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Agricultural Household Models: Genesis, Evolution, and Extensions*

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Abstract

This paper offers a synthesis of agricultural household modeling, its evolution and uses; presents a general yet simple agricultural household model, estimated with Mexican village data and programmed using General Algebraic Modeling System (GAMS) software; and uses this model to explore household-level impacts of agricultural policy changes on production and incomes under alternative rural-market scenarios. We point out limitations of household-farm models in heterogeneous rural economies and discuss how to integrate multiple household models into economy-wide models designed to overcome these limitations.

Key Words: Agricultural Household Models, Household-Farm Models, Computable General Equilibrium Models, Mexico, NAFTA

JEL Classification: O1 Economic Development

Agricultural Household Models: Genesis, Evolution, and Extensions

Agricultural household models are a staple of micro research on less-developed country (LDC) rural economies. Originally envisioned as a tool for price policy analysis, household-farm modeling techniques have been used in a gambit of research ranging from technology adoption and migration to deforestation and biodiversity. They are the basic building block of micro economy-wide, including village, models. Recently, they have begun to be recast to reflect imperfect-market environments characterizing LDC rural economies. Missing or incomplete markets for output and inputs, including labor and capital, result from high transaction costs endemic to poor economies. Household-farm models are a useful tool to study how household-specific transaction costs shape the impacts of exogenous policy and market changes in rural areas. In the common case where many households (e.g., in the same village) face similar transaction costs, however, economy-wide modeling with multiple households is required.

This paper has three objectives: (1) building upon classic works by Inderjit Singh, Lyn Squire and John Strauss (1986) and others, to provide a synthesis of agricultural household modeling, trace the evolution and uses of these models and summarize the diversity of their applications; (2) to present a graphical and mathematical depiction of household-farm modeling frameworks under alternative market scenarios; and (3) to offer a general yet simple agricultural household model, estimated with Mexican village data and programmed using General Algebraic Modeling System (GAMS), that can serve as a starting point for students and researchers wishing to build their own models to explore microeconomic impacts of policy and market changes. We use the model to explore household-level impacts of agricultural policy changes under the North American Free-

Trade Agreement (NAFTA) on production and incomes under alternative rural-market scenarios. In the conclusion, we point out some limitations of household-farm models in heterogeneous rural economies and discuss how to integrate multiple household models into economy-wide models designed to overcome these limitations.

1

Evolution and Uses of Agricultural Household Models

Household -farm models were first introduced to explain the counterintuitive empirical finding that an increase in the price of a staple did not significantly raise the marketed surplus in the rural sector of Japan (Yoshimi Kuroda and Pan Yotopoulos 1978). The search for an explanation led to a model in which production and consumption decisions are linked because the deciding entity is both a producer, choosing the allocation of labor and other inputs to crop-production, and a consumer, choosing the allocation of income from farm profits and labor sales to the consumption of commodities and services. Farm profit included implicit profits from goods produced and consumed by the same household, and consumption included both purchased and self-produced goods. As long as perfect markets for all goods, including labor, exist, the household is indifferent between consuming own-produced and market-purchased goods. By consuming all or part of its own output, which could alternatively be sold at a given market price, the household implicitly purchases goods from itself. By demanding leisure or allocating its time to household production activities, it implicitly buys time, valued at the market wage, from itself. This model applies to all but agribusiness-operated commercial farms, which consume a very small share, if any, of their own output and supply few, if any, of their own inputs.

In particular, a model was needed to explain the economic behavior of: (1) the net-surplus producing family farm, typical of small owner-operated farms of medium productivity; (2) the subsistence and sub-subsistence household farm, typical of small-scale, low productivity agriculture, frequently operating under marginal conditions and incomplete markets; (3) small-scale renter and sharecropper farms; and (4) the owner-operated commercial farms producing food for both domestic consumption and agro-industry and export markets. These cases describe the farming systems in which most of the rural population in the developing world is engaged.

In its dual role as producer and consumer, the household makes production, labor allocation and consumption decisions that may be interdependent upon one another. In its most general conceivable form, the household's objective is to maximize a discounted future stream of expected utility from a list of consumption goods including home-produced goods, purchased goods, and leisure, subject to what may be a large set of constraints (discussed below). In practice, research focus, analytical tractability, and available data result in significant simplifications of both the objective function and the constraints. Most agricultural household models are static (eliminating "discounted future stream of" from the preceding sentence) and assume that prospects are certain or, equivalently, that households are risk neutral (changing "expected utility" to simply "utility").[1] Constraints typically include cash income, family time and endowments of fixed productive assets, and production technologies (all of which may be combined into a single "full-income" constraint; see Singh, Squire and Strauss, 1986), and prices of inputs, outputs, and non-produced consumption goods. Price-related constraints either fix prices exogenously (the case of household tradables with perfect markets) or, in the case of missing markets, specify an internal "shadow price" determination condition, i.e., that the household's demand for a good equals its output (the case of household nontradables with missing markets; Strauss, 1986; Alain de Janvry, Marcel Fafchamps and Elizabeth Sadoulet, 1991).

[1] Exceptions include applied theoretical analyses by Israel Finkelshtain and James A. Chalfant (1991) on consumption risk and the dynamic three-period model in Wallace E. Huffman (2001).

The solution to a household-farm model yields a set of core equations for outputs, input demands, consumption demands, and either prices (for household nontradables) or marketed surplus (for household tradables). In the case of produced goods, marketed surplus is output minus household consumption. In the case of labor, it is the household's labor demand minus its labor supply, or net wage-labor supply. The solution to the household-farm model represents all dependent or endogenous variables as functions of exogenous variables (prices of tradables, farm assets, household time constraint, other household characteristics), usually including some that may be influenced by policy (e.g., government-set prices for staples or cash crops). The form of this solution, particularly the interactions between production and consumption that are a trademark of household-farm models, are extremely sensitive to assumptions about the extent to which households are integrated into product and factor markets.

A key motivation for agricultural-household analysis is for policy analysis, based on comparative statics with theoretical or parameterized models. Analytically, agricultural household models resolve the apparent paradox of a positive own-price elasticity of demand for food in farm households, as well as the puzzle of sluggish marketed-surplus responses to food-price changes. Empirical models, using micro-survey data, have made it possible to estimate the magnitude of supply and marketed-surplus elasticities in a number of different country settings, while confirming quantitatively the importance of using household-farm, rather than simply "household" or "farm," models to analyze rural economies.

The fundamental difference between an agricultural household model and a pure consumer model is that, in the latter, the household budget is generally assumed to be fixed, whereas in household-farm models it is endogenous and depends on production decisions that contribute to income through farm profits. Thus, to the standard Slutsky effects of the consumer model, agricultural household models add an additional, "farm profit" effect, which may be positive (e.g., if the price of the home-produced staple increases) or negative (as when the market wage increases, squeezing profits). In a consumer model, when the price of a normal good (say, food) increases, its demand unambiguously decreases: a negative "real income" effect reinforces a negative "substitution" effect, as illustrated in the most basic indifference-curve analysis. However, the household-farm is both a consumer and producer of food. As a consumer, it is adversely affected by a higher food price, but as producer, its profit from food production increases. This adds a positive "farm profit" effect to the negative Slutsky effects on food demand, pushing the budget constraint outward. If this profit effect outweighs the Slutsky effects, the household's demand for food increases with the food price. Indeed, out of seven empirical applications of the basic neoclassical household-farm model presented in Singh, Squire and Strauss (1986), four produced evidence of a positive own-price elasticity of food demand. This higher food demand dampens, and theoretically could reverse, a positive effect of food prices on the marketed surplus of food to urban households.

