Articles

Transactions Costs and Agricultural Household Supply Response

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We develop and estimate a model of supply response when transactions costs create a situation where some producers buy, others sell, and others do not participate in markets. We present two rationales for why producing households may have different relationships to the market: proportional and fixed transactions costs. Using data on Mexican corn producers, we estimate an empirical model that allows for separate tests of the significance of both types of transactions costs, revealing that both fixed and proportional transactions costs matter for the estimation. The results provide consistent estimates of supply elasticity and measures of the relative importance of factors determining both proportional and fixed transactions costs.

Key words: market participation, supply, transactions costs.

Estimates of supply response are needed to predict the impact of policy changes on production. Yet, in developing countries, these estimates are typically unsatisfactory because the models used provide an insufficient specification of the structural context in which decisions about production and market transactions take place. One such structural feature of importance is heterogeneous market participation, wherein some agricultural producers sell a portion of their output, some are deficit producers who purchase crops they also produce, while others are self-sufficient in supply and do not participate in markets. The fact that producers have different relationships to the market has important implications for the estimation of price response. In addition, factors that cause households to choose their relationship to the market may also affect household production and should be accounted for in price response estimation.

Costs associated with market transactions can explain why some households have different relationships to the market. Proportional transactions costs (PTCs) raise the price effectively paid by buyers and lower the price effectively received by sellers of a good, creating a "price band" within which some households find it unprofitable to either sell or buy. PTCs, which include per-unit costs of accessing markets associated with transportation and imperfect information, have been used to explain labor (Eswaran and Kotwal, Sadoulet, de Janvry, and Benjamin) and food (Goetz, de Janvry and Sadoulet) market participation decisions in developing countries. An implication of proportional transactions costs for price response is that policies that affect transactions costs of sellers and buyers differently will result in different production responses for the two groups.

Fixed transactions costs (FTCs) that are invariant to the quantity of a good traded also affect a household's decision to participate in markets (Goetz, for the food market; Skoufias 1995, for the land market). FTCs may include the costs of: (a) search for a customer or salesperson with the best price, or search for a market—search costs are often lumpy since a farmer may incur the same search cost to sell either one ton or ten tons of a product, or to work one day or one year; (b) negotiation and bargaining—these costs may be important when there is imperfect

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information regarding prices (often negotiation and bargaining takes place once per transaction, and these costs are invariant to the size of the transaction); (c) screening, enforcement, and supervision—farmers who sell their product, land, or labor on credit may have to screen buyers to make sure they are reliable, and they may have to pay legal enforcement costs in case of default. Farmers may have to screen potential seed, pesticide, or labor sellers when there is asymmetric information as to the quality of the inputs. Farmers who hire labor may incur supervision costs that do not depend on the quantity of labor hired, as one supervisor can almost as easily monitor one or five workers.

We will show that an implication of fixed transactions costs for supply response is that, as producers enter or leave a market, the movement between autarky and market participation is accompanied by a discrete change in household production and consumption. Consequently, with fixed transactions costs the aggregate price elasticity will depend on how many households enter or leave the market, and how their production changes when their relation to the market changes.

When households do not participate in markets, consumption and production decisions are non-separable: production depends on the price of consumer goods and household preferences (Strauss, de Janvry, Fafchamps, and Sadoulet).[1] In terms of market response, an autarkic household is perfectly price inelastic, unless the price change is sufficient to move this household into the market as either a buyer or seller. Measures of aggregate price response may underestimate price elasticity unless they account for the inelasticity of self-sufficient households.

Whereas a large body of research has examined the labor market supply response for workers and non-workers, with the exception of Goetz there has been little work examining agricultural supply response that takes into account both the farmers' production and market participation decisions. Goetz uses a selectivity model in which marketed surplus is estimated conditional on market participation, with market participation estimated using a reduced form equation. This allows him to identify the role of proportional transactions costs but not of fixed transactions costs. In this paper, we develop an estimation of the structural model with simultaneous decision on market participation and production level. This allows us to separately identify the role of proportional and fixed transactions costs in the household supply decision and separately test for the importance of these transactions costs in the estimation. The model also provides consistent estimates of the aggregate supply response.

We begin by constructing an agricultural household model that includes proportional and fixed costs associated with market transactions. Next, we develop an empirical approach to estimating household supply response that allows us to identify separately proportional and fixed transactions costs. The empirical model is estimated using data on corn producers in Mexico. Tests show that proportional transactions costs are important in selling and fixed transactions costs matter for both sellers and buyers. Finally, we present estimation of aggregate supply elasticities. We find that 60% of the response to an increase in the sale price is due to producers who enter the sales market, while the remaining 40% is due to the response of those who are already sellers. This result suggests the importance of taking proper account of market participation decisions.

A Household Model with Transactions Costs

Structural Model

To concentrate on the role of transactions costs, we construct a static model that ignores several important aspects of households' decisions, notably the role of risk and intra-annual credit constraints. Price risk has been shown to induce asymmetric responses for buyer and seller households (Finkelshtain and Chalfant, Fafchamps). An intra-annual credit constraint gives rise to production behaviors similar to those of missing markets for products or inputs (de Janvry et al.). Constructing a more complete model would certainly improve the relevance of its prediction but would also blur the particular effect of transactions costs that we want to explore here.

To incorporate transactions costs into an agricultural household model framework, it is convenient to specify market participation

[1] Recent work has attempted to test empirically whether production and consumption decisions are separable (Benjamin, Jacoby, Skoufias 1994, Sadoulet, de Janvry, and Benjamin).

as a choice variable. That is, in addition to deciding how much of each good i to consume c_i, produce q_i, and use as an input x_i, the household also decides how much of each good to "market" m_i (where m_i is positive when it is a sale and negative when it is a purchase). If there were no transactions costs, the household's problem would be to maximize the utility function (1) subject to (2)–(5):

$$(1)\quad u(c; z_u)$$

$$(2)\quad \sum_{i=1}^{N} p_i^m m_i + T = 0$$

$$(3)\quad q_i - x_i + A_i - m_i - c_i = 0,\quad i = 1, \ldots, N$$

$$(4)\quad G(q, x; z_q) = 0$$

$$(5)\quad c_i, q_i, x_i \geq 0$$

where p_i^m is the market price of good i, A_i is an endowment in good i, T is exogenous transfers and other incomes, z_u and z_q are exogenous shifters in utility and production, respectively, and G represents the production technology. The cash constraint (2) states that expenditures on all purchases must not exceed revenues from all sales and transfers. The resource balance (3) states that, for each of the N goods, the amount consumed, used as input, and sold is equal to what is produced and bought plus the endowment of the good. The production technology (4) relates inputs to outputs.

