not to be produced in equilibrium.

This basic model illustrates key features of a model in MCP format: inequality constraints have a non-negativity constraint on their corresponding variable, while variables associated with equality constraints are not subjected to such a nonnegativity constraint (Harker and Pang, 1990:167). Note that, as in the CGE format, assumptions on utility and production functions may still be used to assure that unrestricted variables will have a nonnegative value in equilibrium. For example, assuming positive endowments and an increasing utility in all factors for one consumer assure that all prices will be positive in equilibrium.

The MCP format is especially suited for modeling equations of which it cannot be determined beforehand whether they will hold as equalities in equilibrium. Two such cases are relevant in a village context: price bands and alternative technologies. As discussed in Chapter 2 households facing price bands can be can be sellers at the lower bound price, buyers at the upper bound price, or self-sufficient at an internal, household specific, price. Given endogeneity of prices in a general equilibrium model, it will not be clear from the onset which trade regime will be relevant for household decisions. Inequality constraints may then be used to endogenously determine the trade regime for each household type, while also allowing regime shifts in counterfactual analyses (for an example of introducing price bands see Löfgren and Robinson, 1999).

Adoption of new agricultural technologies plays a central role in discussions on policies to promote development. Using a MCP format allows incorporation of alternative technologies, without pre-imposing their use. This may be modeled with alternative technologies for producing a specific goods, with choice for a technology made endogenous (Mathiesen, 1985b:1226).

B.2.3 the negishi format

The presence of household nontradables with unobservable prices makes it worthwhile to consider a less frequently used formulation, the Negishi format. As with the different ways of formulating a household model, the underlying theoretical model is identical as with a dual format. But instead of deriving first order conditions, the model is written as a maximization problem. The main attraction

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[1] The symbol '⊥' indicates a complementary slackness condition: $a \le 0 \perp b \ge 0$ represents $a \le 0$, $b \ge 0$ and $ab=0$ (Gunning and Keyzer, 1995:2029).

in the present context is that one does not need to specify prices since these follow from the maximization problem.

The central planner approach discussed in Chapter 2 is the only approach to village equilibrium modeling involving an explicit maximization discussed that has been discussed until now. The Negishi format also employs a central planner approach, suggesting similar problems of individual versus collective optimization discussed in Chapter 2. However, as opposed to the single optimization procedure of the centrally planned village models, the Negishi format follows an iterative procedure that searches for an centrally planned optimum coinciding with individually rational choices (examples of applications can be found in Rutherford, 1999).

The Negishi format is based on the Negishi theorem, stating that "a competitive equilibrium can be represented through a welfare optimum (a central plan that allocates goods over agents) with nonzero welfare weights α_h, which are such that all consumers satisfy their budget constraints" (Ginsburgh and Keyzer, 1997:93, definition welfare optimum added between brackets). Key to the Negishi format is finding a centralized solution that can be decentralized using only prices as a signal. This solution mimics the allocation achieved by a decentralized solution in which households interact through markets.

The Negishi formulation of a competitive equilibrium can be formulated as the following welfare program (Ginsburgh and Keyzer, 1997:21):

$$\max \sum_h \alpha_h u_h(c_{hg}) \qquad \text{with } \sum_h \alpha_h = 1 \qquad \text{(b.5)}$$

subject to

$$\sum_h \mathbf{c}_{hg} + A_g(\hat{\mathbf{p}}_g, \hat{\mathbf{p}}_f)\mathbf{q}_g \le \mathbf{q}_g \qquad (\mathbf{p}_g) \qquad \text{(b.6)}$$

$$\sum_h \mathbf{c}_{hf} + A_f(\hat{\mathbf{p}}_f, \hat{\mathbf{p}}_g)\mathbf{q}_g \le \sum_h \boldsymbol{\omega}_{hf} \qquad (\mathbf{p}_f) \qquad \text{(b.7)}$$

with welfare weights α_h set in a feedback loop such that the budget constraint holds for every household h:

$$\mathbf{pc}_{hg} + \mathbf{pc}_{hf} = \mathbf{p}_f \boldsymbol{\omega}_{hf} \,,. \qquad \text{(b.8)}$$

The objective function of the maximization problem is defined in (b.1): the weighed sum of utility of individual households derive from consuming goods $u_h(c_{hg})$. This maximization is constrained by commodity balances for goods and factors. Although at first sight appearing similar to the other two formats, there are two major differences. First, household consumption is not longer a price dependent demand function but a variable directly chosen such as to maximize utility. Second, the prices appearing in the input-output matrices are fixed, thus effectively fixing the input-output coefficients during maximization (indicated by the ^).

The key to the Negishi format, setting it apart from the centrally planned village models, is the use of feedback loops to determine the welfare weights. The first step in applying a Negishi format is to solve the maximization problem defined by Equation B.5-B.7 for given welfare weights. This yields consumption expenditures for each household, while the Lagrange multipliers of the commodity balances give the (shadow) prices of the commodities. Consumption, price and endowments are then used in the second step to calculate the budget constraint (b.3). The prices are also used to adjust the input-output matrices to reflect cost minimization at the new prices. If all households satisfy their budget constraint, and the input-output matrices satisfy cost minimization at the current prices, the program finishes. If not all households are on their budget constraint the welfare weights are adjusted. If cost minimization is not satisfied the input-output matrices are adjusted. After these adjustments the program returns to the first step.

Formal proof of the Negishi theorem can be found in Ginsburgh and Keyzer[2] (1997:93-96). Intuitively, the argument goes as follows. Profit maximization is implicit in the setting of the input-output coefficients, as in the other two formats. Utility maximization is explicit in maximizing an aggregate welfare function; the resulting allocation must be Pareto-efficient to be a maximum of the welfare program. This allocation is then a competitive equilibrium (with zero transfers) given the second welfare theorem: "any Pareto-efficient allocation with positive utilities … is a competitive equilibrium with transfers" (Ginsburgh and Keyzer, 1997:25).

B.2.4 comparing formats for use in village modeling

The choice of format of an applied model depends on the specific features of the model. For village equilibrium models there are a number of important issues relating to shadow prices, utility functions, price-bands and solvability of the model. Table B.2 gives a qualitative assessment of the ease with which these can be dealt with by the three formats.

Table B.2: Qualitative assessment of formats for village equilibrium modeling

		CGE	*MCP*	*Negishi*
Shadow prices	- household nontradables	-	-	+
	- SAM description of economy	+	+	-
Utility functions	- utility function estimation	+	+	-
	- welfare analysis	-	-	+
Price-bands	- endogenous trade-regime shifts	-	+	+
Solvability	- household production activities	-	-	+
	- availability of standard solvers	+	+	-

The presence of household nontradables with unobservable prices is the main motivation for applying a Negishi format. Formulated in physical terms a model in Negishi format does not require estimation of household shadow prices. The two dual formats, CGE and MCP, use demand functions with prices as arguments. These thus require estimation of shadow prices in order to include household nontradables in household demand functions.

Household nontradables with unobservable shadow prices create a problem for constructing a village SAM. By avoiding estimation of shadow prices[3], the Negishi format also looses the use of a SAM to describe the economy. Consistency of the model will be assured as long one verifies that the data satisfy the commodity balances used in the model. Not constructing a SAM implies that

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[2] The website of the book by Ginsburgh and Keyzer (1997) also contains an example of an applied general equilibrium model in Negishi format.

[3] In this study we refer to unobservable prices of nontraded household commodities as 'shadow prices'.

one does not get the overview of the economy provided by a SAM, which provides information for deciding on the structure of the general equilibrium model. Furthermore, the process of constructing the SAM provides valuable insights in the way the economy is structured, tradability of commodities and so on.

The advantage of the Negishi format in terms of shadow prices, comes at the cost of having to parameterize an utility function. The dual formats rely on demand functions which can be estimated from observed consumption pattern. Some functions, most notably those of the CES family, allow retrieval of the utility function from the demand function. More flexible forms that are often used in studies of demand, like the Almost Ideal Demand System (AIDS), do not have an analytical primal from and thus do not provide an utility function that can be used in a Negishi format.

Welfare analysis plays an important role when analyzing the results of general equilibrium models. In a Negishi format this is straightforward, since its objective function consists of aggregated welfare. For models in CGE of MCP format welfare calculations have to be made separately after solving the model. If flexible forms are used to model demand functions no analytical primal is available, prohibiting calculation of the welfare impacts.

The presence of price-bands has been put forward as a main reason for moving from a CGE to a MPC format. The Negishi format can also be modified to allow for price bands. This leaves two formats capable of dealing with endogenous shifts between trade regimes.

The need for household specific activities to accurately represent the consequences of household nonseparability is a recurring theme in this study. Introducing these features in the model creates interdependencies between production and consumption decisions, and increases the dimensions of the model. The CGE and MCP formats consist of systems of equations that are solved simultaneously. These formats thus have to deal with all complications resulting from nonseparability at the same time. A model in Negishi format structured as in (b.5-B.8) can deal with these issues on a household by household basis in the feedback loop.

The last entry in Table B.2 does not have to do with the way the model is structured, but the way it is solved. The CGE and MCP format are easiest to use in applied modeling since for both standard solvers are readily available. In the case of Negishi format model-specific algorithms have to be written. Although the Negishi format has been successfully applied to complex models, the algorithms are not directly available, nor well-documented.

The different themes in Table B.2 are of varying importance for choosing between formats. Estimation of a utility function becomes a major issue only when flexible functional forms are used to model demand. With very few exceptions (see for example Pogany, 1996), general equilibrium models use functions from the CES family to model demand that are self-dual. This implies that in case of a Negishi format the utility function can be retrieved from estimated demand functions, while in the CGE and MCP format the utility function associated with the demand functions can be used for welfare calculations. In practice the utility function issue thus provides no practical guidelines on choosing a specific format. Nor does the inclusion of price bands, since both in the primal as in the dual form (MCP) price bands can be incorporated.

A choice of format is therefore driving by issues related shadow prices and model solvability. Once shadow prices are estimated a village SAM can be constructed, providing all the advantages for model development discussed in Section B.2. Estimation of shadow prices also provides insight in the way which markets function (see the estimation of shadow prices in Chapter 5), which helps developing a model that reflects the structure of the village. These considerations favor the use of a dual format, CGE or MCP, depending on the need to model price bands and alternative technologies.

Another option would be to estimate shadow prices in order to benefit from the structured view on the data provided by a SAM, while still developing a model in Negishi format. In terms of model solvability this offers an advantage for dealing with household-specific production activities. This advantage is outweighed by the need for writing a model specific algorithm, where software packages are readily available for models in dual form. Given the complex multi-regional models that are solved in dual format, these software packages should be able to solve a village model with nonseparable households as well.

