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Rethinking the Supply Response to Market Reforms in Agriculture: Household Heterogeneity in Village General Equilibrium Analysis from Mexico

George A. Dyer, J. Edward Taylor and Steve Boucher[*]

Abstract

We present a new, village general-equilibrium modeling approach to explain agricultural households' apparently perverse responses to policy reforms. Most supply-response studies are partial, ruling out the transmission of influences among households. We propose a general-equilibrium approach that integrates individual agricultural household models into a village economy wide model. Simulation results illustrate how changes in staple prices and other policy shocks influence production even in subsistence households facing high transaction costs. Findings offer an explanation for the lack of supply response to lower maize prices in Mexico following NAFTA.

I
Introduction

Governments in less developed countries (LDCs) often have been frustrated by agricultural households' apparently perverse response to policies. Economists have gone a long way towards explaining "hidden" motivations underlying household responses. Kuroda and Yotopoulos (1978) and Singh *et al.* (1986) described the effect of agricultural profits on the marketed surplus of staples; Finkelshtein and Chalfant (1991) and Fafchamps (1992) elaborated on the effects of multivariate price risk on production and consumption, and de Janvry *et al.* (1991) explain an inelastic supply response in households facing high transaction costs. However, economists often have as much difficulty as government officials in predicting micro responses to agricultural policies.

The basic premise of this paper is that interactions among heterogeneous actors in a local general-equilibrium context shape the outcomes of policy changes in developing rural economies. Others have suggested that high transaction costs isolate some rural households from changes in staple prices (*e.g.*, de Janvry *et al.*, 1995; Key *et al.*, 2000). However, interactions among households through multiple (input and output) markets ensure that no rural household is entirely unaffected by a given policy or market shock, even in a predominantly subsistence economy. We demonstrate empirically that a small number of commercial farms can be sufficient to transmit the impacts of policy and market changes into a village and generate unexpected outcomes, including negative output elasticities with respect to market prices.

We integrate 48 individual agricultural-household models into a village-wide computable general equilibrium (CGE) model to illustrate the role of interactions among heterogeneous households in shaping supply response. We show how market shocks are transmitted into a predominantly subsistence economy, subjecting different households to different sets of indirect influences and generating household-specific responses. We then describe how these responses affect the aggregate supply response.

In Zoatecpan, a village in east-central Mexico, differences in land endowments are critical in explaining contrasting responses to maize-price changes, with some households reducing maize production and others expanding it. Simulations suggest that responses of maize growers to recent policy changes have largely cancelled each other out, leaving the impression of a lack of responsiveness to reforms.

Household heterogeneity and supply response

The ability to predict supply response (or lack of response) in less-developed rural economies is limited by the lack of an integrated macro-microeconomic analysis that accounts for interactions among heterogeneous rural households. Countrywide models capture aggregate general-equilibrium effects, but (as pointed out by de Janvry *et al.*, 1995) they necessarily neglect heterogeneity across rural households revealed in microeconomic analysis. Microeconomic models have their own limitations. In order to predict aggregate responses, it is not sufficient to add up responses estimated from representative micro-household models. One must also account for interactions among heterogeneous households in local markets.

Heterogeneity in households' endowments largely determines participation in markets. For instance, only relatively land-rich households that produce a surplus participate in commodity markets, while land-poor and landless households must engage

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in labor markets to earn cash income. Heterogeneity is inconsequential to agricultural production under the assumption of perfect markets, but this assumption is rarely valid in less-developed rural areas, where missing or incomplete markets tie production to consumption and household preferences (Singh *et al.*, 1986; de Janvry *et al.*, 1991). Transaction costs may limit some producers' access to extant markets, causing markets to be thin or entirely absent. Missing markets influence production decisions by generating household-specific shadow values that differ from the market price of output. Transaction costs generate a band around the market price of a good that buffers the household from output-price fluctuations (de Janvry *et al.*, 1995; Key *et al.*).

As long as some of the output in a village remains tradable, subsistence producers are not likely to be isolated from price changes, because of their involvement in other local markets. A household's participation in a market determines its initial reaction to a shock in that market, but since shocks in one market are transmitted to other markets, a household's particular integration into the local economy determines its overall response (Taylor and Adelman, 1996). For instance, only surplus growers react to shocks in commodity markets, but they transmit these shocks to subsistence and landless households who work for them. The aggregate supply response reflects indirect or general equilibrium effects of changes in the complete set of prices, including household-specific shadow prices, in the local economy. The interplay of households' heterogeneous responses in local and regional markets determines aggregate responses to policy changes.

Local conditions are absent from both single-household models and countrywide CGE models, but they are central to village-wide models. To date, village models' potential for capturing interactions among heterogeneous households has not been fully realized for two reasons. First, models have not allowed for differences in household-specific response to exogenous shocks, such as differences between surplus and subsistence growers. Second, although village models have been used to explore impacts of policy shocks under various labor and staple-market scenarios, they have not incorporated local land markets. In Mexico, privatization of ejido, or reform-sector, lands potentially increases the flexibility of land markets in response to output-price changes.[1]

We use a village-wide model to demonstrate how interactions among surplus and subsistence households in local markets shape the outcomes of a nationwide change in the price of maize and the effectiveness of compensatory policies. Our model allows for heterogeneous household responses to market signals by incorporating household-specific shadow prices for subsistence maize production. A series of individual household-farm models is embedded within the village model. This makes it possible to link micro responses with aggregate outcomes in a manner not possible using conventional computable general equilibrium approaches.

II
The Model

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[1] Despite legal restrictions on *ejido* land, rental was already common throughout rural Mexico prior to the recent reform of land tenure laws (Dewalt and Rees, 1994).

Rather than being aggregated into groups as in other CGE models, households in our model respond individually to changes in market prices. Agricultural household models are the building blocks of the village model. As in Strauss, deJanvry, Fafchamps and Sadoulet, and others, households maximize utility U(**CD**) where **CD**=[$CD_1, CD_2, \ldots, CD_{ip}$] is a vector of traded and/or nontraded (i.e., subsistence) goods, subject to:[2]

(a) An income (Y) constraint:
$$Y = \sum_{f \in tradables} Y_f + \overline{Y} \leq 0$$

where Y_f is household income from supplying factor f to activities on or off the farm and $\overline{Y}$ denotes exogenous income;

(b) A subsistence constraint equating output to consumption for nontradables:
$$Q_{ip} = CD_{ip} \text{ for ip} \in \text{nontradables; and}$$

(c) Technology constraints in the form of production functions:
$$Q_{ip} = Q_{ip}(L_{ip}, x_{ip}; \overline{A}_{ip})$$

where L_{ip} and x_{ip} are, respectively, vectors of variable factors and inputs, and $\overline{A}_{ip}$ is a vector of fixed factors and inputs.