Proportional transactions costs raise the price effectively paid by a buyer and lower the price effectively received by a seller. PTCs include many transportation and marketing costs that are unobservable or cannot be easily recorded in a survey. For example, it is difficult to measure the value of farmers' time spent selling their crops in the market, and it is difficult to measure transportation and time costs for farmers who transport their crops themselves. We can, however, observe a certain number of factors that explain these transactions costs. If we express the PTCs in monetary terms, the cash constraint becomes

$$\sum_{i=1}^{N} \left[\left(p_i^m - t_{pi}^s(z_t^s) \right) \delta_i^s + \left(p_i^m + t_{pi}^b(z_t^b) \right) \delta_i^b \right] m_i + T = 0$$

where δ_i^s is equal to one if $m_i > 0$ and zero otherwise, and δ_i^b is equal to one if $m_i < 0$ and zero otherwise. The price effectively received by the seller is lower than the market price p_i^m by the unobservable amount t_{pi}^s, and the price effectively paid by the buyer is greater than p_i^m by the unobservable amount t_{pi}^b. PTCs are expressed as a function of observable exogenous characteristics, z_t^s and z_t^b, that affect these costs when selling and buying, respectively.

As mentioned in the introduction, some transactions costs are invariant to the quantity of the product or factor transacted. Like PTCs, FTCs are generally unobservable, though we may observe exogenous factors, z_t^s and z_t^b, that can explain these costs. When there are both fixed and proportional transactions costs, the cash constraint can be written

$$(6)\quad \sum_{i=1}^{N} \left[\left(p_i^m - t_{pi}^s(z_t^s) \right) \delta_i^s + \left(p_i^m + t_{pi}^b(z_t^b) \right) \delta_i^b \right] m_i - t_{fi}^s(z_t^s)\delta_i^s - t_{fi}^b(z_t^b)\delta_i^b + T = 0$$

where the household pays the fixed cost t_{fi}^s if and only if it sells good i, and pays t_{fi}^b if and only if it buys it. Hence, allowing for both types of transactions costs, the household problem is expressed by equations (1) and (3)–(6).

Supply and Demand Conditional on Market Participation

To derive the supply and demand equations for a household facing both FTCs and PTCs, define the Lagrangian:

$$\mathrm{L} = u(c; z_u) + \sum_{i=1}^{N} \mu_i (q_i - x_i + A_i - m_i - c_i) + \phi G(q, x; z_q) + \lambda \left[\sum_{i=1}^{N} \left[(p_i^m - t_{pi}^s)\delta_i^s + (p_i^m + t_{pi}^b)\delta_i^b \right] m_i - t_{fi}^s \delta_i^s - t_{fi}^b \delta_i^b + T \right]$$

where μ_i, ϕ, and λ are the Lagrange multipliers associated with the resource balance, the technology constraint, and the cash constraint, respectively. As the FTCs create discontinuities in the Lagrangian, the optimal solution cannot be found by simply solving the first order conditions. The solution is decomposed in two steps, solving first for the optimal solution conditional on the market participation regime, and then choosing the market participation regime that leads to the highest level of utility. Under the usual assumptions for utility and technology, the conditional optimal supply and demand are obtained by solving for the first order conditions.

The first order conditions (FOCs) are, for consumption goods:

$$(7)\quad \frac{\partial u}{\partial c_i} - \mu_i = 0, \qquad i \in \{i|c_i > 0\}$$

for outputs:

$$(8)\quad \mu_i + \phi\frac{\partial G}{\partial q_i} = 0, \qquad i \in \{i|q_i > 0\}$$

for inputs:

$$(9)\quad -\mu_i + \phi\frac{\partial G}{\partial x_i} = 0, \qquad i \in \{i|x_i > 0\}$$

and for traded goods:

$$(10)\quad -\mu_i + \lambda\left[(p_i^m - t_{pi}^s)\delta_i^s + (p_i^m + t_{pi}^b)\delta_i^b\right] = 0, \qquad i \in \{i|m_i \neq 0\}.$$

Define the decision price p_i as (see de Janvry, Fafchamps, and Sadoulet)

$$p_i = \begin{cases} p_i^m - t_{pi}^s & \text{if } m_i > 0, \text{ seller} \\ p_i^m + t_{pi}^b & \text{if } m_i < 0, \text{ buyer} \\ \tilde{p}_i = \frac{\mu_i}{\lambda} & \text{if } m_i = 0, \text{ self-sufficient.} \end{cases}$$

When the household good is not traded, the decision price is the unobservable internal shadow price μ_i/λ. When the good is traded, the household's decision price includes the PTCs. Using the decision price p defined above, the FOCs (7) to (10) are formally similar to the FOCs resulting from the separable producer and consumer problems. This indicates that the solution can be written as that of a separable model (although obviously this is not a separable model because the decision price is itself endogenous): (*a*) profit maximization subject to the technology constraint (4) which leads to a system of output supply equations $q(p, z_q)$ and input demand equations $x(p, z_q)$, and (*b*) utility maximization subject to the income constraint

$$(11)\quad \sum_{i=1}^{N} p_i c_i = y = \sum_{i=1}^{N}\left[p_i(q_i - x_i + A_i) - t_{fi}^s\delta_i^s - t_{fi}^b\delta_i^b\right] + T$$

which leads to a system of demand equations for consumer goods $c(p, y, z_u)$. In this system, income y is measured at the decision price.

Market Participation with Proportional and Fixed Transactions Costs

We can now establish the conditions that determine the market participation of a household facing PTCs and FTCs. Whereas this may become quite cumbersome when there are several commodities that can be either purchased or sold, the principle can be shown with a simplified model in which there is choice of regime for only one commodity which is produced and consumed by the household (e.g., a food crop). Market participation is determined by comparing the utility obtained from selling, buying, and remaining self-sufficient in this particular commodity.

Because all three regimes can be formally written as similar optimization problems by using the relevant decision price for each case, the maximum utility that can be attained in each regime can also be formally written with the same indirect utility function. Let $V(p, y, z_u)$ be this indirect utility function, where p is the decision price of the good that we consider (and for simplicity not keeping explicit the vector of decision prices for all other goods). For convenience, define $y_0(p)$ as the household income before incurring fixed transactions costs:

$$y_0(p) = \sum_{i=1}^{N} p_i(q_i - x_i + A_i) + T.$$

The utility levels to be compared are

$$(12)\quad V^s = V\left(p^m - t_p^s, y_0(p^m - t_p^s) - t_f^s, z_u\right), \text{ if seller}$$

$$V^b = V\left(p^m + t_p^b, y_0(p^m + t_p^b) - t_f^b, z_u\right), \text{ if buyer}$$

$$V^a = V\left(\tilde{p}, y_0(\tilde{p}), z_u\right), \text{ if autarkic.}$$

Figure 1 shows these three indirect utilities as function of the market price. The vertical line indicates the utility V^a obtainable by an autarkic household, which is independent of the market price. Consider first a household who faces PTCs but no FTCs. Comparison of expressions in (12) indicates that a household will be indifferent between selling and being autarkic if $p^m - t_p^s = \tilde{p}$, shown as point C_0 in the figure. From the FOCs (7) to (10), it can

