**MSSD Discussion Paper No. 36**

# EFFECT OF TRANSACTION COSTS ON SUPPLY RESPONSE AND MARKETED SURPLUS: SIMULATIONS USING NON-SEPARABLE HOUSEHOLD MODELS

by

**Nicholas Minot**

**International Food Policy Research Institute**
**2033 K Street N.W.**
**Washington, D.C. 20006**
**Tel. (202) 862-5600 and Fax (202) 467-4439**
**http://www.cgiar.org/ifpri**

**October 1999**

**Contact: Diana Flores**
**Tel. (202) 862-5655 or Fax (202) 467-4439**

# CONTENTS

CONTENTS ........ i

ABSTRACT ........ iii

1. INTRODUCTION ........ 1

2. INTUITIVE ANALYSIS OF TRANSACTION COSTS ........ 5

3. MODELING AN INDIVIDUAL HOUSEHOLD FACING TRANSACTION COSTS ........ 9

- DESCRIPTION OF THE MODEL ........ 9
- CALIBRATION OF THE MODEL ........ 12
- RESULTS ........ 13

4. MODELING AGGREGATE MARKET BEHAVIOR WITH TRANSACTION COSTS ........ 15

- METHOD ........ 15
- RESULTS ........ 16

5. SUMMARY ........ 21

6. DISCUSSION ........ 23

7. ANNEX ........ 26

- EQUATIONS IN A NON-SEPARABLE HOUSEHOLD MODEL WITH TRANSACTIONS COSTS ........ 26

8. REFERENCES ........ 39

## TABLES

Table 1-Assumptions regarding initial values for household model.................... 29

Table 2 -Assumptions regarding demand elasticities for household model........ 30

Table 3 -Assumptions regarding output supply and input demand elasticities for household model........................................................................... 31

## FIGURES

Figure 1-Household supply and demand with transaction costs as a function of the household shadow price............................................................ 32

Figure 2: -Household supply and demand with transaction costs as a function of the market price............................................................................ 33

Figure 3-Household supply and demand as a function of market price and transaction costs ............................................................................ 34

Figure 4-Aggregate supply and demand as a function of market price and transaction costs ............................................................................ 35

Figure 5-Price elasticities of supply and demand as a function of market price and transaction costs ...................................................................... 36

Figure 6-Proportion of self-sufficient households as a function of market price and transaction costs ...................................................................... 37

Figure 7-Elasticity of market surplus as a function of market price and transaction costs.......................................................................................... 38

# ABSTRACT

This paper explores the effect of transaction costs on aggregate supply and demand and marketed surplus. A five-good non-separable household model is used to illustrate the effect of transaction costs on a generic African household. Then, the paper examines the aggregate behavior of a market consisting of 50 such households with varying production capacities. The simulations reveal that transaction costs not only decrease market surplus but that they can substantially reduce the elasticity of supply and demand. Under other circumstances (when almost all households are net sellers), transaction costs can also make supply and demand more elastic. Finally, the results show that transaction costs generally increase the price elasticity of marketed surplus. The implications for research in agricultural marketing are discussed.

# 1. INTRODUCTION

Studies of the determinants of agricultural supply and marketed surplus generally distinguish between price and non-price, or structural, factors. Structural factors such as transportation infrastructure, irrigation, and literacy are generally assumed to shift the supply schedule outward (see Binswanger *et al*, 1987 and Chibber, 1989). This paper shows that, in the case of food markets in developing countries, improved transportation infrastructure should not only shift agricultural supply outward but it should increase the elasticity of agricultural supply.

Transportation costs are simply the most concrete form of transaction costs, defined as the monetary and/or opportunity costs associated with carrying out a sale or a purchase. Other transaction costs include those associated with finding a buyer (or seller), negotiating a contract, financing the payment, and enforcing the transaction agreement. Models of household behavior generally exclude transaction costs by assuming that the household faces a unique exogenous price in each market, a price at which it can buy and sell (see Yotopolous, *et al.* 1976; Singh *et al*, 1986). This assumption simplifies the analysis because production decisions are unaffected by (or "separable" from) consumption decisions. When transaction costs are introduced, the wedge between buying and selling price makes the model non-separable and thus more difficult to solve[1]. In particular, it introduces inequalities into the model: with transaction costs, household shadow prices are less than or equal to the buying price and greater than or equal to the selling price.

In a pioneering study, de Janvry, Fafchamp, and Sadoulet (1991) examine the effect of “missing markets” using a household model calibrated to represent a generic African household. They show that if households cannot buy or sell food or labor, the supply of cash crops become more inelastic. In the absence of food markets, for example, households must be self-sufficient[2] in food, limiting their ability to reallocate land and labor to cash crops. In their model, the net position of the household for each commodity (whether it is a buyer, a seller, or self-sufficient) is imposed exogenously. Transaction costs are used to explain why a market might be “missing”, but they are not part of the model. This approach avoids the use of inequalities but is only valid only for small price changes, since large changes may cause the household to change net position. Furthermore, the model does not demonstrate the effect of changes in transaction costs on household behavior.

---

[1] Non-separability can result from other factors as well, such as market power, risk, and imperfect substitutability between home goods and purchased goods (see Roe and Graham-Tomasi, 1986 and de Janvry and Sadoulet, 1996).

[2] Throughout this paper, we use "self-sufficient" as a synonym for autarkic, meaning that the household neither buys nor sells the commodity in question.

At the national level, Delgado (1992) argues that high transport costs make starchy staples non-tradable, so the competitiveness of exports may be constrained by low productivity in wage-good food crops. At the household level, Goetz (1992) uses a switching regression model to demonstrate that transaction costs affect farmer decisions whether to buy, sell, or not participate in the market. Jayne (1994) and Omamo (1998) show that high transportation costs help to explain farmer decisions to grow food rather than cash crops, even if the latter generates higher returns (where returns are calculated using market prices rather than farm-level opportunity costs). Lofgren and Robinson (1999) use mixed complementarity programming (MCP) to develop a household model in which the net position in each market is endogenous. They embed models of small and large farms in a computable general equilibrium model to study market interactions in the presence of transaction costs.

This paper examines the effect of transaction costs on the own-price elasticities of demand, supply, and marketed surplus. It begins with a simple graphic analysis to illustrate the effect of transaction costs on household supply and demand. Next, a model is presented that simulates the behavior of a utility-maximizing household facing transaction costs, using MCP as proposed by Lofgren and Robinson. The model is used to explore the effects of transaction costs on the supply and demand schedules of an individual household. Finally, the effect of transaction costs on aggregate market behavior is examined by modeling the combined effect of a large number of households, each facing transaction costs.

