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IFPRI Discussion Paper 00745

December 2007

# Determinants of Smallholder Commercialization of Food Crops

## Theory and Evidence from Ethiopia

John Pender, International Food Policy Research Institute
and
Dawit Alemu, Ethiopian Institute of Agricultural Research

Environment and Production Technology Division
and
Markets, Trade and Institutions Division

## INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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## Contents

## List of Tables



## List of Figures

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## ABSTRACT

In this paper, we develop a theoretical farm household model of food crop production and marketing decisions, derive testable hypotheses concerning the determinants of these decisions, and test these hypotheses, using data on cereal production and marketing collected from a nationally representative survey of 7,186 farm households in Ethiopia. Focusing on production and marketing decisions for teff and maize, the two most important crops in Ethiopia, we find that most producers of these crops are either autarkic or net buyers (especially for maize) and that net buyers and autarkic households are poorer in many respects than net sellers. This implies that interventions to increase cereal productivity will favorably affect distribution for most producers. The econometric analysis shows that increasing production of teff and maize is the most important factor contributing to increased sales, and that increased smallholder access to roads, land, livestock, farm equipment, and traders is key to enabling increased smallholder production and commercialization of these crops.

**Keywords: Smallholder production, commercial behavior, market participation, cereal crops, Ethiopia**

# 1. INTRODUCTION

Promoting commercialization of agricultural production is a cornerstone of the rural development and poverty reduction strategies of Ethiopia, as well as numerous other developing countries. Policymakers in Ethiopia and elsewhere view agricultural commercialization as an essential part of the process of agricultural modernization, specialization, and structural transformation of the economy toward more rapid and sustainable growth. Past empirical research on smallholder commercialization in developing countries generally supports this view, although the impacts of commercialization are dependent on the local context and policy environment (von Braun and Kennedy 1994). A review of case studies conducted in 10 countries in Africa, Asia, and Latin America found that commercialization increased household incomes in most cases, as a result of increased labor and land productivity on farms as well as increased employment opportunities for hired labor (von Braun 1994). In most cases, increased incomes resulting from commercialization led to increased food consumption (Bouis 1994) and improved nutrition (Kennedy 1994). In cases where incomes, food consumption, and nutrition did not improve, factors such as insecure land tenure, gender biases, or policy biases against smallholders often contributed to adverse consequences (von Braun and Kennedy 1994). Hence there is a strong case for promoting agricultural commercialization while seeking to ensure that the benefits and costs of the process are equitably distributed.

Considering the importance of agricultural commercialization in agricultural and rural development policy in Ethiopia and its potentially strong and favorable impacts on agricultural productivity, rural poverty reduction, and food and nutrition security, it is important to understand the factors affecting the extent of commercialization in Ethiopia. The driving forces generally behind commercialization include population growth and demographic change; urbanization; development of infrastructure and market institutions; development of the nonfarm sector and broader economy; rising labor opportunity costs; and macroeconomic, trade, and sectoral policies affecting these forces (von Braun, Bouis, and Kennedy 1994; Pingali and Rosegrant 1995). At the local level, commercialization is also affected by many factors, including agro-climatic conditions and risks; access to markets and infrastructure; community and household resource and asset endowments; development of local commodity, input, and factor markets; laws and institutions; and cultural and social factors affecting consumption preferences, production, and market opportunities and constraints (Pender, Ehui, and Place 2006). These factors influence commercialization by affecting the conditions of commodity supply and demand, output and input prices, and transaction costs and risks faced by farmers, traders, and others in the agricultural production and marketing system.

Since the early 1990s, several articles in the literature have modeled the effects of transaction costs on agricultural supply and marketing response (de Janvry, Fafchamps, and Sadoulet 1991; Goetz 1992; Omamo 1998a, 1998b; Key, Sadoulet, and de Janvry 2000; Renkow, Hallstrom, and Karanja 2004). The essential insight of these analyses is that transaction costs lead to three distinct production and marketing regimes for a particular commodity: sellers, buyers, and autarkic households. Proportional transaction costs (costs such as transportation and handling that are proportional to the amount being transacted) increase the price paid by buyers and reduce the price received by sellers, similar to the effect of a sales tax. Fixed transaction costs (costs that do not depend upon the amount transacted, such as costs of searching for and screening potential buyers or sellers, negotiating the transaction, and enforcing the terms of the agreement) do not directly affect the incentive price but affect whether a household will find it advantageous to buy or sell any amount, requiring a minimum scale of transaction (Key, Sadoulet, and de Janvry 2000).[1] The incentive price faced by producers depends upon which regime they are in, with sellers facing the lowest price and buyers the highest price. Since many smallholder farmers are buyers of food crops (Omamo 1998a, 1998b; Renkow, Hallstrom, and Karanja 2004) and sellers or potential sellers of cash crops (crops intended primarily for sale, not for domestic consumption), they face greater incentive to continue producing food crops and less incentive to produce cash crops than if transaction costs were lower (Omamo 1998a, 1998b). Thus, the impacts of investments in infrastructure, development of marketing institutions, or other measures intended to reduce transaction costs will also depend upon the type of commodities that farmers are producing or may produce.

Although these studies have contributed many important new insights about farmers' commercialization behavior and the effects of transaction costs on agricultural supply response, they do not address several other important factors affecting production and marketing decisions of smallholder farmers in developing countries, such as production and marketing risks, intra-annual credit and liquidity constraints, and the timing of production and marketing decisions (Key, Sadoulet, and de Janvry 2000; Renkow, Hallstrom, and Karanja 2004). In addition, these studies do not derive testable hypotheses from the theories presented concerning the expected impacts of many of the underlying factors influencing

1 One may question whether many of these costs are actually fixed if one considers multiple transactions occurring over a marketing season. Although fixed for each transaction, if a farmer conducts multiple small transactions in a season, with the size of each transaction possibly limited by the amount of produce the farmer is able to carry to the market, some of these "fixed costs" may turn out to be roughly proportional to the total amount transacted over the season. On the other hand, there may be other costs that are fixed for an entire season (such as the cost of renting a stall at the market for the season) or startup investment costs that must be incurred the first time the farmer produces or markets a commodity that he or she has not produced or marketed before (such as costs of specialized production, storage, or transport equipment; of learning how to produce or market the commodity; of establishing connections with buyers; and of certification in the case of certified niche market commodities). Startup investment costs are likely to be particularly important constraints to diversification into new cash commodities, especially in the context of the irreversible nature of many such investments, uncertainty, and liquidity constraints (Dixit and Pindyck 1994; Fafchamps and Pender 1997). Distinguishing such different types of "fixed costs," their implications for commercialization, and the role of policy and program interventions in addressing the constraints that these pose to commercialization likely would be valuable avenues for future research.

commercialization, other than transaction costs, or use such hypotheses to interpret the empirical results presented.