Given the advantages of the dual formulations in terms of the insights derived from a SAM and the ready availability of well documented software for solving these models, this study will use a dual formulation to construct an applied village equilibrium model. Each model in CGE format may be solved in a MCP format (with the reverse not being true). Using a nonlinear programming algorithm, however, will generally be more efficient for models with only equality constraints (Mathiesen, 1985b:1226). Models in this study will therefore be developed in CGE format, from which extensions including price bands are readily obtained by introducing inequality constraints and switching to a mixed-complementarity algorithm.

B.2.5 model closure

An important aspect of models in dual form is the model closure. Interpreted purely in mathematical terms it means assuring the system of equations can be solved. In other words, that the number of equations matches the number of variables in the model. Closure rules thus consist of determining which variables are exogenous, and which are endogenous.

Where from a mathematical point of view closure is a purely technical matter, since any variable could be made exogenous in order to obtain a solvable system of equations, from an economic point of view it requires a statement about the way in which the economy functions. A mathematically appropriate closure could make no sense in economic terms, resulting in inappropriate model results. For example, assuming a fixed capital stock can make perfect sense for a short term model, while not making sense in a long term model. The time-frame covered by model thus affect the choice of closure. By changing the closure of the model, a wide range of different models can be generated *without* changing the behavioral or accounting equations of the model. Closures reflect the time frame of the analysis and the structural features of the economy. They summarize in one or more equations the way in which the (village) economy operates.

In the context of the village model we will use closures rules to capture differences in the way in which village markets operate, modifying some parts of the general village model described above to capture the specifics of the case study village. In the village equilibrium model as defined above, it has been assumed that endowments are fixed (Equation 3.3), letting factor prices adjust to clear markets. This specification implicitly assumes full employment of all factors, an often made (neoclassical) assumption which may not be realistic. In the case study village, for example, we found tractors not to be fully utilized. This feature of the village economy can be captured by the an 'unemployment closure', making the endowments of tractors endogenous and fixing the price of tractor services. The total number of endogenous variables thus remains the same, however demand for tractor services can no expand while prices remain fixed capturing the feature of unutilized tractor capacity in the village.

The price numeraire is a specific type of closure. The model being linear homogeneous in prices it can only be solved in terms of relative prices, and thus one price needs to be fixed to determine a single solution (Pyatt,, 1988). In village equilibrium models generally most prices (for example of external inputs, externally sold output and purchased consumption goods) will be exogenous, providing the anchor for the endogenous prices in the village economy. Although a consumer price index could still be defined, for example to summarize the impact of shocks on the households, it should not fix any of the endogenous prices. This would imply a 'double normalization' and would introduce an unwarranted structural feature into the economy.

Apart from resulting in a model that can be mathematically solved and makes economic sense, changing the closure rules can also be used to change the general equilibrium model in a partial equilibrium model. By fixing variables that are endogenous in a general equilibrium context, a partial equilibrium model can be derived from the general equilibrium model in a straightforward way. We use such a closure change in Chapter 5 for eliminating interactions among households. Comparing the outcomes of the separate household models to results of the village model yields and insight in the impact of within-village interactions on household response.

B.3 behavioral equations and analyzing model outcomes

At this point we have discussed the construction of a SAM which yields the accounting equations of the model. We then motivated the choice for a dual format, which determines the way in which the behavioral equations are modeled. Selection of a format is a first step towards conceptualizing the behavioral relations in the model. To get a full description of the behavior of the households, and the way in which inputs and outputs interact in production, functional forms have to be chosen and parameters specified. Next to these two final steps towards an applied model, this section discusses some issues related to analyzing model outcomes.

B.3.1 selecting functional forms

The village equilibrium model in dual format requires specification of demand functions (for inputs in agricultural production and for consumed commodities) and of output supply functions for all activities. These functions are derived from the first order condition of utility maximization of each representative household. When introducing household nonseparability of household decisions in Chapter 2, it has already been stressed that the usual conditions of utility and profit maximization still hold in terms of endogenous household prices.

For the development of an applied village equilibrium model this implies that production and consumption can be treated separately from each other, with endogenous household prices providing the link between these two parts of the household models. In this sense the model will not look different form macro level models separating consumers and firms. This implies that the same functional forms can be used for modeling the two components of household behavior, as are used in macro level general equilibrium models.

Empirical studies of household demand and production decisions tend to use flexible functional forms, like Almost Ideal Demand Systems and translog production functions, to limit the number of assumptions that are imposed on the data. Although flexible functional forms are preferable from a theoretical point of view, applied general equilibrium models use functions from the CES family. The same flexibility that gives a better fit to empirical data creates problems when solving the model.

Perroni and Rutherford (1998) compare the properties of the translog, generalized Leontief and normalized quadratic production, and (nested) CES functions. Their conclusion is that although these flexible functions perform better in local approximations (like econometric estimates), their global properties do not satisfy the requirements of an applied general equilibrium model. When searching for an equilibrium, the solution algorithm may search the whole domain of the model, moving far from the initial point at which the function is originally specified. For a general equilibrium model it is therefore essential that the cost functions are well behaved (non-negative, monotonic and concave in prices) globally, *i.e.* over the full domain of the model. If cost functions are not well behaved the model may fail to solve.

The CES function derives its name from its constant elasticity of substitution property. To circumvent this restrictive property of a constant elasticity of substitution among all inputs, most general equilibrium models use nested CES functions. These contain several layers (consisting of CES, Cobb-Douglas or Leontief functions), to allow for differences in substitution elasticities among different types of inputs. By choosing different levels of nesting, functional forms, and substitution parameters, the eventual substitution elasticities between individual inputs can be far from the identical substitution elasticity in a one-level CES. Despite a wide variety of options to model production with CES functions, the resulting substitution elasticities once determined remain fixed over the whole domain of the function, resulting in the global regularity required for solving an applied general equilibrium model. Nesting of CES functions will be used in Chapter 8 for modeling agricultural production.

Functions form the CES family are also regularly used to model consumption demand in applied general equilibrium models. The main objection against using CES functions, like Cobb-Douglas, to model utility functions is that they are linearly homogeneous. This implies that if income doubles, the expenditure shares on, say, food and luxury items remain the same. This violates the well-known empirical finding that households reduce the share of income spend on food, while increasing the share of income spend on luxury items as incomes increase (a phenomenon described by Engel functions). If the model simulations involve large income changes, or if there are other reasons to expect significant changes in expenditure shares, one could opt for a more flexible functional form, like the Constant Difference Elasticity (CDE) function. This function takes a step towards the fully flexible forms, allowing expenditures shares to change when income levels change (it is used to model consumer demand in a global trade model, for a detailed description see McDougall, 2002).

B.3.2 parameters: estimation versus calibration

Having selected functional forms to represent production and consumption decisions, the last step to arrive at an applied model is to specify the parameters to pin-point the exact shape of the functions. There are two approaches: estimation and calibration. The estimation method applies statistical methods to (simultaneously) estimate unknown parameters of the model. The calibration method combines parameters from the literature with calibrated parameters. The latter are selected such that the model replicates a benchmark dataset (*e.g.* a SAM).

In practice, most general equilibrium models are calibrated, despite the 'econometric critique' on this practice. This critique questions the functional and numerical structure of applied general equilibrium models, and can be summarized in four points: inappropriate elasticities, complete reliance on benchmark data, use of CES functions, and lack of statistical tests (Arndt *et al.*, 2001:3; McKitrick, 1998:544).

Inappropriate elasticities. Selecting elasticities means defining the curvature of isoquants and indifference curves. Calibration on a dataset of a single year, as is often the case, does not allow determination of elasticities since it only provides a single point on these curves. (Shoven and Whalley, 1992:104) Values for elasticities are therefore often taken from the literature. These elasticities are 'estimated for commodity and/or industry classifications which are inconsistent with those maintained in the model, and/or for countries other than the one(s) represented by the model, and/or obsolete estimates from past literature, not to mention outright guesses when no published figures are available' (McKitrick, 1998:544). Availability of appropriate elasticities is hampered by a lack of effort on developing econometric methods for estimating technology and preference parameters in general equilibrium models (Francois and Reinert, 1997:17).

Reliance on benchmark data. A key assumption for calibration is that the benchmark dataset represents an equilibrium. To this end, data are represented in a SAM. To make data satisfy the equilibrium conditions of a SAM, procedures like RAS (row-and-column sum) are employed. The RAS procedure adjusts row and column entries such that row and column sums are equal. This mechanical procedure introduces untraceable biases in SAM entries that affect estimation of parameters. A second concern with calibration on a single year is that data from any chosen year will always reflect particular circumstances in that year. Calibrating on a single year thus assumes that these particular circumstances also hold for to all other years (McKitrick, 1998:544).

CES functions. Next to the problems of global properties of flexible functional forms, CES functions are often used because of difficulties in estimating parameters. Compared with more flexible functional forms, CES functions require relatively few parameters (Arndt *et al.*, 2001:1). This benefit in terms of a limited number of parameters comes at the cost of restrictive assumptions on the structure of the model. As a result, the model specification may not adequately represent the underlying preferences, nor technology (McKitrick, 1998:544).

Statistical testing. Calibration relies on a deterministic procedure to calculate parameter values (Shoven and Whalley, 1992:105). Robustness of parameter values can thus not be tested (Arndt *et al.*, 2001:3). Sensitivity analysis can provide some inside in robustness of the model. However, this analysis is generally performed for only a limited number of parameters. More importantly, the calibration procedure does not provide any guidance on which parameter to select in case the model proves not to be robust for particular values (McKitrick, 1998:545).

The 'econometric critique' of the calibration method would not matter much for applied models if the Walrasian general equilibrium framework (*i.e.* the analytical structure) would largely determine the model solution. In this case the effect of different functional forms and parameters (the functional and numerical structure) would not matter much. Not surprisingly functional and numerical structure do matter for applied models build to reflect economic reality. Comparison of a CES-based model with a normalized quadratic specification reveals that the effects of policy measures may even reverse when a different model specification is chosen (McKitrick, 1998).

Despite this criticism, most applied general equilibrium models are still calibrated. In practice the objections against calibration are outweighed by four points of critique against econometric estimation: use of annual data, use of long time-series, data requirements, and equilibrium conditions.