The results show that transaction costs generate discontinuous behavior in which the household is a net seller over a certain market price range, self-sufficient over a (lower) price range, and a net buyer over another (still lower) price range. Extending the model to represent market behavior, we show that transaction costs shift both supply and demand, as well as affecting price elasticities. In most cases, transaction costs dramatically reduce the own-price elasticities of aggregate supply and demand. Somewhat surprisingly, the study also finds that transaction costs can, under different but plausible circumstances, make supply and demand *more* elastic. Another unexpected result is that even when transaction costs make supply and demand less elastic, they generally make the marketed surplus *more* price elastic. Thus, the high transaction costs that characterize food markets in developing countries can explain high rates of food self-sufficiency as well as inelastic supply and demand. On the other hand, high transaction costs (as modeled here) cannot explain inelastic marketed surplus.

## 2. INTUITIVE ANALYSIS OF TRANSACTION COSTS

Suppose that a household must incur a transaction cost, t, in order to sell or buy a commodity. This may be interpreted as the cost of transporting goods between the farm and the market and any other costs associated with finding a buyer/seller and negotiating an agreement. To simplify the exposition, we assume that transaction costs are equal for buyers and sellers and that they are proportionate to the volume bought or sold[3]. The transaction costs (t) drive a wedge between the exogenous market price ($p_m$) and the endogenous household shadow price ($p_h$), but the direction of the wedge depends on whether the household buys or sells the commodity. For deficit households, $p_h = p_m + t$, and for surplus households, $p_h = p_m - t$. At the same time, the net position of a household depends on the relationship between the shadow price ($p_h$) and the autarky shadow price (ASP), defined as the shadow price at which the household is self-sufficient. The household will be a net buyer (seller) if $p_h$ < ASP ($p_h$ > ASP). Combining these two sets of relationships, we find that for net buyers, $p_h = p_m + t <$ ASP or (rearranging terms) $p_m <$ ASP - t. By the same logic, for net sellers, $p_h = p_m - t >$ ASP or $p_m >$ ASP + t. A third possibility is that ASP - t < $p_m$ > ASP + t (or, equivalently, $p_m + t >$ ASP > $p_m - t$). In this range, transaction costs

---

[3] The model presented later can easily incorporate transaction costs that are assymetric and/or have a non-linear relationship with volume.

make it unprofitable for the household to buy or sell so the household is self-sufficient and $p_h$ = ASP[4].

Sadoulet and de Janvry (1995) illustrate the effect of transaction costs on household decision-making with Figure 1 which shows household supply and demand as a function of the household shadow price ($p_h$). In this figure, $p_m + t >$ ASP $> p_m - t$ so the household is self-sufficient ($S=D=Q_0$). For small shifts in household supply or demand, the ASP changes but the household remains self-sufficient. Only if the shift is large enough to push ASP above $p_m + t$ (below $p_m - t$) does the household becomes a net buyer (net seller). For small changes in market prices, the household remains self-sufficient and production and consumption are unchanged. In fact, for any market price between ASP + t and ASP - t, the household shadow price is unchanged, so production and consumption are also unchanged. Only if the market price moves out of this range does trade become profitable. Specifically, if the market price falls below ASP - t, the household will begin to buy and if the market price rises above ASP + t, the household starts to sell.

---

[4] These relationships are analagous to those found in international trade in which (in the absence of distortions) the domestic price of a tradable good is bounded by the CIF and FOB prices, but may not be equal to either if the country is self-sufficient in the good.

Another way to look at transaction costs is to graph household supply and demand as a function of the *market* price ($p_m$), as shown in Figure 2. Without transaction costs, the household supply and demand schedules are represented by $S(p_m, t=0)$ and $D(p_m, t=0)$, respectively. In this case, the household would be a net seller (buyer) when $p_m$ > ASP ($p_m$ < ASP). With transaction costs, the household will only be a net seller when $p_h$ > ASP implying that $p_m$ > ASP + t. The price at which selling begins has shifted up by t. In fact, at any market price $p_m + t$, the net seller behaves as if the price were $p_m$ and there were no transaction costs. This implies that the whole upper portions of the original supply and demand curves shift upward by t. Likewise, the household will not buy until $p_h$ < ASP implying that $p_m$ < ASP - t. By the same logic, the lower portion of both curves shifts down by t. In the region where ASP - t < $p_m$ < ASP + t, the household is self-sufficient and unaffected by market prices. This is represented graphically by a vertical line where supply and demand coincide.
I will refer to this figure as the “reflected-Y” diagram, since it resembles a Y on a mirror. It illustrates the intuitive idea that at high market prices, the household is a net seller, at low prices a net buyer, and at a range of intermediate prices, the household is self-sufficient. The length of the vertical portion of the diagram is equal to 2t, so increasing transaction costs will widen the range of market prices

over which the household is self-sufficient. Higher transaction costs also reduce the volume of trade for any given market price[5].

It is important to note that kinks in Figure 2 do not represent any discontinuity or irrationality in behavior with respect to household shadow price. Rather they are the result of a discontinuous relationship between the household shadow price and market prices. In particular, transaction costs introduce a wedge between the two that changes sign when the household switches from buying to selling. Transaction costs also create a range of market prices over which the household supply equals household demand and neither is affected by small changes in market prices.

Having provided an intuitive understanding of the effect of transaction costs on household supply and demand, we now simulate the effect of transaction costs on household supply and demand using a formal household model. Household supply and demand, we now simulate the effect of transaction costs on household supply and demand using a formal household model.

---

[5] The reflected-Y diagram can also be used to describe national supply and demand as a function of world prices. At high world prices, the country is an exporter, at low prices an importer, and over a range of intermediate world prices, it is self-sufficient.

# 3. MODELING AN INDIVIDUAL HOUSEHOLD FACING TRANSACTION COSTS

## DESCRIPTION OF THE MODEL

The underlying model involves the maximization of utility subject to exogenous market prices, production technology, and transaction costs. Since the constraints relating prices and transaction costs are inequalities, the first-order conditions are described by the set of Kuhn-Tucker conditions, consisting of both equalities and inequalities. It is these first-order conditions that constitute the household model as programmed (see Lofgren and Robinson, 1998).

The model consists of six sets of equations that describe household behavior with regard to five goods: food, a cash crop, manufactured goods, fertilizer, and labor. Although the index i represents all five goods, the parameters are set to ensure that there is no production of manufactured goods and no consumption of the cash crop or fertilizer[6].

The first block specifies the production of food and cash crops ($q_i$) and the demand for fertilizer and labor ($-q_i$) as a function of output and input prices ($p_{hi}$).

[6] These restrictions are not necessary to solve the model; they are only intended to reduce the parameter requirements and make the model fit the stylized facts of rural households in developing countries. An obvious extension of the model would be to allow non-farm activities that produce manufactured goods.

