Intra-Household Modelling Farm-Household Systems

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1. Introduction

In recent years, there has been increasing evidence of differential impacts of policy interventions within the household. While governments strive to combat poverty and improve the living conditions of people, some policies have unwittingly resulted to a decline in welfare of some members of the household. For instance, emphasis on cash cropping, in some circumstances, has led to negative effects on nutrition of household members.

The problem is that most rural development policies and programs are assumed to be gender neutral. That is, there is an (often implicit) expectation that they will have equal impacts on both men and women. Unfortunately, this assumption is not necessarily true. It is, therefore, important to examine closely the processes that go on within the household if the aim is to design more effective rural development policies. A model that would allow differential impacts of policy interventions on household members to be assessed may therefore be a useful aid for policy making.

In this paper, a conceptual model of a farm-household system that takes into consideration intra-household aspects is developed. The model incorporates facets of household relations that are commonly ignored in conventional farm-household models. These include consideration of different preferences of household members, gender roles and assignments of tasks, allocation of productive activities within the farm-household system, productive resources available to household members and their access and control over the use of those resources.

An empirical model of a farm-household system was developed for a dryland mixed crop-livestock farming system in the Philippines. Using the farm-household framework, a mathematical programming model was constructed in which production, consumption and time allocation decisions and intra-household aspects are incorporated. The model reflects rigidities and flexibilities in work roles of men and women and includes crop and animal production activities as well as home production activities. The model also explicitly takes into consideration both the risk behaviour of the farm-household decision makers and the riskiness of farming.

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2. Frameworks Used to Analyse Farm-Household Systems

Farm households play an important role in the development of a country. Consequently, governments often seek to intervene, via policy instruments and programs, with the view of improving the general welfare of the people either by increasing income, improving health and nutrition, or providing better education. The success of government policies in affecting the lives of people depends to a large extent on the manner by which households respond to these policy interventions. Understanding the behaviour of the household can provide a means of analysing household reaction to different conditions and, hence, of predicting the consequences of policy interventions.

2.1 Farm-Household Models

The conventional way of analysing impacts of policy interventions is by focussing on farm households as the unit of analysis. One of the earliest models of a farm household was that of Chayanov (1925) who provided a theory of peasant behaviour at the level of the individual family farm. Chayanov hypothesised that households act to maximise utility by striking a balance between the satisfaction of consumption and a distaste for labour.

A related class of models based on Chayanov's ideas has become known as the *new household economics* (NHE) models, first introduced by Becker (1965). The new household economics models assume that the household acts as a unified unit of production and consumption which aims to maximise utility subject to its production function, income and total time constraint. The NHE framework has been widely adopted in many studies and has provided a foundation for the study of household behaviour (Hossain 1989; Khandker 1988; Rosenzweig and Schultz 1983; Rosenzweig and Wolpin 1982; Strauss 1982, 1984; Banskota and Evenson 1978; Canlas 1978; Gronau 1977; Ben-Porath 1973; Willis 1973).

In his seminal work on *The Subjective Equilibrium Theory of the Farm Household*, Nakajima (1986) extended the NHE theory to agricultural households and developed several kinds of models depicting various agricultural household situations. These agricultural household models, also known as integrated production-consumption models, integrated farm-household models, or simply farm-household models, are important as they provide a framework for predicting the responses of farm households to variations in such things as output prices, input prices, wage rates, technology, and family structure. These models also incorporate aspects of farm-household choices regarding home consumption of output versus sale of output to purchase non-farm consumption needs.

2.2 Intra-Household Theory

In recent years, there has been a shift in attention to the intra-household dimension. This new wave of research was brought about by the realisation of existing inequalities among household members and the disparities in the distribution among members of returns from production and benefits derived from government policies and programs. Many cases of inequalities among household members have been reported. These include imbalances in food allocation among household members (e.g., between adults and children, between husband and wife, between male and female children); gender differences in investments in children (e.g., schooling); and differences in the distribution of labour among household members (e.g., Chen *et al*. l981; Gopaldas *et al*. 1983; Pitt, Rosenzweig and Hassan 1990; Behrman *et al*. 1982, Rosenzweig and Schultz l982; Pitt and Rosenzweig 1985; Behrman 1988).

A review of the literature would show that different situations exhibit different conditions. It would be simple to prescribe policy options if it were to be assumed that what applies to one part of the globe applies to another. The reality is that much ambiguity exists in the field and conflicting situations occur. For instance, Rosenzweig and Schultz (1982) reported that, in South Asia, intra-household distribution of nutrients was biased towards boys. While the cases in Bangladesh (Pitt *et al*. 1990), the Philippines (Evenson *et al*. 1980) and India (Behrman and Deolalikar 1993) were consistent with Rosenzweig and Schultz's finding, Psacharapolous and Arriagada (1989) provided evidence that discrimination against boys in school attendance occurred in Brazil. On the other hand, the studies by Deaton (1987) in Cote d'Ivoire and Gronau (1985) in the United States showed little evidence of gender bias in the allocation of expenditures among household members.