Annual data. Most econometric estimates rely on annual data. Since general equilibrium models employ a time-horizon of typically three to five years, annual elasticities are expected to underestimate the responsiveness in the model[4]. (Arndt *et al.*, 2001:2)

Data requirements. Applying econometric techniques for estimating parameters poses huge data requirements. An applied general equilibrium model can have thousands of parameters. Simultaneously estimating these requires impossible amounts or data, or reliance on restrictive assumptions that will affect estimated values. (Shoven and Whalley, 1992:106)

Equilibrium conditions. Estimated parameters should be in accordance with the equilibrium conditions of the general equilibrium model. With calibration this is achieved by specifying the model such that the benchmark equilibrium is reproduced. However, incorporating equilibrium conditions in maximum-likelihood estimations is difficult (Shoven and Whalley, 1992:106) Without equilibrium conditions, estimated parameters may describe historical observations, but violate equilibrium conditions in the model they ought to represent (Arndt *et al.*, 2001:2).

Recently maximum entropy (ME) methods have been developed that seem capable of combining the best of both econometric and calibration methods. ME is akin to econometric estimations in that (i) all available data are used for estimation, and not those of a single year; (ii) statistical tests are available for assessing estimated parameters. ME is akin to calibration in that (i) the estimated model satisfies equilibrium conditions; (ii) can be used with limited data. Partly due to their recent development, partly due to the lack of standard software packages (implying a the need to program and solve nonlinear programming models for each application), these methods have not been widely used yet[5].

The above discussion has been based on literature on macro general equilibrium models. As in the case of macro models the specification of elasticities is the main issue in developing an applied village equilibrium model, since the SAM does not provide information in this respect. In the case of village equilibrium modeling there will be generally be very limited, if any, literature from which elasticities can be taken. Nor will there be existing SAMs from other years that can serve as a check on the specification of the model.

Village equilibrium models have an advantage over macro level models in being developed on the basis of household surveys designed for this specific purpose. This provides a level of detail in the data not generally available in macro level studies. On the other hand, panel data are scarce and most village equilibrium models will be build using only cross-section data. Estimation of income elasticities is possible using cross-section data. Estimation of price elasticities requires sufficient variation in the prices households face. In cross-section data such variation can be obtained by introducing spatial variation, *i.e.* sampling households from locations with different access to markets, and thus different prices (see Sadoulet and de Janvry, 1995: Chapter 2). In practice the development of an applied model requires careful balancing between calibration and estimation.

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[4] Strictly speaking this criticism also applies to calibrated models using econometrically estimated elasticities from the literature (McKitrick, 1998).

[5] For more information on ME econometrics in general see Golan *et al.* (1996), for an application to estimating general equilibrium parameters see Arndt *et al.* (2001).

B.4 analyzing model results

Having taken all steps towards an applied model, the model can be used to analyze the impact of exogenous shocks to the system. These shocks could be policies, like an increase in certain prices, or other shocks, like an exogenous decrease in production levels to simulate adverse production circumstances. There is a close relation between the closure of the model and the type of shocks that can be analyzed. Recall that the model closure determines which variables are exogenous, and only exogenous variables can be shocked. Thus if a neoclassical closure is chosen (full employment and endogenous wages), the model cannot be used to analyze an increase in a minimum wage. To analyze the implications of a minimum wage first the closure needs to be changed (fixed wages and endogenous labor endowment).

Two major issues arise when analyzing model results. First, the nonlinear character of general equilibrium models gives rise to issues regarding multiple equilibria, which may create problems for interpreting the model results. Second, analyzing the outcomes of complex nonlinear models can be a daunting task. The large number of endogenous variables creates demand for a single number summarizing the overall impact of the shock. Several welfare measures have been developed capable of summarizing the impact of a shock in single variable for each household.

B.4.1 multiple equilibria

General equilibrium models are nonlinear, and thus there is an issue of multiplicity of equilibrium. This is relevant for applied modeling, since with multiple equilibria the impact of a shock could be ambiguous. If in one equilibrium a households is worse off, while in another equilibrium it is better off, the impact of shock cannot be determined.

With standard assumptions on consumer and producer behavior, the number of equilibria will be finite, but existence of multiple equilibria is not precluded (Ginsburgh and Keyzer, 1997:11-12). The common practice in applied general equilibrium modeling is to assume that 'nonuniqueness is largely a theoretical curiosum' (Mercenier, 1994:2). If the model involves nonconvexities in the production technologies, however, it can be assumed that a equilibrium will not be unique. Models including imperfect competition and strategic behavior thus have to deal with the issue of multiple equilibria (Mercenier, 1994:1).

The (theoretical) discussion on multiple equilibria in general equilibrium modeling refers to multiple global optima., *i.e.* there several points in which the system is in equilibrium, but none of these is superior to all others. When numerically solving a nonlinear model there is also the issue of local optima. Solution algorithms generally do not search the full domain of the model, but instead use rules to determine whether or not to continue searching for an equilibrium. These rules could lead to a local optimum being found as a solution of the model. To avoid such issues genetic algorithms are being developed that systematically search for a global optimum. These algorithms are time-consuming and not readily available. As a result multiple equilibria are not reported in the literature, nor is there a check on whether found solution found is global optimum.

B.4.2 tracing shocks and measuring welfare

Having solved the model the results need to be interpreted. Given the interdependencies and nonlinearities in a general equilibrium model, this interpretation is not an easy task. A practical rule of thumb is to follow the shock throughout the system. If the shock consist of an increase in fertilizer price, for example, the analysis could start with the change in input use, then looking at the implications for output produced, the change in marketed output, consumption and so on.

Tracing a shock through the system provides valuable insight in which ways and why the new equilibrium differs from the initial state of the economy. Due to the general equilibrium character of the model, however, there are generally a multitude of changes. This raises the basic question: has the situation improved or not? The most natural way to address this question is to assess the change in welfare of the household. Since utility functions only a rank preferences, changes in levels of utility are not meaningful. Therefore alternative measures have been developed, based on monetary valuations of welfare. Changes in these indicators do provide a meaningful summary of the impact of the shock on a household.

The most simple welfare indicator is the change in real income (nominal income divided by a price index). Different price indices are available, of which the Laspeyres and the Paasche index are the most well-known. These two indices use different weights (base period or current period) that bias the outcome if not all prices change proportionally. In a general equilibrium context prices are endogenous and there is no *a priori* reason to expect a proportional change in prices. Therefore Fisher's Ideal Price Index is preferable which, as an approximation of the true price index, takes the geometric mean of the Laspeyres and the Paasche index. Since in a general equilibrium context incomes are endogenous and affect by prices, we also need to account for changes income. The overall impact of simultaneous price and income changes can be measured as (Sadoulet and de Janvry, 1995:15):

$$\frac{\Delta y_h^r}{y_h^r} = \frac{\Delta y_h^n}{y_h^n} - \frac{\Delta P_h^F}{P_h^F}, \qquad \forall\, h \in H \qquad \text{(b.9a)}$$

with

$$P_h^F = \sqrt{\frac{\sum_j q_{hj}^b p_{hj}^a \sum_j q_{hj}^a p_{hj}^a}{\sum_j q_{hj}^b p_{hj}^b \sum_j q_{hj}^a p_{hj}^b}}, \qquad \forall\, h \in H \qquad \text{(b.9b)}$$

where y_h^r is real income, y_h^n is nominal income, P_h^F is the Fisher's Ideal Price Index, q_{hj} is the quantity consumed of commodity *j*, and p_{hj} is its price. Superscripts *b* and *a* indicate base (before the shock) and current (after the shock) levels. Since both consumption patterns and prices (with nonseparability) are household specific, and index *h* has been added to all variables.

The main merit of using real income as a proxy for welfare change is its simplicity, which may not be far off the mark with small changes and limited substitutability. More complete measures of welfare changes are compensating and equivalent variation. Both these measures require specification of the utility function, which is not a problem if the demand functions have an analytical primal (which functions from the CES family have).

Compensating variation (CV) is “the amount of money which, when taken away from the consumer after the prices and income change, leaves him with the same level of utility as before the change” (Sadoulet and de Janvry, 1995:13). The CV measures how much people are willing to pay (if welfare increases) or willing to accept (if welfare decreases) to leave them just as well off as before the change. The CV thus takes the utility level before the change occurs as the reference point.

In contrast, the equivalent variation (EV) takes the utility after the change has occurred as its reference point, being “the amount of money which, when paid to the consumer, achieves the same level of utility before the change that would be enjoyed with the economic change” (Sadoulet and de Janvry, 1995:13). The CV measures how much people are willing to accept (if welfare increases) or are willing to pay (if welfare decreases) to leave them just as well off as after the change.

The CV and EV can be expressed in terms of the expenditure function $e(p,y)$, the minimum income required for a given level of utility for given prices (Sadoulet and de Janvry, 1995:14):

$$CV_h = y_h^a - y_h^b - [e_h(p_h^a, u_h^b) - e_h(p_h^b, u_h^b)] \qquad \forall\ h \in H \qquad \text{(b.10a)}$$

$$EV_h = y_h^a - y_h^b - [e_h(p_h^a, u_h^a) - e_h(p_h^b, u_h^a)]\,. \qquad \forall\ h \in H \qquad \text{(b.10b)}$$

These expression clearly show the different level of utility used by these two measures, which is the only difference between these two measures. After deriving the utility function corresponding to the demand functions used in he model, the above expressions can be used to either calculate the CV or EV for each household type.

Most general equilibrium models use EV to measure welfare changes. The main reason for this choice is that scenarios are generally analyzed in terms of the base run of the model. For comparison across such pair wise analyses the EV is most suited, using base prices and base year income as the reference point (Shoven and Whalley, 1984).

Unlike utility, welfare changes measured by the CV or EV can be summed over all households. This sum indicates not only if the policy is overall acceptable, but also indicates if compensation schemes are required to make the policy acceptable to each household group.

APPENDIX C

household behavior and accounting relations

The village equilibrium model is formulated in dual from, using demand and supply functions, and consists of household models linked to by village trade and a village balance of payments (see Chapter 3 for the general outline of the model). The village level equations will be used in the model as specified in Chapter 3. This appendix therefore focuses on deriving the household demand and supply equations from the household maximization problem.

To simplify the notation the remainder of this section will focus on a single household, dropping the household subscript from all equations. The utility function then simplifies to:

$$\max_{q_j^c, q_j^{ia}, q_j^s, q_j^{ht}, q_j^p} \quad u(q_j^c), \qquad \forall\, j \in C \qquad \text{(c.1)}$$

where q_j^c is the consumption of commodity j. To be able to derive demand functions we assume that the utility function has the standard properties (continuous and strictly concave) needed to yield Marshallian demand functions (Mas-Colell *et al.*, 1995:52). Furthermore, utility functions are assumed to be nonsatiated.