The functional form adopted here is derived from the generalized Leontif profit function. Thus, the parameter describing output supply and input demand are theoretically consistent with each other, obeying symmetry and zero-degree homogeneity in prices.

The second block specifies the consumer demand for food, manufactured goods, and labor (leisure) as a function of prices and income. We use the Almost Ideal Demand System which (except for the linearized price index) corresponds to a translog cost function. Again, the constraints associated with demand theory are imposed on the parameters.

The third block of equations defines full income as the total value of production and labor time endowment minus the total cost of production including family labor. This is equivalent to the net income from production (including the value of home produced food) plus the value of leisure time. Because $q_i$ describes output supply and *negative* input demand, Ó$q_i p_{hi}$ is equal to full income.

The fourth block of equations ensures commodity balance: the sum of production and market demand for each good must be equal to consumption plus market sales. The fifth block is a set of inequalities that require that the household shadow price of commodity i ($p_h$) be less than or equal to the market price plus transaction costs ($p_m + t$). Similarly, the sixth block specifies that the household shadow price ($p_h$) be greater than or equal to the market price minus transaction costs ($p_m - t$).

The model is written in GAMS (General Algebraic Modeling System) and solved using mixed complementarity programming (MCP), an algorithm for solving problems expressed as a set of equalities and inequalities (see Brooke *et al*., 1992 and Rutherford, 1995). MCP requires the programmer to specify one complementary variable to be associated with each inequality constraint[7]. In this model, the complementary variables linked to the fifth and sixth blocks are market purchases and market sales, respectively. The economic intuition is that if the autarky shadow price (ASP) is greater than the buying price ($p_m + t$), then inequality (6) is binding and purchases must be strictly positive. Similarly, if ASP $< p_m - t$, inequality (7) is binding and sales are strictly positive. If $p_m - t <$ ASP $< p_m + t$, neither (6) nor (7) is binding, and the household neither buys nor sells, becoming self-sufficient.

[7] MCP solves a "square" system of equations, implying that there is no objective function and the number of equations is equal to the number of endogenous variables. A binding inequality is equivalent to an equality in the system, while a non-binding inequality is equivalent to omitting the equation from the system. In order to maintain a balance between equations and endogenous variables, a variable (known as the complementary variable) must drop out of the system by becoming zero when the inequality is non-binding. Likewise, it must enter the system by becoming strictly positive when the inequality is binding.

GAMS gives the solution for one set of values of the exogenous variables, but we are interested in tracing out the supply and demand schedules over a range of market prices for food. For this reason, a price "subscript" is added to all the endogenous variables in the model so that solutions are found simultaneously for various values of the market price for food (these subscripts are not shown in Annex A to simplify the exposition).

## CALIBRATION OF THE MODEL

The demand functions are generated by specifying a reference price and quantity for each of the three consumption goods, as well as the income and price elasticities at those points. The relative prices and quantities are selected to represent values typical for a small farm household in sub-Saharan Africa. The quantities are expressed in kilograms (except labor which is expressed in person-days). Similarly, the income and price elasticities of demand are within the range of estimates from sub-Saharan Africa[8]. The reference price and quantities are shown in Table 1, while the income and price elasticities of demand are shown in Tables 2.

[8] The supply elasticity for food is assumed to be 1.0, higher than most empirical estimates. The reason for this is that econometric studies estimate the elasticity of supply with respect to market price ($p_m$), whereas the elasticities in the model are with respect to household shadow prices ($p_h$). In the presence of transaction costs, the household-level elasticities will generally be larger (in absolute value) than the market-level elasticities.

Output supply and input demand are specified at a reference price, as well as the matrix of desired output-supply-input-demand elasticities at that point[9]. The constants in the supply equation are then set to ensure that output supply and input demand curves pass through the reference price and quantity points. The matrix of output supply elasticities and input demand elasticities is shown in Table 3.

Although the model can represent different transaction costs for each commodity, the results presented here incorporate transaction costs only in the market for food. Transaction costs are generally most important in the case of staple foods because the value/weight ratio is lower than for cash crops, fertilizer, and manufactured goods. Transaction costs of 0.1, 0.2, and 0.3 are used, representing 10, 20, and 30 percent of the autarky shadow price for food.

## RESULTS

Figure 3 shows the results of the household model for different market prices (solved in increments of 0.1) with each line representing a different level of

[9] Because it is difficult to select *a priori* parameters to satisfy symmetry and homogeneity, I use linear programming to find the matrix of supply coefficients that a) satisfies the desired own-price elasticities, b) satisfies symmetry and homogeneity, and c) minimizes the sum of squared errors between the desired and actual cross-price elasticities.

transaction costs. When t=0, supply and demand form the standard AX" diagram, but when $t > 0$, they trace out the reflected-Y diagram described in the previous section. The vertical section of the diagram describes the price range over which supply and demand are equal, implying self-sufficiency. In this range, $ASP - t < p_m < ASP + t$ and transaction costs prevent the household from participating in the market. As a result, small changes in market prices in this range have no effect on the household shadow price and hence on household behavior. At market prices above (below) this range, the household becomes a net seller (buyer) and both supply and demand respond to prices.

The elasticity of supply and demand with respect to market prices are affected by transaction costs in several ways. First, over the range $ASP - t > p_m > ASP + t$, the household is self-sufficient so the elasticities of supply and demand with respect to market prices are zero. Second, transaction costs affect the elasticity even outside this price range because a one percent change in the market price ($p_m$) corresponds to a different percentage change in the household shadow price ($p_h$). Specifically, if the household is a net seller (buyer), transaction costs make supply and demand more (less) elastic with respect to market price. Third, transaction costs change the slopes of the supply and demand curves at a given market price (unless they are linear), as well as the quantities supplied and demanded. The implications of these changes are discussed in the next section.

## 4. MODELING AGGREGATE MARKET BEHAVIOR WITH TRANSACTION COSTS

Instead of a single household, we now assume that there are a number of households that carry out all purchases and sales in a single market place and that there are costs to transporting goods to and from this market. The household differ in their fixed factors, such as land and farm equipment, so they have different output supply schedules. These differences result in variation across households in production, income, and demand. Thus, the value of ASP varies from one household to another.

### METHOD

The aggregate market behavior of 50 households is simulated by placing the household model within a loop with 50 iterations, so that equilibrium values of the endogenous variables are calculated for each household. Household variation in fixed factors of production is represented by multiplying the constant in the food supply equation by a term, è, that is distributed N(1, 0.25). The distribution of è across real farm households will not necessarily be normal or even symmetric, but this is a plausible initial assumption.