These examples highlight the fact that caution must be exercised when introducing government policies and programs. A deeper understanding of the issues is needed for successful policy and program implementation. While insights and examples of household behaviour are important, they are not sufficient in guiding analysts about the possible consequences of government policies. It is in this context that understanding intra-household aspects are important.

2.3 Models Used in Intra-Household Analysis

2.3.1 Unified household models

A framework that has been widely used to analyse intra-household issues is the unified household model. This class of models is based on the new household economics framework first espoused by Becker (1965) and discussed earlier in this chapter. Unified household models have also been referred to as unitary models, common preference models and unified preference models. Various applications of the theory include intra-household allocation, fertility decisions and the impact of government policies on different outcomes such as nutrition and schooling.

Unified household models assume that the household acts as a single unit of analysis. The household is assumed to make decisions in such a way as to maximise its utility subject to various household-level constraints on production, income and time. Production and consumption decisions are integrated within the framework of the household. The household optimises among its choice of consumer goods, as well as its supply of labour to the market and to production.

A central feature of the unified household model is the use of a single utility function for the household. There is an implicit assumption that no conflict exists within the household and hence the objective is to maximise a unified preference function. Adoption of a single utility function for the entire household is based on either one of the following assumptions: (1) that all members have the same utility function so that maximising the household utility would yield similar results as maximising individual functions; or (2) that there exist some rules for aggregating individual utility functions. The usual practice is to adopt the utility function of a household member, usually the (male) household head, to represent the utility of the entire household. This proposition is based on the assumption that household members will sacrifice their individual preferences for the common good of the household. In return, the altruistic head will make decisions based on what is best for the household as a whole. According to Becker (1974b, 1976), differences in preferences are resolved through what has become known as the 'rotten kid theorem'. This theorem states that if a household has a head who 'cares sufficiently about all other members to transfer general resources to them, then redistribution of income among members would not affect the consumption of any member as long as the head continues to contribute to all' (Becker 1974b, p. 1076). Therefore, even if some kids are selfish, as long as an altruistic parent provides a transfer to the children, then the children have incentives to behave in a manner that will maximise household income.

A strong feature of the unified household model is its flexibility. It can be used to examine a wide variety of issues. It can be used to explain decisions about the quantity of goods consumed by the household, time allocation, as well as the distribution of goods among individual members of the household (King and Evenson 1983; Rosenzweig 1986, 1990; Horton 1986; Pitt and Rosenzweig 1990; Behrman, Rosenzweig and Taubman 1994).

2.3.2 Bargaining models

An alternative approach to the study of household behaviour is offered by the bargaining framework. Under the bargaining framework, it is recognised that household members may have different preferences. Conflict may arise among household members, but this is resolved through a bargaining process. The advantage of the bargaining approach over the neo-classical unified preference approach is that it explicitly allows for differential utility functions and provides a means by which differences are reconciled (Manser and Brown 1980, McElroy and Horney 1981).

A critical component of the bargaining model is the identification of threat points, *i.e.*, the utility level which is guaranteed to the individual if no agreement or bargain is achieved (McElroy and Horney 1981). These threat points are crucial in determining distribution within the household. Although Manser and Brown (1980) refer to divorce or dissolution of the marriage as the threat point, this may not necessarily be the appropriate threat point. It could be the outcome of non-cooperation between the husband and wife. For instance, Lundberg and Pollak (1992) introduced the 'separate spheres model' in which household members bargain over the gains from marriage, such as the joint production of household goods and children, in a cooperative bargaining framework. Failure to reach an agreement by the couple may result in refusal to work in the partner's dominant sphere of activity. Under such breakdown, gender roles would determine each individual's activities and contributions to the household. Lundberg and Pollak (1992, p. 12) state that 'because socially prescribed gender roles assign primary responsibility for certain activities to the husband and others to the wife, the separate spheres default equilibrium may be established and maintained without negotiation'. Under the bargaining framework, each person contributes to the public goods within their dominant spheres with, for example, men providing housing and women taking care of the children and doing the household chores (Doss 1996). According to Doss (1996), since the public goods are provided voluntarily, it is possible that, like most public goods, they may be under-provided within the household.

One of the features of the bargaining approach is that it recognises the role played by individual endowments in the bargaining process. Any change in the endowment could result in an alteration of the bargaining power of the individual player and, hence, the optimal solution to resource allocation within the household. For instance, a change in the wage rates of working husbands and wives would be reflected in their bilateral bargaining process. Similarly, exogenous factors that influence the threat points of individuals may affect the distribution within households even if the resources of individuals and total household resources remain the same. For example, an increase in the wages of women (or men) may affect the allocation of resources within households, even in households where women (or men) are not employed (Doss 1996).