This constrained optimization problem yields supply functions of the form:
$$Q_{ip}^* = Q_{ip}^*(P, \overline{A}_{ip})$$

where $\overline{A}_i$ includes land if there is no rental market, and demand functions of the form
$$CD_{ip}^* = CD_{ip}^*(P, Y)$$

For a given household, the vector P may include three different kinds of prices: prices exogenous to the village, $\overline{P}$; prices exogenous to households but determined by equilibrium conditions in village markets, P^e; and household-specific "shadow prices," r. That is, $P = [\overline{P}, P^e, r]$, where $\overline{P}$, P^e and r are vectors.

The genesis of prices is central to micro economy-wide models because endogenous prices are a primary vehicle through which influences are transmitted among (and within) households in the local economy. Table 1 summarizes how the prices a given household "sees" are determined under alternative agricultural household and village model specifications. In what we call the textbook agricultural household model, all prices are exogenously determined in extra-village markets; i.e., $p_{ip} = \overline{p}_{ip} \ \forall$ ip. [The exception is land, which is generally assumed to be a fixed input and thus implicitly has a household-specific shadow price.] In the autarkic or subsistence household model, prices are endogenous household-specific "shadow prices" at which the constraint $Q_{ip} = CD_{ip}$ holds; i.e., $p_{ip} = r_{ip}$ for ip $\in$ nontradables. In village models, prices may either be: determined outside the village ($p_i = \overline{p}_i$); household-specific shadow prices ($p_i = r_i$); or village-equilibrium prices, exogenous to the household but endogenous to the village ($p_i = p_i^e$). An example of the latter would be prices for goods or factors (e.g., land or

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[2] For simplicity, we suppress household subscripts; all equations correspond to households, unless otherwise noted.

labor) that are tradable within the village but not between the village and the rest of the world. Village equilibrium prices are determined by the condition $\sum_{h} MS_{h,ip} = 0$, where

$MS_{h,ip}$ is the marketed surplus of good ip in household h. (In the case of village tradables, the price is exogenous and $\sum_{h} MS_{h,ip}$ equals the village marketed surplus, or net sales to outside markets.)

Comparative statics are complex, involving direct effects (e.g., Slutsky effects of exogenous price changes on demands) as well as indirect effects (household-farm profit effects and influences acting through endogenous village equilibrium prices and household-specific shadow prices). This multiplicity of direct and indirect effects renders comparative statics analytically intractable; signing as well as quantifying total impacts of policy shocks requires the use of a programming approach—in this case, a village CGE model.

The village model was programmed using GAMS. Building on previous village-wide models, the model includes the five equation blocks described by Taylor *et al.* (1999a,b; 2001), but for individual agricultural households instead of for household groups: (1) a production block, (2) an income block, (3) an expenditure block, (4) a set of general-equilibrium-closure equations, and (5) a price block. It also incorporates two new equation blocks: (6) a household-surplus block and (7) a village-supply block. Equation blocks (1) – (3) and (6) define household behavior; blocks (4) and (7) define closure for village markets. The variables in the model are defined in Appendix 1, and the village model is summarized in Appendix 2.

Household Blocks

The production equation block includes one equation per household per activity, so the difference between production and consumption determines the household's activity surplus, not the village-wide surplus.[3] The difference between production and consumption at the household level constitutes the household-surplus block.

The production block consists of a production function and a set of factor demand equations for each household activity. Production technologies are specified as Cobb-Douglas. Household activities are defined over six different sectors: maize and other agriculture, livestock (hogs and chickens), non-agricultural goods and commerce. Factors include local and migratory labor, land, animal capital and other capital. Land and local labor are tradable among households; migratory labor, animal capital and other capital are household non-tradables. Household income is the sum of factor income (including migrant remittances) and government subsidies (including Procampo; see **Simulations**, below). The expenditure block is defined over subsistence activities (*e.g.*, maize production for subsistence households) as well as market goods.[4] Consumption demands are modeled using a linear expenditure system (LES) with no minimum

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[3] This is in contract to previous village models, in which the production block consists of one production function per activity implying that households share production technologies.

[4] Subsistence households spend part of their income on activities such as maize production (purchasing inputs) in order to consume their market and non-market benefits. For them, home-produced maize is a type of "Becker" good.

required quantities (Deaton and Muellbauer, 1980).[5] Prices are endogenous for subsistence activities and determined by internal household supply-demand equilibria. Changes in the market price of maize may have indirect influences on subsistence production. In a micro household-farm model with missing markets, this would happen only if the subsistence household moved out of the price band. In our model, it results from market interactions among households; subsistence households in the model remain within their staple-price bands.

Market Block

The equation blocks described in the previous section determine the behavior of 48 individual households. The remaining equations aggregate these households into village markets. The village-supply block sums household activity surpluses to obtain village-wide commodity supplies. This requires a set of commodity accounts in addition to production accounts. The village-supply block is similar to the commodity-production-and-allocation block used in countrywide models (see Löfgren *et al.*, 2001), transforming activity outputs of household tradables into commodity surpluses using fixed coefficients. The general-equilibrium closure equations determine the (net) marketed surplus of tradable commodities as the difference between village-wide supply and demand. Prices for village tradables are exogenous, determined in markets outside the village. Prices of village nontradables are endogenous. If village markets exist, these prices satisfy local market-clearing conditions, and individual households are price takers within the village. If village markets do not exist, prices are unobserved household "shadow prices." Total supplies of land and labor are fixed at the village level—that is, wages, like land rents, are endogenous. We believe that this assumption is realistic. Although the Mexican rural labor force is relatively mobile, significant variation in the agricultural wage across the countryside suggests the existence of market imperfections generating local wages or at least significant wage rigidities.[6] In our simulations, below, we test the sensitivity of our results to the endogenous-wage assumption.