It is assumed that a) only the food supply function varies across households, b) the other supply parameters remain unchanged, c) only the food market is subject to transaction costs, and d) transaction costs in the food market are constant across households[10]. Although none of these assumptions is required by the model, they simplify the interpretation of the results. Aggregate demand and supply are calculated as the sum of household demand and supply, respectively, at each market price level.

RESULTS

Figure 4 shows the aggregate supply and demand schedules with different levels of transaction costs. The graph demonstrates that transactions costs make supply and demand more inelastic, but the effect is not uniform across the range of prices. Toward the upper end of the price range, transaction costs have little effect on the slope of the supply and demand curves. This is because at high prices, most households are participating in the market as net sellers and are thus responding to price changes. Instead, transaction costs simply shift the supply curve back and the demand curve out[11]. Transaction costs shift supply

---

[10] As pointed out by Chris Delgado (personal communication), similar results can be obtained by assuming that transaction costs vary across households due to spatial dispersion of farms and different distances to the market.

[11] The vertical axis represents market prices. Since transaction costs affect the household shadow price for any given market price, changes in transaction costs are

back because they reduce the selling price ($p_m$ - t) that farmers receive for any given market price. It is less obvious why transaction costs increase food demand, since the buying price of food is raised by transaction costs. The explanation is that, in this price range, most households are net sellers, for whom the buying price is not relevant. The shadow price of food for net sellers is the selling price, which is lowered by transaction costs. The lower shadow price of food reduces the opportunity cost of consuming rather than selling food.

Toward the lower end of the price range, transaction costs again have little effect on the slopes of the curves because most households are net buyers and thus respond to price changes. Transaction costs cause demand to shift back by increasing the prices household pay for food, and they shift supply outward by increasing the value of household food production. Since most households are net buyers in this price range, higher transaction costs raise the shadow price of food and encourage production to meet household needs.

In the middle price range, the supply and demand curves shift less because some are net buyers and others are net sellers, so transaction costs have mixed effects on household shadow prices. On the other hand, aggregate supply and

---

represented by shifts in the supply and demand schedules rather than movement along them.

demand become more inelastic because a large number of households are self-sufficient in this price range.

Figure 5 shows the supply and demand elasticities as a function of the size of transaction costs and the market price, where price is plotted on the vertical axis to aid comparison with previous figures. Over most of the price range, higher transaction costs are associated with more inelastic supply and demand, but the size of the effect varies with the price. This effect is greatest when the market price ($p_m$) is near the center of the distribution of household autarky shadow prices (ASP).

The crossing lines at the top of Figure 5 reveal that, at high prices, transaction costs can actually make supply and demand *more* elastic. This is because, in the presence of transaction costs, a given percentage change in the market price will result in a larger percentage change in the household shadow price[12]. This effect applies to all net sellers, but only becomes dominant at high prices where few households are self-sufficient. This effect does not apply to net buyers, for whom the market price is less than the household shadow price. It is conceivable but unlikely that transaction costs could make supply or demand

[12] This corresponds to the rule that, with fixed marketing margins, the elasticity of supply with respect to the wholesale price will be greater than the elasticity of supply with respect to the farm-gate price.

more elastic for net buyers (it would require unusual curvature in supply and demand: $M^2q_d/Mp^2 > 0$ and $M^2q_s/Mp^2 < 0$).

Figure 6 confirms that the proportion of food-self-sufficient households is highest in the middle price range, where the center of the distribution of household ASP values is found. In addition, the figure demonstrates that, for any given market price, higher transaction costs are associated with a higher proportion of self-sufficient households. If the transaction costs are large enough, there is a price range over which $p_m + t > ASP > p_m - t$ for all households, implying that none of the households participates in the market.[13] In this case, the aggregate supply and demand elasticities are zero.

Figure 7 shows the absolute value of the elasticity of market surplus (or deficit) with respect to market price at different levels of transaction costs. The elasticities for the middle range of market prices are not shown because they are either undefined (when market surplus changes from zero to non-zero) or very large. What is striking about this graph is that for a given market price, higher transaction costs are associated with higher price elasticities of marketed surplus. In other words, even though transaction costs reduce the level of

---

[13] With an infinite number of households, there would always be some households whose autarky shadow price (ASP) is outside the range associated with self-sufficiency, but we simulate a finite number of households (50) resulting in a finite range of ASP.

marketed surplus, they increase the price elasticity of market surplus. The elasticity of marketed surplus (MS) is defined as (MMS/Mp)(p/MS). The first term, the partial derivative of marketed surplus with respect to price, changes only slightly due to curvature in the supply and demand schedules. In fact, given the normal curvature ($M^2q_d/Mp^2 < 0$ and $M^2q_s/Mp^2 > 0$), we expect the partial to be somewhat larger in absolute value under transaction costs. More importantly, however, the level of marketed surplus (MS) is lower with transaction costs. Since MS appears in the denominator, this tends to raise the elasticity of market surplus.

## 5. SUMMARY

This paper explores the effect of transportation costs and other transaction costs on supply, demand, and marketed surplus. It shows that these "structural" factors influence household and market behavior by changing the household shadow prices that correspond to a given market price. In doing so, transaction costs can cause a household to become self-sufficient, neither buying from nor selling to the market over a certain market price range. The size of the price range is proportional to the size of the transaction costs. When transaction costs are introduced, the supply and demand curves of the individual household take the form of a "reflected Y" diagram rather than the traditional "X" diagram.

The effect of transaction costs on aggregated supply and demand is somewhat different because of variation across households. Aggregate supply and demand become less elastic in the price range where transaction costs induce households to be self-sufficient. This is because the self-sufficient households are unresponsive to small changes in market prices. Even above and below the price range over which households are self-sufficient, the elasticities of supply and demand are affected by shifts in aggregate supply and demand that result from transaction costs.

This study revealed two somewhat unexpected results. First, at high prices, transaction costs can make supply and demand *more* elastic. The explanation is that in this price range few households are self-sufficient, but a given percentage change in the market price corresponds to a larger percentage change in the household shadow price. Second, even when transaction costs make supply and demand less elastic, they will generally make the elasticity of marketed surplus larger. This is because the partial of marketed surplus with respect to market price is approximately the same with and without transaction costs (differing only due to non-linearities in supply and demand), but the level of marketed surplus is smaller with transaction costs.

Thus, efforts to improve transportation networks and reduce transaction costs will not only increase market participation, shifting supply outward, but they will make the supply and demand of food more responsive to changes in market prices. Although investment in transportation infrastructure will increase market surplus, it should not be expected to increase the elasticity of marketed surplus. In fact, the analysis presented here suggests the reverse may be true.