In this paper, we contribute to the theoretical and empirical literature on determinants of commercialization of food crop production by developing two versions of a theoretical agricultural household model of food production, consumption, and marketing (without and with binding credit constraints) and deriving the testable implications of the model in terms of the exogenous factors in the model. These implications are tested using a structural econometric model that is derived explicitly from the theory, using data on Ethiopian farm households' net market position, production, and marketing decisions (sales or purchases) and the factors influencing these decisions. The data were collected using a nationally representative household survey of 7,186 households during 2005. In the econometric analysis, we focus on production and marketing of teff and maize, which are the two most important crops grown in Ethiopia in terms of area planted and value of production (CSA 2005). The focus on food crops leads to a model with three distinct marketing regimes, as in the models of Goetz (1992); Key, Sadoulet, and de Janvry (2000); and Renkow, Hallstrom, and Karanja (2004), which would not be the case for cash crops (since production of such crops is primarily for sale). Although the decision to produce cash versus food crops is also an important issue in agricultural commercialization, it is not the decision faced by most smallholder producers in Ethiopia, and we do not address it in this paper.

As in much of the previous literature on this topic, cited above, the theoretical model developed is deterministic; hence it does not consider the implications of production and marketing risks. A deterministic model was chosen to make derivation of model implications tractable and not because this assumption is particularly realistic in the Ethiopian context. We believe, however, that adequately understanding the deterministic model is an essential first step to modeling the more complex situation with production and marketing risks, and that many of the insights from the deterministic case will carry over to the stochastic case, with some modifications.[2] Another limitation of the study is that the empirical work is based on data collected during one year only. Households may change their marketing decisions from one year to the next depending on production and market conditions, and we are unable to address this in this study. Such limitations may be addressed in future work building upon this study. Despite

[2] For example, incorporating production risk during the preharvest period would cause producers to consider the probabilities of the marketing regimes that they may be in during the second period, considering their subjective perceptions of the probability distribution of the exogenous factors affecting production (such as rainfall and pests) and the effects of their preharvest decisions (such as input use). Thus, instead of using certain knowledge of the marketing regime to determine their preharvest decisions, producers would optimally take into account the likelihood of each regime occurring, as well as the incentives existing under each of those. Without price or marketing risks, the second (postharvest) period of the model would be the same whether or not production risks were incorporated. Incorporating price and marketing risks would reduce the expected utility from relying on the market (for risk-averse households), leading to a greater tendency for autarky (similar to the effect of larger transaction costs), as well as affecting production and marketing behavior of market participants.

these limitations, we believe that this study contributes substantially to improved understanding of the factors affecting smallholder commercialization of food crops, particularly in Ethiopia.

The remainder of this paper is organized as follows. In section 2, we develop the theoretical models of smallholder commercialization and derive their implications. In section 3, we derive the empirical specification used for the econometric analysis and discuss econometric issues. In section 4, we present the data and descriptive results. In section 5, we present and discuss the econometric results, and in section 6 we discuss conclusions and implications.

## 2. THEORY OF SMALLHOLDER COMMERCIALIZATION OF FOOD PRODUCTION

### Model

We consider a farm household that consumes two commodities, food ($C_{ft}$) and nonfood ($C_{nt}$) goods during two periods ($t$ = 1 and t = 2), the preharvest and postharvest seasons, providing utility determined by a quasi-concave utility function ($U$), which we assume to be additively separable between periods 1 and 2:

$$U(C_{f1}, C_{n1}, C_{f2}, C_{n2}) = U_1(C_{f1}, C_{n1}) + U_2(C_{f2}, C_{n2}).$$

We assume that $C_{ft}$ and $C_{nt}$ are normal goods. The household produces the food commodity ($Y_f$), using inputs of labor ($L_f$), other variable inputs ($X$), and the services of productive quasi-fixed capital stocks ($K$), with production determined by the production function: $Y_f = \mathrm{F}(K, L_f, X)$. We assume that the production function is constant returns to scale, concave, increasing in each factor, and twice differentiable; that inputs $L_f$ and $X$ are normal inputs; and that the marginal productivity of each input is not reduced by the other ($F_{LX} = F_{XL} \geq 0$).[3] The household has an endowment of family labor $\underline{L}_t$, which we assume is inelastically supplied in each period.[4] Besides working on farm, the household can hire labor out ($L_{ot}$) at wage rate $w_t$, where $t$ indexes the season. The household earns exogenous income ($T_t$) in each period.[5]

The price of purchased inputs is $p_x$ and the market prices of food and nonfood items in each period are $p_{ft}$ and $p_{nt}$, respectively. Food purchases ($P_{ft}$) and sales ($S_{ft}$) are subject to proportional transaction costs of $t_{bt}$ and $t_{st}$, respectively. We ignore transaction costs in purchasing nonfood goods and variable inputs and in obtaining off-farm employment, as these can be considered as part of $p_{nt}$, $p_x$, and $w_t$. The household may borrow cash in the preharvest period ($B_1$) and repay the lender $(1+r_1)B_1$ in the postharvest period.

The household's decision problem is to maximize $U(C_{f1}, C_{n1}, C_{f2}, C_{n2})$, subject to the following constraints:

[3] In our notation, a partial derivative is denoted by a subscript. For example, "$U_{1f}$" means $\partial U_1/\partial C_{1f}$, "$F_L$" means $\partial F/\partial L_f$, "$F_{LX}$" means $\partial^2 F/\partial L_f \partial X$, and so forth. The assumption of nonnegative cross partial derivatives of $F$ holds if $F$ is a constant elasticity of substitution (CES) production function [$\mathrm{F}(K,L,X)=(a_k K^\rho + a_l L^\rho + a_x X^\rho)^{1/\rho}$], since it can be shown that the sign of the cross-partial derivatives is equal to the sign of $1 - \rho$, and $\rho \leq 1$ for the CES production function. This assumption also holds for the cases of Cobb-Douglas and linear production functions, which are special cases of the CES function.

[4] We make the assumption that labor is inelastically supplied to increase the tractability and reduce the presentational complexity of the model. Most of the qualitative predictions of the model are similar if leisure is included in the utility function. We discuss areas in which the results would differ (mainly relating to off-farm labor supply) in our discussion of model implications.

[5] The value of initial stocks of liquid assets, including food stocks, can be considered part of $T_1$.