III
Simulations

We use the village-wide model to explore the implications of a decrease in the market price of maize (reflecting recent price reforms) and two alternative cash-transfer programs that are cornerstones of Mexico's policy reforms. First, we simulate the village-wide and household-specific impacts of a 10-percent decrease in the market price

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[5] Although more complicated functional forms are possible, our experience with micro economy-wide models suggests that little is gained from the use of alternative functional forms—and necessary "guesstimates" of accompanying elasticities. We have found the results of our policy experiments using similar models to be robust to the specification of functional forms; see Taylor *et al.*, (1999b). This is not surprising, inasmuch as the model is always calibrated at the same point given by the survey data, and policy experiments involve marginal changes in exogenous variables. These functional forms permit estimation of a a separate model for each agricultural household in the sample. It should be emphasized that, despite these simplifying assumptions at the household level, aggregate responses to price and other shocks are highly nonlinear, pieced together from outcomes in each of the households in the model and shaped by indirect influences on incomes and prices.

[6] According to data from the 2003 Mexico National Rural Household Survey (Encuesta a Hogares Rurales de Mexico—ENHRUM), daily wages in rural Mexico ranged from 40 to 140 pesos in summer 2003 (estimates by authors).

of maize.[7] Two alternative compensatory programs are simulated concurrent with a price decrease to evaluate their effect on income distribution and its consequences for production. In the first, households receive a subsidy proportional to the amount of land cultivated in maize in the base case. The aggregate subsidy for the village is equal to the decrease in village maize output (valued at market prices) that results from the 10-percent decrease in price. This replicates the Procampo agricultural subsidy, introduced in 1994 in the context of NAFTA to compensate rural households for the loss of revenue from declining agricultural prices (Sagarpa, 2001). In the second simulation, all household heads receive a cash payment of [$161] that, aggregated across households, is also equivalent to 10 percent of the average base value of maize production.

Since there is no reason to expect households to earmark additional income from a given source when deciding how to spend it, Procampo and lump sum transfers could have similar effects on a village's economy. However, an important difference between the two programs arises from the distribution of payments. Procampo payments are proportional to farmers' land use. Hence, we would expect Procampo to accentuate differences in the distribution of income with particular consequences for maize production.[8] The total cost of subsidies in both simulations is assumed to be the same in order to facilitate comparison.

Thinking About Impacts of Market-Price Shocks

Given the complexity of the model, it may be helpful to compare the potential impacts of a decrease in market price of staples in the village model with those in micro agricultural-household models.

In the textbook agricultural household model, where the household has fixed land inputs and is a price taker, a decrease in staple price unambiguously reduces output, regardless of whether the household is commercial (produces a marketed surplus) or not (Singh, Squire and Strauss, 1986). In the autarkic or subsistence household model with endogenous shadow prices, a change in market price of the staple has no effect (unless it nudges the household out of its "price band;" see Strauss, 1986; deJanvry, Fafchamps and Sadoulet, 1991; Key et al., 2000). In a village composed entirely of subsistence households, by extension, a change in market price would not affect output (Holden, Taylor and Hampton). Micro agricultural-household models are partial, in the sense that they rule out the transmission of price shocks through local market linkages.

It takes only a single commercial staple household in a village to transmit a change in market price to subsistence households. The channels through which this price transmission may occur depend on the structure of local markets. Consider three scenarios, which are analogous to the ones we use in our simulations:

    a. Exogenous wage and fixed land inputs. Most micro agricultural household models assume that land (like other capital) is fixed and wages are exogenous, determined either in outside (regional, national, or international) markets or

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[7]A 10-percent decrease is chosen for convenience. Maize prices actually dropped 13% between 1994—the start of NAFTA—and 1999—the year of our survey (INEGI, 2003). Although the international price of maize is expected to drop 9% before maize trade is completely liberalized (FAPRI, 2003); however, it is impossible to predict the drop in the domestic price due to uncertainty in Mexican agricultural policy (Yúnez and Barceinas, 2000) and politics (see Dyer and Dyer, 2003).

[8] By construction, the Gini coefficient for Procampo transfers in our sample (0.562) is the same as for land use; see below.

else by some kind of non-market mechanism (e.g., Lewis). Commercial producers scale back production in response to a decrease in output price and reduce their demand for labor from subsistence households. This affects subsistence household incomes negatively or not at all, depending upon the labor-market allocation mechanism:

> i. *Labor-Market Rationing or "Friction."* Wages are set institutionally, as in Lewis, and decreased demand for labor on commercial farms increases unemployment in subsistence households. Households cannot adjust by allocating labor to other (e.g., migration) labor activities. This protects household income, relatively to a flexible wage scenario (see below) but does not entirely prevent a negative income effect on subsistence households' demand for the staple, driving down their staple "shadow price." Output on subsistence farms falls, reinforcing the negative effect of the market price change on commercial output. This is represented graphically by a leftward shift in subsistence households' staple-demand curve.

> ii. *Migration.* Wages are set in outside (regional, national, or international) markets to which those displaced on local commercial farms may supply their labor. Income, and thus output, on subsistence farms remains the same; only the source of wage income changes.

The results of Scenario (a) may be different if commercial households can shift resources, including land and labor, into other production activities. If the alternative production activity is relatively labor intensive, total demand for labor on commercial farms theoretically could increase as a result of the decrease in staple price. This would result in higher subsistence-household incomes and staple production in Scenario a(i). Traditional staple production (e.g., maize in Mexico), however, tends to be relatively labor intensive.

b. <u>Endogenous wage and fixed land</u>. Local wages fall in response to commercial farmers' decreased demand for labor. In contrast to the scenario a(i) where some individuals become unemployed, everyone is impacted by the lower wage. Lower wages create a positive input-price effect on production and labor demand, counteracting the negative effect of the lower output price. Commercial production and labor demand fall by less than in the fixed-wage scenario. This cushions the incomes of labor-supplying subsistence households to some degree. If subsistence households hire labor, their production may increase, despite a negative income effect on staple demand. Graphically, the negative income effect shifts subsistence households' demand inward by more than before, but the positive labor-cost effect shifts their supply (marginal cost) outward. The result of these competing influences may be an increase, rather than a decrease, in subsistence staple production.

c. <u>Local land market</u>. Decreased demand for land on commercial farms depresses local land rents. Because land is an input for both commercial and subsistence farms, lower rents stimulate output, ceteris paribus. Graphically,

the subsistence supply curve shifts further to the right, increasing the likelihood of an increase in subsistence production of staples.

While the scenario in (a) results in a decrease in subsistence-farm output in response to a change in the market price (even if the household remains within its price band), the scenarios in (b) and (c) create the possibility that production by subsistence households will increase in response to a decrease in the market price of the staple.