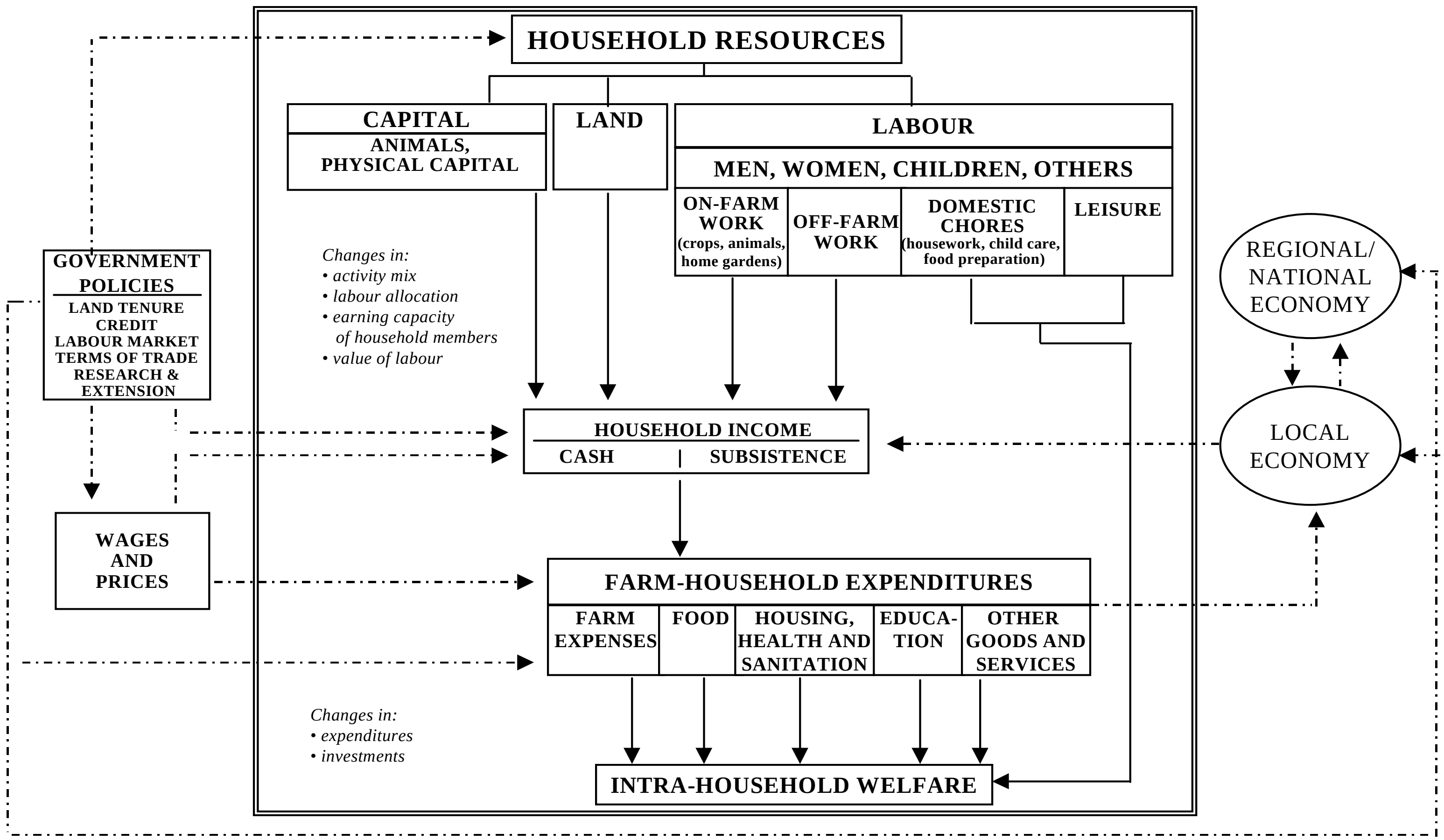
3. Modelling Intra-Household Dynamics in Farm-Household Systems

3.1 A conceptual model of an intra-household model

The behaviour of farm households is often a subject of interest to policy makers and government decision makers because of the importance of agriculture in many countries. The farm-household system is a complex system of interactions between and among a variety of endogenous and exogenous variables. It is a resource-allocating unit, where decisions are made on how scarce household resources are to be distributed among various needs to attain household goals. Often, decisions on resource allocation affect the welfare of the entire household as well as the welfare of individual members of the household. A conceptual framework for analysing the farm household is illustrated in Figure 1.

As illustrated in the figure, the farm household has resources such as land, labour and capital which it allocates among competing activities in accord with the household utility function. The farm household is interlinked with the local, regional and national economy through its linkages with the labour, credit, input and output market, and through social and religious interactions with the local community. Exogenous factors such as changes in wages and prices and government policies may induce changes in the system. For instance, land tenure policies may influence decisions regarding the types of crops to grow, which in turn could possibly alter the pattern and combination of activities and the allocation of labour among household members. Similarly, labour market policies may affect the perceived value of labour, and the earning capacity of members, possibly triggering a change in the activity mix and labour allocation among household members. These changes may also alter time use patterns, such as time spent by household members on paid employment, farm work, domestic chores and leisure. Changes in farm and non-farm income of individual household members are reflected in the total household income. Expenditures on production, consumption, education and other household expenditures are influenced by decisions on income allocation and possibly the degree of income pooling. In turn, the allocation of food, education and other household resources, as well as leisure, affect the welfare of household members.