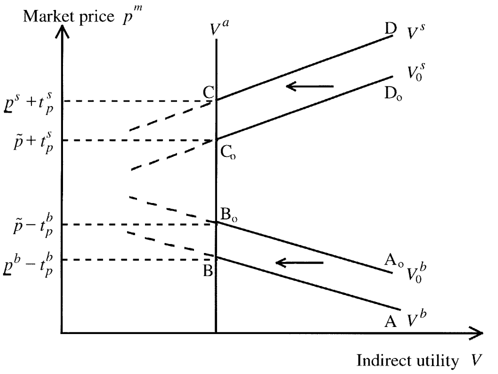

Figure 1. Household indirect utility under proportional and fixed transactions costs

be established that utility is increasing in the decision price for sellers and decreasing in the decision price for buyers. Hence, starting from autarky point C_0, a household who faces no fixed transactions costs will be better off selling at market prices above $\tilde{p} + t_p^s$, thereby obtaining utility V_0^s as shown in figure 1 by the half-line C_0D_0. Similarly, the household will be indifferent between buying and being self-sufficient if $p^m + t_p^b = \tilde{p}$, and better off buying at any market price below $\tilde{p} - t_p^b$, thereby obtaining utility V_0^b as shown in the figure by the half-line B_0A_0. The optimal market participation for a household is to follow the path $A_0B_0C_0D_0$. In the particular case of no PTCs, points B_0 and C_0 are identical.

Equation (11) indicates that an increase in FTCs directly lowers household income and consequently lowers utility at any given price. This is shown in the figure by a shift of the utility curves to the left. Households facing a market price p^m and both PTCs and FTCs can achieve utility V^s as sellers and utility V^b as buyers. This shows that there exists some market price above $\tilde{p} + t_p^s$ such that utility from selling just equals utility under autarky, represented by C in the figure. For further derivation, it will be easier to define the corresponding decision price $\underline{p}^s$ rather than this market price. Thus, let $\underline{p}^s = p^m - t_p^s$ be the decision price at which the household enters the market as a seller, defined by

$$(13) \quad V\left(\underline{p}^s, y_0\left(\underline{p}^s\right) - t_f^s, z_u\right) = V\left(\tilde{p}, y_0(\tilde{p}), z_u\right).$$

As shown in figure 1, if the household faces a market price above $\underline{p}^s + t_p^s$, it is better off selling (half-line CD), whereas for market prices below $\underline{p}^s + t_p^s$, it is better off not selling.

Analogously, there is a buying decision price threshold $\underline{p}^b$ that solves

$$V\left(\underline{p}^b, y_0\left(\underline{p}^b\right) - t_f^b, z_u\right) = V\left(\tilde{p}, y_0(\tilde{p}), z_u\right)$$

below which the utility from buying is greater than V^a. Hence, the household will buy the good if the market price is below $\underline{p}^b - t_p^b$ (half-line BA in the figure).

The optimal market participation for a household is to follow the path ABCD, buying for market prices below $\underline{p}^b - t_p^b$, being self-sufficient for market prices $\underline{p}^b - t_p^b < p^m < \underline{p}^s + t_p^s$, and selling for market prices above $\underline{p}^s + t_p^s$.

Supply Curve with Proportional and Fixed Transactions Costs

Figure 2 represents the household's supply for the home produced good as a function of the market price under proportional and fixed transactions costs. Let SS represent the supply curve in absence of any proportional or fixed transactions costs, $q\left(p^m, z_q\right)$. With transactions costs, the supply curve is

$$q^s = q\left(p^m - t_p^s, z_q\right) \quad \text{for sellers}$$

$$q^b = q\left(p^m + t_p^b, z_q\right) \quad \text{for buyers}$$

$$q^a = q\left(\tilde{p}, z_q\right) \quad \text{for autarkic households.}$$

Hence FTCs do not affect the supply curve, while PTCs shift the supply curve upward for sellers and downward for buyers. Combining the market participation decision with the supply curve under each regime gives the overall supply curve which has three distinct regions: it follows the buyer's supply curve q^b for market prices below $\tilde{p} - t_p^b$, the seller's supply curve q^s for market prices above $\tilde{p} + t_p^s$, and the autarkic supply q^a between these two thresholds, as represented by the curve AB_0C_0D in figure 2a. With FTCs, entry into the market as a seller is delayed until the market price reaches the higher level of $\underline{p}^s + t_p^s$. However, once in the market, supply is not affected by the FTCs, because only the marginal return to production affects production decisions. Hence, in figure 2b, the seller's supply curve is CD. Similarly, entry in the market as a buyer is delayed until the market price is sufficiently low at $\underline{p}^b - t_p^b$, but the buyer's supply curve BA is independent of the FTCs. The house-

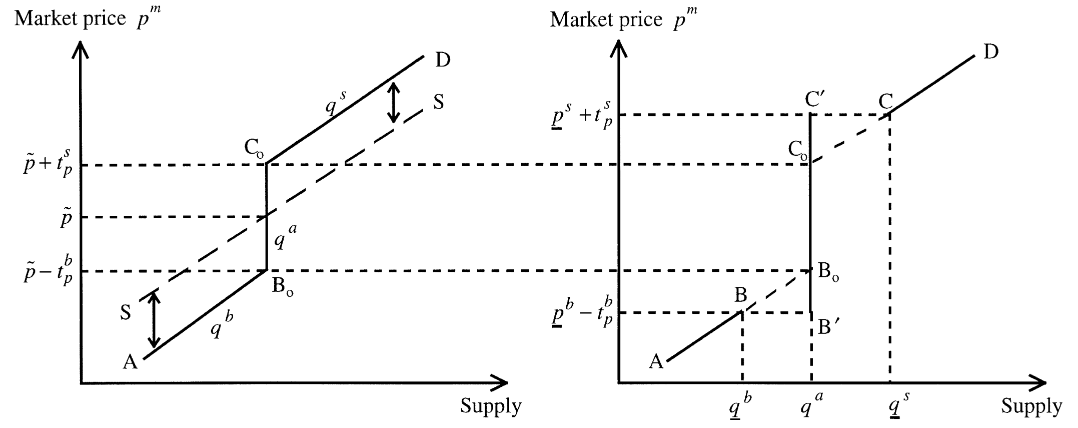

Figure 2. Household supply under (a) proportional and (b) proportional and fixed transactions costs

hold remains self-sufficient, producing the autarkic level q^a between these two thresholds. The broken line ABB′C′CD thus represents the household's overall supply curve. Under PTCs and FTCs, supply also has three distinct regions, but the transition between autarky and buying or selling is accompanied by a discrete change in production. The discrete change occurs because, at the point at which it becomes profitable to either sell or buy, the decision price faced by the household changes discretely.

We now define the selling and buying production thresholds $\underline{q}^s$ and $\underline{q}^b$ as the production level when the household enters the market as a seller or a buyer, respectively, i.e., when decision prices are at their threshold levels $\underline{p}^s$ and $\underline{p}^b$:

(14) $\underline{q}^s \equiv q(\underline{p}^s, z_q)$

(15) $\underline{q}^b \equiv q(\underline{p}^b, z_q)$.