Budget constraints in each period:

$$(p_{f1}+t_{b1})C_{f1}+p_{n1}C_{n1}+p_x X \le w_1 L_{o1}+B_1+T_1 \text{, and} \tag{B1}$$

$$(p_{f2}+t_{b2})P_{f2}+p_{n2}C_{n2}+(1+r_1)B_1 \le (p_{f2}-t_{s2})S_{f2}+w_2\underline{L}_2+T_2 . \tag{B2}$$

Food supply constraints in each period:

$$C_{f1} \le P_{f1} \text{, and} \tag{F1}$$

$$C_{f2}+S_{f2} \le F(K, L_f, X)+P_{f2} . \tag{F2}$$

Nonfood supply constraints in each period:

$$C_{nt} \le P_{nt} \text{, t = 1, 2.} \quad \text{(N1 and N2)}$$

Labor supply constraint in each period:

$$L_f + L_{o1} \le \underline{L}_1 \text{, and} \tag{L1}$$

$$L_{o2} \le \underline{L}_2 . \tag{L2}$$

Credit constraint:

$$B_1 \le \underline{B}_1 . \tag{C1}$$

We also assume that nonnegativity constraints hold in all periods for all decision variables ($C_{ft}$, $C_{nt}$, $L_f$, $L_{ot}$, $X$, $P_{ft}$, $S_{ft}$, $P_{nt}$, $B_1$). In the case of consumption and production inputs, we assume that the marginal utilities and marginal products for zero use are sufficiently large relative to prices that positive amounts are always demanded. In the case of purchase and sales of food and borrowing, corner solutions are possible.

Except for the credit constraint, all of the constraints above will hold as equalities at the optimum since, otherwise, not all resources would be used; that is, utility could be increased by using more factors and increasing consumption. For the credit constraint, we assume initially that this constraint is not binding and derive the first-order conditions for the unconstrained case. We then consider the constrained borrowing case, imposing C1 as an equality.

The first-order conditions for this problem are as follows.[6]

Food – nonfood consumption trade-off in period (1):

$$\frac{U_{1f}}{U_{1n}} = \frac{p_{f1}+t_{b1}}{p_{n1}} \tag{1}$$

[6] In the first-order conditions, a partial derivative is denoted by a subscript. For example, "$U_{1f}$" means $\partial U_1/\partial C_{1f}$, "$F_L$" means $\partial F/\partial L_f$, and so forth

Labor use trade-off in food production versus off-farm employment:

$$F_L = \frac{U_{1n}}{U_{2f}} \frac{w_1}{p_{n1}} \tag{2}$$

Purchased input use trade-off of food production versus nonfood consumption:

$$F_X = \frac{U_{1n}}{U_{2f}} \frac{p_x}{p_{n1}} \tag{3}$$

Kuhn-Tucker conditions for food purchases in period 2:

$$P_{f2}[U_{2f} - U_{2n}(\frac{p_{f2} + t_{b2}}{p_{n2}})] = 0 \tag{4a}$$

$$U_{2f} - U_{2n}(\frac{p_{f2} + t_{b2}}{p_{n2}}) \leq 0 \tag{4b}$$

Kuhn-Tucker conditions for food sales in period 2:

$$S_{f2}[-U_{2f} + U_{2n}(\frac{p_{f2} - t_{s2}}{p_{n2}})] = 0 \tag{5a}$$

$$-U_{2f} + U_{2n}(\frac{p_{f2} - t_{s2}}{p_{n2}}) \leq 0 \tag{5b}$$

Kuhn-Tucker conditions for pre-harvest credit:

$$B_1[\frac{U_{1n}}{p_{n1}} - \frac{U_{2n}}{p_{n2}}(1 + r_1)] = 0 \tag{6a}$$

$$\frac{U_{1n}}{p_{n1}} - \frac{U_{2n}}{p_{n2}}(1 + r_1) \leq 0 \tag{6b}$$

These first-order conditions plus the constraints specified earlier determine the household's optimum choice of the decision variables. The assumptions made on preferences and opportunities assure that the solution to the first-order conditions exists and is an optimum.

## Implications

Several interesting implications can be derived from this model.

### *Marketing Regimes in Period 2*

As with the models of Key, Sadoulet, and de Janvry (2000) and Renkow, Hallstrom, and Karanja (2004), transaction costs imply the existence of three distinct marketing regimes for food. It is straightforward to show from equations (4a) to (5b) that the household will not both purchase and sell food in the same period, and that there is a range of the shadow price for food in which the household is autarkic. Equations (4a) and (5a) imply that for a positive amount of both food purchases and sales in period 2, the following condition must hold:

$$p_{n2}\frac{U_{2f}}{U_{2n}} = p_{f2} - t_{s2} = p_{f2} + t_{b2},$$

which is not possible if either $t_{s2} > 0$ or $t_{b2} > 0$. The three regimes are determined by

$$p_{n2}\frac{U_{2f}}{U_{2n}}\Big|_{P_{f2}=0, S_{f2}=0} < p_{f2} - t_{s2} \rightarrow \text{Household sells food in period 2;} \tag{7a}$$

$$p_{n2}\frac{U_{2f}}{U_{2n}}\Big|_{P_{f2}=0, S_{f2}=0} > p_{f2} + t_{b2} \rightarrow \text{Household buys food in period 2;} \tag{7b}$$

$$p_{f2} - t_{s2} \le p_{n2}\frac{U_{2f}}{U_{2n}}\Big|_{P_{f2}=0, S_{f2}=0} \le p_{f2} + t_{b2} \rightarrow \text{Household is autarkic in period 2.} \tag{7c}$$

Thus, the relationship between the shadow price of food in period 2 ($p_{n2}U_{2f}/U_{2n}$) in autarky and the farm-level price net of transaction costs determines the choice of regime.

### *Production Incentives for Market Participants*

The incentive to use labor and other variable inputs in food production in period 1 depends upon what marketing regime the household is in during period 2. Assuming that the household is a seller in period 2 and that borrowing is unconstrained in period 1, one can show, using equations (2), (3), (5a), and (6a) that labor and input use are determined by the following equations:

$$F_L = (1 + r_1)\frac{w_1}{p_{f2} - t_{s2}} \tag{8a}$$

$$F_X = (1 + r_1)\frac{p_X}{p_{f2} - t_{s2}} \tag{8b}$$

Equations (8a) and (8b) are the usual conditions for profit-maximizing input use, with the output price adjusted by the transaction cost and discounted to the first period by the interest rate ($r_1$). Thus, the presence of proportional transaction costs does not affect the separable household model result of profit maximization for a household that is selling its output, as long as credit is not constrained. Similarly, for a household that purchases food in period 2, we have

$$F_L = (1 + r_1)\frac{w_1}{p_{f2} + t_{b2}} \tag{9a}$$

$$F_X = (1 + r_1)\frac{p_X}{p_{f2} + t_{b2}} \tag{9b}$$

Note that $F_L$ and $F_X$ will be less for the buying household than for the selling household, which implies that a buyer will use more inputs and obtain higher production than a seller if both households have the same production function and productive capital (*K)*. Of course, differences in access to technology and capital are important reasons for differences in marketing regime, but such differences in regime choice may also arise from differences in household demand conditions (such as household size and composition). The point here is that sellers face a lower incentive price than buyers. Autarkic households face an incentive price (their shadow price) between that of buyers and sellers and thus have intermediate incentive to use inputs:

$$(1+r_1)\frac{w_1}{p_{f2}+t_{b2}} \le F_L = (1+r_1)\frac{U_{2n}}{U_{2f}}\frac{w_1}{p_{n2}} \le (1+r_1)\frac{w_1}{p_{f2}-t_{s2}} \qquad (10a)$$

$$(1+r_1)\frac{p_X}{p_{f2}+t_{b2}} \le F_X = (1+r_1)\frac{U_{2n}}{U_{2f}}\frac{p_X}{p_{n2}} \le (1+r_1)\frac{p_X}{p_{f2}-t_{s2}} \qquad (10b)$$

These relationships refute the notion that commercialization (in the sense of producing for sale) increases farmers' incentive to use inputs in production. Quite the contrary, their incentive to use inputs is reduced. However, it may be that commercialization increases farmers' ability to use purchased inputs when credit constraints are binding. We take up the issue of credit constraints below.