Figure 1: A conceptual framework of farm-household processes and intra-household welfare



3.2 Data Requirements

The analysis of complex systems such as the farm-household systems illustrated in Figure 1 requires a large set of information, including household resources, production activities (crop and livestock), income (cash and kind) from farm and non-farm sources and expenditures on various production and consumption needs. Incorporating intra-household aspects into the farm-household framework involves the inclusion of more detailed information about the farm household. To collect such information demands a close examination of various activities undertaken by members of the farm household, including farm work, non-farm work, other productive endeavours such as livestock raising and home gardening, and domestic work. Intra-household level data are also needed on labour allocation, decision-making, access to resources and household goals. Information on the village institutional setting, demographic variables and a host of other factors are also needed for a complete analysis. A summary of the data required for modelling a farm household which incorporates intra-household dynamics is presented in Table 1.

Table 1: Summary of data requirements

Household composition and structure
- number of members, age, sex, education
- relationship to household head
- gender of the household head

Income and expenditure
- individual income by source and type (farm, off-farm, home gardens, livestock; cash, in-kind; primary, secondary)
- who handles cash, degree of income pooling, cash allocation and control over use
- rates of pay for various activities

Labour and time allocation
- task allocation by household members and by task (household chores, crop production, home-gardens and animal husbandry)
- individual time use and time constraints (farm, off-farm, household chores, home gardens, livestock, leisure, etc.)
- task boundaries/roles (i.e., are certain activities the responsibilities of certain members, is there rigidity or flexibility in the performance of tasks)

Resources
- types of resources owned (land, capital, animals, etc.)
- control of resources

Social and cultural norms
- restrictions on types of work or place of work (by gender)
- degree to which these restriction are observed

Household goals, behaviour and constraints
- goals of members, particularly, of the husband and wife
- problems and constraints [resource constraints, etc.]

Local economy
- village institutional set-up
- services available (credit, social, religious, health and financial institutions)
- organisations (farmers' groups, women's groups, cooperatives)
- input and output markets
- job availability (by type, by gender, by season)
- communal resources (public grazing land, artesian wells or water pumps)
- government programs/projects

Farm and other production activities
- crops, livestock, etc. produced (quantities and type; prices/costs)
- area devoted to crop(s) (by crop and by season)
- input quantities by crop (seed, fertiliser, pesticides)
- labour allocation by crop or production activity (by task, by season, by hired and family labour, by gender)
- cropping pattern
- technology
- cultural practices
- wages for hired labour
- labour hiring arrangements
- risks and uncertainty

4. Mathematical Modelling of Farm-Household Systems

Micro-level information, such as information about household goals or objectives, resource availability and utilisation, agricultural prices, access to common property resources, infrastructure and other services, are important in understanding farm-household structures and functions and the rural institutional systems. To be useful for policy analysis, however, such information need to be analysed and articulated in a consistent and structured framework. Mathematical models are useful for this purpose.

4.1 The Additive Joint Utility Model

The principal criticism of the unified household model is the assumption regarding the use of a single household utility function, as discussed above. A number of authors have proposed some rules for aggregating individual preferences[2]. (Keeny and Raiffa 1976, Cohon 1978; see Sen 1970 for a review). For instance, for bargaining models, Nash (1953) proposed multiplication of individual gains and losses measured relative to the status quo. Another aggregation scheme as proposed by Harsanyi (1955) is through the maximisation of expected utility. According to Harsanyi (1955), a (higher order) household utility function can be derived. He postulated a set of conditions for aggregating individuals preferences such that:

$$U_G = \sum_{i=1}^{n} w_i U_i$$

where: U_G = group utility function;
U_i = utility of individual i;
w_i = weight of individual i's utility.

According to Harsanyi (1955), if two alternatives are indifferent to each individual, then they are indifferent for the group as a whole. Keeney and Raiffa (1976) showed that the condition set by Harsanyi is equivalent to what they termed as the assumption of additive independence and the assumption of strategic equivalence, combined. That is, for a group utility function, the set of attributes U_1, U_2 ... U_n is independent. In addition, the decision maker's conditional utility function over the attribute U_i is strategically equivalent to individual i's utility function U_i. Given these assumptions, the household utility function for a two-person household can be represented by:

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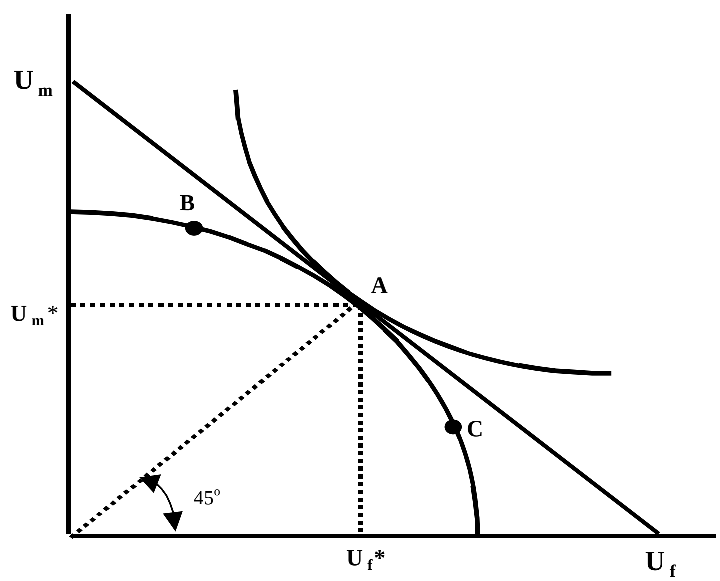
[2] Since Arrow's (1951) publication, a number of modifications to his conditions and/or proposals on other conditions have been offered (see Luce and Raiffa 1957). Luce and Raiffa (1957, pp. 130-132) discussed some advantages of allowing interpersonal comparisons at the expense of independence.

$$U_H = \lambda_m U_m + (1\text{-}\lambda_m) U_f$$

where : U_H = household utility function;
U_m = utility of male;
U_f = utility of female;
λ_m = weight of male's utility function

The additive joint utility framework can be presented as follows (Figure 2). The objective is to maximise the expected utility of the household, which is equal to the weighted sum of the individual utilities. If two individuals, *m* and *f*, have equal weights, then the optimal position would be at point A where the utility of individual m is equal to U_m* and the utility of individual f is U_f*. A higher weight of the utility of individual *m* is indicated by a movement along the frontier to point B and vice versa.

Figure 2: Graphical presentation of the additive joint utility framework



4.2 The Bargaining Framework

The objective in the bargaining framework is to maximise the Nash-bargaining solution, *N*. In general terms:

$$N = [U_m - V_m] [U_f - V_f]$$

where: U_m = utility of individuals *m*;

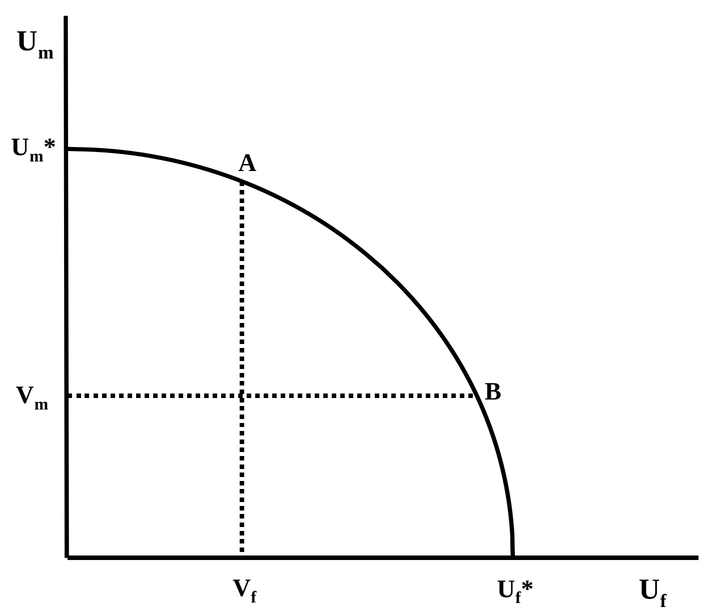
U_f = utilities of individuals *f*;

V_m = threat points of individuals *m*; and

V_f = threat points of individuals *f*.

The bargaining framework can be represented by the following graph (Figure 3). A feature of the bargaining model is the threat point levels represented by V_m and V_f for individuals, *m* and *f*, respectively. The intra-household bargaining process will result to an optimal solution between points A and B. Outside the range of the threat point levels, the bargaining breaks down which could result in either non-cooperation or divorce.

Figure 3: Graphical presentation of the bargaining model



5. Operationalising Intra-Household Modelling of Farm-Household Systems for Policy Analysis

Model building is often a complex task. As Hazell and Norton (1986) pointed out, building a model requires a clear understanding of the issues to be addressed. The conceptual model constructed above is therefore a first step in the modelling process. To be of practical value, a model not only has to be well-grounded in theory but also expressed in a simple and interpretable way. In addition, the analytical method should also be appropriate for the problem at hand. A number of factors need to be considered in the choice of the analytical method. These include the characteristics of the systems to be modelled, the environment faced by decision makers, the behaviour and the goals of the subject or decision maker. Two common approaches to mathematical modelling are the econometric approach and mathematical programming.