## 6. DISCUSSION

The results presented in this paper are based on a simulation model, raising the question as to whether similar patterns would be found in real life. The structure of the model itself is not controversial: it is based on standard assumptions of household behavior combined with conventional rules of spatial arbitrage. Furthermore, the model agrees with several stylized facts regarding food markets in developing countries: 1) that a significant proportion of rural households does not participate in food markets, 2) that market participation is lowest in the more remote areas, 3) that market participation is lowest for staples with low value/bulk ratios, and 4) that supply response is lower is the least developed countries and regions.

Important questions remain, however. What is the relative importance of transaction costs and risk[14] in motivating households not to participate in the market? If risk is the dominant factor, then improving transportation infrastructure is less likely to increase supply responsiveness. Also, to what degree does food self-sufficiency reduce the elasticity of supply and demand? It is important to know not just the proportion of households that are self-sufficient,

[14] Risk may be considered a type of transaction cost. Here, however, we define transaction costs more narrowly to include only the expected value of the cost of getting produce to or from the market.

but *which* households are self-sufficient. Even if half of all rural households are self-sufficient, the impact on supply elasticities could be modest if they account for a small proportion of production, as would be the case in a country with a dualistic agricultural sector.

We can identify at least four approaches that test empirically the results presented here. First, in cross-country studies of supply response, transportation infrastructure should be included both as a shifter and as an interaction term with price. We expect the coefficient on the interaction term to be positive, suggesting that reducing transportation costs increases the responsiveness of supply to price. Second, the supply response of different regions within a country to prices in a given market should be inversely related to the distance between the market and the region. Third, supply response should be greater in regions and countries with a low proportion of self-sufficient households. Fourth, the supply and demand elasticities obtained from aggregate data should be lower than those obtained from household data, provided that the latter uses some estimate of household-level shadow prices, taking into account the costs of buying and selling.

Apart from empirical tests of the findings in this paper, a strong case can be made that agricultural marketing research needs to focus greater attention on the incidence and determinants of household food self-sufficiency. As part of this effort, it would be useful to develop and test methods for estimating the household shadow price as a function of observable variables.

Finally, this study demonstrates that advances in software and solution algorithms make the incorporation of transaction costs into household models relatively simple. This allows researchers to model farmer choices more realistically, particularly in situations where transaction costs are high such as in food markets in low-density developing countries. Here, the method was used to model transaction costs in food marketing, but it can easily be applied to modeling imperfect labor markets, credit constraints, and other manifestations of "missing markets."

# 7. ANNEX

## EQUATIONS IN A NON-SEPARABLE HOUSEHOLD MODEL WITH TRANSACTIONS COSTS

1 Output supply and input demand

$$q_i = \sum_j b_{ij} \sqrt{p_j / p_i} + \sum_m b_{im} z_m$$

2 Consumer demand

$$\frac{p_i c_i}{x} = \mathrm{a}_i + \sum_j \mathrm{b}_{ij} \log(p_i) + \mathrm{g}_i \log\left( \frac{x}{\sum_j w_j \log(p_j)} \right)$$

3 Full income

$$x = \sum_i p_i (q_i + E_i)$$

4 Commodity balance

$$q_i + mktdem_i = c_i + mktsup_i$$

5 Lower limit on shadow prices

$$p_i \geq p_i^m - t$$

6 Upper limit on shadow prices

$$p^m + t \geq p_i$$

Endogenous variables

| | |
|---|---|
| $q_i$ | Output supply of or (negative) input demand for good i |
| $p_i$ | Household shadow price for good i |
| $c_i$ | Consumption of good i |
| x | Full income |
| $mktdem_i$ | Market demand for good i |
| $mktsup_i$ | Market supply for good i |

Exogenous variables

| | |
|---|---|
| $E_i$ | Household endowment of good i |
| $p_i^m$ | Market price for good i |
| $z_m$ | Fixed factors of production |
| t | Transaction cost |
| $w_i$ | Initial budget share of good i |

Table 1-Assumptions regarding initial values for household model

| | **Price** | **Output supply and input demand** | **Consumption** | **Endowment** |
|---|---|---|---|---|
| Food | 1 | 500 | 500 | 0 |
| Cash crop | 5 | 100 | 0 | 0 |
| Manufactured good | 5 | 0 | 80 | 0 |
| Fertilizer | 2 | -50 | 0 | 0 |
| Labor | 1 | -700 | 300 | 1000 |

Table 2 -Assumptions regarding demand elasticities for household model

| | **Income elasticity of demand** | **Elasticities of demand with respect to the price of:** | | |
|---|---|---|---|---|
| | | **Food** | **Mfg. good** | **Labor** |
| Food | 0.80 | -1.00 | 0.10 | 0.10 |
| Manufactured good | 1.50 | -0.12 | -1.50 | 0.10 |
| Labor | 0.90 | 0.12 | 0.32 | -0.80 |

Table 3 -Assumptions regarding output supply and input demand elasticities for household model

| | Elasticities of supply (input demand) with respect to the price of: | | | |
|---|---|---|---|---|
| | **Food** | **Cash crop** | **Fertilizer** | **Labor** |
| Food | 0.50 | -0.24 | -0.08 | -0.18 |
| Cash crop | -0.24 | 1.00 | -0.28 | -0.48 |
| Fertilizer | 0.40 | 1.40 | -2.00 | 0.20 |
| Labor | 0.13 | 0.34 | 0.03 | -0.50 |

Figure 1-Household supply and demand with transaction costs as a function of the household shadow price