The available production technology provides the first set of constraints. The general model developed in Chapter 3 allows production of a single good by different activities. As the SAM indicates this is relevant for the Chinese case study village, as for example the production of feed by three different cropping activities indicates. To facilitate derivation of first-order conditions, the explicit mentioning of activities used in Chapter 3 is replaced by a general specification that allows commodities to be both inputs and outputs:

$$q_j^o = f(q_{jk}^i). \qquad \forall\, j \in O,\, k \in I \qquad \text{(c.2)}$$

We assume production functions to have the standard properties (continuous and concave) to be able to derive input demand functions (Mas-Colell *et al.*, 1995:141).

The commodity balances poses the second set of constraints to utility maximization:

$$q_j^c + \sum_{k \in O} q_{kj}^i + q_j^s + q_j^{ht} \leq q_j^o + \overline{q}_j^{\omega} + q_j^p. \qquad \forall j \in J \qquad \text{(c.3)}$$

The cash constraint poses the last constraint to utility maximization:

$$\sum_{p\in P}\tilde{p}_j^p q_j^p \le \sum_{s\in S}\tilde{p}_j^s q_j^s + \sum_{ht\in HT}\tilde{p}_j^{ht} q_j^{ht} + \sum_{l\in L}\bar{y}^l \cdot \tag{c.4}$$

The households is assumed not to be able to manipulate the price of traded commodities. From the household's perspective prices of tradables are thus fixed. Household tradables that are village nontradables may have endogenous village prices. To indicate that prices perceived as fixed by the household may be endogenous at village level the tilde (~) is used. This contrasts with the fixed sources of cash income ($\bar{y}^l$) and the fixed endowments ($\bar{q}^\omega$) both of which are fixed at household-level.

For commodities subject to a price band (belonging to set *P* and *S*, see Chapter 3 for a discussion of the different sets) the household chooses a position in the market (net buyer, autarkic or net seller). As will be seen below this can be assured by including the following two constraints when deriving the solution of the model:

$$q_j^p \ge 0 \qquad \forall\, j \in P \tag{c.5a}$$

$$q_j^s \ge 0 \qquad \forall\, j \in S \tag{c.5b}$$

$$\tilde{p}_j^p > \tilde{p}_j^s \,. \tag{c.5c}$$

Substituting the production function (c.2) into the commodity balance (c.3), the Lagrangean of this problem can be formulated as

$$\begin{aligned} L = u(q_j^c) + \sum_j \mu_j \left[f(q_{kj}^i) + \bar{q}_j^\omega + q_j^p - q_j^c - \sum_{k\in O} q_{kj}^i - q_j^s - q_j^{ht} \right] \\ + \lambda \left[\sum_{s\in S}\tilde{p}_j^s q_j^s + \sum_{ht\in HT}\tilde{p}_j^{ht} q_j^{ht} + \sum_{l\in L}\bar{y}^l - \sum_{p\in P}\tilde{p}_j^p q_j^p \right] \end{aligned} \tag{c.6}$$

yielding the following first-order conditions:

$$\frac{\partial L}{\partial q_j^c} = \frac{\partial u(q_j^c)}{\partial q_j^c} - \mu_j = 0 \tag{c.6a}$$

$$\frac{\partial L}{\partial q_{kj}^i} = \mu_k \frac{\partial f(q_{kj}^i)}{\partial q_{kj}^i} - \mu_j = 0 \tag{c.6b}$$

$$\frac{\partial L}{\partial q_j^p} = \mu_j - \lambda\tilde{p}_j^p \le 0; \quad q_j^p \ge 0; \quad q_j^p(\mu_j - \lambda\tilde{p}_j^p) = 0 \tag{c.6c}$$

$$\frac{\partial L}{\partial q_j^s} = \lambda\tilde{p}_j^s - \mu_j \le 0; \quad q_j^S \ge 0; \quad q_j^s(\lambda\tilde{p}_j^s - \mu_j) = 0 \tag{c.6d}$$

$$\frac{\partial L}{\partial q_j^{ht}} = \lambda\tilde{p}_j^{ht} - \mu_j = 0 \tag{c.6e}$$

$$\frac{\partial L}{\partial \mu_j} = f(q_{kj}^i) + \bar{q}_j^\omega + q_j^p - q_j^c - \sum_{k\in O} q_{kj}^i - q_j^s - q_j^{ht} = 0 \tag{c.6f}$$

$$\frac{\partial L}{\partial \lambda} = \sum_{s\in S} \tilde{p}_j^s q_j^s + \sum_{ht\in HT} \tilde{p}_j^{ht} q_j^{ht} + \sum_{l\in L} \bar{y}^l - \sum_{p\in P} \tilde{p}_j^p q_j^p = 0 \cdot \qquad \text{(c.6g)}$$

It will be useful to define household shadow prices as $p_j^* = \mu_j / \lambda$ .Using this definition of household shadow prices and rearranging we can rewrite the decisions regarding household tradables (c.6c-e) as follows:

$$\tilde{p}_j^p \geq p_j^*; \quad q_j^p \geq 0; \quad q_j^p(\tilde{p}_j^p - p_j^*) = 0 \qquad \forall\, j\in P \qquad \text{(c.7)}$$

$$p_j^* \geq \tilde{p}_j^s; \quad q_j^s \geq 0; \quad q_j^s(p_j^* - \tilde{p}_j^s) = 0 \qquad \forall\, j\in S \qquad \text{(c.8)}$$

$$\tilde{p}_j^{ht} = p_j^* . \qquad \forall\, j\in HT \qquad \text{(c.9)}$$

For tradables not subjected to a price band (*HT*) the household shadow price is equal to the exogenous outside price (c.9). For commodities subjected to a price band there are three relevant prices: exogenous purchase and sales prices and an endogenous shadow price that lies in between the purchase and sales price. Equation (c.7) and (c.8) determine which of these prices is used in decision-making. If the commodity is purchased the household shadow price is equal to the purchasing price. Since by (c.5c) the purchase price exceeds the sales price, the shadow price will be above the sales price and by (c.8) the sold quantity is equal to zero. A reverse argument holds if the commodity is sold. A third possibility is that the commodity is neither bought nor sold. By (c.7) and (c.8) the household shadow price will then be in between the purchase and sales price, *i.e.* the households operates within the price band.

Dividing by λ, using the definition of household shadow price and rearranging (c.6b) provides the input demand of the household,

$$p_k^* \frac{\partial f(q_{jk}^i)}{\partial q_{jk}^i} = p_j^* , \qquad \forall\, j\in O,\, k\in I \qquad \text{(c.10)}$$

which is the usual result that the value of the marginal product of an input equals its price. This again illustrates that standard results of producer and consumer theory apply to nonseparable households when accounting for endogeneity of prices.

Having described production decisions of the household by (c.10), we now turn to deriving consumption decisions. Dividing by λ, using the definition of household shadow price and rearranging (c.6a) provides the consumption decisions of the household,

$$\frac{\partial u(q_j^c)}{\partial q_j^c} = \lambda p_j^* . \qquad \forall\, j\in C \qquad \text{(c.11)}$$

This is the usual result of consumer theory, where λ represents the marginal utility of wealth (Mas-Colell *et al.*, 1995:55). Again, with nonseparability, standard results from economic theory can be used to describe behavior if endogeneity of prices is accounted for.

It will be useful to rewrite the remaining two constraints (c.6f and g) into a single full-income constraint. The assumptions on the utility function assure that expenditures on consumption will exhaust full-income (w),

$$\sum_{c\in C} p_j^* q_j^c = w \cdot \qquad \text{(c.12)}$$

The next step is to find an expression for full income. We start by generalizing the cash constraint (c.6g) to all commodities,

$$\sum_{j\in J} p_j^* q_j^s + \sum_{j\in J} p_j^* q_j^{ht} + \sum_{l\in L} \bar{y}^l - \sum_{j\in J} p_j^* q_j^p = 0 \cdot \qquad \text{(c.13a)}$$

This generalization is allowed since for nontradables quantities sold and purchased are zero, while for sold and purchased commodities the household shadow prices will equal the exogenous market prices. Rearranging terms then yields ,

$$\sum_{j\in J} p_j^* (q_j^s + q_j^{ht} - q_j^p) + \sum_{l\in L} \bar{y}^l = 0 \cdot \qquad \text{(c.13)}$$

We then use the commodity balance (c.6f) to find an expression for the term within brackets in (c.13). Substituting the production function and rearranging we find

$$q_j^s + q_j^{ht} - q_j^p = q_j^o + \bar{q}_j^\omega - q_j^c - \sum_{k\in O} q_{kj}^i \cdot \qquad \text{(c.14a)}$$

Substituting (c.14a) in (c.13) multiplying through and rearranging yields

$$\sum_{j\in J} p_j^* \bar{q}_j^\omega + \sum_{l\in L} \bar{y}^l + \sum_{j\in J} p_j^* q_j^o - \sum_{k\in J}\sum_{j\in J} p_j^* q_{kj}^i = \sum_{j\in J} p_j^* q_j^c \cdot \qquad \text{(c.14)}$$

The next step is to find an expression for the income derived from production represented by the last two terms at the left-hand side of (c.14). A zero profit condition (equating the value of production to the value of inputs), is a standard feature in general equilibrium models. In the village equilibrium model, however, profits earned with off-farm employment are introduced to deal with the gap between household shadow prices and off-farm wages:

$$\pi = \sum_{j\in O} p_j^* q_j^o - \sum_{k\in O}\sum_{j\in I} p_j^* q_{kj}^i \cdot \qquad \text{(c.15a)}$$

This more general specification also allows activities to have non-zero (positive or negative) profits. We can now derive a definition of full income that allows profits in off-farm employment activities by substituting (c.15a) and (c.12) into (c.14),

$$\sum_{j\in C} p_j^* q_j^c = \sum_{j\in J} p_j^* \bar{q}_j^\omega + \sum_{l\in L} \bar{y}^l + \pi = w \cdot \qquad \text{(c.14)}$$

Full income available for consumption thus consists of the value of endowments, plus exogenous income, plus profits earned with off-farm employment activities.