The structure of markets in which the household is embedded is critical in shaping the response to exogenous policy and other shocks. A key assumption of most agricultural household models is that the household can obtain perfect substitutes for family labor in local labor markets—and conversely, that it can sell its own labor at a given market wage. This permits the household to decouple production from leisure: in response to a policy or market change, it can increase production (and demand more labor) while at the same time consuming more leisure, by hiring workers to fill the resulting excess demand for labor.

We can illustrate comparative statics in a basic household-farm model as follows: Consider an increase in the (market or policy-determined) price of staples. The immediate effect of the price increase is to raise the marginal product of all inputs, including labor. The standard profit-maximizing rules that apply to the firm also apply to the household as producer: both hire inputs at the point where the marginal value product of the input equals the input price. Thus, the higher marginal value product of labor results in an increased labor demand for staple production.

In a household that uses its labor both to produce on the family farm and to sell on the labor market, an immediate effect of the staple-price increase is to allocate more labor to on-farm production and less to wage work, because the opportunity cost of labor on the farm has gone up. Alternatively (and, in the basic model, equivalently), it may continue to supply labor to the market while hiring workers needed to expand staple production and maximize profits. In any case, the on-farm production effect for the crop whose price has increased is unambiguously positive, given the usual assumptions of production economics.

As a consumer, the household now faces a higher staple price; however, it also experiences an increase in its income due to higher profits from farm production, leading to a positive income effect competing with the negative Stutsky effects outlined above. The effect on household consumption of the crop whose price has risen becomes ambiguous; it depends on the slope of the household's utility function as well as the magnitude of the profit effect. In the case of a staple-price increase and perfect hired-labor market, there is no ambiguity on the labor side: the opportunity cost of leisure remains the same, equal to the market wage; the initial increase in the marginal value product of labor on the farm, due to the staple price change, is erased by the increased demand for labor on the farm (due to the assumptions of a fixed wage plus decreasing marginal physical product of labor); and the increase in income, due to higher profit from staple production, unambiguously increases leisure demand (reducing family labor supply), assuming that leisure is a normal good.

Shocks other than staple price changes may produce more complex, and analytically ambiguous, results. For example, the impact of an increase in market wage on leisure demand (the mirror of family labor supply) has three components in an agricultural household model: (1) a negative Slutsky effect, as the higher market wage increases the opportunity cost of leisure; (2) a positive labor endowment effect, familiar to those who have studied upward-sloping labor supply curves; plus (3) a negative farm profit effect, because labor is an input in farm production. The addition of the household-farm profit effect to the Slutsky and endowment effects does not resolve the ambiguity implicit in labor-supply models; however, it makes it more likely that the effect of a wage increase on leisure demand (labor supply) will be negative (positive) (see Wallace E. Huffman, 1980).

As these examples illustrate, there is potential for large biases if the interdependence between production and consumption is ignored when modeling economic actors who are engaged simultaneously in both.

Estimated household-farm models can be used to analyze a multitude of policy issues relating to agricultural development. The early uses were concerned primarily with farm price policy. The level at which agricultural terms of trade are set has wide implications for both efficiency and equity. Geographically diverse econometric studies (Kuroda and Yotopoulos (1978) in Japan; Lawrence J. Lau, Yotopoulos, Erwin C. Chou and Justin Y.F. Lin (1978) in Taiwan; Choon Yong Ahn, Singh and Squire (1981) in Korea; Peter Hazell and Alisa Roell (1983) in Malaysia and Nigeria; Strauss (1984) in Sierra Leone; Kamphol Adulavidhaya, Kuroda, Lau and Yotopoulos (1984) in Thailand) demonstrate that, as expected from neoclassical models, an increase in the price of a crop increases production of that crop (the own-price supply elasticity is positive). However, they also reveal positive consumption effects through farm profits. In four out of seven studies reviewed by Singh, Squire and Strauss (1986), the consumption effect was large enough to significantly dampen the increase in marketed surplus of the crop whose price rose. This may negatively affect urban consumers, agro-industry processors and exporters.

Despite an early emphasis on price policy, the uses of farm household models included applications to such diverse topics as off-farm labor supply, technology policy, nutrition policy, downstream growth, labor supply, migration, income distribution, savings and family planning. Huffman (1980, 1991, 2001) used an agricultural household model to examine off-farm labor supply, production, and consumption decisions by U.S. farmers. Singh and Subramanian

Janakiram (1986) studied the impact of government input and output policies on modern input use by Korean farmers. Strauss (1984) investigated the determination of food consumption and calorie intake by rural households using a household farm model and found that the effect of price policies on calorie intake are especially pronounced for low-income, semi-subsistence farmers. Howard Barnum and Squire (1979), studying the Muda River valley of Malaysia, found that production and marketed surplus responses to crop prices can be counterintuitive if market wages rise sufficiently: both production of the crop whose price has risen and labor allocations to other crops can decrease. Whether that does or does not happen depends both on how households trade off income versus leisure (the substitution effect) and how much the value of the marginal product of labor increases (the income effect). These effects depend not only on the household's economic characteristics but also on its socio-demographic characteristics (e.g., education and sex-composition; Griffin 1986). Barnum and Squire (1979) used a household farm model to estimate the opportunity cost of migration. Their estimates indicated that the true opportunity cost is about half of the marginal product of labor on the farm when allowances are made for the increase in supply of family labor remaining on the farm in response to reductions in household size, along with the effects of migration on market wages. Government income-redistribution, wage increase, and asset transfer policies have been studied with regard to their effects on production, factor demands, labor supply and consumption expenditures across households (Lau, Yotopoulos, Chou and Lin (1978). Constantino Lluch, Alan Powell and Ross A. Williams (1977) found that the savings rate is sensitive to the price of food and that this sensitivity is greatest for poor households. Strauss (1984) and Barnum and Squire (1979) use household models to estimate the net benefits of family planning, by using household farm models to study the cost-benefits of having one less family member when consumption, time allocation and production decisions are modeled simultaneously. Other applications of agricultural household models in developing country settings include Mark

Rosenzweig (1980), Hanan Jacoby (1993), and Awudu Abdulai and Christopher L. Delgado (1999).