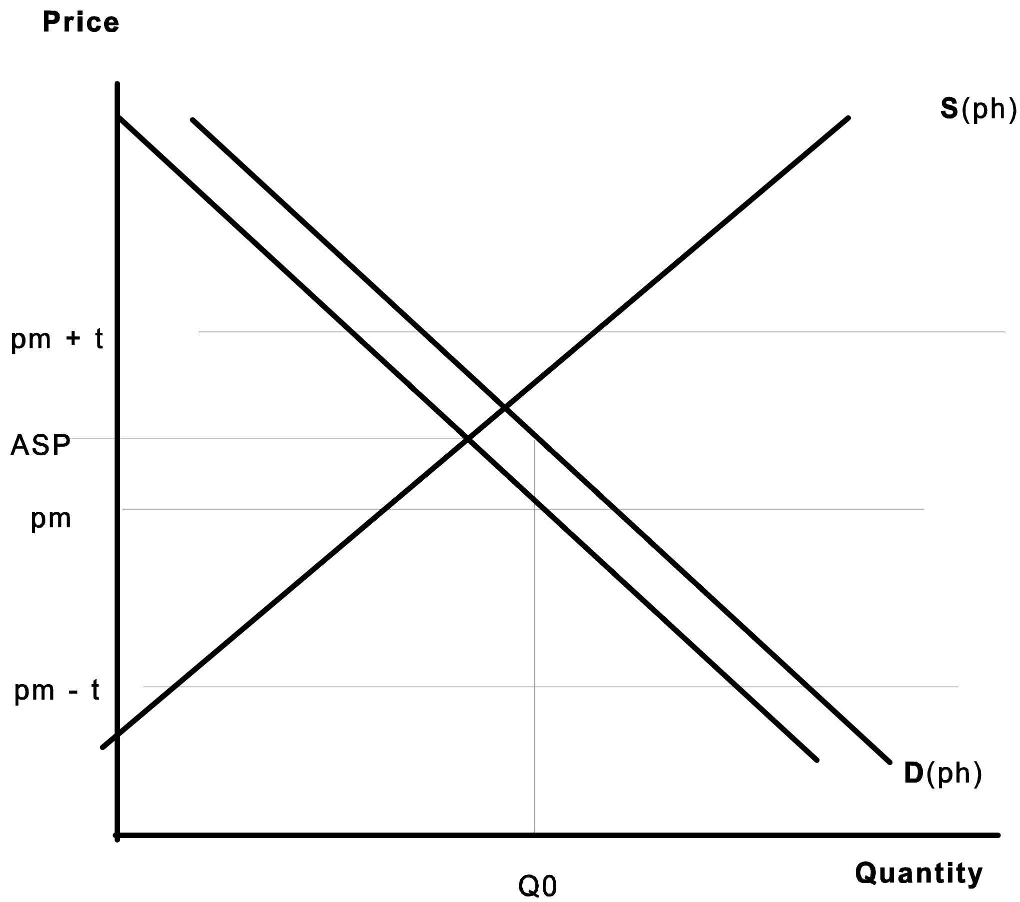


Figure 2: -Household supply and demand with transaction costs as a function of the market price

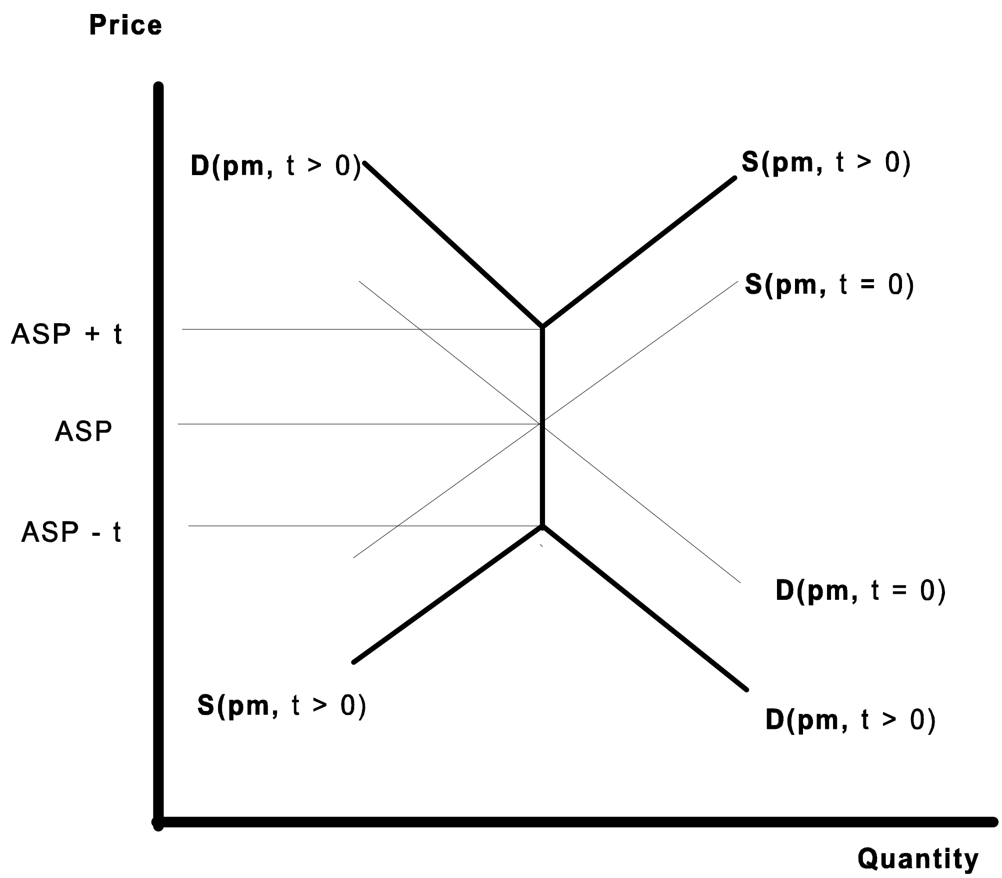


Figure 3-Household supply and demand as a function of market price and transaction costs

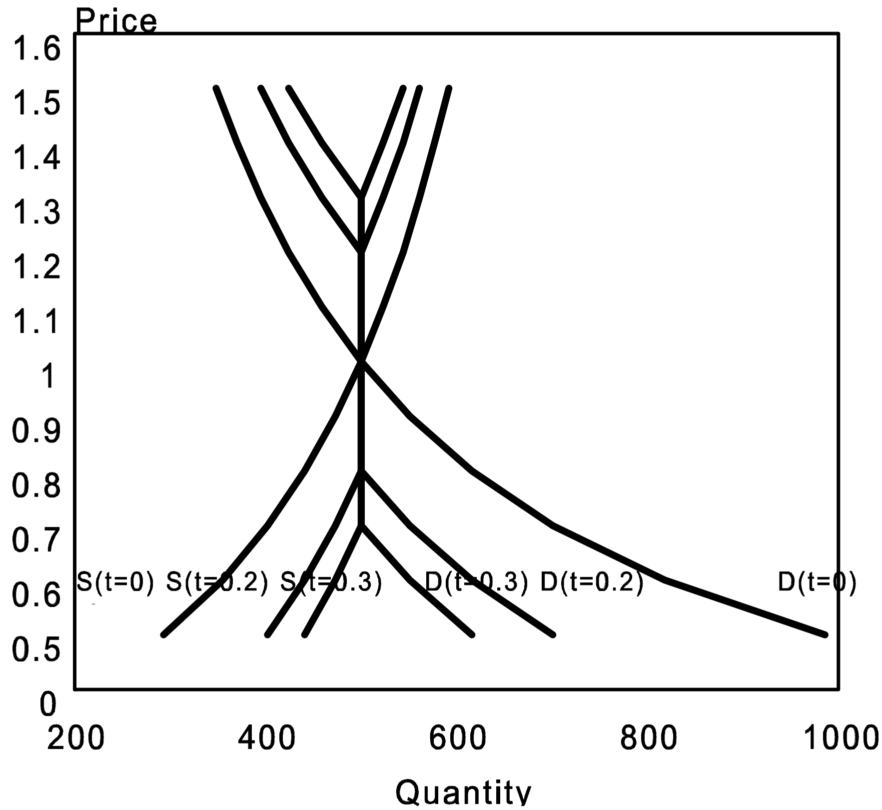


Figure 4-Aggregate supply and demand as a function of market price and transaction costs