These relationships also demonstrate that the farmer's incentive to produce does not depend upon whether he is a "net" seller or buyer, as is sometimes asserted. If he is a seller in period 2, the selling price in that period minus transaction costs, discounted to period 1, is his incentive price, regardless of how much he purchases in period 1. Thus, it is irrelevant whether he purchases enough in period 1 to be a net seller or net buyer over the entire year.

Note that for a selling household, reducing the transaction cost increases its incentive price, leading to greater use of inputs and greater production. For a buying household, by contrast, a reduction in transaction costs reduces its production incentive, use of inputs, and production. However, in both cases, the household is better off as a result of the reduced transaction costs. This emphasizes that it is important not to equate impacts on production or commercialization with impacts on household welfare, as these effects may be quite different. For autarkic households, a reduction in transaction costs has no effect unless the change is large enough to cause them to become buyers or sellers. The impacts on production will depend on whether the household becomes a buyer or seller (more production if it becomes a seller, less if it becomes a buyer), although again the impacts on welfare will be positive in both cases.

Other factors influencing production incentives of market participants include the market prices of the food commodity ($p_{f2}$), purchased inputs ($p_X$), the opportunity cost of labor ($w_1$), the interest rate ($r_1$), and the household's endowment of productive capital ($K$). Households that are sellers or buyers behave as profit maximizers (subject to the relevant price for food, taking transaction costs into account) and the standard results for the impacts of these variables apply. For example, an increase in $p_{f2}$ or a decrease in $r_1$

increases the incentive to use inputs; hence it increases use of labor, inputs, and food production (Table 1). An increase in $p_x$ (or $w_1$) reduces use of both purchased inputs, labor, and food production.[7] An increase in $K$ increases the marginal productivity of purchased inputs and labor; hence it results in increased use of these inputs and increased food production. Changes in nonfood prices, the food price in the first period, the household's labor endowment, exogenous income, or other exogenous factors do not affect the production incentives of market participants, as seen by the absence of these factors in equations (8a) and (8b) and (9a) and (9b). Such factors do affect the production incentives of autarkic households, however, by affecting the shadow price of food. We will consider the autarky case, after considering impacts of exogenous factors on consumption, marketing, and borrowing behavior of market participants.

### *Consumption, Marketing, and Borrowing Incentives of Market Participants*

The effects of changes in commodity prices on consumption and marketing decisions of market participants have been derived elsewhere (Strauss 1984; Singh, Squire, and Strauss 1986). For a household that both produces and consumes a commodity (such as food in our model), the effects of a change in the price of that commodity are given by

$$\frac{dC_j}{dp_{f2}} = \frac{dC_j}{dp_{f2}}|_U + (Y_f - C_{f2})\frac{dC_j}{dI} \qquad (11)$$

where $C_j$ refers to consumption of the *jth* good ($C_{f1}$, $C_{n1}$, $C_{f2}$, and $C_{n2}$ in our model) and $dC_j/dI$ refers to the effect of a change in income on demand for the *jth* good, which is positive in our model, since we assume all goods are normal goods. The term $dC_j/dp_{f2}|_U$ refers to the effect on compensated demand (holding utility constant) of a change in the price of food, which will be negative for $C_{f2}$. If the other commodities are net substitutes for $C_{f2}$, an increase in the price of $C_{f2}$ leads to an increase in the compensated demand for the other goods.[8] In this case, equation (11) implies that an increase in $p_{f2}$ will lead to an increase in $C_{f1}$, $C_{n1}$, and $C_{n2}$ if the household is a seller of food ($Y_f - C_{f2} > 0$), since both the substitution and income effects in equation (11) are positive for these other goods. Conversely, the effect of an increase in $p_{f2}$ on $C_{f2}$ is ambiguous for a seller, since the income and substitution effects are in opposite directions. For a food-buying household ($Y_f - C_{f2} < 0$), the income effect of an increase in the food price is the opposite of that for a seller; that is, the household's real income decreases. As a result, the effect of an increase in $p_{f2}$ on $C_{f2}$ is unambiguously negative for a food buyer, while the effect on consumption of other goods is ambiguous.

[7] The negative own input price effect is a standard result of production theory and results from the concavity of the production function. The negative cross-input price effects (for example, that an increase in $p_x$ reduces $L_f$) follows from the assumption of nonnegative cross-partial derivatives of the production function. In the limiting case in which cross-partial derivatives of the production function are zero, the cross-input price effects are also zero.

[8] If there are only two goods, they must be net substitutes (Nicholson 1995, 180). If there are more than two goods, net substitution must be the prevalent relationship; that is, $\sum_{i \neq j}(p_i dC_j/dp_i|_U) \geq 0$ (Nicholson 1995, 193).