The examples cited above are for "whole" household-farm models, in which researchers estimate both the consumption and production sides of the model. Inspired in part by Ramon Lopez' (1986) exploitation of the potential separability of agricultural household production from consumption decisions, a new generation of empirical rural economic research has emerged, grounded in household-farm theory but involving estimation of partial agricultural household models. These studies illustrate ways in which agricultural household theory informs microeconomic research on myriad topics. Taylor (1987) adds to the effects on which migration is conditioned the rural income-effect of remittances from the migrants. On average, estimated remittances from migrants are about three times the expected contribution to household income of the same individuals had they stayed on the farm. Scott Rozelle, Taylor and Alan deBrauw (1999) and deBrauw, Taylor, and Rozelle (2002) design and estimate a nonrecursive or simultaneous agricultural household model with data from rural Chinese households to test the proposition of the new economics of labor migration that migrant remittances loosen various market constraints on rural households (see Taylor and Philip L. Martin, 2001 and papers by various authors in Oded Stark, 1991). They find significant negative effects of families' loss of labor to migration on farm production, incomes, and crop yields, but also significant positive effects of remittances on all of these variables. These findings contradict the assumptions of perfect markets and are evidence that rural Chinese households face imperfections in labor and credit markets. They also offer some assurance to policy makers concerned about negative effects of migration on food production in China. Agricultural household models have been used to analyze critical environmental issues (Stephen B. Brush, Taylor and Mauricio Bellon, 1992; Bellon and Taylor, 1993; George Dyer, 2001; Eric M. Vandusen, 2000; Erika Meng, Brush and Taylor, 1998). An agricultural-household perspective is implicit in a number of models of access to, and terms of, credit (Michael Carter, 1988, Anjini Kochar, 1997) and a small literature on impacts of credit constraints on production (Carter, 1989, Maqbool Sial and Carter, 1996), building upon seminal work by Gershon Feder, Lau, Lin and Xiao-Peng Luo (1990). It also informs empirical and applied-theoretical studies of household strategies to overcome constraints in labor and product markets (Strauss, 1986; de Janvry, Fafchamps and Sadoulet, 1991) and risk (Finkelshtain and Chalfant, 1991). Increasingly, the starting point for microeconomic research on small-farm economies, theoretical or applied, is an agricultural household (or, more generally, given the increasing diversity of rural economies, a household-firm) theoretical framework.

2

Household-Farm Models: A Graphical and Analytical Presentation

Household-farm models may be viewed as either trade models or very small general-equilibrium models. In this section, we borrow from trade theory to analyze household-farm economies at the two extremes of market integration, illustrated in Figures 1 and 2. We have found such diagrams, focusing on production possibility frontiers defined at the household level, to be the most compact way to illustrate the agricultural household model under alternative market scenarios.

Both diagrams depict a simple, two-good household-farm economy, in which households obtain utility by consuming food (C_f) and leisure (C_{le}), given by a utility function of the form $U(C_f, C_{le}; Z_h)$, where Z_h represents household characteristics influencing the marginal utilities of food and leisure consumption, and the utility function is assumed to be well-behaved. Food is produced by combining labor (L_f) with capital (K_f , e.g., land), the latter assumed to be fixed in this static or short-run model. The production technology is described by a production function: $Q_f = Q_f(L_f, \overline{K}_f)$, assumed to exhibit the usual properties: increasing in labor but at a decreasing rate, given the fixed-capital constraint. Leisure is "produced" simply by not allocating household time to production or (when there is a labor market) to wage work. The simplification of this model to only two goods is more restrictive than the usual representation of household-farm models (e.g., Singh, Squire and Strauss, 1986), but it greatly facilitates graphical analysis and can easily be extended to include more than 2 goods as well as variable inputs besides labor.

The household's objective is to maximize utility subject to its budget constraint, which in turn depends on food production. The solution to this utility-maximization problem is always for the household to situate itself on the highest indifference curve attainable, subject to its budget constraint. The budget constraint, however, assumes different forms, according to the market environment in which the household finds itself.

2.1. The Extreme Case of No Markets

In the extreme case where the household has no access to labor or food markets to provide it with prices or the opportunity to exchange food for leisure (Figure 1), the household faces a production possibility frontier (PPF) depicting the direct tradeoff between producing food and consuming leisure. Lacking access to a labor market, the household must supply its own labor to production. Hired substitutes are not available; food output cannot be increased without sacrificing leisure. That is, $C_l^c = \overline{T} - L_f^c$. (In Figure 1, the superscript "c" denotes market constrained.) If the household produces no food, it can allocate all of its time to leisure ($C_l^{\max} = \overline{T}$). By sacrificing leisure, it can increase food production in accordance with its production technology. The curvature of the production possibility frontier (PPF) reflects diminishing marginal returns to labor in food production, given fixed capital. By allocating all of its time to production, it can achieve a maximum food output equal to $Q_f^{\max} = Q_f(\overline{T}, \overline{K})$. This extreme missing-markets scenario depicts a Chayanovian world in which households face severe labor-leisure tradeoffs. The production possibility frontier is the de-facto budget constraint.

The highest achievable utility in the absence of all markets is depicted by point A in Figure 1. Here, the slope of the production possibility frontier, or marginal rate of transformation (MRT) of leisure into food, equals the slope of the indifference curve, or marginal rate of substitution (MRS). The optimal (market-constrained) consumption/production levels at this solution are $Q_f^c = C_f^c$ and C_l^c. Associated with this solution are relative "shadow prices" of food, ρ_f, and household time, ω. Although unobservable, the ratio of these implicit valuations of food and time is equal (in absolute value terms) to the MRT and the MRS at point A; that is, $MRT = MRS = -\omega / \rho_f$. In theory, these shadow prices can be estimated from the PPF and observed production/consumption bundle. There is probably little incentive to do so from a policy point of view, however, because without any markets, there are almost no instruments or outcomes that can be influenced by policy. The obvious policy intervention suggested by Figure 1 is to provide household-farms with access to markets.

2.2. The Other Extreme: Perfect Neoclassical Markets

The perfect-markets neoclassical model represents the opposite extreme: all markets exist for the household and all prices are determined exogenously in those markets. There are no unobserved "shadow prices," because market prices represent the opportunity cost of food and time in both production and consumption activities. This results in the standard labor economics conclusion that agents equate the marginal rate of substitution to the (negative of) the ratio of market prices for time and food instead of to the shadow-price ratio above. Labor in production is no longer influenced by the household's time endowment; workers can now be hired from a local labor market to produce food. This means that there is no longer a tradeoff between work and leisure; the household can produce food at any point along the PPF while demanding any (nonnegative) level of leisure (up to its total time endowment, $\overline{T}$). The "shadow price" line in Figure 1 is replaced by a market price line with slope equal to $-w/p_f$ and both w and p_f exogenous to the household. No longer constrained to be self-sufficient or autarkic, the household decouples production from consumption decisions, producing where the marginal rate of transformation (now interpreted as the marginal product of labor) equals the ratio of market prices for labor and food (in absolute-value terms; see point B in Figure 2). Subsequently, it uses markets to trade to its optimal consumption point (C in Figure 2), at which the ratio of market prices equals the marginal rate of substitution between leisure and staples (again, in absolute-value terms). If staple production exceeds household consumption demand, as in Figure 2, the surplus is sold. Profits from staple sales, in effect, provide cash to hire labor, so the household can "consume" more leisure while producing more staples. Net hired labor equals the amount of labor required to produce the profit-maximizing output, L^*_f, minus the household's labor supply, the difference between total time and leisure ($\overline{T} - C_l^*$). The household hires labor if $L_f^* > \overline{T} - C_l^*$ and sells labor if $L_f^* < \overline{T} - C_l^*$.

Households, like countries, are better off with access to markets than without. Intuitively, missing markets impose constraints on households, and removing constraints logically cannot make households worse off than before. (The household is on a higher indifference curve at point C than at point A.) Households still may choose to be self-sufficient, if they wish.