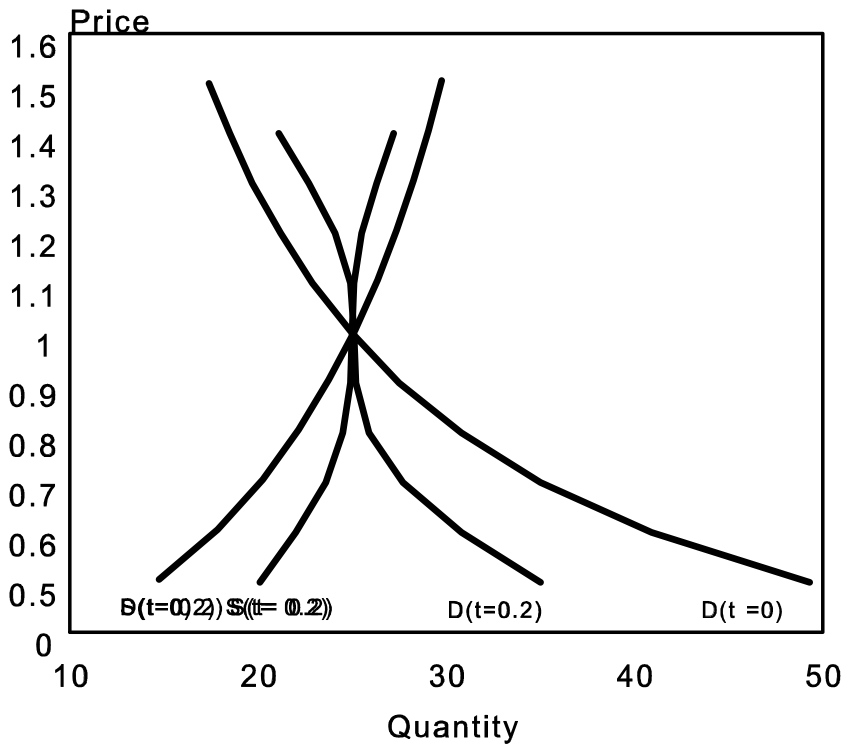


Figure 5-Price elasticities of supply and demand as a function of market price and transaction costs

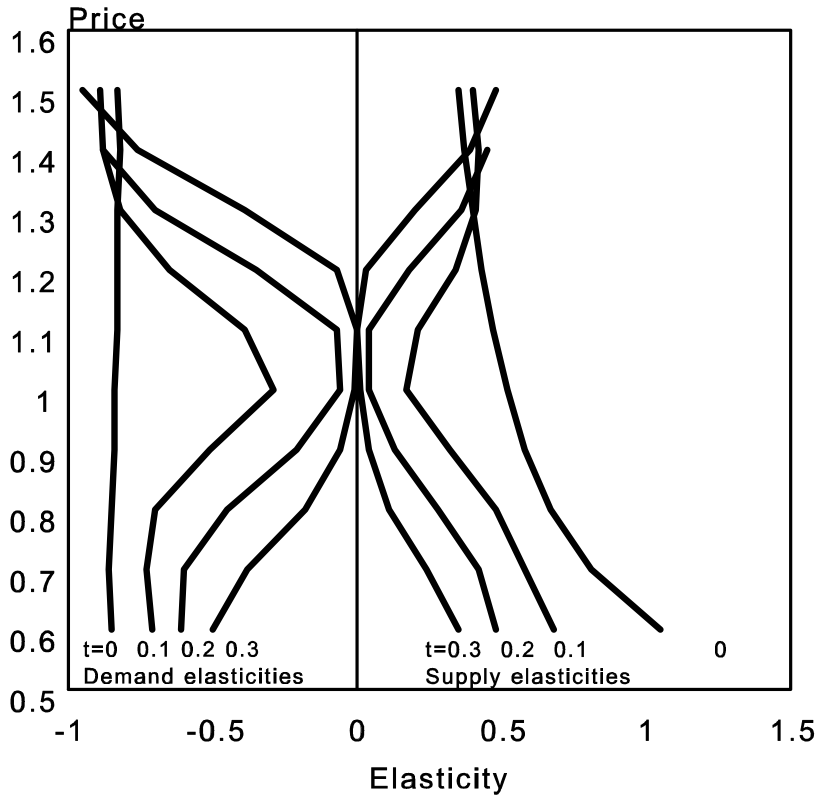


Figure 6-Proportion of self-sufficient households as a function of market price and transaction costs