**Table 1. Summary of model implications, borrowing constraint not binding**

| Exogenous variable | Food market position in period 2 | $L_f$ | $L_{o1}$ | X | Y | $C_{f1}$ | $C_{n1}$ | $C_{f2}$ | $C_{n2}$ | $p^s_{f2}$ | $S_{f2}$ | $P_{f2}$ | $B_1$ | Utility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $p_{f2}$↑ | S | + | - | + | + | $+^n$ | $+^n$ | ? | $+^n$ | + | ? | 0 | + | + |
| | B | + | - | + | + | ? | ? | - | ? | + | 0 | - | ? | - |
| | A | 0/+ | 0/- | 0/+ | 0/+ | $0/+^n$ | 0/+ | 0/? | $0/+^n$ | 0/+ | 0/+ | 0 | 0/+ | 0/+ |
| $t_{s2}$↓ | S | + | - | + | + | $+^n$ | $+^n$ | ? | $+^n$ | + | ? | 0 | + | + |
| | A | 0/+ | 0/- | 0/+ | 0/+ | $0/+^n$ | $0/+^n$ | 0/+ | $0/+^n$ | 0/+ | 0/+ | 0 | 0/ | 0/+ |
| $t_{b2}$↓ | B | - | + | - | - | ? | ? | + | ? | - | 0 | + | ? | + |
| | A | 0/- | 0/+ | 0/- | 0/- | 0/? | 0/? | 0/+ | 0/? | 0/- | 0 | 0/+ | 0/? | 0/+ |
| $p_{f1}$↑ | S/B | 0 | 0 | 0 | 0 | - | ? | ? | ? | 0 | ? | ? | ? | - |
| | A | ? | ? | ? | ? | ? | ? | ? | ? | ? | 0/? | 0/? | ? | - |
| $t_{b1}$↓ | S/B | 0 | 0 | 0 | 0 | + | ? | ? | ? | 0 | ? | ? | ? | + |
| | A | ? | ? | ? | ? | ? | ? | ? | ? | ? | 0/? | 0/? | ? | + |
| $p_{n1}$↑ | S/B | 0 | 0 | 0 | 0 | ? | - | ? | ? | 0 | ? | ? | ? | - |
| | A | ? | ? | ? | ? | ? | ? | ? | ? | ? | 0/? | 0/? | ? | - |
| $p_{n2}$↑ | S/B | 0 | 0 | 0 | 0 | ? | ? | ? | - | 0 | ? | ? | ? | - |
| | A | ? | ? | ? | ? | ? | ? | ? | ? | ? | 0/? | 0/? | ? | - |
| $p_x$↑ | S/B | - | + | - | - | - | - | - | - | 0 | $?^{(-)}$ | $?^{(+)}$ | $?^{(-)}$ | - |
| | A | ? | ? | - | - | ? | ? | - | ? | ? | 0/? | 0/? | ? | - |
| $w_1$↑ | S/B | - | + | - | - | + | + | + | + | 0 | - | + | ? | + |
| | A | ? | ? | ? | ? | $+^n$ | $+^n$ | ? | $+^n$ | + | 0 | 0/+ | ? | + |
| $r_1$↑ | S/B | - | + | - | - | - | - | ? | ? | 0 | ? | ? | - | - |
| | A | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | - |
| K↑ | S/B | + | - | + | + | + | + | + | + | 0 | + | - | + | + |
| | A | + | - | + | + | ? | ? | + | ? | - | 0/+ | 0 | ? | + |
| $\underline{L}_1$↑ | S/B | 0 | + | 0 | 0 | + | + | + | + | 0 | - | + | - | + |
| | A | + | + | + | + | $+^n$ | $+^n$ | + | $+^n$ | + | 0 | 0/+ | ? | + |
| $\underline{L}_2$↑ | S/B | 0 | 0 | 0 | 0 | + | + | + | + | 0 | - | + | + | + |
| | A | + | - | + | + | $+^n$ | $+^n$ | + | $+^n$ | + | 0 | 0/+ | + | + |
| $T_1$↑ | S/B | 0 | 0 | 0 | 0 | + | + | + | + | 0 | - | + | - | + |
| | A | + | - | + | + | $+^n$ | $+^n$ | + | $+^n$ | + | 0 | 0/+ | ? | + |
| $T_2$↑ | S/B | 0 | 0 | 0 | 0 | + | + | + | + | 0 | - | + | + | + |
| | A | + | - | + | + | $+^n$ | $+^n$ | + | $+^n$ | + | 0 | 0/+ | + | + |

Symbols: S = seller, B = buyer, S/B = seller or buyer, A = autarkic
+ = positive impact, – = negative impact, 0 = no impact, 0/+ = no or positive impact, ? = ambiguous impact
$^n$ means $C_{f1}$, $C_{n1}$, $C_{f2}$, and $C_{n2}$ are assumed to be net substitutes for each other for these results.
$^{(-)}$ means effect is negative if $\varepsilon_{x,px} < -1$; $^{(+)}$ means effect is positive if $\varepsilon_{x,px} < -1$.

Since an increase in $p_{f2}$ has an ambiguous impact on food consumption of a food-selling household, it also has an ambiguous impact on food sales ($S_{f2}$) (Singh, Squire, and Strauss 1986). Borrowing ($B_1$) unambiguously increases, however, since increased purchases of inputs, increased on-farm labor use (hence reduced off-farm labor earnings), and increased consumption of both food and nonfood goods in the first period all require increased borrowing to satisfy the first-period budget constraint. The welfare of a selling household increases as $p_{f2}$ increases because the household's real income has increased.

For a food-buying household, an increase in $p_{f2}$ reduces food purchases since $Y_f$ increases and $C_{f2}$ decreases. The effect on borrowing is ambiguous since the impacts on first-period consumption are ambiguous. The welfare of buying households is reduced by an increase in $p_{f2}$.

The effects of changes in proportional transaction costs for food are equivalent to changes in the household-level price of food. That is, a reduction in the transaction costs faced by sellers ($t_{s2}$) leads to the same effects as an increase in $p_{f2}$, while a reduction in transaction costs faced by buyers ($t_{b2}$) leads to the same effects as a decrease in $p_{f2}$.

The effects of a change in nonfood prices are determined by the normal Slutsky decomposition, since households are assumed not to produce the nonfood good:

$$\frac{dC_j}{dp_{n2}} = \frac{dC_j}{dp_{n2}}\Big|_U - C_{n2}\frac{dC_j}{dI} \tag{12}$$

Equation (12) implies that an increase in the price of nonfood items in period 2 ($p_{n2}$) will reduce $C_{n2}$, but it will have ambiguous impacts on $C_{f2}$, $C_{f1}$, and $C_{n1}$, since income and substitution effects are in opposite directions for other goods (assuming other goods are net substitutes for $C_{n1}$). Impacts on food sales or purchases are ambiguous, since impacts on food consumption are ambiguous. Impacts on borrowing are ambiguous since impacts on first-period consumption are ambiguous. The household's welfare declines since an increase in nonfood prices reduces real income.

The effects of an increase in food or nonfood prices in period 1 are analogous to the effects of an increase in $C_{n2}$. Changes in these prices have no impact on the use of inputs or food production, reduce consumption of the good whose price has increased, and have ambiguous effects on consumption of other goods. The effects on food sales or purchases are thus ambiguous, as is the effect on borrowing. Increases in either of these prices reduce household welfare, since the household is a purchaser of these goods.

A reduction in transaction costs of purchasing food in the first period ($t_{b1}$) is equivalent to a reduction in the food price faced by the household, and has the same impacts. Note that an improvement in access to infrastructure or in market institutions is likely to reduce transaction costs in both periods, and the total effects are the combined effects of reducing transaction costs in both periods.