IV
Study Area and Data

Throughout modern history, marked heterogeneity among producers has characterized agriculture in Mexico, where a majority of land-poor, subsistence households coexists in more or less isolated markets with a small number of land-rich commercial (*i.e.*, surplus) growers (Hewitt, 1976; Esteva, 1982; Appendini, 1993). The extent of their interaction is such that social scientists often explain each group's actions in relation to those of the other group (see Bartra, 1982; Fox, 1992). This has not been the case in the economics literature. Mexican maize agriculture is also marked by panoply of market failures. Transaction costs have been described in relation to maize markets (de Janvry *et al.*, 1995; Key *et al.* 2000), and a diversity of crops and services associated with maize are typically non-tradable (see Clawson, 1985; Hernández, 1985; Martínez *et al*., 1995; Evangelista, 1998; Faust, 1998; González, 2001).[9] However, enormous geographical heterogeneity suggests that the particular combination of market failures affecting this sector varies widely.

Data to estimate the village model are from a 1999-2000 survey of 49 households in Zoatecpan, an indigenous community in the rugged Sierra Norte de Puebla, Mexico. Maize is overwhelmingly the main agricultural output in this village. Nearly all households own land, but endowments vary widely: 2% of households own 50% of the land, and the average land holding is only 0.4 hectares. There is an active land rental market in which nearly half of all households participated. Forty six percent of households rented in land (all for maize), and 5% of households rented out land. The fact that the few households that rented out land for maize are the largest landholders in the village does not make Zoatecpan an exception; this pattern is widespread in the region. The rental market fosters a more progressive distribution of arable land among local households and nearly doubles the cultivated maize area for the average household. Most (around 94%) of households are formally subsistence maize growers; only 4% can be considered commercial growers of maize (*i.e.*, households that grow maize with the intention to sell).

Quarterly household income and expenditure data were gathered over the 1999/2000 crop cycle by surveying a random sample of households representing slightly more than 10 percent of the village household population. To increase reliability, each household in the sample was interviewed four times (three months apart), and data were collected on the previous month's consumption. Income and production data were gathered for the entire quarter during each visit.

Social accounting matrices (SAMs) for each individual household, all nested within a village SAM, provide the basis for the estimation of model parameters. In

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[9] Non market benefits of maize include economic, social and ritual services; *e.g*., food security, income diversification and social standing.

accordance with first order conditions for household utility maximization, production factor shares in value added for each activity were used to estimate exponents, $a_{h,f,ip}$, in household-specific Cobb-Douglas production functions. Likewise, households' observed consumption shares were used to parameterize household-specific demand functions (Table 2). This allows us to obtain separate parameter estimates for every household in the sample. The calibrated village model reproduces the SAM in the base case.

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V

Results

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In each simulation, the model yields estimated impacts of the simulated changes on every household in the sample. This distinguishes the present model from previous village-wide models and is critical for estimating differential impacts of staple price shocks across households. Results of the maize-price experiments are reported in Tables 3 and 4, and the results of the two transfer experiments are summarized in Tables 5 and 6. These tables report village-wide impacts of the policy changes in the aggregate and separately for commercial and subsistence households. They also report distributional effects, as measured by Gini coefficients estimated from outcomes in individual households.[10]

Experiment 1: 10% Decrease in Market Price of Maize

A. With Local Land and Labor Markets.

Surplus growers perceive a decrease in the price of maize as a direct incentive to reduce production. Their demand for land and labor decreases substantially, forcing local rental rates and wages downward by 14.1% and 9.6%, respectively. Lower costs partially compensate lower output prices, but commercial production of maize still goes down by 28.5% in equilibrium. Marketed surplus, which is low in the base, shrinks by 57.2%. In contrast, because of lower costs, subsistence growers find it optimal to increase their scale of production, by up to 12.5%. Subsistence maize production increases 4.7% overall. Despite the fact that (by construction) both production factors are always fully employed, the less efficient use of land and labor by small subsistence growers results in a 4.9% decrease in the village's maize output. A smaller surplus and a higher demand for maize (due to the price drop) result in a 15.5% increase in the village's maize deficit.

Lower rents and wages due to the decrease in maize price reduce household incomes, decreasing the consumption demand for non-maize goods and services. Low demand for non-tradables harms local activities that do not make intensive use of land or labor, such as non-agricultural activities and, in some households, livestock. The price of village non-tradables drops, counteracting the drop in demand, but demand for fixed-priced imports decreases more sharply, spurring the decline of the formal-commerce sector. As a result, the village's GDP decreases by 7.3%. Although every household experiences a decrease in nominal income, changes in real income range from a 2.7% increase to a 12.4% decrease; 7 out of every 10 households experience a real-income decrease. Households engaged in formal commerce experience the greatest decreases, even greater than those of commercial maize growers. Households whose chief income source is migrant remittances, as well as those dependent on public welfare, experience

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[10] These are not obtainable from previous village or aggregate CGE models.

increases in real income. They benefit from the lower prices of local goods without being adversely affected by the decrease in local wages.

These events redistribute income in a marginally progressive fashion: the Gini coefficient for income drops from 0.356 to 0.351.[11] The redistribution of land use is also progressive: the Gini coefficient for land decreases from 0.562 to 0.518. Nearly 15% of households split up land plots previously cultivated by commercial growers (Table 5).[12] Redistribution of land and its conversion into subsistence production promote consumption of homegrown maize, which increases 5.3% – more than the 4.5% rise in consumption of purchased maize. Tthe shadow value of maize falls for all subsistence households.

A sensitivity analysis suggests that most of these changes are gradual. As price decreases go from 5% to 10% to 13%, household responses intensify with a cumulative effect on village aggregates. Some of these results differ when assumptions such as an endogenous wage or a local land market are relaxed; however, differences are largely quantitative, not qualitative.