Note that the selling decision price threshold $\underline{p}^s$ implicitly defined by (13) is an increasing function of the FTCs, but not a function of the PTCs. This is because the utility attained by a seller does not depend on the market price and the PTCs independently of each other, but only on the net of the two, the resulting decision price. A household will switch from autarky to selling when the decision price that it will receive is sufficiently high to compensate for the fixed transactions cost. Hence, the selling production threshold $\underline{q}^s$ is also function of the FTCs but not of PTCs. Similarly, since $\underline{p}^b$ is decreasing in FTCs, the buying production threshold $\underline{q}^b$ is decreasing in FTCs, but does not depend on PTCs. The other variables that enter into the definition of the production threshold are the determinants of the utility levels, i.e., z_q, z_u, T, and A. The impact of these variables on the production thresholds cannot be unambiguously signed.

In sum, we have characterized the household's relationship to the market as resulting from the comparison between its desired level of production and two production thresholds. The market participation and the corresponding functional relations for output supply under PTCs and FTCs are given by

(16) if $q(p^m - t_p^s, z_q) > \underline{q}^s(t_f^s, z_q, z_u, T, A)$,

then seller and supply is

$$q^s = q(p^m - t_p^s, z_q)$$

if $q(p^m - t_p^s, z_q) \le \underline{q}^s(t_f^s, z_q, z_u, T, A)$ and

$q(p^m + t_p^b, z_q) \ge \underline{q}^b(t_b^s, z_q, z_u, T, A)$,

then autarkic and supply is

$$q^a = (\tilde{p}, z_q)$$

with $\tilde{p}$ defined by

$$c + x - A = q$$

if $q(p^m + t_p^b, z_q) < \underline{q}^b(t_b^s, z_q, z_u, T, A)$,

then buyer and supply is

$$q^b = q(p^m + t_p^b, z_q).$$

Empirical Model and Estimation Procedure

Equations (16) show that market participation depends on both fixed and proportional transactions costs, while the supply decision, conditional on market participation, only depends on PTCs. The standard unbiased estimation of this model is based on the joint estimation of the reduced form of the market participation equation and the supply function (Goetz). By contrast, here we propose to estimate the structural model, keeping separate the supply functions from the production threshold functions. The key element that will allow us to econometrically identify the separate roles of the PTCs and the FTCs is the fact that the supply functions depend on PTCs and not on FTCs, while the production threshold functions depend on FTCs but not on PTCs.

For the empirical analysis, we assume linear expressions for the supply functions and the PTCs:

$$q(p, z_q) = p\beta_m + z_q\beta_q$$

$$t_p^s = -z_t^s\beta_p^s$$

and

$$t_p^b = z_t^b\beta_p^b.$$

This leads to linear expressions for the supply by sellers, q^s, and by buyers, q^b:

$$q^s = p^m\beta_m + z_t^s\beta_t^s + z_q\beta_q$$

and

$$q^b = p^m\beta_m + z_t^b\beta_t^b + z_q\beta_q.$$

For the autarkic households, supply is function of its implicit price, $\tilde{p}$, which is not observed but is a function of all the variables that determine household supply and demand. Hence, a linear approximation of q^a is

$$q^a = z_q\beta_q^a + z_c\beta_c^a$$

where z_c now includes z_u, T, and A to simplify notation.

We also use a linear expression for the production threshold levels $\underline{q}^s$ and $\underline{q}^b$:

$$\underline{q}^s = z_t^s\alpha_t^s + z_q\alpha_q^s + z_c\alpha_c^s$$

and

$$\underline{q}^b = z_t^b\alpha_t^b + z_q\alpha_q^b + z_c\alpha_c^b.$$

Note that neither the shadow price $\tilde{p}$, solution of the household equilibrium, nor the selling decision price threshold $\underline{p}^s$, solution of (13), can be linear functions of their arguments for commonly used functional forms of the utility function. Therefore, the linear expressions for the autarkic production equation q^a and for the threshold equations $\underline{q}^s$ and $\underline{q}^b$ are best interpreted as approximations.

The econometric specification is obtained by adding error terms to the three supply equations and the two production threshold equations and defining the market participation regimes as follows:

$$(17)\quad q^{s^*} = p^m\beta_m + z_t^s\beta_t^s + z_q\beta_q + u_1 \equiv x_1\beta_1 + u_1$$

$$(18)\quad \underline{q}^s = z_t^s\alpha_t^s + z_q\alpha_q^s + z_c\alpha_c^s + u_2 \equiv x_2\beta_2 + u_2$$

$$(19)\quad q^{b^*} = p^m\beta_m + z_t^b\beta_t^b + z_q\beta_q + u_3 \equiv x_3\beta_3 + u_3$$

$$(20)\quad \underline{q}^b = z_t^b\alpha_t^b + z_q\alpha_q^b + z_c\alpha_c^b + u_4 \equiv x_4\beta_4 + u_4$$

$$(21)\quad q^{a^*} = z_q\beta_q^a + z_c\beta_c^a + u_5 \equiv x_5\beta_5 + u_5$$

$$(22)\quad q^s = \begin{cases} q^{s^*} & \text{if } q^{s^*} > \underline{q}^s \text{ and } q^{b^*} > \underline{q}^b \\ \text{unobserved otherwise} \end{cases}$$

$$(23)\quad q^b = \begin{cases} q^{b^*} & \text{if } q^{b^*} < \underline{q}^b \text{ and } q^{s^*} < \underline{q}^s \\ \text{unobserved otherwise} \end{cases}$$

$$(24)\quad q^a = \begin{cases} q^{a^*} & \text{if } q^{s^*} < \underline{q}^s \text{ and } q^{b^*} > \underline{q}^b \\ \text{unobserved otherwise.} \end{cases}$$

In these equations, q^{s^*} is the latent supply if the household is a seller and it is observed when it is higher than the threshold for market participation; q^{b^*} and q^{a^*} are defined similarly.

Because we do not a priori impose restrictions on parameters that will necessarily insure that the selling decision price is above the buying decision price, and yet do not have households that both buy and sell in our data, the participation in the market as a seller needs to be specified more completely than in equation (16). Equation (22) thus states that sellers satisfy the condition to be a seller but do not satisfy the condition to be a buyer, and similarly for market participation as a buyer in equation (23).

Note that if z_t^s and z_q have no common variables other than the constant terms, the reduced form parameters β_t^s are equal to $\beta_p^s\beta_m$. Hence, estimation of (17) allows identification of the parameters β_p^s and measurement of the selling PTCs, t_p^s, up to a constant term, and similarly for the buying PTCs. This is not possible for the FTCs, however, because the threshold equations (18) and (20) are only approximations. Estimation of these equations allows us to identify whether the parameters associated with z_t^s and z_t^b are statistically significant, and to test whether the FTCs can be reduced to a constant term, but not to compute the value of the FTCs.