An increase in the price of the purchased input ($p_x$) results in less consumption of all goods, since this reduces the profit and income of food producers and hence their consumption demands. Since both food production and consumption are reduced, the effect on food sales or purchases is ambiguous in general. However, a sufficient (but not necessary) condition for food sales ($S_{f2}$) to decline or food purchases ($P_{f2}$) to increase as $p_x$ increases is that the demand elasticity of $X$ with respect to $p_x$ ($\varepsilon_{x,px}$) be less than –1.[9] In this elastic input demand case, borrowing decreases since expenditures on inputs ($p_xX$) and $L_f$ decrease (hence $L_{o1}$ increases), while $C_{f1}$ and $C_{n1}$ also decrease, reducing the demand for credit to meet the first-period budget constraint. More ambiguous impacts on marketing and borrowing can occur if input demand is inelastic. An increase in $p_x$ reduces the household's welfare since this reduces its income.

An increase in $w_1$ has the opposite effect of an increase in $p_x$ on household income, since the household is assumed to be a net seller of labor.[10] In this case, since food consumption increases and food production decreases, sales must decrease for a food seller and purchases must increase for a food buyer. The impact on borrowing is ambiguous since input use declines but first-period consumption and wage income increases. Welfare increases since real income has increased.

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[9] *Proof*: To simplify notation, define prices net of transactions costs: $p_{f1}^n = p_{f1}+t_{b1}$, $p_{f2}^n = p_{f2}-t_{s2}$ if the household is a seller and $p_{f2}^n = p_{f2}+t_{b2}$ if the household is a buyer. Dividing budget constraint (B2) by $1+r_1$, adding it to budget constraint (B1), substituting for $P_{ft} - S_{ft}$ from constraints (F1) and (F2), and rearranging terms, we obtain the two-period budget constraint:

$$p_{f1}^{\,n}C_{f1} + p_{n1}C_{n1} + \frac{p_{f2}^{\,n}}{1+r_1}C_{f2} + \frac{p_{n2}}{1+r_1}C_{n2} = w_1\underline{L}_1 + \frac{w_2}{1+r_1}\underline{L}_2 + T_1 + \frac{T_2}{1+r_2} + \frac{p_{f2}^{\,n}}{1+r_1}Y_{f2} - p_xX - w_1L_f\,. \quad (13)$$

The first four terms on the right side of equation (13) represent the discounted full-endowment income (FEI), and the last three terms represent the discounted profit from food crop production ($\pi$). We define full income (FI) as $FEI+\pi$. Differentiating equation (13) with respect to $p_x$ and rearranging terms, we obtain

$$p_{f1}^{\,n}\frac{dC_{f1}}{dp_x} + p_{n1}\frac{dC_{n1}}{dp_x} + \frac{p_{f2}^{\,n}}{1+r_1}\frac{dC_{f2}}{dp_x} + \frac{p_{n2}}{1+r_1}\frac{dC_{n2}}{dp_x} = \frac{p_{f2}^{\,n}}{1+r_1}\frac{dY_f}{dp_x} - X\left(1+\frac{p_x}{X}\frac{dX}{dp_x}\right) - w_1\frac{dL_f}{dp_x}\,. \quad (14)$$

*(footnote 9 continued)*

Rearranging equation (14), we obtain

$$p_{f1}^{\,n}\frac{dC_{f1}}{dp_x} + p_{n1}\frac{dC_{n1}}{dp_x} + \frac{p_{n2}}{1+r_1}\frac{dC_{n2}}{dp_x} + X(1+\varepsilon_{x,px}) + w_1\frac{dL_f}{dp_x} = \frac{p_{f2}^{\,n}}{1+r_1}\left(\frac{dY_f}{dp_x} - \frac{dC_{f2}}{dp_x}\right). \quad (15)$$

Equation (15) implies that $d(Y_f-C_{f2})/dp_x < 0$ if $\varepsilon_{x,px} \leq -1$. This is a sufficient but not a necessary condition; this result may hold even if $\varepsilon > -1$.

[10] *Proof:* Differentiate the combined budget constraint (equation (13) in the previous footnote) to obtain:

$$p_{f1}^{\,n}\frac{dC_{f1}}{dw_1} + p_{n1}\frac{dC_{n1}}{dw_1} + \frac{p_{f2}^{\,n}}{1+r_1}\frac{dC_{f2}}{dw_1} + \frac{p_{n2}}{1+r_1}\frac{dC_{n2}}{dw_1} = \underline{L}_1 + \frac{d\pi}{dw_1}\,. \quad (16)$$

By the envelope theorem, $d\pi/dw_1 = -L_f$. Therefore, the right side of equation (16) equals $\underline{L}_1 - L_f = L_{o1} > 0$. Thus the income effect of an increase in $w_1$ is positive, and since $C_{f1}$, $C_{n1}$, $C_{f2}$, and $C_{n2}$ are all assumed to be normal goods, all increase. Note that if the household is a net buyer rather than a net seller of labor, the income effect would be negative and consumption of all goods would decrease. This is the same as the case for $X$.

An increase in $r_1$ results in a reduction in full income, both because this reduces the discounted full endowment income and because it reduces the discounted price received for food production (hence reduces discounted profit). It also amounts to a reduction in the discounted price of $C_{f2}$ and $C_{n2}$. Hence, an increase in $r_1$ leads to a reduction in both $C_{f1}$ and $C_{n1}$ because both income and substitution effects are acting in this direction for first-period consumption.[11] The effects of $r_1$ on second-period consumption are ambiguous since income and substitution effects are in opposite directions.[12] Borrowing in the first period declines because consumption, input use, and farm labor use decline (implying that off-farm labor use increases), resulting in less demand for credit. Welfare also declines since the increase in the interest rate reduces the household's real income.

An increase in $K$ increases food production and profits and hence increases $C_{f1}$, $C_{n1}$, $C_{f2}$, and $C_{n2}$. Although both food production and consumption increase, food production increases by more than food consumption in the second period; hence food sales increase if the household is a food seller or food purchases decrease if the household is a food purchaser.[13] Borrowing increases because food

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[11] *Proof*: Define $V_1(E_1) = \max U_1(C_{f1}, C_{n1})$ subject to $p_{f1}^n C_{f1} + p_{n1}C_{n1} = E_1$ and $V_2(E_2) = \max U_2(C_{f2}, C_{n2})$ subject to $p_{f2}^n C_{f2} + p_{n2}C_{n2} = E_2$. Then the household's problem is equivalent to maximizing $V_1(E_1)+V_2(E_2)$ subject to $E_1 + E_2/(1+r_1) = FEI+\pi$, where FEI and $\pi$ are defined in footnote 7. The first-order conditions of this problem are

$$\frac{\partial V_1}{\partial E_1} - (1+r)\frac{\partial V_2}{\partial E_2} = 0 \tag{17}$$

$$(1+r_1)E_1 + E_2 - (1+r_1)(FEI+\pi) = 0 \tag{18}$$

Totally differentiating equations (17) and (18) with respect to $r_1$ and applying Cramer's rule, one can show that

$$\frac{dE_1}{dr_1} = \frac{\dfrac{\partial V_2}{\partial E_2} - (1+r_1)B_1\dfrac{\partial^2 V_2}{\partial {E_2}^2}}{\dfrac{\partial^2 V_1}{\partial {E_1}^2} + (1+r_1)^2\dfrac{\partial^2 V_2}{\partial {E_2}^2}} < 0 \tag{19}$$

The result $dE_1/dr_1 < 0$ follows from the concavity of $V_1$ and $V_2$ and the fact that $V_2$ is increasing in $E_2$. Since both $C_{f1}$ and $C_{n1}$ are normal goods, consumption of both decline as $E_1$ declines.