B. With Fixed Wages and Local Land Markets.

When the labor market is open and the wage is fixed, maize production does not benefit from lower labor costs as in the previous scenario (where the wage is variable), so the sector's overall contraction is nearly three times as large. Commercial production contracts substantially (48% vs. 29% with a variable wage) and subsistence production does not grow as with a variable wage. Subsistence maize production, like the rest of the economy, is not affected directly by the decrease in the market price of maize, but it suffers multiple indirect effects. Differences in indirect effects with the previous scenario can be explained by the influence of wages on production and income, since land rental rates decrease by around 14% in both cases. Wage income falls less with a fixed wage than with a variable wage. (Wage rates decrease by up to 9.6% in the second case, but labor demand decreases by only 3.5% in the first.) As a result, household income decreases only half as much with a fixed wage as with a variable wage (0.9% versus 1.7%). In the fixed-wage scenario, a more stable income helps maintain demand for goods and services, including market and homegrown maize. The drop in the price of maize raises market demand—up 50% from the variable-wage scenario—as well as home consumption of maize among surplus growers. Surpluses disappear and village maize imports soar as a result. Among subsistence producers, expenditure on homegrown maize is greater under a fixed-wage than a variable-wage scenario; however, demand for homegrown maize decreases slightly overall—compared with a 5.3% increase when the wage is variable—due to high production costs associated with fixed wages. Higher income mitigates somewhat the contraction of non-ag activities and commerce witnessed in the variable wage scenario. The livestock sector grows, stimulated by lower feed costs. However, other (export) agriculture is completely unaffected in the fixed-wage scenario inasmuch as it does not depend on local demand and both its output price and labor costs are unchanged.

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[11] See Deaton (1997) for the formula to estimate the Gini coefficient.

[12] This occurs as the landlord, who previously rented out a large plot of land to a single grower, now parcels it out among several households.

Fixed wages prevent the feedback between local employment and wages and thus exacerbate the decline of local maize agriculture. However, they protect workers income, thus mitigating contraction in the rest of the economy. That is, fixed wages are detrimental to local agriculture but create positive income-growth linkages in the local economy. In our simulations, all local maize production becomes a subsistence activity under fixed wages. At the same time, more maize is demanded from the market, generating a large village maize deficit. The result is a substantial increase in maize imports, due partly to the decline in local production and partly to the preservation of income under a fixed versus a variable wage regime.

C and D. Maize Price Simulations with Fixed Land Inputs

Scenarios C and D correspond to a pre-ejido reform situation in which households were required to work their own ejido land or risk losing it through redistribution. A missing local land market generally mitigates impacts of falling maize prices described in the previous two scenarios. The response of commercial growers is muted when land is fixed; commercial farmers are "forced" to grow land which they otherwise would rent out. Fixed land inputs support employment and thus wages under the variable-wage scenario, and this dampens the negative demand effects on other sectors in the village. Thus, paradoxically perhaps, income falls less sharply when land inputs are fixed; adverse indirect income effects on the local economy are attenuated.

When land inputs are fixed, the shadow price of land decreases for surplus growers but rises for subsistence growers. When wages are variable (scenario C), subsistence output increases, but by less than in the perfect land market scenario (A). With fixed wages and land inputs (D), subsistence production contracts sharply; factor-input prices do not fall to compensate for the negative income effect on the demand for (and "shadow prices" of) home-grown maize. The results in Column D might correspond to a scenario in which subsistence households have access to outside (e.g., migrant) labor markets with given wages, and migration expands to absorb workers shed from crop production.

In other respects, the effects of a fixed wage are generally the same whether there is a local land market or not. That is, the differences between scenarios A and B are generally the same as those between scenarios C and D: a fixed wage results in greater declines in maize agriculture but mitigates income effects on the rest of the economy.

Two Alternative Compensation Programs

The two simulated cash-transfer programs are remarkably similar in counteracting the effects of a decrease in the price of maize (Table 5). Both programs effectively compensate aggregate household income after the price drop. Income compensation does not affect commercial maize agriculture directly, but it stimulates household expenditure. Increased expenditure partially offsets the contraction of local non-agricultural activities generated by the price decrease. On the downside, compensation exacerbates the contraction of maize output as well as the reduction in household maize surpluses, increasing the village's maize deficit. The reactivation of non-agricultural activities after compensation pushes wages upwards, reallocating labor out of agriculture. At the same time, compensation stimulates demand for homegrown maize through the income effect. This has a marginal but important effect on rental rates that further pushes land out of

commercial and into subsistence maize production. Lower efficiency among subsistence growers explains the decrease in maize output under compensation.

Minor differences arise from the two programs at the aggregate village level. While Procampo generates greater growth of the livestock sector, the contraction of commerce, non-agricultural activities and village GDP is less pronounced with a lump-sum transfer. Differences across programs are more pronounced at the individual household level (Table 6). For instance, although both programs compensate aggregate village income almost exactly, 42% of households experience a decline in real income under PROCAMPO (Gini coefficient of income = 0.351), but only 25% (half of them store owners) do so under a lump-sum transfer program (Gini coefficient = 0.348). Both programs allow increases in consumption of homegrown and market goods (including purchased maize). Maize surpluses decline by more than 75% in comparison with the base case (around 50% more than without subsidies), and both programs raise village maize purchases from the rest of Mexico by an additional one-third. The decline in surpluses is greater under PROCAMPO, because the largest grower consumes his previous surplus. Both programs further slightly the redistribution of land triggered by the drop in market price of maize.

Discussion: Changes in the village economy

The presence of only a few commercial producers is sufficient to transmit the impacts of price and other policy shocks into a largely subsistence economy, with often surprising production outcomes. Commercial producers can transmit shocks from national and international markets to the local economy through their interactions with other households in local factor markets. Their reactions to price changes affect local households by influencing the demand for and price of factors, thereby altering production costs for all producers. While both commercial and subsistence producers experience changing input costs, only commercial producers see a change in the market value of their output. This difference can push the net value of production for commercial and subsistence producers in different directions. Production adjustments also influence households through their effect on rent and wage income, which in turn alter household-specific shadow prices; the total effect on household income can be either positive or negative depending upon household endowments. Market orientation is an important source of household heterogeneity that can affect production in unexpected ways in an imperfect-market context where production and consumption decisions for some households are non-separable.

When factors of production are in limited supply, even small relative changes in the value of production across households influence where factors will flow, amplifying differences in supply response among heterogeneous households. Moreover, due to their effect on production, changes in the distribution of income also determine factor distribution among growers, affecting production output and marketed surplus. Herein lies the relevance to production of different cash-transfer schemes.

Our results suggest a local explanation for the unexpectedly inelastic supply response to maize-price liberalization witnessed across Mexico. In Zoatecpan's largely subsistence economy, a drop in the real price of maize induced commercial maize growers to scale back production, reducing their demand for land and labor. Subsistence growers suffered from the decreased demand for their labor on commercial farms; most

experienced declines in real income. As incomes dropped, so did expenditures, which resulted in a contraction of demand for local goods and village imports. On balance, the village became more self-reliant, as households substituted local goods for imports they could no longer afford and homegrown goods for purchased goods. In the end, a lower maize price was deleterious for seven out of ten households in a mostly subsistence community. Thus, the decline in maize price did not trigger a shift away from subsistence maize cultivation—as experts predicted (Levy and van Wijnbergen, 1992)—but rather, stimulated all subsistence activities including maize and other goods and services.