A fundamental trait of the perfect-markets model is that it is "separable" or "recursive." That is, production decisions are independent of consumption decisions (although consumption clearly depends upon production, via the budget constraint). This distinguishes the perfect markets model from the missing markets model in Figure 1. In the latter, production and consumption of staples are equated by a subsistence constraint, and any increase in production implies sacrificing leisure. When one or more markets are missing, production and consumption decisions are simultaneous, rather than recursive; the model is nonseparable.

2.3. Mixed Market Scenarios

In real life, households may face missing markets for some goods but not others, resulting in a mixture of tradables and nontradables at the household level. In general, a market is missing if the cost of participating in it (transaction costs) are so high that self-sufficiency is the household's optimal strategy. Transaction costs subtract from the sales price of producers while adding to the purchase price of consumers. This creates a wedge between the (high) consumer price and the (low) producer price, or a "price band" (Nigel Key, Sadoulet and de Janvry, 1991). If the household shadow price that would obtain in the absence of a market lies between the producer and consumer prices (within the price band), the household's optimal choice is to withdraw from the market and be self-sufficient or "autarkic." That is because, as a producer, its shadow price, or subjective valuation of the good, is higher than the market price, minus transaction costs, so it is better off supplying to itself than to the market. As a consumer, its shadow price is lower than the market price, so it is better off "purchasing" the good from itself. Many mixed-market scenarios are possible. For example, markets for food (and other consumption goods) may exist, with market-determined prices, but the labor market may not, as high labor-transaction costs (e.g., costs of monitoring workers' effort) discourage hired labor use. Alternatively, a labor market might exist, but the cost (time, information-gathering, transportation) of selling food output or buying food for consumption at the nearest market center may discourage households from participating in food markets. In the simple 2-goods case, a missing labor market would force the household back to the subsistence point A in Figure 1. Lacking a second market good, it would have no rationale for producing in excess of its consumption demands. The result in this simple case would be precisely the same if the household had access to a labor market but not to a market for food.

More generally, however, when there are three or more goods (say, staples, a cash crop, other market goods, and leisure), a missing labor market may either dampen or stimulate production of specific goods. It will tend to dampen supply (and provoke a shift towards less labor-intensive activities and technologies) if the household faces a relative labor shortage (that is, if it would use a labor market to hire in workers). However, in a labor-abundant household, a missing labor market effectively traps family labor on the farm by preventing it from engaging in wage work. In this case, lack of access to a labor market depresses the household "shadow wage," stimulating production and/or leisure demand. Through its production activities, the household can transform a nontradable (labor) into a tradable (e.g., cash crop).

Multiple other missing market scenarios are possible, most with similarly ambiguous impacts on household production and consumption.

2.4. Use of Household-Farm Models for Comparative Static Analysis

The primary motivation for constructing agricultural household models is to understand impacts of policies and other exogenous shocks on household-farm behavior. Comparative statics analysis attempts to determine the sign and, in empirical models, also the magnitude of impacts of exogenous shocks on variables of interest, including production, consumption, marketed surplus, and household resource use. Difficulty in signing effects is a hallmark of household-farm models and a chief motivation for empirical models. In general, ambiguities grow with the number of endogenous variables in the model. However, even in the simplest of models, the perfect-markets case with all prices determined outside the household, the effect of most interest to early household-farm modelers, the own-price elasticity of marketed surplus, could not be signed analytically. To see why, consider an increase in the price of food when markets are perfect. As shown in Figure 2, this flattens the market price line tangent to the PPF by raising the price of food relative to labor. The household always produces at the point of tangency between the highest market price line and the PPF then trades along the line to its optimal consumption level.[2] The new optimal production point, D, corresponds to a higher level of food output than the original perfect-markets level, at B (this is based on the assumption of a positive supply response to own price). However, the new consumption point, E, entails a different mix of leisure and food than before the price change. Higher profits from food production allow the household to consume on a higher indifference curve (I_2). As depicted here (but not necessarily in all cases), the new consumption bundle includes an increased demand for food. Increased consumption, given output, dampens marketed surplus ($Q_f - C_f$). In theory, the marketed surplus response to own price could be negative (if the change in consumption exceeds the change in output), implying a high income elasticity of demand for food and/or an inelastic supply response due to technological or environmental constraints on food production. In practice, researchers find that a positive profit effect on food demand dampens, but does not reverse, the positive marketed-surplus response to food price changes (e.g., see Singh, Squire and Strauss, 1986).

When the household faces missing markets, analytical challenges intensify and the scope for conducting policy experiments narrows, because the modeler (like the policy maker) is free to change only exogenous variables, not the endogenous shadow prices that accompany missing markets. The decision of whether or not to participate in a market is endogenous and discrete, shaped by the household's reservation or shadow price and by the price band, including transaction costs. However, models of household farms with missing markets generally omit the market participation decision, due to its theoretical and empirical complexity (an exception is Dyer, 2001). Instead, they explore the sensitivity of comparative static results to alternative missing market scenarios.

The most general form of the comparative static equations is:

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[2] In the pure consumer model, the budget line pivots when one price changes. Here it shifts in a non-parallel fashion.

(1) $$\frac{dZ}{dX} = \frac{\partial Z}{\partial X}_{\bar{P}} + \frac{\partial Z}{\partial P}\frac{dP}{dX}$$

where Z is an endogenous variable of interest (say, cash-crop production), X is an exogenous variable (e.g., cash-crop price), and P is a vector of endogenous prices of nontradable goods. In the perfect markets case, all prices are given to the household exogenously by markets, and the last term above vanishes. The first right-hand term, $\frac{\partial Z}{\partial X}_{\bar{P}}$, contains all of the Slutsky plus farm profit effects depicted in Figure 2 (for Z a consumption good) and direct production effects of the change in X (for Z an output or input demand), holding all endogenous prices P (except X, if it is a price) constant:

(2) $$\frac{\partial Z}{\partial X}_{\bar{P}} = \frac{\partial Z}{\partial X}_{\bar{P},\bar{Y}} + \frac{\partial Z}{\partial Y}\frac{dY}{dX}_{\bar{P}}$$

The second right-hand term in equation (1) represents indirect effects of the X-change through its influence on endogenous prices of nontradables. For example, suppose that Z is cash-crop output, X is cash-crop price, and the endogenous price, P, is the staple price (i.e., the staple market is missing for the household). Holding staple prices constant, the increased cash-crop price will induce the household to increase its production of cash crops and raise household income, through cash-crop profits. This creates a perceived scarcity of staples in the household, as higher income from cash crops increases the demand for normal goods, including staples. The shadow price of staples, therefore, increases as the market price for the cash crop goes up. The upward pressure on the staple price will intensify if increasing cash-crop production requires shifting fixed household resources (e.g., land or scarce human capital) out of staple production. The higher shadow price of staples induces the household to invest additional resources in staple production, possibly reducing its cash-crop supply response to the price increase.