[12] *Proof*: Also using Cramer's rule, one can show that

$$\frac{dE_2}{dr_1} = \frac{-B_1\dfrac{\partial^2 V_1}{\partial {E_1}^2} - (1+r_1)\dfrac{\partial V_2}{\partial E_2}}{\dfrac{\partial^2 V_1}{\partial {E_1}^2} + (1+r_1)^2\dfrac{\partial^2 V_2}{\partial {E_2}^2}} \tag{20}$$

This expression is of ambiguous sign since the terms in the numerator are positive and negative.

[13] *Proof*: Differentiate equation (13) with respect to $K$ to obtain

$$p_{f1}^{\ n}\frac{dC_{f1}}{dK} + p_{n1}\frac{dC_{n1}}{dK} + \frac{p_{f2}^{\ n}}{1+r_1}\frac{dC_{f2}}{dK} + \frac{p_{n2}}{1+r_1}\frac{dC_{n2}}{dK} = \frac{p_{f2}^{\ n}}{1+r_1}\frac{dY_f}{dK} - p_x\frac{dX}{dK} - w_1\frac{dL_f}{dK} < \frac{p_{f2}^{\ n}}{1+r_1}\frac{dY_f}{dK}. \tag{21}$$

The inequality in (21) results because $dX/dK > 0$ and $dL_f/dK > 0$, as shown earlier. The left side of equation (21) is greater than $p_{f2}^n/(1+r_1)(dC_{f2}/dK)$, since $dC_{f1}/dK$, $dC_{n1}/dK$, and $dC_{n2}/dK$ are all greater than 0. Hence $dC_{f2}/dK < dY_f/dK$.

consumption and input and farm labor use increase in the first period. Welfare increases because real income increases.

An increase in $\underline{L}_1$ increases the household's endowment income; hence $C_{f1}$, $C_{n1}$, $C_{f2}$ and $C_{n2}$ increase. Since production is unaffected by a change in $\underline{L}_1$ (for a market participant), food sales must decline if the household is a food seller, and food purchases must increase if the household is a food purchaser. Although consumption increases in the first period, income from off-farm labor increases even more, so borrowing decreases.[14] Household welfare increases since real income increases. An increase in $\underline{L}_2$ has similar impacts, except that borrowing increases rather than decreases. This is because first period income is not increased in this case, while first-period consumption (and second-period income) increases, requiring increased borrowing to shift income to the first period. If both $\underline{L}_1$ and $\underline{L}_2$ increase, the impacts will be the combined effects of both, resulting in similar qualitative predictions for all variables except borrowing, for which the impacts will be ambiguous.

An increase in $T_1$ has qualitatively similar impacts to a change in $\underline{L}_1$: it has no effect on input use of food production, while consumption of all goods increases, food sales decline or food purchases increase, borrowing declines,[15] and welfare increases. An increase in $T_2$ has similar impacts, except that borrowing increases, as with an increase in $\underline{L}_2$.

### *Implications for Autarkic Households*

The model implications for autarkic households can be derived from the results for market participants, taking the "given" price of food in period 2 as the shadow price ($p_{f2}^s$), which equates food supply and demand:

$$Y_f(p_{f2}^s, Z) = C_{f2}(p_{f2}^s, Z) \tag{24}$$

where $Z$ is the vector of exogenous variables in the model. Equation (24) determines $p_{f2}^s(Z)$.
Writing the reduced form for endogenous variable $y_j$ when $p_{f2}$ is exogenously determined as $y_j(p_{f2}, Z)$, substituting $p_{f2}^s(Z)$ for $p_{f2}$ in this expression and totally differentiating this by $Z_i$, we obtain the effect of any particular exogenous variable ($Z_i$) on any $y_j$:

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[14] *Proof*: Using the first-period budget constraint to solve for $B_1$, and differentiating with respect to $\underline{L}_1$ (and recalling that $dX/d\underline{L}_1 = 0$ and $dL_f/d\underline{L}_1 = 0$), we obtain

$$\frac{dB_1}{d\underline{L}_1} = p_{f1}^n \frac{dC_{f1}}{d\underline{L}_1} + p_{n1}\frac{dC_{n1}}{d\underline{L}_1} - w_1 \tag{22}$$

Differentiating equation (13) with respect to $\underline{L}_1$, we obtain:

$$p_{f1}^n \frac{dC_{f1}}{d\underline{L}_1} + p_{n1}\frac{dC_{n1}}{d\underline{L}_1} + \frac{p_{f2}^n}{1+r_1}\frac{dC_{f2}}{d\underline{L}_1} + \frac{p_{n2}}{1+r_1}\frac{dC_{n2}}{d\underline{L}_1} = w_1 \tag{23}$$

Equations (22) and (23) imply that $dB_1/d\underline{L}_1 < 0$, since $dC_{f2}/d\underline{L}_1$ and $dC_{n2}/d\underline{L}_1$ are greater than zero.

[15] The proof that $dB_1/dT_1 < 0$ is completely analogous to the proof in the previous footnote that $dB_1/d\underline{L}_1 < 0$.

$$\frac{dy_j}{dZ_i} = \frac{\partial y_j}{\partial Z_i}\Big|_{p_{f2}^s} + \frac{\partial y_j}{\partial p_{f2}} \frac{\partial p_{f2}^s}{\partial Z_i} \tag{25}$$

The first term on the right side of equation (25) is the effect of $Z_i$ on $y_j$ in the model with exogenous (fixed) $p_{f2}$, and the second term is the effect via the impact of $Z_i$ on the shadow price of food. Effects on the shadow price can be determined by total differentiation of equation (24), which results in

$$\frac{dp_{f2}^s}{dZ_i} = -\frac{\frac{\partial C_{f2}}{\partial Z_i} - \frac{\partial Y_f}{\partial Z_i}}{\frac{\partial C_{f2}}{\partial p_{f2}} - \frac{\partial Y_f}{\partial p_{f2}}} \tag{26}$$

For an autarkic household, equation (11) implies that $\partial C_{f2}/\partial p_{f2} < 0$ (since income effects of a food price change are zero for autarkic households), while $\partial Y_f/\partial p_{f2} > 0$ as shown earlier. Hence, the sign of the denominator in equation (26) is negative, and the sign of $dp_{f2}^s/dZ_i$ is the same as the sign of $\partial(C_{f2}-Y_f)/\partial Z_i$, evaluated at the shadow price where equation (24) is satisfied. In other words, if increasing $Z_i$ in autarky would lead to excess demand for $C_{f2,}$ the shadow price will increase, and conversely, if increasing $Z_i$ leads to excess supply, the shadow price will decrease.