Nelson and Cogan estimated models with an unobserved censoring threshold allowing for possible correlation between the threshold and censored equations. Here, with the joint estimation of three regimes, we have simplified the statistical assumptions and have assumed that the five error terms are independently and normally distributed, with variances given by σ_1^2 *to* σ_5^2, respectively. This is clearly a shortcoming of our analysis that will require elaboration in future work.

The likelihood of observing a seller characterized by the exogenous variables x and production q^s is

$$(25)\quad L_s = \text{pdf}\Big(q^{s^*} = q^s \mid q^s \geq \underline{q}^s \text{ and } q^{b^*} > \underline{q}^b\Big)$$
$$= \text{pdf}\Big(u_1 = q^s - x_1\beta_1\Big) \times \text{prob}\Big(u_2 \leq q^s - x_2\beta_2\Big) \times \text{prob}(u_3 - u_4 > x_4\beta_4 - x_3\beta_3)$$
$$= \frac{1}{\sigma_1}\phi\left(\frac{q^s - x_1\beta_1}{\sigma_1}\right)\Phi\left(\frac{q^s - x_2\beta_2}{\sigma_2}\right) \times\left[1 - \Phi\left(\frac{x_4\beta_4 - x_3\beta_3}{\sqrt{\sigma_3^2 + \sigma_4^2}}\right)\right]$$

where pdf stands for probability density function and ϕ and Φ indicate the standard normal probability density and distribution functions, respectively.

The likelihood function that includes all three possible market participation regimes is written

$$(26)\quad L = \prod_{\text{sellers}} \frac{1}{\sigma_1}\phi\left(\frac{q^s - x_1\beta_1}{\sigma_1}\right) \times\Phi\left(\frac{q^s - x_2\beta_2}{\sigma_2}\right) \times\left[1 - \Phi\left(\frac{x_4\beta_4 - x_3\beta_3}{\sqrt{\sigma_3^2 + \sigma_4^2}}\right)\right]$$
$$\times \prod_{\text{autarkic}} \frac{1}{\sigma_5}\phi\left(\frac{q^a - x_5\beta_5}{\sigma_5}\right) \times\Phi\left(\frac{x_2\beta_2 - x_1\beta_1}{\sqrt{\sigma_1^2 + \sigma_2^2}}\right) \times\left[1 - \Phi\left(\frac{x_4\beta_4 - x_3\beta_3}{\sqrt{\sigma_3^2 + \sigma_4^2}}\right)\right]$$
$$\times \prod_{\text{buyers}} \frac{1}{\sigma_3}\phi\left(\frac{q^b - x_3\beta_3}{\sigma_3}\right) \times\Phi\left(\frac{x_2\beta_2 - x_1\beta_1}{\sqrt{\sigma_1^2 + \sigma_2^2}}\right) \times\left[1 - \Phi\left(\frac{q^b - x_4\beta_4}{\sigma_4}\right)\right].$$

Maize Supply in Mexico

Estimation Results

The model is estimated using data collected in a national survey of the *ejido* sector conducted in 1994 by the Mexican Ministry of Agrarian Reform.[2] The data are described extensively in de Janvry, Gordillo, and Sadoulet. For the estimation, we use a sub-sample of the data consisting of corn producers owning at least one hectare of land. Households with less than one hectare of land cultivate garden plots with a different economic logic.[3] Of the total 382 corn producers, 190 were sellers, sixty-nine were buyers, and the remaining 123 were self-sufficient in their supply of corn.[4] We focus here on the corn market, ignoring potential other market imperfections that also lead to heterogeneous participation regimes, notably in the labor and credit markets. The number of possible combinations of market participation grows

[2] The *ejido* sector consists of farmers of land redistributed after Mexico's social revolution. *Ejido* land represents about one-half of all arable land in Mexico.

[3] These households cultivate corn as part of complex farming systems that correspond to a different specification of the production function.

[4] In the sample there is a fourth market regime—households that sell and buy. However, because there are only a few such households, and their behavior cannot possibly be explained by the theoretical framework that we have adaopted, we did not include these households in the data used for estimation. Such behavior has to come from either product differentiation between produced and consumed good, seasonal patterns of price, stock behavior, or seasonal cash constraint and debt problems, which all require a different theoretical framework.

very rapidly with the number of markets considered, making it in fact impossible to conduct empirical analysis with small data sets as we have. On the other hand, ignoring the heterogeneity of household behavior on the labor and credit markets as we do creates noise in our classification that could well blur the results that we are estimating. Notably, labor self-sufficiency and credit constraints lower the supply response on other markets. Hence our results are likely to be downward biased. We try to correct for this by using a dummy variable for access to formal credit, which is exogenous, as a production shifter.

In practice, most households do not face one market price, but rather face distinct buying and selling prices. In Mexico, the average selling price for corn was 680 pesos while the average buying price was 895 pesos in 1994 (SRA). The margin between the observable selling and buying prices results, in part, from markups by marketing intermediaries. The difference is also explained by the fact that selling and buying intermediaries are not necessarily the same, with typically purchases made in small local stores, while sales are either done at the farm gate or to large intermediaries who export the crops out of the villages. In the empirical analysis that follows, we therefore use two different "market" prices, a market selling price in (17) and a market buying price in (19).

The variables z_q used to explain the production of corn include human capital (a dummy if the head of the household was over 55), land assets, local area technology characteristics (county (*municipio*) average use of high yielding varieties, agro-chemicals, and fertilizers, and the level of mechanization of production), supply-constrained technology shifters (access to technical assistance and access to formal credit), and factors affecting the demand for corn as an input to livestock production (access to common property pastures and livestock assets).

The explanatory variables for both proportional and fixed transactions costs for sellers z_t^s include transportation costs to the selling point, which include monetary costs paid to the intermediary and distance for the transportation done by the farmer itself,[5] a dummy for whether the purchaser of the harvest was the official food company (Conasupo), whether the purchaser was a private consumer, whether the farmer owned a pickup truck, and a measure of the extent of local membership in an agricultural organization or a transportation organization.[6] The variables explaining buying transactions costs z_t^b include the cost of transporting the purchased product from the buying point if someone else transported the crop; the distance to the buying point if transported by the farmer; dummies for whether the household purchased corn from an official source, purchased corn from an individual producer, and owned a pickup truck; and a measure of the local extent of membership in a transportation organization. Unfortunately, because of the survey design, the selling and buying prices and all the transactions cost variables except the vehicle ownership and organization membership dummies were only observed for market participants. To address this missing data problem, we attributed the county average values for sellers (or buyers) to the non-sellers (or non-buyers). By doing so, we assume a high degree of homogeneity among households in close geographical proximity, justified in part by group habitat in the Mexican countryside.