5.1 Econometric Approach

Among the most widely used approaches to modelling farm households are the econometric approach and the mathematical programming approach. Econometric methods are used to establish relationships between and among variables in the farm- household systems. Modelling farm households using econometric approaches involves estimation of a set of functional relationships indicating the production behaviour of a farm and the consumption behaviour of the household with the use of production or profit functions and demand functions.

A conventional assumption in most complete econometric farm-household models is that production and consumption are separable. That is to say, production decisions are independent of consumption decisions. This assumption allows the model to be solved in a recursive manner whereby production decisions are first made, after which consumption decisions are made. The interaction between production and consumption can then be traced through the responses that have been estimated.

There are strict conditions needed to justify the separability assumption. As outlined by Singh, Squire and Strauss (1986), these include the presence of perfect and complete markets, the assumption that production decisions can be made independently of consumption and labour supply decisions, and separability in the specification of the utility function and the technology set.

There have been some attempts to develop farm-household models that account for simultaneous decisions in production and consumption in recent years (Lopez 1984, Jacoby 1992). For example, Lopez (1984) modelled simultaneous decision making in production and consumption in Canadian farm- households and concluded that non-separable models are theoretically and empirically sounder than separable models. However, as pointed out by Fleming and Hardaker (1991), there are some difficulties involved in dropping the assumption of separability in econometric models. One of the problems is the demanding data requirements which in many cases may not be met. A second problem is that the ensuing estimation procedures are complex if the separability assumption is dropped and, at the same time, are also based on strong assumptions about farm-household behaviour. Finally, model results are likely to be sensitive to changes in specification (Fleming and Hardaker 1991, pp. 5 and 9). For these reasons, most econometric farm-household studies adopt the separability assumption.

According to Upton and Dixon (1994) econometric methods represent the most rigorous and objective techniques for establishing economic relationships and have the added advantage of allowing significance testing. However, there are some operational problems with the use of comprehensive econometric models, particularly when used for modelling farm-household systems for planning purposes. The main limitations of comprehensive econometric models revolve around the separability assumption. First, unlike in commercial farms, the assumption that production is not influenced by consumption is seldom realistic in the case of peasant farm households. Second, the condition of fully working and complete factor and product markets are stringent and seldom hold true in developing countries (Benjamin 1992). This raises questions about the validity of valuing outputs (selling and buying prices) uniformly at market prices. Values attached to commodities are partly internal to the household – a surplus producing household would value produce at the margin at the price it can sell it at, while a deficit household would value it at what it must pay for the commodity. One that is more or less self-sufficient would value the commodity somewhere in between. Thus, the relevant prices are different for different household, and some - the in-between ones - are not observable. Valuing outputs at uniform selling and buying prices thus, to some extent, undermines the validity of conventional separable econometric models. Moreover, although there had been some attempts to incorporate risk (e.g., Roe and Graham-Tomasi 1986), Fleming and Hardaker (1991) claimed that risk is as yet not adequately taken into account in most econometric farm-household models.

Other difficulties associated with the use of econometric techniques are identifying the exact form of the production function or consumption function and the difficulty of including all the necessary factors and products in the systems model (Fleming and Hardaker 1991). The issue of representativeness poses another problem. Usually, the analysis is based on an average farm household, presumed to be representative of the population of such households. In reality, there are good reasons to suspect serious aggregation bias problems. Data deficiency in terms of quality and quantity of data is also a major concern when using econometric techniques. This problem is particularly acute in many developing countries because of the high costs associated with data collection (Norton and Schiefer 1980, Fleming and Hardaker 1991).

5.2 Mathematical Programming

An alternative method for modelling farm households is mathematical programming (MP). Mathematical programming is a constrained optimisation technique wherein a specified objective function is optimised. It involves specifying an objective function that embodies as closely as possible the objectives of the farm household, along with a matrix of input-output coefficients and the resource and technical constraints faced by the farm-household systems.

There are several advantages of the mathematical programming framework in modelling farm-household systems. Because of the nature of the farm household as an integrated production and consumption unit, ideally, analysis of farm-household systems is best approached in a whole farm-household context (Anderson, Dillon and Hardaker 1977; Hardaker 1979; Dent, Harrison, and Woodford 1986; Hazell and Norton 1986). Assessments of farm-household level impacts must consider the farm household's resource base as well as the household's consumption needs. Mathematical programming models offer a consistent way by which production and consumption are explicitly taken into consideration without the often unrealistic assumption of separability embodied in most econometric models. The mathematical programming framework has flexibility in describing production structures which, as pointed out by Day (1964), cannot be duplicated by behavioural supply equations and, at the same time, has the capability of integrating consumption decisions in a fairly straightforward manner. Features of risk and uncertainty are also relatively less difficult to accommodate in mathematical programming models than in econometric models.