The drop in local rental rates and wages following the contraction in commercial maize production gave subsistence growers an incentive to take up the slack and expand their maize production. Moreover, inasmuch as employment and wages dropped sharply throughout Mexico during this period, subsistence production was an alternative to migration. In Zoatecpan, the decline in rental rates was large enough to lure landless households into subsistence agriculture and allowed even households that lost real income to rent more land. Lower wages promoted other subsistence activities within the household, including livestock. Although some households with migrants managed to increase their real income through remittances, local wage workers were hurt by the shift towards an inward looking, subsistence economy. Perhaps most adversely affected, as the subsistence economy took over, were households engaged in formal commerce that depends on trade with the rest of the country.

This reconstruction is generally consistent with Sadoulet *et al.*'s (2001) description of observed changes in household income among *ejidatarios* following NAFTA. That analysis found that for the average *ejidatario*, the shares of wage, agricultural, and other off-farm income fell, while the shares of livestock, non-agricultural self-employment and migrant remittance income increased. Interestingly, Sadoulet *et al.* (2001) found that the average *ejidatario* household experienced a 14% increase in real income between 1994 and 1997. This may be explained by the fact that their analysis excludes landless households, who are more dependent on wage income and did not receive compensation for the adverse price effects of NAFTA and domestic agricultural reforms.

As for the maize-supply response in Zoatecpan, results suggest that total output decreased slightly even as planted area remained constant.[13] Although a constant maize acreage in Zoatecpan is consistent with the nation-wide pattern, reduced maize output is not. The fall in local output was the result of decreases in productivity, as land was taken up by less efficient farmers unwilling or unable to purchase fertilizers. Maize consumption increased. Greater consumption of maize, combined with the decline of commercial maize agriculture and the decrease in local market surpluses, contributed to a village grain deficit, which was filled with "imported" maize. This is consistent with statistics at the national level, which show that Mexican maize imports increased sharply

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[13] This is despite the assumption of LES demands, which limits substitutability between purchased and home-grown maize. Our data do not permit direct estimation of the cross-price elasticity of demand for subsistence maize, and as mentioned earlier, analysis of survey (including experimental) data failed to uncover evidence that purchased and subsistence maize are close substitutes in the study area (Dyer, 2000). Imposing greater substitutability on consumption demands would tend to magnify negative cross-price effects, causing our simulation results to diverge from observed impacts of maize-price liberalization on subsistence production in the village and nationally.

during the 1990s even though maize acreage and domestic production did not drop as expected (INEGI, 2003).

Our simulations reveal complex influences of land-market reforms as well as price shocks in rural areas. Privatization of ejido lands increases the supply elasticity on commercial farms. However, it also contributes to a positive supply elasticity on subsistence farms. At first glance, increases in subsistence maize production in response to a lower market price for maize might appear to be perverse. Here as in other models of subsistence production (Key, et al., de Janvry, et al., and Strauss), household-specific "shadow prices" determine subsistence production, and these shadow prices fall as a result of negative income effects of lower commercial maize production. Other things being equal, lower shadow prices would result in a contraction in subsistence production, as well. However, the fall in maize shadow prices is not proportional to decreases in market prices, and falling prices of land and labor, transmitted to subsistence households through local factor markets, mitigate and in some cases reverse the negative supply effects of falling maize prices.

To the extent that our interpretation can be generalized, it suggests that NAFTA and agricultural policy reforms made maize agriculture an increasingly subsistence activity across agriculturally marginal but densely populated areas in Mexico. The specific nature of this transformation in Zoatecpan reflects the village's particular land property and rental regimes. The unequal distribution of land across households and the small size of the average landholding guaranteed that many households would expand their subsistence agricultural activities as commercial growers withdrew from maize production. This situation may be characteristic of indigenous communities where private land has been atomized (see *e.g.*, Heath, 1987). In *ejidos* and agrarian communities where land is owned by the state, land distribution may be more egalitarian and the average landholding larger, diminishing the reliance on land rental markets for subsistence production.[14] Also characteristic of Zoatecpan is the lack of alternative crops, which undoubtedly contributed to the retention of land in maize and its conversion from a commercial to a subsistence activity.[15] Commercial farmers in this village were not sufficiently large to benefit from input subsidies that buffered commercial farmers in other parts of Mexico from a fall in staple prices. Undoubtedly, heterogeneous local conditions have produced a variety of policy and market outcomes across Mexico.

Simulation findings, here as in all general-equilibrium models, are sensitive to market-closure assumptions. For example, while endogenous local wages and land rents transmit benefits to producers in the form of lower input prices, a fixed wage and restrictions of land rental (e.g., prior to the ejido land privatization) keep production costs high while the price of output drops, causing a steeper contraction of commercial maize production and inhibiting the positive supply response on subsistence farms. Commercial

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[14] For example, in the agrarian community of Frontera Corozal, Chiapas (another community in which we are doing field work), land property among *comuneros* is highly homogeneous: every *comunero* holds a fixed 50 hectares of land. At the onset of NAFTA, Corozal households grew an average of 10 hectares of maize, produced several times more than their consumption demand, and sold surpluses to Conasupo. Today, Conasupo has shut down its operations, the price of maize has fallen, and the average household grows only three hectares of maize (Dyer, 2001).

[15] In the community of Ahuacapan, Jalisco, landholders who previously grew maize commercially now rent out their land to land-poor households who grow maize for subsistence, but they also rent land to corporations that grow agave to produce tequila (M. Young, IAD, UC Davis, personal communication).

producers and landowners suffer, but wageworkers are able to migrate in search of jobs. Ultimately, the effects on household income and on the distribution of factors of production among households under alternative scenarios are difficult to predict, reinforcing our conclusion that interactions among households in local and regional markets generate heterogeneous and sometimes contrasting household responses. These interactions depend on local conditions, generating local outcomes to nation-wide policies. A modeling approach that allows for heterogeneous micro responses and interactions among actors in a general-equilibrium context can help explain unexpected local responses and predict changes in developing rural economies.