The log of the likelihood function was maximized using a Newton–Raphson algorithm, with the gradient and Hessian matrix computed numerically. Table 1 presents the estimated coefficients and P-values for the production and the production threshold equations. Recall that $z_t \beta_t^s$ represents the negative value of the selling proportional transactions costs, $-t_p^s$, while $z_t \beta_t^b = t_p^b$. Hence, a positive sign on $\beta_t^s (\beta_t^b)$ indicates that an increase in z_t lowers (raises) the selling (buying) PTCs. As shown in the table, selling to an official source and being in a region with high membership in agricultural organizations increase production and, by implication, decrease selling PTCs (lower selling PTCs imply a higher decision price and therefore greater production). It is likely that the decision price to the official source is higher because Conasupo provides sellers with subsidy payments for "marketing" costs that are

[5] Transportation to the market can be done partly by intermediaries and partly by the farmers themselves. For the part done by intermediaries, monetary costs are directly observed. When farmers transport their crop themselves, they incur direct costs for the transportation (gasoline, time, etc.). As the latter were not observed, we use distance as a determinant of these costs.

[6] An agricultural organization is concerned with the marketing of crops, while a transportation organization is concerned with the repair of roads and bridges. Note that individual participation in an organization, like individual use of any technology, is an endogenous choice of the farmer. However, the level of local membership in an organization reflects the exogenous local availability of such an organization, and likewise, the average local use of technology reflects the opportunity for technological choice.

Table 1. Estimated Model Coefficients

Variables	Production Equations: Sellers (equation (17))		Production Equations: Buyers (equation (19))		Production Equations: Autarkic (equation (21))	
Proportional transactions costs (z_t^s, z_t^b)	β_t^s	P-value	β_t^b	P-value		
Crop transport costs (pesos/m.ton)	0.025	0.19	0.023	0.55		
Distance to/from market (km)	0.012	0.91	0.003	0.91		
Sell to/buy from official source	5.202	0.00	0.123	0.90		
Sell to consumer/buy from grower	0.360	0.78	0.359	0.70		
Own pick-up truck	−1.823	0.04	−0.791	0.62		
Local membership in agric. org.(%)	3.770	0.01	—	—		
Local membership in transport. org.(%)	−1.664	0.34	−0.630	0.61		
Constant	−0.126	0.92	−2.889	0.03		
	Sellers and Buyers					
Production shifters (z_q)	β_q	P-value			β_q^a	P-value
Head of household over 55 years	−0.446	0.34			0.295	0.33
Crop and pasture land (ha)	0.040	0.26			0.008	0.68
Local high yielding varieties use (%)	5.712	0.00			−0.010	0.99
Local chemical pesticides use (%)	−0.341	0.77			0.762	0.15
Local natural or chem. fertilizer use (%)	0.153	0.93			0.672	0.39
Local level of mechanization (index)	6.000	0.02			0.443	0.77
Access to formal sector credit	3.783	0.00			−0.649	0.78
Access to common property pasture	−0.816	0.16			−0.002	0.99
Livestock assets (index)	0.070	0.90			0.527	0.05
	β_m	P-value				
Price	0.0052	0.00				
Consumption shifters (z_c)					β_c^a	P-value
Household caloric demand					0.018	0.79
Predicted household income					−0.013	0.38
Constant					1.673	0.00
	σ_1	P-value	σ_3	P-value	σ_5	P-value
Standard error	3.78	0.00	1.57	0.00	1.25	0.00

Variables	Threshold Equations: Selling Threshold (equation (18))		Threshold Equations: Buying Threshold (equation (20))	
Fixed transactions costs (z_t^s, z_t^b)	α_t^s	P-value	α_t^b	P-value
Crop transport costs (pesos/m.ton)	0.041	0.04	−0.058	0.15
Distance to/from market (km)	0.075	0.53	−0.005	0.89
Sell to/buy from official source	8.028	0.00	−0.803	0.41
Sell to consumer/buy from grower	2.776	0.10	−3.904	0.00
Own pick-up truck	−2.979	0.07	−0.776	0.91
Local membership in agricultural org. (%)	2.759	0.35	—	—
Local membership in transportation org. (%)	0.346	0.89	0.159	0.91
Constant	3.928	0.02	3.908	0.00
Production shifters (z_q)	α_q^s	P-value	α_q^b	P-value
Head of household over 55 years	0.611	0.56	−0.656	0.22
Crop and pasture land (ha)	−0.012	0.88	0.002	0.97
Local high yielding varieties use (%)	6.659	0.11	7.253	0.00
Local chemical pesticides use (%)	−3.181	0.15	−0.085	0.95

Table 1. Continued

Variables	Selling Threshold (equation (18))		Buying Threshold (equation (20))	
Local natural or chem. fertilizer use (%)	0.529	0.87	−2.461	0.25
Local level of mechanization (index)	4.460	0.37	−1.50	0.64
Access to formal sector credit	4.837	0.10	2.092	0.45
Access to common property pasture	−1.479	0.16	−0.749	0.24
Livestock assets (index)	1.358	0.37	0.521	0.43
Consumption shifters (z_c)	α_c^s	P-value	α_c^b	P-value
Household caloric demand	0.183	0.41	0.079	0.06
Predicted household income	0.015	0.74	0.013	0.06
	α_2	P-value	α_4	P-value
Standard error	3.19	0.01	1.22	0.00

not included in the selling price. These payments were not recorded in the survey, but they raise the decision price for sellers. Membership in an agricultural organization can increase decision prices by lowering information and marketing costs for sellers. Pick-up truck ownership is associated with lower production and consequently higher PTCs. This result is not what we expected a priori, and it could be that truck ownership is correlated with other productive assets (which would be elements of z_t). There are no significant buying PTC variables.

Production for sellers and buyers increases significantly with the local use of high yielding varieties of corn, a higher local level of mechanization of production, and greater access to formal credit. Production also responds positively to price with a one peso increase resulting in 0.0052 metric tons of additional production. We calculate the price elasticity in the next subsection. None of the variables explaining the production of autarkic households was significant except for the livestock assets.

Estimated parameters for the production thresholds are presented in the second part of table 1. Recall that the selling threshold increases with FTCs while the buying threshold decreases with FTCs. Higher transportation costs are associated with both a greater selling production threshold and a lower buying production threshold and consequently raise the FTCs associated with selling and buying. Selling to Conasupo is also associated with a higher selling production threshold and consequently greater selling FTCs. Because selling to Conasupo is also associated with greater production (as seen in the first part of table 1), selling to the official source appears to impose higher FTCs but lower PTCs. Direct transactions with individuals (selling to consumers or buying from producers) incur higher FTCs, implying higher search or negotiation costs associated with these transactions. Pick-up truck ownership is associated with a lower production threshold for sellers, and consequently with lower FTCs, as expected. Several production and demand function variables are significant, but we had no prior expectations as to the signs of these variables.