Summarizing, household decisions can be described four blocks of equations. The *price block* describes relevant decision-making prices for the households (Equation c.7-c.9). The *production block* describes household production decisions. These consist of two types of equations: input demand functions (relating input demand to (relative) prices (c.10)) and production functions (relating the output achieved with the demanded inputs (c.2)). The *consumption block* describes consumption decisions. As with production these consist of two types of equations. A single equation full income (c.14) and consumption demand equations (c.11) relating consumption demand to prices and income. Finally, the *commodity block* replicates the commodity balances defined in (c.3). The cash constraint included in the optimization model is implicit in the full income constraint and thus does not appear in the household model. Apart from the these four blocks of household equations describing household behavior, the model includes village level commodity balances and a village balance of payment as defined in Chapter 3.

APPENDIX D

calibration of the linear expenditure system

In this appendix we show that calibrating demand functions using Equation (6.9') yields the income elasticities used as an input in calibration[1]. Start with the division of consumption in subsistence levels (σ_{hj}^{c}) and above subsistence levels (v_{hj}^{c}) using normalized elasticities as defined in Chapter 6,

$$\sigma_{hj}^{c} = (1 - \frac{\eta_{hj}}{\max\limits_{j}(\eta_{hj})})q_{hj}^{c}, \qquad \forall\ h \in H, j \in C \qquad \text{(d.1a)}$$

$$v_{hj}^{c} = q_{hj}^{c} - \sigma_{hj}^{c} = \frac{\eta_{hj}}{\max\limits_{j}(\eta_{hj})} q_{hj}^{c}. \qquad \forall\ h \in H, j \in C \qquad \text{(d.1b)}$$

For ease of exposition we drop the consumption superscript and the household subscript in the remainder of this derivation. We furthermore replace the normalization with the maximum elasticity with an arbitrary constant, z. In addition we define income (y) as the total expenditures on consumption, and above subsistence income (y^{v}) as the expenditures on above subsistence consumption,

$$y = \sum_{j \in C} p_j q_j \qquad \text{(d.2a)}$$

$$y^{v} = \sum_{j \in C} p_j v_j . \qquad \text{(d.2b)}$$

To derive the income elasticities we need to explore the implications of an increase in income. Assume that total income increases with ε percent. By definition the subsistence quantities do not respond to the income increase, implying that the above subsistence expenditures absorb the full shock in income. *Ceteris paribus* none of the prices changes, and the above subsistence consumption levels will increase with the same percentage as the income increase,

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[1] This derivation of the calibration of the linear expenditure system (LES) is based on Dellink (2003:80).

$$\frac{dy}{y} = \varepsilon, \qquad dy^v = dy = \varepsilon y, \tag{d.3a}$$

$$d\sigma_j = 0, \quad dv_j = dq_j = \varepsilon. \tag{d.3b}$$

It will be useful to define the change in above subsistence consumption levels,

$$\frac{dv_j}{v_j} = \frac{dy^v}{y^v} = \varepsilon \frac{y}{y^v}. \tag{d.4}$$

Due to the unitary income elasticities the percentage change in above subsistence consumption is thus identical for all consumed commodities. For the derivation below it will also be useful to derive an expression for the last term at the right-hand side of (d.4),

$$\frac{y}{y^v} = \frac{y}{\sum_{j \in C} p_j v_j} = \frac{y}{\sum_{j \in C} p_j \frac{\eta_j}{z} q_j} = z \frac{y}{\sum_{j \in C} p_j \eta_j q_j} = z \frac{1}{\sum_{j \in C} \eta_j \frac{p_j q_j}{y}} = z \tag{d.5a}$$

The last step in (d.5a) only holds if the income elasticities satisfy restriction (6.10),

$$\sum_{j \in C} \eta_j \frac{p_j q_j}{y} = 1. \tag{d.5b}$$

We are now ready to explore the total change in consumption following the change in income. Relating the change in total consumption to the change in above-subsistence consumption, substituting (d.4) and (d.5a) yields an expression for the change in consumption in terms of the income elasticity and the income shock,

$$\frac{dq_j}{q_j} = \frac{dv_j}{\frac{z}{\eta_j} v_j} = \frac{\eta_j}{z} \frac{dv_j}{v_j} = \frac{\eta_j}{z} \varepsilon \frac{y}{y^v} = \eta_j \varepsilon. \tag{d.6.a}$$

Having defined the change in consumption we can now define the income elasticities,

$$\frac{dq_j / q_j}{dy / y} = \frac{\eta_j \varepsilon}{\varepsilon} = \eta_j. \tag{d.7}$$

Using the income elasticities to divide consumption into subsistence and above-subsistence parts thus yields the original income elasticities, even if these have been normalized with an arbitrary constant z. This result, however, hinges on the income elasticities satisfying the constraint derived from the Stone-Geary utility function (d.5b). In case elasticities are used that do not satisfy this restriction, income elasticities after calibration will differ from the elasticities used to allocate consumption to subsistence and above subsistence levels.

APPENDIX E

descriptives of variables used in the calibration of nested production functions

This appendix describes the data used in calibration of the production structures in Chapter 7.

Table E.1: Descriptives one season rice data (N=80)

		Mean	*Standard deviation*
Output	Two season rice (jin)	2885.6	379.3
Factors	Land (mu)	3.9	0.5
	Labor (days)	183.2	15.4
	Animal traction (days)	4.2	0.4
	Tractor (days)	0.1	0.1
Intermediate inputs	Fertilizer (jin)	324.5	44.3
	Manure (jin)	423.6	89.0
	Herbicides and pesticides (yuan)	56.6	7.5
	Other inputs (yuan)	42.5	5.2

Table E.2: Descriptives two season rice data (N=128)

		Mean	*Standard deviation*
Output	Two season rice (jin)	6764.7	318.1
Factors	Land (mu)	11.5	0.6
	Labor (days)	545.2	32.8
	Animal traction (days)	10.5	0.8
	Tractor (days)	0.4	0.1
Intermediate inputs	Fertilizer (jin)	982.8	60.6
	Manure (jin)	1714.6	296.0
	Herbicides and pesticides (yuan)	135.9	7.0
	Other inputs (yuan)	150.4	9.4

Table E.3: Descriptives other crops data (N=150)

		Mean	*Standard deviation*
Output	Other crops (yuan)	2000.5	156.3
Factors	Land (mu)	1.2	0.1
	Labor (days)	88.8	6.0
	Animal traction (days)	1.7	0.2
Intermediate inputs	Fertilizer (yuan)	64.4	9.8
	Manure (jin)	886.1	242.7
	Herbicides and pesticides (yuan)	19.9	1.8
	Other inputs (yuan)	72.0	6.5

Table E.4: Descriptives pig production data (N=136)

		Mean	*Standard deviation*
Output	Output (yuan)	2522.9	123.8
Factors	Labor (days)	4.2	1.2
Intermediate inputs	Crop residues (yuan)	2436.0	332.0
	Purchased feed (yuan)	520.8	227.8
	Other inputs (yuan)	508.2	41.2

Table E.5: Descriptives other livestock production data (N=114)

		Mean	*Standard deviation*
Output	Output (yuan)	268.8	32.2
Factors	Labor (days)	0.6	0.1
Intermediate inputs	Crop residues (yuan)	96.2	15.3
	External inputs (yuan)	79.1	33.6

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SUMMARY

Within the time-span of less than a generation, the Chinese turned an inward-looking agricultural society into an outward-looking and increasingly industrialized one. Opening of the Chinese economy has led to unprecedented growth rates. Although the economic growth has irrefutably increased the well-being of a massive number of people, the benefits have not been distributed evenly. Rapid transformations of the economic structure, in combination with policies hampering the spread of economic benefits across regions and across people, resulted in a rising income inequality between urban and rural regions threatening social stability and future growth. The urban incomes attract a large number of rural migrants, transmitting part of the higher urban incomes to the rural areas. Access to urban employment, however, depends on households' endowments and the rising income inequalities are thus transmitted to rural village economies.

This study provides the first quantitative analysis of the impact of rural-urban migration on a Chinese village economy. It contributes to the existing literature by analyzing the impact of interactions within a Chinese village on rural household decisions. Although other studies mention imperfect markets as relevant in the Chinese context, their impact on the interactions among households has not yet been analyzed quantitatively. Existing analyses of the Chinese economy either focus on aggregate patterns at national or provincial or county level, or on household-level. Imperfect markets, however, can generate local income and expenditure effects through which households affect each other. Accounting for feedback within a village economy modifies household response compared to results obtained from a separate household analysis, and may thus alter implications for policy-making.

Apart from providing the first quantitative analysis of a Chinese village economy, this study makes three contributions to existing village equilibrium models: (i) accounting for nonseparability of household decisions; (ii) modeling the impact of migration on household consumption demand; and (iii) empirically establishing (non)separability of factors and intermediate inputs in production.

The study starts by assessing the existing literature on modeling rural household behavior. In Chapter 2 we develop a framework allowing us to compare a wide variety of studies using a common reference point. Modeling is the construction of a simplified representation of reality. Choices on which aspects to include and which to leave out are generally not discussed explicitly, clouding a comparison of applied models and an identification of assumptions driving model results. In Chapter 2 we identify the main choices that need to be made when modeling rural household behavior and shortly discuss different approaches taken in the literature. To this end separate strands of literature are pulled together in a matrix with key elements and key issues as its two dimensions. The *key elements* describe the essentials of the household and its environment. The *key issues* describe fundamental modeling choices that need to be made when representing each element in a model.

The five key elements in a model of rural household decisions are *natural resources*, *technology*, *household*, *markets* and *non-market institutions*. For each of these five elements there are four key issues that need to be addressed. First of all, the elements need to be *conceptualized* or represented in the

model. After this definition of model elements, *interactions* among similar elements (among households, for example) and different elements (among households and natural resources, for example) can be defined. The remaining two key issues are *aggregation* (how to deal with differences among individual units) and *dynamics* (how to deal with changes over time). The combination of the five key elements and four key issues results in a matrix with twenty cells that, when applied to a specific model, describe the essential choices made in an applied model.

In Chapter 3 we continue the literature review by applying the matrix of key elements and issues to existing household, village and sub-regional models. This review adds a third dimension, modeling approach, to the choices to be made during modeling: reduced-form, optimization or a system of equations. The choice of modeling approach affects the way in which the key elements are dealt with. Relevance of specific key elements depends on the research question and therefore determines the choice of modeling approach. The review of existing models indicates that a village equilibrium model is a promising approach for capturing interactions among households. The review also shows that existing village models do not adequately reflect the findings of the household literature on the impact of market imperfections on household decisions.