An insightful application of the missing markets model is by de Janvry, Fafchamps and Sadoulet (1991), who use a programming model of a hypothetical household-farm to explore the effects of a change in the price of a cash crop under four different market scenarios: perfect markets for all goods, a missing staple market, a missing labor market, and a combined missing staple and labor market. Their simulation results reveal the intuitive finding that missing markets reduce the own-price supply response of cash crops. This finding, however, is largely by construction, in that a plausible alternative model specification could yield a different outcome. The negative effect of missing markets on cash crop supply response depends on a fundamental and complex assumption: the cash crop competes with nontradables for inputs that are mobile across activities and whose total availability to the household is fixed. "Competition" implies that cash crop production makes relatively intensive use of the nontraded input. Here, the nontraded inputs are land (in all scenarios) and labor (in the missing labor market scenario). If land inputs are fixed by activity (e.g., quality constraints inhibit land from being shifted from staples to cash crops, at least in the short run), a missing staple market alone will not affect the cash crop supply response. If cash crops do not make intensive use of labor, a shift into cash crop production may reduce overall labor demand. In a missing labor market model, this would depress the shadow wage, bolstering the supply response. In Part 3 of this paper, we illustrate both of these scenarios using a household-farm model for a region of Mexico in which land is not highly mobile across activities and the main cash alternative to staples, livestock production, makes little use of labor.

3

Agricultural Household Models: An Application

In this section we present a general yet simple agricultural household model estimated with village household data from Mexico and programmed using the General Algebraic Modeling

System (GAMS). We begin by presenting the basic equations of the model in mathematical form. We then briefly describe the Mexico data, present the estimated model, and use it to explore impacts of agricultural policy changes mandated by NAFTA.

3.1. Mathematical Model

The solutions to all household-farm models have at least two core sets of equations: one for production inputs, including labor, and the other for consumption demands. To these are added equations for shadow prices of nontradables, if applicable. Other equations are not central to the model but derive impacts of interest from the core model variables.

Solution to the production side of the model yields labor demand equations of the following form:

$$L_i = L_i(P, \overline{K_i})$$

where L_i denotes the demand for labor by activity i (food or other production activities), P is a vector of input and output prices, and $\overline{K_i}$ denote the fixed (capital) inputs in activity i. These relationships come directly from the first-order conditions:

$$p_i \frac{dQ_i}{dL_i} = w$$

where p_i is the output price for activity i and w is the wage. Note that the vector of prices P may include (endogenous) shadow prices as well as market-determined prices for inputs and outputs. If other inputs, including multiple types of labor that are not perfect substitutes (e.g., family, hired, or different skill types of labor) or land that is fixed in total area but mobile across activities, appear in the production function, the solution to the production problem will include first-order conditions and demand equations for each of the relevant input/activity combinations. For fixed inputs, the first-order condition above determines an implicit rental rate that varies across activities.

Given optimal input demands and the production function, we can derive output, profits, and income:

$$Q_i^* = Q_i(L_i^*, \overline{K_i})$$
$$\Pi_i^* = p_i Q_i^* - wL_i^*$$
$$Y^* = \sum_i \Pi_i^* + w\overline{T}$$

In the above equations, Π_i^* denotes the maximum obtainable profit from activity i, and Y^* is full income, the sum of profits and the value of the household's time endowment. (Other endowment effects may be included, if relevant.)

Full income represents the household's budget constraint. As a consumer, the household selects a consumption bundle that maximizes utility subject to this full income, given prices of all consumption goods. Utility-maximizing consumption levels are of the form:

$$C_i^* = C_i(P, Y^*)$$

As in the standard consumer model, consumption depends upon own price, prices of related goods, and income. However, in contrast to the standard consumer model, income is endogenous in the household-farm model; it depends upon production decisions.

Market equilibrium conditions for individual goods or factors depend upon whether the good or factor in question is tradable or nontradable for the household. For tradables, prices are exogenous, determined by outside markets. Markets clear through trade with these outside markets, thereby determining marketed surplus:

$$MS_i^* = Q_i^* - C_i^*$$

If the market is missing, marketed surplus is zero. Fixed-price constraints are removed, but in their place are added an equal number of internal market-clearing conditions of the general form:

$$C_i^* = Q_i^*$$

In the case of food, this equality is straightforward: it is a subsistence constraint. For leisure, the supply variable is the household's time available for leisure after satisfying all of its production needs when hired alternatives to family labor are not available; that is:

$$Q_{le}^* = \overline{T} - \sum_i L_i^*$$

3.2. The Empirical Household-Farm Model

The first task in going from a mathematical to an empirical model is to specify forms for the production and demand functions. In the model presented below, production technologies are specified as Cobb-Douglas, and consumption demands are modeled using a linear expenditure system (LES) approach. More complicated functional forms are possible and can be incorporated into the model, data permitting. The Mexico model includes four goods (staples, cash crops, market goods, and leisure) and two production factors (labor and capital).

The household model was estimated using data from a 1993 survey of 196 households by one of the authors (Taylor) in Michoacán, Mexico, including 53 in a town or county seat and 143 in the surrounding villages that, together with the town, make up the municipio (analogous to a U.S. county). Most land in the survey area is *ejido* (reform-sector) land. The range of cultivated landholdings in our sample is from 0 to 19 hectares, and the average is 2.8 (sd=3.9; 0.4 for subsistence households (n=115, sd=0.67) and 6.3 for commercial households (n=81, sd=3.9)). Factor inputs and the prices of physical capital and hired labor were observed directly. Family labor value-added was calculated as the value of production minus the costs of intermediate inputs, hired labor, physical capital, and land rents.

Assuming profit maximizing behavior, the output elasticity with respect to labor (the exponent α_i on the Cobb-Douglas production function corresponding to activity i) equals the share of labor in total activity value added. Rearranging the first-order condition for profit maximization given previously and recognizing that, under a Cobb-Douglas technology,

$$\frac{dQ_i}{dL_i} = \alpha_i Q_i / L_i$$

the estimator for α_i is:

$$\alpha_i = \frac{wL_i}{p_i Q_i}$$

The denominator, total revenue from activity i, was observed in the household surveys and summed across all households in the sample. The numerator, the value of total (family plus hired) labor inputs, was calculated by aggregating hired and family labor value added (obtained as described above) across all households in the sample. Other variants on production functions (functional forms or factor inputs, e.g., inclusion of family and hired labor as separate inputs) and on estimation (e.g., econometric estimation of production functions) are possible but, for the sake of simplicity, not used for this model. Average budget shares were calculated from observed consumption (valued at market prices and summed across all households in a given group) and, in the case of leisure, time-use data gathered in the survey and valued using the same wage as on the production side of the model. Our objective in making these assumptions is to keep the model as simple as possible yet flexible for those who wish to experiment with alternative functional forms or estimation methods. The result is a little model for which data requirements are relatively modest.

Production parameters and budget shares are summarized in Table 1. The complete GAMS model is available on-line at www.reap.ucdavis.edu.

3.3. Policy Experiments

Recent agricultural policy changes in the context of the North American Free Trade Agreement (NAFTA) substantially alter the government's terms of engagement in Mexico's agricultural sector. A centerpiece of policy reforms has been a phase-out of price supports for staples, combined with compensating direct income payments to staple producers. By eliminating policy distortions in farm prices, it was hoped that the new policies would "decouple" government support of farmers from production decisions. Here, we use the Mexico household-farm model to test this proposition under alternative market-closure scenarios. Our findings suggest the difficulty of designing a policy that is truly decoupled in a context of rural market imperfections.