The estimation allows for tests of the significance of transactions costs in the model. Because PTCs but not FTCs enter the production equations, we can test for the significance of PTCs (beyond a constant term) by restricting parameters on the PTC variables in the production equations to zero. Similarly, because FTCs and not PTCs enter the threshold equations, we can test for the significance of selling and buying FTCs (beyond a constant term) by restricting to zero the parameters on the selling and buying transactions costs variables, respectively. Having neither selling FTCs nor buying FTCs implies that the selling and buying thresholds are identical (see (20) and (21)). Hence, the test of whether we can assume that all FTCs are zero involves setting the transactions cost parameters to zero and restricting the remaining parameters in the threshold equations (including the constants) to be equal. The parameter restrictions for the six tests that we perform are listed in table 2. The alternative hypothesis in every test is that the parameters are unrestricted.

Table 2. Likelihood Ratio Tests

Tests	$\log L(\hat{\Omega}_0)$	λ	r	P-value
No (or constant) selling PTCs				
$H_0: \beta_t^s = 0$	−1, 322.1	58.0	7	0.001
No (or constant) buying PTCs				
$H_0: \beta_t^b = 0$	−1, 296.2	6.3	6	0.537
No (or constant) selling or buying PTCs				
$H_0: \beta_t^s = 0; \beta_t^b = 0$	−1, 325.4	64.7	13	0.001
No (or constant) selling FTCs				
$H_0: \alpha_t^s = 0$	−1, 312.9	39.8	7	0.001
No (or constant) buying FTCs				
$H_0: \alpha_t^b = 0$	−1, 307.2	28.4	6	0.001
No selling or buying FTCs				
$H_0: \alpha_t^s = 0; \alpha_t^b = 0; \alpha_q^s = \alpha_q^b; \alpha_c^s = \alpha_c^b$	−1, 350.2	114.4	25	0.001

Note: $\lambda = -2[\log L(\hat{\Omega}_0) - \log L(\hat{\Omega})]$; r = number of restrictions; for the alternative hypothesis (no restrictions), $\log L(\hat{\Omega}) = -1,293.05$; the P-value is defined here as $1 - \text{prob}(\chi^2(\lambda, r) > 0)$.

Likelihood ratio test statistics are also presented in table 2. The null hypothesis is rejected for all tests at the 99% significance level except for the test that buying PTCs are zero. The hypothesis that there are no buying PTCs cannot be rejected. Hence, we conclude that selling PTCs and both selling and buying FTCs are important and should be accounted for in estimating production response.

Supply Response Elasticity

From the supply function defined in (16), expected production by a randomly chosen producer with given characteristics is

$$(27)\quad Eq = \text{prob(sell)}E[q^s|\text{sell}] + \text{prob(buy)}E[q^b|\text{buy}] + \text{prob(autarky)}E[q^a|\text{autarky}].$$

Consider first the effect on production of a change in the selling price but not in the buying price. A change in the selling price will change the probability of a household being a seller, buyer, or self-sufficient, and will change the production of sellers (but not of buyers or autarkic households). Denoting elasticities by E,

$$(28)\quad \text{E}(Eq/p^s) = \theta^s[\text{E}(\text{prob(sell)}/p^s) + \text{E}(E[q^s|\text{sell}]/p^s)] + \theta^b\text{E}(\text{prob(buy)}/p^s) + \theta^a\text{E}(\text{prob(autarky)}/p^s)$$

where $\theta^s = (\text{prob(sell)}E[q^s|\text{sell}])/Eq$ is the expected share of total output produced by a household if it were a seller, and θ^b and θ^a are the analogous expected shares if buyer or autarkic, respectively. There is a similar expression for the buying price response, and if both the selling and buying prices change, then a proportional change in expected production can be written

$$(29)\quad \frac{dEq}{Eq} = \left(\frac{dE[q]}{dp^s}\frac{p^s}{E[q]}\right)\frac{dp^s}{p^s} + \left(\frac{dE[q]}{dp^b}\frac{p^b}{E[q]}\right)\frac{dp^b}{p^b}.$$

If a policy results in an equi-proportional change in both the selling and buying price, so that $dp^s/p^s = dp^b/p^b = dp/p$, then it follows that the expected supply response equals the sum of the selling and buying price elasticities:

$$(30)\quad \text{E}(Eq/p) = \text{E}(Eq/p^s) + \text{E}(Eq/p^b).$$

To calculate the aggregate selling price elasticity, the responsiveness of individual producers i is weighted in proportion to their share of total supply:

$$(31)\quad \text{E}(EQ/p^s) = \sum_i \frac{Eq_i}{EQ}\text{E}(Eq_i/p^s)$$

with analogous expressions for the aggregate buying price elasticity and aggregate joint price elasticity.

Table 3 displays the sample mean values of the components of the supply response elasticities of individual producers (28) and the aggregate elasticity (31). As shown in the table, average shares of total expected production by expected sellers, buyers, and autarkic households are equal to 0.60, 0.10,

Table 3. Decomposition of Supply Response Elasticities

	$\frac{dp^s}{p^s} = 1\%$	$\frac{dp^b}{p^b} = 1\%$	$\frac{dp^s}{p^s} = \frac{dp^b}{p^b} = 1\%$
Sample means of components of supply elasticity (equation (28))			
θ^s	0.60	0.60	
E(prob(sell)/p)	0.77	1.40	
$\mathrm{E}(E[q^s \mid \text{sell}]/p)$	0.33	0	
θ^b	0.10	0.10	
E(prob(buy)/p)	−0.42	−3.44	
$\mathrm{E}(E[q^b \mid \text{buy}]/p)$	0	0.68	
θ^a	0.30	0.30	
E(prob(autarky)/p)	−0.42	1.40	
$\mathrm{E}(E[q^a \mid \text{autarky}]/p)$	0	0	
Sample mean of total supply elasticity			
$\mathrm{E}(Eq/p)$	0.49	0.65	1.15
Aggregate elasticity (equation (31))			
$\mathrm{E}(EQ/p)$	0.68	0.32	1.00
Standard error	0.15	0.09	0.19

and 0.30, respectively. A 1% increase in the selling price increases the probability that households will sell by 0.77% on average and decreases the probability that households will buy or be autarkic by an average of 0.42%. A 1% increase in the selling price also results in an average increase in production by sellers of 0.33%. The net effect of an increase in the selling price is an increase in output by 0.49%. The increase in production results from the fact that there are more sellers and those sellers are producing more at a higher price.

A 1% increase in the buying price increases the average probability that households will sell or be autarkic by 1.40% and decreases the average probability that households will buy by 3.44%. A 1% increase in the buying price also results in an average increase in production by buyers of 0.68%. The net effect of the increase in the buying price is an increase in output by 0.65%.[7] The increase results from the fact that there are more sellers and from the fact that buyers are producing more at the higher price (even though there are fewer of them). A policy that increases both the selling and buying prices by 1% would have the net effect of increasing production by 1.15%.