The second part of Chapter 3 presents the structure of the village model developed in this study. This village model applies a macro-level general equilibrium model structure, but modified in such a way that the behavior of the households in the model is fully compatible with the rural household literature. The result is a hybrid village model that accounts for interactions among households within the village, while preserving individual rationality. The position of households in markets as net buyers, autarkic or net sellers is endogenous in the model through the use of mixed complementarity constraints. Both the attention for nonseparability and endogeneity of the household position in markets are departures from existing village models. Furthermore, using a general equilibrium structure, even when there are only few local village markets, allows the use of powerful accounting and theoretical consistency checks.

In Chapter 4 we shift from a comparison of modeling approaches to mapping the economy of a Chinese village. The village used as a case in this study is located in the North-East of Jiangxi Province and is representative for rice producing villages in the plain areas of this province. For this village we construct a social accounting matrix (SAM) on which the village equilibrium model in Chapter 5 is calibrated. We start by defining four groups of representative households based on ownership of draught power and access to migratory employment outside the province. This grouping captures differences in access to agricultural and migratory sources of income.

We then proceed by testing the hypothesis of separability of household production and consumption decisions, which we reject for the major part of the households. Nonseparability implies unobservable household shadow prices. This complicates construction of a SAM on the basis of value flows. An agricultural production function was therefore estimated to derive shadow prices for labor, irrigated land (both of which are imperfectly tradable) and for three household nontradables (manure, crops residues used as feed, and non-irrigated land). The estimated shadow price for irrigated land indicates a supply-constrained land market, which confirms observations of a highly distorted land market during the household survey. Having a complete set of (partly household-specific) prices, we construct a detailed SAM with eleven household-specific production activities, external inputs disaggregated by type, transport costs, and different types of money flows among households and with the outside world. An aggregated version of this detailed SAM forms the basis of applied models in later chapters.

In Chapter 5 we develop the first basic version of the Chinese village model. Production and utility are described through easy to calibrate but restrictive Cobb-Douglas functional forms, leaving the focus of attention on interactions among households. The resulting village model does not have a market structure as typically used in macro-level models. Village prices are assumed to be fixed for most village nontradables, resulting in demand driven markets and non-zero profits. The exception is the village market for animal traction services, which is governed by an endogenous village price.

The second part of Chapter 5 analyses the impact of village interactions on household response. Applying a partial equilibrium closure to the village model results in separate household models. Comparing separate household models with the village model highlights the impact of village interactions on household response to an increase in income from outside province migrants. The results show little difference between household and village models in terms of welfare and income indicators. Analyzing agricultural exports from the village, however, differences between the two approaches become pronounced: accounting for feedback among households roughly halves the response found with separate household models.

The different production response in the village model is due to interactions in the village market for animal traction services. Responding to an increased inflow of outside province remittances, household groups with an outside-province link shift towards a more labor-extensive and capital-intensive production pattern. The shift towards more labor-extensive production also lowers demand for animal traction services. In the village model this decreased demand reduces the price of animal traction services. This price-reduction makes more intensive production more attractive again, undoing part of the initial impact of the increase in remittances on households with an outside link. For the household group lacking an outside link and owning draught power, the reduced demand for animal traction implies a loss of cash-income, resulting in a shift towards more labor-intensive production. The small differences between the household and village models in terms of welfare and income indicators thus obscure adjustments generated by village interactions. Pronounced differences between the separate household models and the village models in total marketed surplus from the village are testimony to these adjustments.

Chapter 5 analyzes household response to an increase in remittances from household members employed outside the province. This analysis is motivated by an expected expansion of labor-intensive Chinese manufacturing industry with continuing trade liberalization. Apart from an increase in income, this expansion is also likely to attract more (transitory) migrants. Chapter 6 therefore analyses the impact of an increase in migration outside the province. To allow an analysis of the impact on consumption, household-level demand functions are replaced by consumption demand in terms of adult equivalents. To allow spending patterns to shift when income levels change, at the same time the Cobb-Douglas utility function is replaced with a Stone-Geary utility function. The demand functions derived from these utility functions are calibrated using income elasticities estimated consistent with the assumptions made in the village equilibrium model. This consistency contrasts with the common use of elasticities from the literature in macro-level general equilibrium models. Comparing the results of Chapter 5 and 6, we find results in terms of income and welfare ranking to be robust to the change in utility functions. Results in terms of marketed surplus from the village, however, are sensitive to the functional form chosen for the utility function. With rising incomes consumption now shifts away from farm produced output, magnifying shifts in agricultural exports found in Chapter 5.

In terms of full income, results are robust to whether only remittances or migration increases. When assessing production response and welfare impacts, however, it does matter whether remittances or migration increase. A comparable increase in household income leads to a higher increase in welfare with a rise in migration than with a rise in remittances. This is due to the reduced consumption demand with an increase in migration. The reduced household size with migration affects production response by changing the scarcity of labor. The total welfare increase is higher with migration than with an increase in remittances for all household groups.

For the agricultural supply response at village level not only within-village interactions matter, but also whether expansion of urban employment is transmitted through remittances, or whether it will increase the outflow of migrants. An increasing outflow of migrants magnifies the shift away from rice towards livestock production. This shift in production pattern is not accounted for in existing studies of the impact of migration on agricultural production in China, but is important from a policy perspective since the rising urban incomes drawing rural migrants, also induce a shift from grain to meat consumption.

The household production response to a change in relative prices depends on the substitution possibilities within a production activity, as well as differences in substitution possibilities between production activities. Substitution possibilities are determined by the choice of functional form and parameters of the production function. In chapter 7 we thus shift our attention to modeling agricultural production activities. Using the household survey data we test separability of inputs. We find each activity requiring a specific functional form. This introduces a variety in substitution possibilities across activities and across household groups. The calibrated production structures reject the separation of factors and intermediate inputs commonly assumed in applied general equilibrium and existing village models.

Calibrated substitution elasticities of the nested CES production functions used in Chapter 7 differ from the unitary substitution elasticity implied by the Cobb-Douglas specification in earlier chapters. There is no consistent pattern in these differences. This implies that we cannot conclude *a priori* whether a Cobb-Douglas specification over- or underestimates substitution possibilities.

To assess the impact of changing the production function we repeat the increased migration simulation of Chapter 6. Although in qualitative terms the household response is similar to findings in earlier chapters, nested CES production functions generate quantitative differences. The nested CES production structure leads to a more moderate household production response, by increasing the substitution possibilities between inputs. This allows more scope for adjustments, therefore tempering household response to external shocks. Apart from a more moderate production response, benefits from migration are higher for households involved in migration with nested CES production functions, while households lacking access to migration benefit less. This difference is as large as a 63 percent lower increase in full income for the household group lacking access to migration and owning draught power. In terms of policy implications the use of nested CES production functions thus generates more concern for the rising income inequalities due to asymmetric access to migration.

Finally, Chapter 8 concludes this study by returning to the matrix of key elements and key issues of Chapter 2, identifying the contributions and limitations of the current study. The key choices when developing the village equilibrium model are driven by a household perspective on general equilibrium modeling and by capturing essential features of the Chinese case study village. The result is a hybrid model which blends features standard in household optimization models, like nonseparability of household production and consumption decisions, with features standard in applied general equilibrium modeling, like interactions between households. Where possible, household survey data are used to determine the structure of the model and the functional forms. In case insufficient data were available, for example regarding trade flows among household groups, the most straightforward solution (like fixing market shares) is chosen to make model results as tractable as possible.

The most important limitations of the current model are the lack of data on village land and credit markets, both of which can be expected to be instrumental in dispersing the benefits from migration throughout the village economy. Another fruitful direction for future research is a move from the current static to a dynamic version of the model. The applied village model developed in this study provides a firm foundation for such future research directions. The approach taken in this study can be applied to other villages in China as well as in other countries. The approach developed in this study results in an applied village model firmly anchored in farm household theory, thus bridging the currently existing gap between household- and village-level models. The result is a case-specific village model that can be used to gain (policy) insights that cannot be obtained from other types of models.

SAMENVATTING

Binnen één generatie hebben de Chinezen een naar binnen gekeerde agrarische maatschappij omgevormd in een naar buiten georiënteerde en in toenemende mate geïndustrialiseerde maatschappij. De hervormingen van de Chinese economie hebben tot ongekende economische groei geleid. Alhoewel deze groei onweerlegbaar de welvaart van een indrukwekkend aantal mensen heeft verbeterd, zijn de baten van deze groei ongelijk verdeeld. De snelle transformatie van de economische structuur in combinatie met een beleid dat de verspreiding van baten over regio's en bevolkingsgroepen beperkt, heeft geleid tot een stijging van de inkomensongelijkheid tussen urbane en rurale regio's die de sociale stabiliteit en toekomstige economische groei belemmert. Hogere urbane inkomens trekken grote aantallen rurale migranten. Door het naar huis sturen van geld geven deze migranten de hogere inkomens deels door aan de rurale gebieden. Toegang tot urbane werkgelegenheid is echter afhankelijk van de hulpbronnen die huishoudens tot hun beschikking hebben, zodat ook een stijgende inkomensongelijkheid ontstaat in rurale dorpseconomieën.

Deze studie is de eerste kwantitatieve analyse van de invloed van ruraal-urbane migratie op een Chinese dorpseconomie. Het draagt bij aan de bestaande literatuur door een analyse van de invloed van interacties binnen een Chinees dorp op rurale huishoudbeslissingen. Alhoewel bestaande studies imperfecte markten relevant noemen in de Chinese context, is de invloed hiervan op interacties tussen huishoudens niet eerder kwantitatief geanalyseerd. Bestaande analyses van de Chinese economie concentreren zich of op geaggregeerde patronen op nationaal, provinciaal of districtsniveau, of op huishoudniveau. Imperfecte markten kunnen echter lokale inkomens- en uitgaveneffecten creëren, waardoor de beslissingen van huishoudens in een dorp elkaar onderling beïnvloeden. Rekening houdend met feedback in de dorpseconomie verandert de huishoudrespons ten opzichte van resultaten verkregen uit afzonderlijke huishoudmodellen, wat implicaties voor beleidsvorming kan hebben.

Naast de eerste kwantitatieve analyse van een Chinese dorpseconomie, levert deze studie drie bijdragen aan bestaande dorpsmodellen: (i) het rekening houden met de onscheidbaarheid van consumptie- en productiebeslissingen op huishoudniveau; (ii) het modelleren van de invloed van migratie op de huishoudconsumptie; en (iii) het empirisch vaststellen van de (on)scheidbaarheid van productiefactoren en intermediaire producten in productie.