We performed three sets of agricultural policy experiments on three alternative market scenarios. Experiment I simulates the household impact of a 10-percent decrease in the support price for staples. Experiment II combines this support-price decrease with a compensating lump-sum income transfer to staple producers, similar to what actually occurred under Mexico's PROCAMPO program. Experiment III simulates the impacts of the direct income transfer without the staple price change; that is, a rural income experiment.

The three model specifications are: (1) a perfect-markets neoclassical specification, in which the household is a price taker in all markets with the exception of capital and land (which are in fixed supply); (2) a missing labor market scenario, in which household resource allocations are guided by implicit household "shadow wages;" and (3) a missing market for staples. The third scenario corresponds to a world in which the household faces high costs of transacting in staple markets. Rural Mexico is characterized by a patchwork of some staple surplus-producing areas and others producing little or no surplus for regional or national markets; fewer than half of Mexico's staple producers market their crops. If a household lacks access to outside staple markets, it is forced to be self-sufficient in staples, and production and consumption decisions are guided by a subjective valuation of staples, or "shadow price."

3.4. Results

Tables 2 through 4 report the results of our policy experiments. The columns in each table correspond to the market-closure scenarios, the rows, to the outcome variables.

3.4.1. Experiment 1: Decrease in Staple Price Supports

In all market-closure scenarios except (C), the 10-percent reduction in the support price for staples sharply reduces staple output, as marginal value products of factors in this sector fall (Table 2). In the perfect-markets scenario (A), staple production falls by 7 percent. With market-determined prices for all goods and fixed capital inputs, effects of the staple price change on other production sectors are nil. Because the household economy is highly diversified, the decreased staple price has a relatively small income effect; household total income declines by less than 1.5 percent.

The staple price change influences household interactions with markets. With wages fixed by the market, labor demand falls by 4.4 percent. In addition to reducing output, the lower staple price stimulates demand (by 9.5 percent); thus, marketed surplus of staples falls sharply (by just over 15 percent). The negative effect on demand for market goods reflects farm-nonfarm demand linkages in Mexico. These shift the influences of rural income changes into other sectors of the economy.

Column B of Table 2 reports impacts of the staple price change when the household lacks access to a labor market, that is, the value of family time is reflected in a "shadow wage" internal to the household. The negative effect of the price drop on labor demand depresses the family wage, which drops by 2.6 percent. This, in turn, stimulates both leisure demand and production of both staples and cash crops. The effect of the price change on staple output is still negative but smaller in absolute value (-5.4 percent, compared with -7.1 percent in the perfect markets case);

the endogenous wage dampens the negative marketed-surplus effect of the staple price change. Cash-crop output rises by just under 1 percent. Comparing columns A and B, it is clear that the existence of the nontradable family input, mobile across sectors, is the key to this nonzero cross-price effect. The lower family wage stimulates leisure demand, which now increases by 0.9 percent instead of decreasing.

It is not possible to simulate the staple-price change in the third market scenario, where the household lacks access to staple markets and faces an endogenous shadow price for staples.

3.4.2. Experiment 2: Decreased Staple Price and Income Transfer (PROCAMPO)

Under the PROCAMPO price decoupling strategy, staple producers receive a compensating income transfer based on their past cultivation of staples. Table 3 reports the effects of the 10-percent staple price decrease combined with a direct income transfer equal to 10 percent of the value of staple production in the base.[3]

The direct effects of Experiment 2 on the household economy are twofold. First, as in Experiment 1, lower staple prices induce the household to shift production out of staples and into competing nonstaple activities. Second, the income transfer shifts the household budget constraint outward, increasing demand for normal goods.

In Scenarios A and B, lower staple production coupled with a positive income-transfer effect on demand reduce the marketed surplus of staples by an amount slightly greater than in the first experiment (just under 16 and 14 percent, respectively, under Scenarios A and B). In the perfect-markets case, production effects are identical to those in the first experiments. With all prices exogenous to the household, there is no mechanism to create a linkage between income transfers

[3] Under the actual PROCAMPO "decoupling" scheme, payments were made on a per-hectare basis, an administrative necessity when output is not known or information about output is asymmetric. Our experiment was designed to capture the spirit of PROCAMPO, while offering a basis to compare impacts of price and incomes policies of similar (direct) magnitudes.

and the production side of the model; that is, the model is recursive or separable. In the missing labor market case (Scenario B), however, the shadow wage creates a linkage between the consumption and production sides of the model, transmitting influences of the transfer to production. This can be seen by comparing production effects in Column B of Tables 2 and 3. The PROCAMPO payment, by contributing to household income, increases the demand for leisure (now a positive response under both scenarios). This helps mitigate the negative effect of the price drop on the family wage, which now decreases by 1.9 (instead of 2.6) percent. With a higher family wage than in the first experiment, negative effects on staple production are greater and positive effects on other production, smaller. Because the household adjusts its production in response to the staple price change, the PROCAMPO payment slightly overcompensates for the adverse effects of the price change in the perfect-markets scenario. Household full income increases by 0.5 percent. However, with the missing labor market (column B), depressed wages reduce the (shadow) value of the time endowment and, through this, full income.

3.4.3. *Experiment 3: Income Transfer without Decrease in Staple Price*

The third experiment explores the impact of the PROCAMPO income transfer without the staple price change, that is, it simulates a rural income policy. The income transfer in all scenarios is identical to that in Experiment 2. Because the staple price does not change in this experiment, a closed staple market scenario can be considered in addition to the perfect markets and missing labor market scenarios.

Results of the pure transfer experiment appear in Table 4. Under Scenario A (the recursive version of the model), transfers have no production-side effects, but they increase the demand for normal goods, including staples. Marketed surplus decreases because of higher staple demand. Higher income also stimulates leisure demand (by around 1.5 percent). In order to maintain its production levels, the household hires more labor from the market. Although total labor demand, like production, is unaffected, hired labor demand rises by 2.2 percent.

Without access to a labor market (Scenario B), the household cannot hire labor to increase leisure demand while keeping production constant. A 0.65-percent increase in family wage mitigates the leisure-demand effect while transmitting a negative influence to the production side of the model. Staple and cash-crop production fall by 0.45 percent and 0.18 percent, respectively. The smaller negative effect on cash crops reflects a lower labor intensity of this activity, which includes livestock.

In the case of a missing staple market (Scenario C), the transfer effect on demand drives up the household's shadow price of staples (by 0.5 percent). In response to a perceived scarcity of staples, the household increases its staple production (by 0.4 percent). That is, the agricultural policy reform increases, rather than decreases, staple production--exactly the opposite of what was predicted by most models of effects of agricultural policy changes under NAFTA (e.g., Santiago Levy and Sweder van Wijnbergen). Small and, in some locales, even positive impacts of price changes on staple production are consistent with what actually transpired in Mexico under PROCAMPO. Nationwide, despite an 18-percent real drop in the support price for white corn between 1994 and 1997, corn output declined only slightly, from 18.13 to 18.02 million metric tons and mostly on large commercial farms, not in the small-farm sector where most of Mexico's producers are found and where most migration originates (Mexican Ministry of Agriculture, SARH). In rural economies that were largely isolated from the price policy (i.e., distant from government purchase points), the agricultural reforms may, paradoxically, have had a small expansionary effect on staple production—or at least not significantly discouraged it.