Unfortunately, the issue of representativess is also a concern with mathematical programming. Likewise, the MP approach is also confronted by the same data-related problems that are encountered in econometric modelling. Often, the data available to the analyst are incomplete and questions on data reliability are also not uncommon. However, as Norton and Schiefer (1980, as cited in Fleming and Hardaker 1991) pointed out, due to a number of factors such as insufficiency of degrees of freedom, problems of validity of model results in relation to the estimation period, inability to effectively account inequality constraints and incomplete data on the full range of explanatory variables, econometric models are more constrained by data deficiencies than mathematical programming models (Fleming and Hardaker 1991). Moreover, if there are concerns about the reliability of the data set, information derived from field experts or from persons familiar with the farming systems being modelled can be utilised to check data consistency and/or refine the technical coefficients, improving the utility of MP models. Other considerations are the time and costs involved in mathematical programming. As Fleming and Hardaker (1991) pointed out, building mathematical programming models is time consuming. This is particularly so if the model is large and complex. However, weighing the theoretical advantages of mathematical programming over the econometric approach, it appears that mathematical programming is more suitable for capturing realistic aspects of the farming systems. It lends itself easily for studying the complexities of small mixed-farming systems of households with low resources and multiple goals and constraints, common in most developing countries. The constrained optimisation technique of mathematical programming closely corresponds to the actual behaviour of farm households. It is also well suited to studies on farm household resource allocation problems and for providing optimised plan and suggestions. Thus, a mathematical programming model of a farm household is developed and presented in this paper.

5.3 An Intra-Household Model of a Farm-Household System in the Philippines

A model of a farm household was constructed based on the conceptual framework discussed in Section 3. The model constructed was based on a representative farm household in a dryland (upland) village in Misamis Oriental, in Southern Philippines. The average size of households in the survey was 5.33 members or 3.33 adult equivalents. This model took into consideration intra-household dynamics. A number of factors were also considered such as the characteristics of the system being modelled, the risk environment faced by decision makers, and the risk behaviour and goals of the decision makers.

The full MP model was comprised of 338 rows and 365 columns representing the consumption, technical and resource constraints and the various activities included in the model. The matrix for the model was constructed in Microsoft Excel (version 5). The mathematical programming models for the joint utility model (additive function) and the bargaining model (multiplicative function) were run in GAMS. The matrix structure of the model is presented in Table 2.

Mathematical models for both the additive joint utility model and the bargaining model were constructed. Examination of results showed that for this particular case, solutions of the two models were comparable in terms of the activity levels and the resource use. Therefore, either of the two models could be used for further policy analyses. Because of space constraints, further development of only one of the models will be presented in this paper. The additive joint utility model will be presented, mainly because the weights placed on the utilities of men and women can be varied in the model, making it attractive for examining the effects of various gender-sensitive policies.

Table 2: Structure of the basic LP model

				Activities										
	Unit	**B column**	**Sign**	**Fallow activities**	**Crop**	**Animal production**	**Domestic**	**Labour hiring**	**Labour selling**	**Processing**	**Consumption**	**Buying**	**Selling**	**Fodder**
Objective function	**Pesos**				-	-		-	+			-	+	
Resource constraints														
Land														
Wet land	**h**	**b**	**L**	+	+									
Dry land	**h**	**b**	**L**	+	+									
Rotational constraints	**h**	**b**	**L**	-	+									
Labour by season														
Male	**h**	**b**	**L**		+	+	+	-	+	+				
Female	**h**	**b**	**L**		+	+	+	-	+	+				
General	**h**	**b**	**L**		+	+	+	-	+	+				
Hired labour														
Maximum male	**h**	**b**	**L**		+			+						
Maximum female	**h**	**b**	**L**		+			+						
Labour selling														
Maximum male	**h**	**b**	**L**						+					
Maximum female	**h**	**b**	**L**						+					
Animal														
Draught capacity	**ani-day**	**b**	**L**		+	-								
Manure pool	**t**	**b**	**L**		+	-								
Animal minima & maxima														
Minima	**ani-unit**	**b**	**G**			+								
Maxima	**ani-unit**	**b**	**L**			+								
Household tie row	**hh unit**	**b**	**E**				+							
Home garden constraint	**m^2**	**b**	**L**				+							
Feed pools	**t**	**b**	**L**		-	+								
Production output	**t**	**b**	**L**		-					+	+	-	+	+
Transfer rows	**t**	**b**	**L**							+ / -				
Food pools	**t**	**b**	**L**			-	-				+			
Marketing constraints	**t**	**b**	**L**										+	

* *'L' means resource use must not be greater than B column; 'G' means resource use must not be less than B column; 'E' means resource use must be equal to B column.*

'+' means activity uses resource; '-' means activity generates resource.