Deze studie begint met het in kaart brengen van de bestaande literatuur over het modelleren van rurale huishoudbeslissingen. In hoofdstuk 2 ontwikkelen we een raamwerk dat als referentiepunt dient om een grote variëteit aan studies te vergelijken. Een model is een gesimplificeerde representatie van de werkelijkheid. De hierbij gemaakte keuzes worden over het algemeen niet expliciet besproken. Dit bemoeilijkt een vergelijking tussen modellen en de identificatie van kritieke aannames die modeluitkomsten bepalen. In hoofdstuk 2 bespreken we de belangrijkste keuzes die gemaakt moeten worden bij het modelleren van rurale huishoudens, en tevens de verschillende benaderingen die hiervoor in de literatuur gebruikt worden. Hiervoor brengen we verschillende literatuurstromingen samen in een matrix met twee dimensies: kernelementen en kernaspecten. De *kernelementen* beschrijven de essentie van een huishouden en zijn omgeving. De *kernaspecten* beschrijven de fundamentele keuzes die nodig zijn om de kernelementen in een model te representeren.

De vijf kernelementen van een model van rurale huishoudbeslissingen zijn *natuurlijke hulpbronnen, technologie, huishouden, markten* en *niet-markt instituties*. Voor elk van deze vijf kernelementen komen vier kernaspecten aan de orde. Alle kernelementen worden *geconceptualiseerd* in het model. Na het definiëren van de kernelementen worden *interacties* tussen gelijke elementen (bijvoorbeeld tussen huishoudens) en tussen verschillende elementen (bijvoorbeeld tussen huishoudens en natuurlijke hulpbronnen) gedefinieerd. De overige twee kernaspecten zijn *aggregatie* (hoe om te gaan met verschillen tussen individuele eenheden) en *dynamiek* (hoe om te gaan met verandering in de tijd). De combinatie van vijf kernelementen met vier kernaspecten geeft een matrix met twintig cellen die, toegepast op een specifiek model, de essentiële keuzes samenvatten die gemaakt zijn in het model.

In hoofdstuk 3 vervolgen we de literatuurstudie door de matrix van kernelementen en kernaspecten toe te passen op bestaande huishoud-, dorps- en subregionale modellen. Naar aanleiding hiervan kunnen we een derde dimensie, modelbenadering, toevoegen aan de keuzes die gemaakt moeten worden tijdens het ontwikkelen van een toegepast model: gereduceerde vorm, optimalisatie of een systeem van vergelijkingen. De keuze van modelbenadering beïnvloedt de manier waarop omgegaan wordt met de kernelementen in het model. Relevantie van specifieke kernelementen is afhankelijk van de onderzoeksvraag en bepaalt daarmee de modelbenadering. Het overzicht van bestaande modellen geeft aan dat een evenwichtsmodel op dorpsniveau een veelbelovende benadering is om interacties tussen huishoudens te modelleren. Tevens toont de literatuurstudie aan dat bestaande dorpsmodellen niet de bevindingen van de huishoudliteratuur over de invloed van marktimperfecties op huishoudbeslissingen reflecteren.

Het tweede deel van hoofdstuk 3 presenteert de structuur van het dorpsmodel ontwikkeld in deze studie. Het dorpsmodel gebruikt de structuur van een algemeen evenwichtsmodel op macroniveau. Maar deze structuur is zodanig aangepast dat het gedrag van de huishoudens overeenstemt met de rurale huishoudliteratuur. Het resultaat is een hybride dorpsmodel dat rekening houdt met de interacties tussen huishoudens in een dorp, terwijl de individuele rationaliteit gewaarborgd blijft. De positie van huishoudens als netto kopers, autarkisch of netto verkopers is endogeen in het model. Zowel de onscheidbaarheid van consumptie- en productiebeslissingen als de endogene marktpositie van huishoudens wijken af van bestaande dorpsmodellen. Verder biedt het gebruik van een algemeen evenwichtsstructuur, zelfs als er slechts enkele lokale dorpsmarkten zijn, een krachtige controle op de consistentie van het model.

In hoofdstuk 4 verschuiven we de aandacht van een vergelijking van modelbenaderingen naar het in kaart brengen van de economie van een Chinees dorp. Het voor deze studie als case gebruikte dorp ligt in het noordoosten van de Jiangxi provincie en is representatief voor rijst producerende dorpen in de vlakke gebieden van deze provincie. Voor dit dorp creëren we een sociale accounting matrix (SAM) waarop het dorpsmodel in hoofdstuk 5 gekalibreerd wordt. We beginnen met het definiëren van vier groepen representatieve huishoudens gebaseerd op het eigendom van trekkracht (dierlijk of tractoren) en de toegang tot migratie naar buiten de provincie. Dit beschrijft de verschillen in toegang tot inkomen uit de landbouw en door migratie.

We vervolgen de analyse met toetsing van de hypothese van scheidbaarheid van productie- en consumptiebeslissingen van huishoudens. Deze verwerpen we voor de meerderheid van de huishoudens. Onscheidbaarheid impliceert niet-observeerbare schaduwprijzen. Dit bemoeilijkt het construeren van een SAM op basis van waardestromen. We schatten daarom een agrarische productiefunctie voor het bepalen van de schaduwprijzen van arbeid, van geïrrigeerd land (beide zijn imperfect verhandelbaar) en van drie goederen die niet verhandelbaar zijn op huishoudniveau (mest, gewasresten gebruikt als veevoer en niet-geïrrigeerd land). De geschatte schaduwprijs voor geïrrigeerd land geeft aan dat de landmarkt beperkt is vanuit de aanbodskant en bevestigt hiermee de observatie van een sterk verstoorde landmarkt in de uitgevoerde huishoudenquête. Met een complete set van (gedeeltelijk huishoud-specifieke) prijzen construeren we een gedetailleerde SAM met elf huishoud-specifieke productieactiviteiten. Hierin onderscheiden we externe inputs, transportkosten, en verschillende typen geldstromen tussen de huishoudens en met de rest van de wereld. Een geaggregeerde versie van deze gedetailleerde SAM vormt de basis van de toegepaste modellen in latere hoofdstukken.

In hoofdstuk 5 ontwikkelen we de eerste versie van het Chinese dorpsmodel. Productie en nut worden beschreven met eenvoudig te kalibreren maar restrictieve Cobb-Douglas functies. Hierdoor blijft de aandacht in dit hoofdstuk gericht op de interacties tussen de huishoudens. De marktstructuur in het toegepaste dorpsmodel is namelijk anders dan gebruikelijk in modellen op macroniveau. Dorpsprijzen liggen vast voor de meeste producten. Dit resulteert in vraaggedreven markten en het bestaan van winsten. De uitzondering is de dorpsmarkt voor dierlijke tractie, waar het evenwicht bepaald wordt door endogene dorpsprijzen.

Het tweede deel van hoofdstuk 5 analyseert de invloed van interacties binnen het dorp op de respons van huishoudens. Door het toepassen van een 'partial closure' verdelen we het dorpsmodel in losse huishoudmodellen. Vergelijking van de resultaten van deze losse huishoudmodellen met die van het dorpsmodel geeft de invloed van interacties op de huishoudrespons. We simuleren een stijging van het inkomen ontvangen van migranten van buiten de provincie. Voor welvaart en inkomensindicatoren toont de vergelijking weinig verschil aan. Maar bij het analyseren van de agrarische exporten vanuit het dorp worden de verschillen tussen de twee benaderingen onmiskenbaar: rekening houdend met feedback tussen huishoudens halveert ruwweg de respons in het dorpsmodel ten opzichte van de losse huishoudmodellen.

Het verschil in productierespons in het dorpsmodel is het gevolg van interacties in de dorpsmarkt van dierlijke tractie. Als reactie op het toegenomen inkomen door de migranten, verschuiven huishoudens met relaties buiten de provincie naar een arbeidsextensiever en kapitaalintensiever productiepatroon. De verschuiving naar een arbeidsextensiever productiepatroon gaat gepaard met een daling van de vraag naar dierlijke tractie. De resulterende prijsdaling maakt intensievere productie weer aantrekkelijker. Dit maakt een deel van de initiële invloed van een verhoging van inkomen op huishoudens met relaties buiten de provincie ongedaan. Voor de huishoudgroep die geen relaties buiten de provincie heeft maar wel trekdieren bezit betekent de dalende vraag naar dierlijke tractie een verlies aan inkomen, resulterend in een arbeidsintensievere productie. Het kleine verschil in welvaart en inkomen tussen het dorpsmodel en de huishoudmodellen verbergt dus achterliggende productieverschuivingen die het gevolg zijn van dorpsinteracties.

Hoofdstuk 5 analyseert de respons van huishoudens op een verhoging van inkomen ontvangen van huishoudleden die buiten de provincie werken. De reden voor deze analyse is de verwachte expansie van de arbeidsintensieve urbane industrie in China, volgend op de verdergaande liberalisatie van de internationale handel. Naast een toename van het inkomen, is het waarschijnlijk dat deze urbane expansie meer (tijdelijke) rurale migranten aantrekt. Hoofdstuk 6 analyseert derhalve de impact van een toename van de migratie buiten de provincie. Om een analyse van de invloed van migratie op consumptie mogelijk te maken worden de vraagfuncties op huishoudniveau vervangen door vraagfuncties op basis van volwassenenequivalenten. Om uitgavenpatronen van huishoudens afhankelijk te maken van het inkomen wordt tevens de Cobb-Douglas nutsfunctie vervangen door een Stone-Geary nutsfunctie. De van de nutsfunctie afgeleide vraagfuncties worden gekalibreerd met inkomenselasticiteiten die geschat zijn in overeenstemming met de aannames in het dorpsmodel. Dit contrasteert met het gangbare gebruik van elasticiteiten uit de literatuur in algemeen evenwichtsmodellen op macroniveau . Vergelijken we de resultaten van hoofdstuk 5 en 6, dan vinden we dat de resultaten met betrekking tot inkomen en welvaart robuust zijn bij het veranderen van de nutsfuncties. Resultaten met betrekking tot het vermarkte surplus op dorpsniveau zijn daarentegen gevoelig voor de functionele vorm van de nutsfunctie. Bij stijgende inkomens neemt nu de consumptie van op het bedrijf geproduceerde producten af, wat de veranderingen in agrarische dorpsexporten vergroot.