The missing labor and staple market scenarios above neatly illustrate the impacts of the income transfer in nonrecursive household models.

4

Conclusions

The goal of this paper has been to offer an accessible introduction to agricultural household models analytically, graphically, and mathematically; to provide a working GAMS model, estimated with Mexican household-farm data, as a basis for household-farm modeling; and to use this model to explore impacts of NAFTA-related policy reforms in Mexico under alternative market scenarios. Simulation findings help explain the surprising small impact of Mexico's agricultural policy reforms on production, rural incomes, and other related variables of interest (e.g., migration).

A treatment of household-farm models would not be complete without discussing the limitations of these models. All household-farm models discussed thus far assume that preferences and incomes are shared by all household members. These assumptions are convenient, permitting researchers to treat the household as though it were an individual engaged in production and consumption activities, but they obviously represent a simplification of the real world, in which interests of individual household members may diverge and all incomes may not enter into a "common pot." Some studies question the basic assumptions of shared preferences and incomes in agricultural household models, inspired by Nash-bargained household models (e.g., see Marjorie B. McElroy and Mary J. Horney, 1981; empirical tests in T. Paul Schultz, 1990 and others in the same issue; for an excellent review of models of the family see Ted C. Bergstrom, 1997). "Neoclassical" agricultural household models may be viewed as a special case of joint decision making. The critical question with regard to model choice is not whether the models discussed here represent simplifications of reality (they certainly do), but rather, what are their costs, in terms of explanatory power and potential prediction bias, when compared with the alternative of specifying behavioral equations for each individual household member and a more complex model of joint decision making within households. The modeling framework presented in Part 3 of this paper could be extended to consider intra-household conflict over resource use, for example, by representing household utility as the product of net utility gains deriving from household membership for individuals within the household.

The policy experiment findings reported in Part 3 offer insights into the likely impacts of policy shocks under alternative market scenarios. However, they, like other empirical and applied-theoretic research, take these market scenarios as given. A priority for future research is to econometrically estimate transaction costs and test hypotheses about household market participation. Households simultaneously make decisions about production, consumption, and market participation. Modeling market participation requires new data (particularly related to household-specific transaction costs) as well as theoretical and econometric extensions of household farm models (i.e., the introduction of switching regimes).

A third and, in our opinion, major limitation of the models presented in this paper is their focus on individual production-consumption units. While offering insight into direct impacts of policy and market shocks on households, the micro focus of agricultural household models risks missing an array of indirect influences shaped by fundamental features of rural economies. Exogenous shocks, in addition to influencing production and consumption within directly affected households, generate linkage effects on other households and other aspects of farm behavior that beyond the purview of household-farm models (John Mellor, 1986; Adelman, Taylor and Stephen Vogel, 1988; Taylor and Adelman, 1996; Hazell and Roell, 1983; Avishay Braverman and Jeffrey S. Hammer, 1986). Food price increases affect many agricultural households simultaneously, raising the demand for hired labor and reducing its availability to other producers and activities, both farm and nonfarm. While having a positive impact on surplus-food producers, the food-price increase is likely to have a significant negative effect on the real incomes of nonfood producers, both rural and urban. Higher wages may or may not compensate for a higher price of food for worker households. Downstream consumption and other linkages transmit impacts of policy changes from directly affected households to others in the local economy.

Income effects of policy changes are not equally distributed among rural households, a fact that is masked by most household-farm models. In the case of food price increases, they are likely to be regressive, raising village income inequality. Expenditure patterns of households directly affected by policy or market shocks are critical in shaping impacts on other households in local economies. For example, Adelman, Taylor and Vogel (1988) found that income transfers to subsistence farm-households would have both the best equity results and the best potential for stimulating downstream growth in a region of rural Mexico, because the expenditure patterns of landless households favor goods and services that are locally produced. Using a village-town CGE model, Taylor, Antonio Yúnez-Naude and Dyer (1999) demonstrate that linkages among households shape the impacts of policy changes in rural Mexico, offering an explanation of why lower corn prices under NAFTA did not stimulate a substantial increase in Mexico-to-U.S. migration. Taylor, et al. (In Press), embedding models of producer-consumers into a general equilibrium framework, find that potential environmental and demographic pressures of tourism in Ecuador's Galapagos Islands is substantially higher than indicated by past research that ignored linkages among household-firms, businesses, and tourists.

Agricultural household analysis may be viewed as a special case of micro economywide models. Stein T. Holden, Taylor and Steve Hampton (1999) explore conditions under which a village model can be decomposed into a series of independent household-farm models, using data from Zambia. In the Zambia field site, each household either (depending upon the commodity) (a) interacted directly with the world outside the village and was a price taker (e.g., maize), or else (b) was completely autarkic, with endogenous shadow prices (e.g., labor and "chitemene," or slash-and-burn staple crops). Thus, there were no true village markets in which any households participated. This may eliminate the need for a village model, if micro household-farm models can be estimated for surplus and non-surplus-producing households and the weights of the two household groups in the local economy are known.

These limitations of existing agricultural household research highlight the importance of moving beyond a microeconomic focus on households and analyzing household-farms’ behavior in the context of both *internal* conflicts over resource use as well as *external* market and nonmarket relationships in which agricultural households are embedded.

Table 1. Estimated Production and Demand Parameters in Mexico Household-Farm Model

Commodity	**Cobb-Douglas Exponents**		**Budget Share**
	Labor	**Capital**	
Staples	0.41	0.59	.05
Cash Crops	0.22	0.78	.12
Market Goods	NA	NA	.60
Leisure	NA	NA	.23

Table 2. Percentage effects of a 10% decrease in staple prices under alternative market closure rules[1]

Outcome Variable	Market Scenario A Neoclassical Perfect Markets	Market Scenario B Endogenous wage
Output		
Staple	-7.06 (-10.00)	-5.36 (-10.00)
Cash Crop	0.00 (N/A)	0.74 (N/A)
Factor Demand		
Labor	-4.40 (N/A)	-0.90 (-2.57)
Household Income	-1.47	-1.68
Consumption Demand		
Staple	9.47	9.25
Cash	-1.47	-1.68
Market	-1.47	-1.68
Leisure	-1.47	0.91
Marketed Surplus		
Staple	-15.10	-12.47
Cash Crop	0.27	1.18
Market Demand		
Market Consumption Good	-1.47	-1.68
Labor	-8.66	-

1. Changes in prices and wages are in parentheses

Table 3. Percentage effects of a 10% decrease in staple prices and compensating income transfer[2] under alternative market closure rules[1]

Outcome Variable	Market Scenario A Neoclassical Perfect Markets	Market Scenario B Endogenous wage
Output		
Staple	-7.06 (-10.00)	-5.81 (-10.00)
Cash Crop	0.00 (0.00)	0.54 (0.00)
Factor Demand		
Labor	-4.40 (0.00)	-1.82 (-1.91)
Household Income	0.50	-0.10
Consumption Demand		
Staple	11.17	11.00
Cash	0.05	-0.10
Market	0.05	-0.10
Leisure	0.05	1.84
Marketed Surplus		
Staple	-15.93	-13.98
Cash Crop	-0.01	0.66
Market Demand		
Market Consumption Good	0.05	-0.10
Labor	-6.43	-