Implications for Compensatory Programs

If programs intended to compensate growers affected by price policies ignore the behavior and heterogeneity of agricultural households, they are bound to suffer from the same limitations as the policies themselves. In Mexico, Procampo was designed to compensate growers after price decreases linked to agricultural liberalization (Sagarpa, 2001). In fact, the program overcompensated subsistence growers, who do not sell maize and therefore did not lose revenue as prices declined. Neglect for general equilibrium effects limits the effectiveness of compensatory programs that target only households that are directly affected by the policy change. Simulation results suggest that while Procampo overcompensated surplus producers, who adjust production levels in response to lower prices, it failed to compensate households that suffered from indirect effects of price liberalization (*e.g.*, wage laborers and households engaged in commerce).[16]

A program that has unforeseen consequences for the distribution of income (and hence on production in imperfect-market environments) can fail to reach its intended goal. In addition to compensation, Procampo was meant to increase productivity while remaining decoupled from production. In our simulations, Procampo promotes local consumption, which cushions the local economy, but it diverts production factors away from staples in the process, deepening this sector's contraction.[17] It also deepens the contraction in the local market supply of maize, since it allows producers to receive a subsidy while consuming maize surpluses within the household instead of selling it at a subsidized price.[18] Surprisingly, a lump-sum transfer program that is independent of agricultural production can compensate those affected by agricultural policies better than Procampo and have equivalent effects on agricultural production.[19]

Effects described here might be the same in other areas where commercial operations and marketed surpluses are small, but probably not in places where they are larger. For instance, in Frontera Corozal, Chiapas, Procampo income allowed commercial growers to leave land fallow (Dyer, 2001). This emphasizes our suggestion that national policies will have a diversity of local outcomes.

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[16] Around 40% of all households experience a net loss in real income.

[17] Sadoulet *et al.*, (2001) document Procampo's effect on non-agricultural sectors across rural Mexico.

[18] Surpluses were both consumed by the household and fed to livestock.

[19] According to our results, a lump-sum program compensates 75% of households in real-income terms, compared with 60% for Procampo.

VI
Conclusions and Prospects

Few agricultural households are totally isolated from all market changes; autarchic households are a rarity. The general-equilibrium approach proposed in this paper integrates individual agricultural household models into a village economy-wide model, thereby relaxing restrictions implicit in the micro-household-farm approach when estimating supply response. In keeping with recent research on supply responses in small-farm economies, our modeling approach retains the assumption by Strauss, deJanvry, et al., and others that transaction costs limit small-household responses to market price changes. Our findings contrast with those of these other studies because our model embeds the responses of individual (commercial as well as subsistence) households within a village general equilibrium framework.

Households may be affected by changes in markets in which they do not participate if they interact with households that participate in those markets. Differences among households generate heterogeneous responses to countrywide market changes and also influence interactions among households in local markets. Subsistence households' interactions with commercial growers in local land and labor markets influence their responses to changes in commodity markets. The outcome may seem paradoxical at times. In Zoatecpan, Mexico, our simulations indicate that subsistence households might increase their scale of maize production in response to decreases in the market price of maize. Obviously, this is not a direct response to the price change, but a result of interactions with commercial growers seeking to adjust to price decreases by scaling back maize production.

Micro agricultural household models, with or without missing markets, are special cases of our general-equilibrium model. Most supply-response studies are partial, ruling out the transmission of influences among households. This may be reasonable when policies constrain factor-market responses (e.g., by restricting land rental markets, as in Mexico's pre-reform *ejido* sector). Under such a restrictive policy environment, supply response to market price changes may be muted. However, as market liberalization enables factor markets to respond in new ways, it is necessary to take general equilibrium effects more seriously.

A fundamental implication of this analysis is that local outcomes of changes in national policies depend upon local conditions. Therefore, findings in the village of Zoatecpan cannot be easily generalized to the rest of the country. However, they illustrate how local outcomes are shaped, and they may serve as a model to understand how policy and market changes play out in other local contexts, in Mexico as well as other LDCs. This is a necessary first step in predicting the impacts of market changes at more aggregate levels.

Although the Mexican maize sector has survived NAFTA relatively unscathed, it is widely expected that, as North American maize markets continue to integrate, small-scale maize producers in Mexico will vanish (Nadal, 1999; Oxfam, 2003). Our findings do not challenge this assumption in the long run. However, they suggest that, in the short run, the Mexican maize sector has already restructured in response to recent reforms, shifting from a commercial towards a subsistence mode of production. They also suggest that subsistence maize production will persist longer than many observers predict, despite apparently adverse market conditions for commercial maize in Mexico.

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Table 1. Price Determination in Agricultural Household and Village Models

Author	Origin of Prices for Agricultural Households
Barnum and Squire (1979); Singh, Squire and Strauss (1986); etc.	$p_{i,h} = \bar{p}_i$ (all i are tradable, with prices determined in some unspecified economic space outside the household)
Strauss (1986); de Janvry, Fafchamps and Sadoulet (1991)	$p_{i,h} = r_{i,h} = m_{i,h} / l_h$ for some $i \in$ nontradables ("virtual" or "shadow" prices endogenous to household)
Taylor and Adelman (1996)	$p_{i,h} = \bar{p}_i^w$ for "local tradables" $p_{i,h} = p_i^e$ for "local nontradables" $p_{i,h} = r_{i,h} = m_{i,h} / l_h$ for "household nontradables"

r_i = Shadow Price

f_i = Shadow Value (Lagrange Multiplier) on Subsistence Constraint for $i \in$ tradables

p_i^w = extra-regional (e.g., world) price

p_i^e = (endogenous) price within the micro-region.

Table 2. Estimated Household Production Parameters and Budget Shares

	Median	Minimum	Maximum
Production shares			
Land	0.12	0.04	0.67
Labor	0.88	0.33	0.93
Budget shares			
Homegrown maize	0.18	0.00	0.50
All subsistence goods[1]	0.29	0.04	0.62
All food[2]	0.63	0.15	0.82
Imports[3]	0.02	0.00	0.48

1. Includes maize.
2. Includes subsistence goods.
3. Household purchases outside village.

Table 3. Percentage effects of a 10% decrease in the market price of maize, Zoatecpan, Mexico.