De resultaten met betrekking tot het huishoudinkomen zijn robuust als we het inkomen ontvangen van migranten of migratie verhogen. Voor de analyse van de welvaartseffecten en productierespons is het echter wel van belang of alleen het inkomen uit migratie of migratie zelf verhoogt wordt. Een vergelijkbare inkomensverhoging op huishoudniveau leidt tot een hoger welvaart bij hogere migratie dan bij enkel inkomensstijging. Dit komt door de verminderde consumptiebehoefte bij een hogere migratie. De verandering in huishoudgrootte als gevolg van migratie verandert verder de productierespons omdat arbeid schaarser wordt. Het uiteindelijke resultaat is dat de welvaartsstijging bij een hogere migratie groter is dan die bij enkel een stijging in migratie-inkomen, ook voor huishoudens die niet zelf deelnemen aan migratie naar buiten de provincie.

Voor de agrarische aanbodrespons op dorpsniveau zijn dus niet alleen interacties binnen het dorp van belang, maar ook of de expansie van urbane werkgelegenheid in de kustprovincies wordt doorgegeven via het inkomen dat migranten naar huis sturen of dat dit de stroom van migranten vergroot. Een grotere migrantenstroom versterkt de verschuiving van rijst naar veeteeltproductie. Deze verschuiving in de agrarische productie wordt niet meegenomen in bestaande studies van de invloed van migratie op de landbouwproductie in China. Dit is echter wel belangrijk voor beleidsvorming omdat stijgende urbane inkomens migranten aantrekken, dat gepaard gaat met een verschuiving van graan- naar vleesconsumptie.

De productierespons van huishoudens hangt af van de substitutiemogelijkheden binnen een productieactiviteit en van verschillen in substitutiemogelijkheden tussen productieactiviteiten. Substitutiemogelijkheden worden bepaald door de gekozen functionele vorm en parameters van de productiefunctie. In hoofdstuk 7 verschuiven we dan ook de aandacht naar het modelleren van productieactiviteiten. Gebruikmakend van de verzamelde huishouddata toetsen we de hypothese van scheidbaarheid van inputs. Het resultaat is dat elke activiteit een andere functionele vorm vereist. Dit impliceert een verscheidenheid aan substitutiemogelijkheden tussen activiteiten en tussen huishoudens in het model. De gekalibreerde productiestructuren verwerpen de hypothese van scheiding van factoren en intermediaire producten, zoals gewoonlijk aangenomen in algemeen evenwichtsmodellen en in bestaande dorpsmodellen.

Gekalibreerde substitutie-elasticiteiten van de geneste CES productiefuncties in hoofdstuk 7 verschillen van de unitaire substitutie-elasticiteiten van de Cobb-Douglas gespecificeerd in eerdere hoofdstukken. Er is geen consistent patroon in deze verschillen. Dit impliceert dat we niet op voorhand kunnen concluderen dat de Cobb-Douglas specificatie de substitutiemogelijkheden over- of onderschat.

Om de impact van een verandering van de productiefunctie vast te stellen herhalen we de simulatie van een toegenomen migratie uit hoofdstuk 6. Alhoewel in kwalitatieve termen de huishoudrespons identiek is aan de respons in eerdere hoofdstukken, genereren geneste CES productiefuncties kwantitatieve verschillen. De geneste CES productiefuncties leiden ook tot een gematigder productierespons door het vergroten van de substitutiemogelijkheden tussen inputs. Dit biedt meer mogelijkheden voor aanpassing, waardoor de reactie van huishoudens op veranderingen in de externe omgeving gematigd wordt. Daarnaast zijn met de geneste CES productiefuncties de baten van migratie hoger voor huishoudens actief in migratie, terwijl huishoudens zonder toegang tot migratie minder meedelen in deze baten. Dit verschil loopt op tot een 63 procent lagere stijging in huishoudinkomen voor de huishoudgroep zonder toegang tot migratie en met eigendom van tractie. Voor beleidsvorming impliceert het gebruik van geneste productiefuncties dus een grotere zorg voor een toenemende inkomensongelijkheid als gevolg van ongelijke toegang tot migratie.

Hoofdstuk 8 besluit de studie door terug te keren naar de matrix van kernelementen en kernaspecten uit hoofdstuk 2 om de bijdrage en beperkingen van deze studie vast te stellen. De essentiële keuzes gemaakt tijdens het ontwikkelen van het dorpsmodel zijn gebaseerd op het combineren van inzichten uit de huishoudmodellering en algemeen evenwichtsmodellen en op de kenmerken van de Chinese dorpseconomie die als casestudie is gebruikt. Het resultaat is een hybride model, dat standaard kenmerken van huishoud optimalisatiemodellen (zoals onscheidbaarheid van consumptie- en productiebeslissingen) combineert met standaard kenmerken van algemeen evenwichtsmodellen (zoals interacties tussen huishoudens). Waar mogelijk zijn huishouddata gebruikt om de structuur van het model en van de functionele vormen te bepalen. In het geval dat onvoldoende data beschikbaar waren, bijvoorbeeld om de handelsstromen tussen huishoudgroepen te bepalen, is de meest simpele oplossing (zoals vaste aandelen in markten) gekozen om de modelresultaten zo traceerbaar mogelijk te houden.

De belangrijkste beperkingen van het huidige model zijn het gebrek aan data over de dorpsmarkten voor land en krediet. Beide zijn instrumenteel in het verspreiden van de baten van migratie door de dorpseconomie. Een andere veelbelovende richting voor verder onderzoek is om de huidige statische versie van het model om te zetten naar een dynamisch model. Het in deze studie ontwikkelde dorpsmodel biedt een degelijke basis voor dergelijke verder onderzoek. De stappen genomen om het model te ontwikkelen kunnen ook toegepast worden op andere dorpen in China en in andere landen. De benadering gebruikt in deze studie leidt tot een toegepast dorpsmodel dat stevig verankerd is in de huishoudtheorie en dat hiermee de bestaande kloof tussen huishoudmodellen en dorpsmodellen overbrugt. Het resultaat is een case-specifiek dorpsmodel dat gebruikt kan worden om (beleids)inzichten te krijgen, die niet verkregen kunnen worden met een ander type model.

CURRICULUM VITAE

Marijke Helene Kuiper was born April 30th, 1972 in Wageningen, Nickerie District, Surinam. She studied at Wageningen University from 1990 to 1993, and from 1994 to 1997, obtaining a M.Sc. degree with honors in Rural Development Studies, with a major in Development Economics. From 1993 to 1994 she studied political science and psychology at Western Washington University, with an Ambassadorial Scholarship of the Rotary Foundation of Rotary International. For her practical training and M.Sc. thesis she worked 8 months at the REPOSA project in Costa Rica. The resulting M.Sc. thesis on a multi-period economic land use model of the Neguev settlement in Cost Rica was awarded the C.T. de Wit Thesis Award in 1998. For her second M.Sc. thesis on a game-theoretic model of joint implementation projects for abatement of greenhouse gasses she spent 3 months at the Department of Energy, Environmental and Mineral Economics, Pennsylvania State University.

In January 1998 she was appointed as a Ph.D. researcher at the Development Economics Group of Wageningen University. The Ph.D. research was conducted within the context of the SERENA project, a cooperation between Nanjing Agricultural University (China), Wageningen University, and the Institute of Social Studies (The Hague), financed by the Netherlands Ministry of Development Cooperation (DGIS). The Ph.D. work included an explorative household survey in 24 villages, as well as detailed surveys in three case-study village of the SERENA project, carried out in close collaboration with researchers from the College of Land Management at Nanjing Agricultural University. As part of her Ph.D. research she spent three months at the Department of Agriculture and Resource Economics, University of California at Davis. In 2002 she successfully completed the doctoral training program of the Netherlands Network of Economics (NAKE).

Her Ph.D. research has been combined with other appointments. From 1999 to 2002 she was assistant project coordinator for EPISODE, an EU-financed project on economic policy reforms and soil degradation in Ethiopia, Kenya and China. In the context of this project she co-edited a volume on bio-economic modeling (N. Heerink, H. van Keulen, M. Kuiper (2000) *Economic Policy and Sustainable land Use: Recent Advances in Quantitative Analysis for Developing Countries,* Heidelberg: Physica-Verlag).

From 2002 on she holds an appointment as researcher at the Agricultural Economics Research Institute (LEI) in The Hague, working for the Trade and Development Division. Research focuses on international trade with specific attention for the position of developing countries. From 2004 on she also holds an appointment as post-doc researcher for the RESPONSE project, a cooperation between Wageningen University and the International Food Policy Research Institute (IFPRI) to analyze policy options for less-favored areas.

TRAINING AND SUPERVISION PLAN

Description	*Institute*	*Year*	*Credits*
General courses:			
Projectmatig Werken in Onderzoeksgroepen	DLO/Kern Konsult	1999	2
Techniques for Writing and Presenting a Scientific Paper	Mansholt Graduate School	2001	2
Multi-disciplinary courses/activities:			
Mansholt course Institutions	Mansholt Graduate School	1999	3
Multi-disciplinary seminar	Mansholt Graduate School	2004	1
Multi-Agents Systems for Natural Resource Management	Mansholt Graduate School	2001	2
Discipline-specific courses:			
Microeconomic Theory	Tinbergen Institute	1998	4
Macroeconomic Theory	Tinbergen Institute	1998	4
Political Economy of Transition	NAKE[2]	1998	2
Current Issues in development Economics	NAKE[2]	1998	2
Mathematical methods	Tinbergen Institute	1999	4
SAM and CGE Models for Development Analysis	Nordic Ph.D. course	1999	2
Applied General Equilibrium Models	NAKE[2]	1999	2
Regional Economics, Agglomeration and the Global Economy	NAKE[2]	2000	2
New Institutional Economics	NAKE[2]	2002	2
Presentations at international conferences:			**2**
Fifth Biennial Meeting of the International Society for Ecological Economics, Santiago, Chile		1998	
Environment and Development 2nd International Conference, Stockholm, Sweden		2000	
American Agricultural Economics Association Annual Meeting, Long Beach		2002	
7th Annual Conference on Global Economic Analysis, Trade, Poverty and the Environment, Washington D.C. , United States		2004	
85th European Association of Agricultural Economists seminar "Agricultural Development and Rural Poverty under Globalization: Asymmetric Processes and Differentiated Outcomes", Florence, Italy		2004	
Teaching activities:			
Quantitative Analysis of Development Policy	Wageningen University	1998/99	
Quantitative Analysis of Development Policy	Nanjing Agricultural University, China	1998	
Total (min. 20 credits)			**36**

[1] 1 credit represents 40 hours; [2] NAKE stands for Netherlands Network of Economics.

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