1. Changes in prices and wages in parentheses

2. The income transfer is equal to 10% of the value of staple production

Table 4. Percentage effects of income transfer[2] under alternative market closure rules

Outcome Variable	Market Scenario		
	A Neoclassical Perfect Markets	B Endogenous wage	C Closed Staple Market
Output			
Staple	0.00 (0.00)	-0.45 (0.00)	0.36 (0.51)
Cash Crop	0.00 (0.00)	-0.18 (0.00)	0.00 (0.00)
Factor Demand			
Labor	0.00 (0.00)	-0.90 (0.65)	0.23 (0.98)
Household Income	1.53	1.58	1.61
Consumption Demand			
Staple	1.53	1.58	1.09
Cash	1.53	1.58	1.61
Market	1.53	1.58	1.61
Leisure	1.53	0.92	1.61
Marketed Surplus			
Staple	-0.74	-1.44	-
Cash Crop	-0.28	-0.51	-0.29
Market Demand			
Market Consumption Good	1.53	1.58	1.61
Labor	2.23	-	2.69

1. Changes in prices and wages in parentheses

2. The income transfer is equal to 10% of the value of staple production

Figure 1. Agricultural Household with Missing Markets

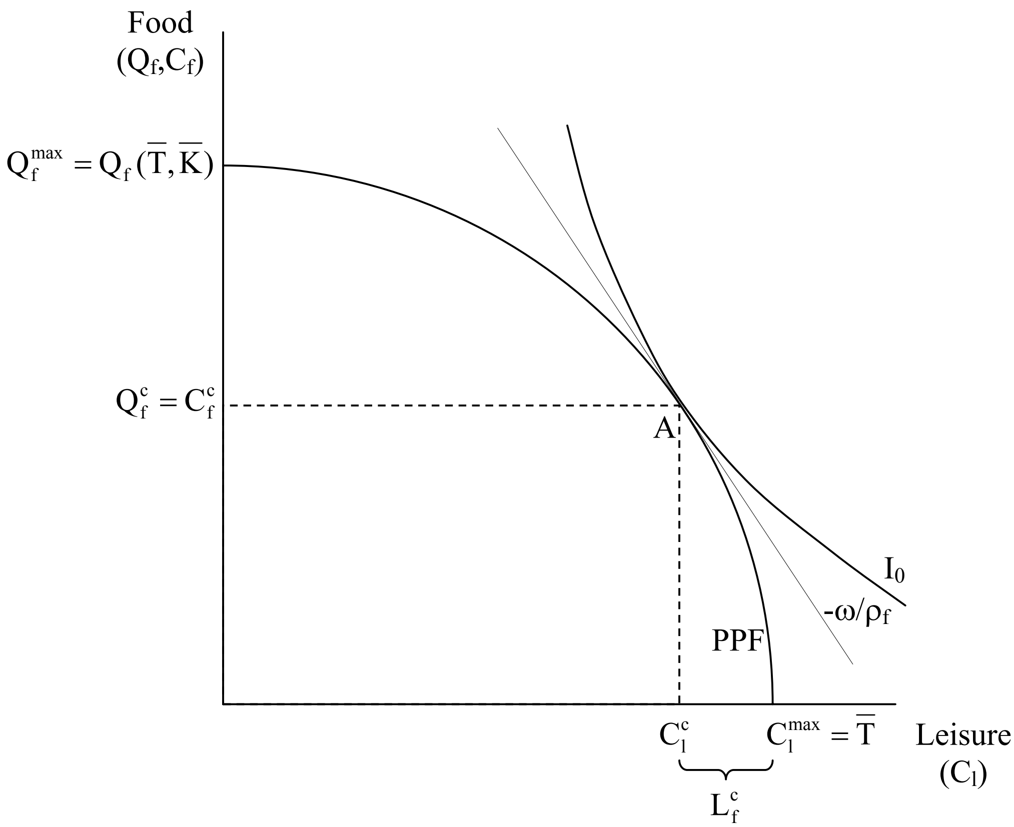
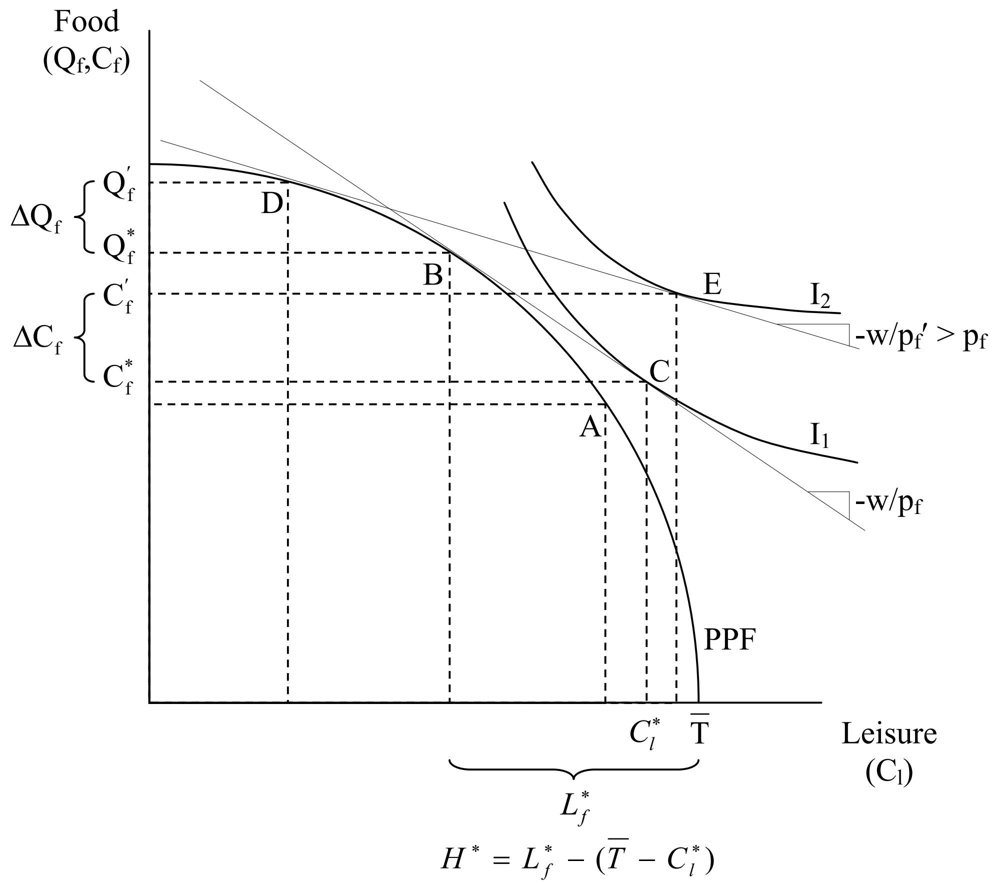


Figure 2. Illustrated Impact of an Increase in Food Price on Output and Consumption



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