Scenarios	(A)	(B)	(C)	(D)
Land market	Local		No market	
Labor market	Local (var. wage)	Open (fixed wage)	Local (var. wage)	Open (fixed wage)
Production activities				
maize (aggregate)	-4.89	-14.22	-2.52	-10.12
(commercial hhs)	-28.52	-47.65	-14.57	-1.53
(subsistence hhs)	4.77	-0.56	2.40	-31.15
Other agriculture	4.45	0.00	2.89	0.00
Livestock	-0.64	0.64	0.32	1.01
Non-ag activities	-18.98	-9.49	-12.50	-7.11
Commerce	-36.19	-18.45	-23.82	-13.81
Labor wage	-9.60	0.00	-6.46	0.00
Rental rate	-14.05	-14.25	—	—
Village GDP	-7.26	-3.77	-4.78	-2.82
Household income	-1.69	-0.87	-0.77	-0.45
(commercial hhs)	-3.97	-3.04	-1.30	0.39
(subsistence hhs)	-1.57	-0.75	-0.74	-0.50
Maize household surplus	-57.20	-100.00	-33.25	-64.55
Demand				
Homegrown maize	5.30	-0.45	3.48	0.02
(commercial hhs)	5.37	0.40	7.39	8.30
(subsistence hhs)	5.29	-0.62	2.67	-1.70
Market maize	4.52	6.72	6.00	7.24
(commercial hhs)	-4.31	0.94	0.70	4.83
(subsistence hhs)	4.54	6.73	6.01	7.25
Animal products	-4.10	-1.85	-2.49	-1.22
Non-ag goods	-4.57	-2.29	-3.01	-1.71
Other food	-10.33	-5.27	-6.80	-3.94

manufactured goods	-9.53	-5.20	-6.22	-3.87
Village maize imports	15.50	23.69	12.98	20.02

Table 4. Effects of a 10% decrease in the market price of maize, Zoatecpan, Mexico.

Variable	original	after a 10% decrease in the price of maize
Gini coef. for real income	0.356	0.351
Gini coef. for land use	0.562	0.518

Table 5. Percentage effects of a 10% decrease in the market price of maize with compensation. Local labor and land market scenario.

	type of transfer	
	Procampo	Lump-sum
Production activities		
Maize	-6.10	-6.26
Other agriculture	4.45	4.45
Livestock	0.73	0.71
Non-ag activities	-12.93	-10.76
Commerce	-22.62	-21.95
Labor wage	-9.60	-9.60
Rental rate	-14.05	-14.05
Village GDP	-6.57	-6.52
Household income	-0.03	<0.01
Maize household surplus	-81.23	-75.98
Demand		
Homegrown maize	8.48	7.17
Market maize	5.66	6.17
Animal products	-2.37	-2.56
Non-ag goods	-3.11	-2.59
Other food	-6.46	-6.26
Manufactured goods	-6.16	-5.91
village maize imports	21.11	20.78

Table 6. Effects of a 10% decrease in the market price of maize with compensation, Zoatecpan, Mexico.

Variable	original	type of transfer	
		Procampo	Lump-sum
Gini coef. for real income	0.356	0.351	0.348
Gini coef. for land use	0.562	0.519	0.518

Appendix 1. Village General Equilibrium Model: Variables

Sets of variables

Ip	Activity
Ic	Commodities
It	Activity and commodities
F	Factors
H	Households

Variables

$Q_{h,ip}$	Household h's output in activity ip
$FD_{h,f,ip}$	Household h's demand for factor f in activity ip
$P_{h,ip}$	Household h's shadow price of activity ip
$PVA_{h,ip}$	and price value added
P_{ic}	Price of commodity ic
$\overline{P}_{maize}$	Price of commodity maize (fixed)
W_f	Factor f's wage
$WFDIST_{h,f,ip}$	Factor f's price proportionality ratio in activity ip for household h.
FVA_f	Factor f's value added
EFD_f	Exogenous demand for factor f
MIG_f	Migration of factor f
Y_h	Household h's income
PW_h	Government transfers to household h
$\overline{Y}_h$	Non-government transfers to household h
$CD_{h,ip}$	Household h's demand for own activity ip's output
$CD_{h,ic}$	Household h's demand for commodity ic
IN_{ic}	Aggregate intermediate demand for commodity ic
DD_{ic}	Aggregate demand for commodity ic
$MS_{h,ip}$	Household h's surplus in activity ip
$HIN_{h,ip}$	Household h's intermediate demand for own activity ip's output
$HS_{ic,ip}$	Transformation coefficient of activity output ip into commodity ic
$HMSC_{ic}$	Aggregate household surplus of commodity ic
OPS_{ic}	Village imports of commodity ic
SPS_{ic}	Local purchases of commodity ic
EXP_{ic}	Village exports of commodity ic
TFD_f	Total demand for factor f
TFS_f	Total supply of factor f

Appendix 2. Village General equilibrium model: Equations

Production Block

$$Q_{h,ip} = b_{h,ip} \prod_f FD_{h,f,ip}^{a_{h,f,ip}}$$

$$FD_{h,f,ip} = a_{h,f,ip} \cdot PVA_{h,ip} \cdot Q_{h,ip} / W_f \cdot WFDIST_{h,f,ip}$$

Price block

$$PVA_{h,ip} = P_{h,ip} - \sum_{jp} s_{jp,h,ip} \cdot P_{jp} - \sum_{ic} s_{ic,h,ip} \cdot P_{ic}$$

Income block

$$FVA = W_f \cdot \left(\sum_h \sum_{ip} FD_{h,f,ip} \cdot WFDIST_{h,f,ip} + EFD_f + MIG_f \right)$$

$$Y_h = \sum_f a_{h,f} \cdot FVA_f + PW_h + NGT_h$$

$$GDP = \sum_f FVA_f$$

Expenditure block

$$CD_{h,ip} = s_{h,ip} \cdot Y_h / P_{h,ip}$$

$$CD_{h,ic} = s_{h,ic} \cdot Y_h / P_{ic}$$

$$IN_{ic} = \sum_{ip} s_{ic,ip} \cdot Q_{ip}$$

$$DD_{ic} = \sum_h CD_{h,ic} + IN_{ic}$$

Household surplus block

$$Q_{h,ip} = HAS_{h,ip} + CD_{h,ip} + HIN_{h,ip}$$

(transformation equations)

$$HS_{ic,h,ip} = s_{ic,ip} \cdot HAS_{h,ip}$$

Village commodity supply block

$$P_{ic} \cdot HMSC_{ic} = \sum_{h} \sum_{ip} P_{h,ip} \cdot HS_{ic,h,ip}$$

General equilibrium block

(goods)

$$OPS_{ic} = DD_{ic} - HMSC_{ic} - SPS_{ic}$$

$$EXP_{ice} = HMSC_{ice}$$

(factors)

$$TFD_{f} = \sum_{h} \sum_{ip} FD_{h,f,ip}$$

$$TFD_{f} = TFS_{f}$$