To facilitate the incorporation of risk aspects in the model, a discrete stochastic programming approach was developed. The objective is to maximise the expected utility of the farm household, subject to resource and technical constraints across a number of different states of nature assumed to have an equally likely probability of occurring. The utility function is of a negative exponential form. Mathematically, the model can be presented as:

maximise	$E(U)$	$=$	$\sum_{t=1}^{8} p_t\, U(Z_{st})$
subject to :	$A_1 x_1$	$\leq$	b_1
	$L_{1t}\, x_1 + A_{st}\, x_{2t}$	$\leq$	b_{st}
	$C_{st}\, x_{st} - I z_{st}$	$=$	f_{st}
and	x_1, x_{st}	$\geq$	$0, \quad t = 1, \ldots T$

where:

U = utility function;

p_t = vector of state probabilities;

$U(z_{st})$ = vector of utility values for state *t*;

A_1 = matrix of technical coefficients of first stage activities;

x_1 = vector of first stage activity levels or decisions;

b_1 = vector of first stage resource availabilities;

L_{1t} = set of matrices linking first and second stage activities for state *t*;

A_{st} = set of matrices representing technical coefficients of second-stage activities for each state *t*;

x_{st} = vector of second-stage activities for state *t*;

b_{st} = right-hand-side vector constraining second-stage decisions for state *t*;

C_{st} = vector of per unit activity net revenues for state *t*;

I = identity matrix to connect stage *s* variables for each state *t*;

Z_{st} = variables to measure total revenue for state *t*; and

f_{st} = vector of fixed costs for state *t*.

For each state *t*, the utility function can be expressed as follows:

$$U_t = 1 - e^{-cyt}$$

where : U_t = utility in state t;

c = coefficient of absolute risk aversion; and

y_t = income in state t.

The objective function for the joint utility approach can be represented by:

$$U_H = \sum_{i=1}^{n} \lambda_i U_i$$

where: U_H = household utility function;

U_i = utility of individual i;

λ_i = weight of individual i's utility.

Therefore:

$$U_H = \lambda_m U_m + (1-\lambda_m) U_f$$

where : U_m = utility of males;

U_f = utility of females;

λ_m = weight of males' utility function.

The objective identified in this study is to maximise income and leisure subject to consumption requirements and resource and technical constraints. Hence, we can define U_m and U_f as:

$$U_m = U [C_m + (L_m) (RPL_m)]$$

and

$$U_f = U [C_f + (L_f) (RPL_f)]$$

where the subscripts *m* and *f* refer to male and female, respectively; *C* refers to the net amount of cash income earned within the areas of the farm-household economy that are conventionally controlled by each gender; *L* refers to leisure (*i.e.*, the total number of hours free of work); and *RPL* refers to the reservation price of labour.

Therefore the objective function to be maximised for the joint utility model can be represented by:

$$U_H = \lambda_m (CE_m) + [(1-\lambda_m) CE_f]$$

which means the objective function of the farm household is to maximise the weighted sum of the utility of the males and the utility of the females, represented by the weighted certainty equivalents of the utilities of males and females. It was for the most part assumed in this study that the utilities of males and females have equal weights, hence lambda takes the value of 0.5. Effects of varying this assumption were examined.

The model developed was then extended to simulate government policies such as credit policies, labour market policies, price policies, land tenure policies and policies that affect research and development and technology in the Philippines (Rola-Rubzen 1997). Simulation of various policy scenarios enabled the analysis of impacts of policy intervention on the farm household, in general, and on members of the household in upland farming system in the Philippines.

6. Summary and Concluding Remarks

This paper outlines a conceptual framework that takes into account intra-household dynamics. The conceptual model is further developed into mathematical models, which could be used for policy analysis. An additive joint utility model and a bargaining model is specified. Apart from capturing intra-household dynamics, aspects of risk such as the risk behaviour of farm households as well as the riskiness of farming were also taken into consideration in the model.

In most developing countries, farm households operate in a risky environment and are faced with many constraints. As a consequence, they partly base their decisions from their risk expectations. The mathematical programming approach was chosen to operationalise the model because of its suitability to capture the constrained environment farmers operate in and the risk inherent in smallholder agriculture. Moreover, mathematical programming provides a framework by which alternative government policies can be analysed and evaluated. Mathematical programming models can be modified and extended with relative ease to examine effects of varying coefficients outside the range of existing values originally used in the estimation of coefficients, making it suitable for policy scenario analysis.

The model presented in this paper has been used in assessing a fairly wide range of policy options, but because of space and time constraints, the results of the applications of the model for policy analysis can not be presented here. The mathematical programming models were used to analyse the effects of government policies on farm households and members of the household (Rola-Rubzen 1997, Rola-Rubzen and Hardaker 1999). Uses of the model for policy analysis include examining the effects of credit pricing and credit availability on farm production mix and technology choice. Policy instruments (e.g., interest rate, wage rate and output price) were likewise modelled individually or in combination with other policy instruments to examine farm level impacts as well as intra-household impacts. The intra-household model was also used to examine the effects of the introduction new technology on farming systems, the farm household and on members of the farm household (Rola-Rubzen 1997).

In conclusion, the model offers an alternative framework for analysing farm household and intra-household impacts and understanding differential effects of external stimuli, such as technology and public interventions, on individual household members and on the household as a whole. It can be applied and adapted for policy scenario analysis in other such studies and could therefore be useful in designing policies that are cognisant of differential preferences of household members and, hopefully, aid in the formulation of sound rural development policies.

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