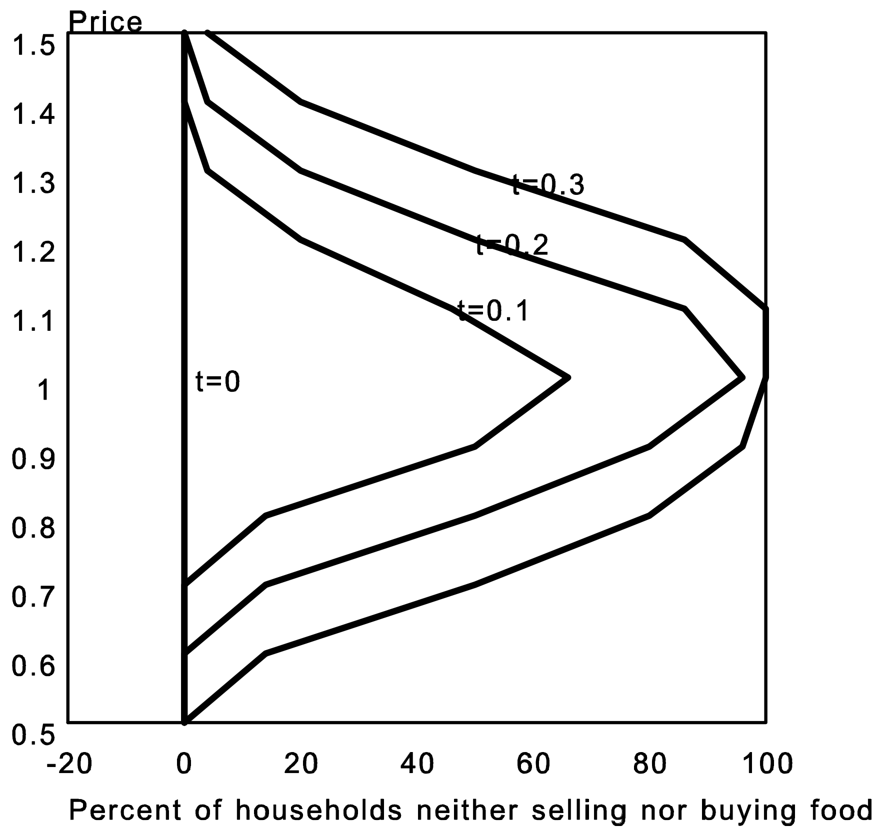
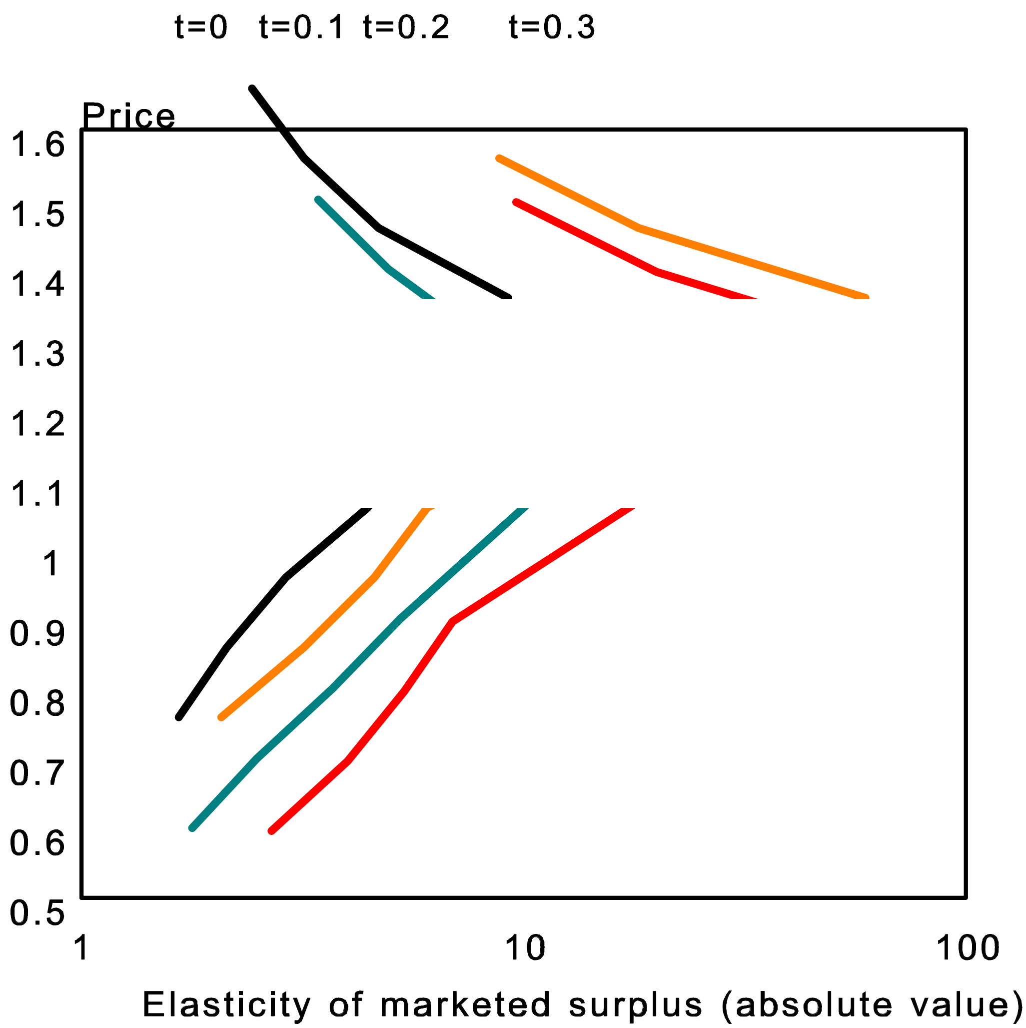


Figure 7-Elasticity of market surplus as a function of market price and transaction costs



# 8. REFERENCES

Binswanger, H., M. Yang, and A. Bowers. 1985. "On the determinants of cross-country aggregate agricultural supply." *Journal of Econometrics* 36: 111-131.

Bloom, D. and J. Sachs. 1998. "Geography, Demography, and Economic Growth in Africa." *Brookings Papers on Economic Activity* (2).

Brooke, A., D. Kendrick, and A. Meeraus. 1992. *GAMS: A User Guide - Release 2.25*. Boyd and Fraser Publishing Company. Danvers, Massachusetts.

Chibber, A. 1989. "The Aggregate Supply Response: A Survey." In Commander, S. (ed.) *Structural Adjustment and Agriculture: Theory and Practice in Africa and Latin America*. Overseas Development Institute. London.

de Janvry, A., M. Fafchamps, and E. Sadoulet. 1991. "Peasant Household Behavior with Missing Markets: Some Paradoxes Explained." *Economic Journal*. 101: 1400-17.

de Janvry, A. and E. Sadoulet. 1995. *Quantitative Development Policy Analysis*. The Johns Hopkins University Press. Baltimore.

Jayne, T. 1994. "Do high food marketing costs constrain cash crop production? Evidence from Zimbabwe." *Economic Development and Cultural Change* 42: 387-402.

Löfgren, H. and S. Robinson, 1999. "To Trade or Not to Trade: Non-separable Farm Household Models in Partial and General Equilibrium." Trade and Macroeconomics Division Discussion Paper No. 37. International Food Policy Research Institute. Washington, D.C.

Omamo, S. 1998. "Transport costs and smallholder cropping choices: An application to Siaya District, Kenya." *American Journal of Agricultural Economics* 80 (February): 116-123.

Roe, T. and T. Graham-Tomasi. 1986. "Yield Risk in a Dynamic Model of the Agricultural Household." In Singh, I., L. Squire, and J. Strauss (eds.). 1986. *Agricultural Household Models: Extensions, Applications, and Policy*. The Johns Hopkins University Press. Baltimore.

Rutherford, T. 1995. "Extension of GAMS for Complementarity Problems Arising in Applied Economic Analysis." *Journal of Economic Dynamics and Control*. 19: 1299-1324.

Singh, I., L. Squire, and J. Strauss (eds.). 1986. *Agricultural Household Models: Extensions, Applications, and Policy*. The Johns Hopkins University Press. Baltimore.

Yotopolous, P., L. Lau, and W.L. Lin. 1976. "Microeconomic Output Supply and Factor Demand Functions in the Agriculture of the Province of Taiwan." *American Journal of Agricultural Economics* 58: 333-40.