Taking into account the relative contributions to aggregate production of individual producers, we find that the effect of a change in the selling price on production is greater, and the effect of a change in the buying price on production is less, than if we did not take the relative contribution into account. That is, a 1% increase in the selling price results in an increase in aggregate production of 0.68% compared to an average unweighted increase for all households of 0.49% and a 1% increase in the buying price results in an increase in aggregate production of 0.32% compared to an average increase for all households of 0.65%. This is because sellers, on average, are larger producers than buyers. A policy that increases both the selling price and the buying price by 1% would result in an increase in aggregate production of 1.00% compared to an average increase for all households of 1.15%. The last row of table 2 displays the estimated standard error of the elasticity estimates.[8] Estimates of the aggregate selling and buying price response elasticities are both significant. The aggregate price response elasticity estimate for a price change affecting both prices proportionately is significant.

To evaluate the importance of considering separately transactions costs for buyers and

[7] The larger price elasticity for the buying price results in part from the fact that we specified a supply function that is linear in price. With a linear function, we expect the price elasticity of small producers to be greater than for large producers. In our sample buyers produced less, on average, than sellers.

[8] The standard errors of the aggregate elasticities were computed using linear Taylor series approximations of the non-linear elasticity functions evaluated at the estimated optimal parameter values, and using the estimated parameter covariance.

sellers, we performed a standard econometric estimation of a supply function on the sample of market participants. We selected the same linear functional form and exogenous variables for production shifters and transactions costs. The two key differences with the model above are that (*a*) transactions costs are not allowed to play differently, and notably with expected opposite signs, on buyers and sellers and (*b*) the choice of market participation is not endogenized. Whereas the effect of production shifters is similar to the results above, the model gives a price elasticity of −0.03, non-significantly different from 0. This illustrates an important point of the methodology that we propose.

It is worth highlighting the differences between the estimation of elasticities used here and standard estimation procedures. First, we have allowed for a separate analysis of the impact of policies that affect the selling price and the buying price differently. Policies that maintain constant consumer food prices mean that producers who are net buyers will be sheltered from policies that affect the selling price. When this is the case, assuming that all market participants will respond as sellers will overestimate the price response. Second, we have accounted for the fact that autarkic households only respond to price when they are induced to enter or leave the market. That is, we have accounted for price response that affects both the output of market participants and also the household's relationship to the market.

Conclusion

Elaborating on the pioneering work of Goetz, this paper constructed a model of household supply response when there are monetary transactions costs in accessing markets as sellers or buyers. The existence of idiosyncratic transactions costs implies that some households will opt for self-sufficiency instead of market participation. The analysis of supply response must consequently endogenize the decisions taken by heterogeneous households whether or not to participate in markets. In addition, if some of the transactions costs are fixed, there are discontinuities in responding to market incentives. Hence, the existence of transactions costs and the type of transactions costs that exist have profound implications for the specification and estimation of total supply response using survey data.

Because the determinants of proportional and fixed transactions costs enter asymmetrically in production decisions, the model allows for a test of whether proportional or fixed transactions costs could be excluded from the estimation without loss of explanatory power. Applying the model to the supply of corn by Mexican households indicates that both types of transactions costs play a significant role in explaining household behavior, with proportional transactions costs being more important in the selling rather than the buying decisions.

Given that transactions costs affect market participation, price policies will have very different behavioral and welfare implications for different subsectors of the farm population. In addition, aggregate supply will respond to changes in the transactions cost structure through its effect on market participation. Policies that reduce transactions costs are consequently important complements to price policies in affecting supply response. Results for Mexico indicate that lowering transactions costs through improved transportation and the promotion of organizations for marketing would increase output by both increasing market participation and increasing production for market participants.

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Appendix A

Below we derive the functional forms for the elasticity with respect to the selling price as they apply to our empirical model. The probability of being in each market regime is

$$\begin{aligned}
\text{prob(sell)} &= \text{prob}\left(q^{s*} \geq \underline{q}^s\right) \cdot \text{prob}\left(q^{b*} > \underline{q}^b\right) \\
&= [1-\Phi(\gamma_s)][1-\Phi(\gamma_b)] \\
\text{prob(buy)} &= \text{prob}\left(q^{s*} < \underline{q}^s\right) \cdot \text{prob}\left(q^{b*} \leq \underline{q}^b\right) \\
&= [\Phi(\gamma_s)][\Phi(\gamma_b)] \\
\text{prob(autarky)} &= \text{prob}\left(q^{s*} < \underline{q}^s\right) \cdot \text{prob}\left(q^{b*} > \underline{q}^b\right) \\
&= [\Phi(\gamma_s)][1-\Phi(\gamma_b)]
\end{aligned}$$

where $\gamma_s = (x_2\beta_2 - x_1\beta_1)/\left(\sqrt{\sigma_1^2+\sigma_2^2}\right)$ and $\gamma_b = (x_4\beta_4 - x_3\beta_3)/\left(\sqrt{\sigma_3^2+\sigma_4^2}\right)$. Since u_1, u_2, u_3, u_4, and u_5 are assumed to be independent, then analogously to the standard truncated regression model, the conditional expectations are

$$\begin{aligned}
E[q^s \mid \text{sell}] &= E[q^{s*} \mid q^{s*} \geq \underline{q}^s] \\
&= x_1\beta_1 + \sigma_1\lambda(\gamma_s) \\
E[q^b \mid \text{buy}] &= E[q^{b*} \mid q^{b*} \leq \underline{q}^b] \\
&= x_3\beta_3 + \sigma_3\lambda(\gamma_b) \\
E[q^a \mid \text{autarky}] &= E[q^{a*}] = x_5\beta_5
\end{aligned}$$

where $\lambda(\gamma_s) = \phi(\gamma_s)/(1-\Phi(\gamma_s))$, $\lambda(\gamma_b) = -\phi(\gamma_b)/\Phi(\gamma_b)$.

Note that the expectation of autarkic production does not have a correction for truncation bias because autarkic production is independent of the selling and buying production and threshold levels.

The response of the expected production of sellers to a change in the selling price is

$$\frac{dE[q^s \mid \text{sell}]}{dp^s} = \beta_m + \sigma_1\left(\frac{\beta_m}{\sqrt{\sigma_1^2+\sigma_2^2}}\right) \times \left[\gamma_s\lambda(\gamma_s) - [\lambda(\gamma_s)]^2\right]$$

where β_m is the coefficient in the vector β_1 corresponding to the selling price.

The changes in the probability of being in a market regime as a function of the selling price are

$$\begin{aligned}
\frac{dE[\text{prob(sell)}]}{dp^s} &= \left(\frac{\beta_m}{\sqrt{\sigma_1^2+\sigma_2^2}}\right) \times \phi(\gamma_s)[1-\Phi(\gamma_b)] \\
\frac{dE[\text{prob(buy)}]}{dp^s} &= \left(\frac{-\beta_m}{\sqrt{\sigma_1^2+\sigma_2^2}}\right) \times \phi(\gamma_s)\Phi(\gamma_b) \\
\frac{dE[\text{prob(autarky)}]}{dp^s} &= \left(\frac{\beta_m}{\sqrt{\sigma_1^2+\sigma_2^2}}\right) \times \phi(\gamma_s)[\Phi(\gamma_b)-1].
\end{aligned}$$