Based on equation (26) and the results in Table 1, we can see that an increase in $w_1$, $\underline{L}_1$, $\underline{L}_2$, $T_1$, or $T_2$ would lead to an increase in $p_{f2}^s$, since these changes increase excess food demand by increasing household income. Sufficiently large increases in these variables may therefore cause an autarkic household to become a food buyer in period 2 (when $p_{f2}^s$ in autarky exceeds the market price) and further increases will have the same impacts as those shown in Table 1 for food buying households. An increase in $K$ would lead to a decrease in $p_{f2}^s$ by increasing excess supply, and a sufficiently large increase may cause the household to become a food seller, with further increases in $K$ leading to the same effects as for food sellers. Changes in most other exogenous variables have ambiguous effects on $p_{f2}^s$ since they have ambiguous impacts on excess food demand or supply.

An increase in the market price of food (or reduction in transaction costs) in period 2 has no direct effect on the household's shadow price as long as the household remains in autarky. However, if the market price increases enough (or the transaction cost for selling falls enough) so that the net market return from selling becomes greater than the household's shadow price, the household will become a food seller (conversely, the household may become a food buyer in period 2 if the market price or transaction cost for buying falls substantially). In this case, the effects of a food price increase (decrease) are qualitatively similar to those for a food seller (buyer). If transaction costs increase, an autarkic household will remain autarkic (if other factors are unchanged).

Using the above results for impacts on shadow prices, the results in the previous section and equation (25), we can show the impacts of changes of some exogenous factors on some endogenous variables in autarky. For example, an increase in $w_1$ leads to an increase in $C_{f1}$, $C_{n1}$ and $C_{n2}$ (assuming these are net substitutes for $C_{f2}$) because the increase in $w_1$ increases them, holding $p_{f2}$ constant, and also because this increases the shadow price of food, which increases the consumption of net substitutes for $C_{f2}$ (income effects of the shadow food price change are zero for autarkic households). The effect of increasing $w_1$ on $C_{f2}$ and $Y_f$ is ambiguous. Essentially, increasing $w_1$ shifts the household's food demand curve out (due to increased income) and the food supply curve in (due to increased costs), resulting in ambiguous impacts on food consumption and production, although the shadow price of food unambiguously increases. The effects on input use and labor use are ambiguous, since the increase in the shadow price of food acts in the opposite direction to the increased price of labor. The effects on borrowing are ambiguous because the effects on input use are ambiguous.

An increase in $K$ increases both the supply of food (by increasing productivity directly and use of $X$ and $L_f$) and the demand for food (by increasing profits from food production, hence income), resulting in increased $C_{f2}$ and $Y_f$ in autarky. The effect on consumption of other goods is ambiguous, since income and substitution effects are in opposite directions. As for market participants, the impact of an increase in $K$ on off-farm employment is negative, since $L_f$ increases. The impact on borrowing is ambiguous because the effects on first-period consumption are ambiguous.

An increase in $\underline{L}_1$, $\underline{L}_2$, $T_1$, or $T_2$ increases the demand for food (by increasing income), while having no direct effect on food supply. This leads to an increase in $C_{f2}$ in autarky and to an increase in the shadow price of food. The increased shadow price of food contributes to increased consumption of other goods (assuming they are net substitutes for $C_{f2}$) and induces an increase in use of inputs and food production to balance the increased demand.

The effects of these variables on off-farm labor supply ($L_{o1}$) differ, however. Since labor used for food production increases, off-farm labor ($L_{o1}$) decreases in all of these cases except when $\underline{L}_1$ is increased. When $\underline{L}_1$ is increased, not all of the increased labor endowment is allocated to food production (although $L_f$ does increase), since additional cash income is needed to finance increased consumption of other goods. Thus, $L_{o1}$ increases when $\underline{L}_1$ is increased.

The effects of changes in $\underline{L}_1$, $\underline{L}_2$, $T_1$, and $T_2$ on borrowing also differ. Increases in $\underline{L}_2$ or $T_2$ increase borrowing, both because the increased income in the second period increases the desire to smooth consumption by borrowing (as shown previously), and because the increase in the shadow price of food induces increased input use and increased first-period consumption (assuming net substitution), thereby increasing demand for credit. In contrast, an increase in $\underline{L}_1$ or $T_1$ has ambiguous impacts on borrowing, because increased income in the first period tends to reduce the demand for credit, while an increase in the shadow price of food induces increased input use that tends to increase credit demand.

The effects of changes in other exogenous variables ($p_{f1}$, $p_{n1}$, $p_{n2}$, $p_x$, $r_1$) are more difficult to prove, because the effects of these variables on excess food supply or demand, and hence upon the shadow price of food, are ambiguous. However, it is possible to prove that an increase in $p_x$ results in a reduction in $X$, $Y_f$, and $C_{f2}$ for autarkic households, as for market participants.[16] This is because an increase in $p_x$ results in a shift inward of the food supply curve (that is, an upward shift of the marginal cost curve) and an inward shift in the demand for food (due to reduced profit from food production). Effects of other changes in exogenous variables are ambiguous.

### *Implications of the Labor–Leisure Choice*

If we had assumed that households choose leisure as well as consumption in each period, and that leisure is also a normal good, few of the model predictions would change. Two additional first-order conditions would be added, equating the implicit value of leisure in each period to the wage rate, similar to the first-order conditions for consumption goods. A change in the price of any non-leisure good would affect leisure in each period in a qualitatively similar way to the impacts on other goods (besides the one whose price was changed), since for a household participating in the labor market, leisure acts just the same as a consumption good with a price of $w_t$. The main changes in the results in Table 1 would be in the impacts on off-farm labor supply ($L_{o1}$), which would be ambiguous for a change in $p_{f2}$ or $t_{b2}$ if the household is a food buyer in period 2, or for a change in $p_{f1}$, $t_{b1}$, $p_{n1}$, $p_{n2}$, or $w_1$. The impacts on $L_{o1}$ are ambiguous in these cases because the impacts on leisure in the first period are ambiguous, since income and substitution effects are in opposite directions. For example, an increase in $p_{f2}$ for a food-buying household has a negative income effect but a positive substitution effect on first-period leisure (assuming leisure is a net substitute for food). Increases in prices of other goods have ambiguous impacts for the same reason. An increase in $w_1$ has a positive income effect but a negative substitution effect on leisure demand.

[16] *Proof*: Suppose that $p_x$ increases but the household does not decrease use of $X$. Then, by equation (25) it must be that the shadow price of food in period 2 ($p_{n2}U_{2f}/U_{2n}$) has increased (that is, $\partial X/\partial p_x \geq 0$ implies that $\partial p_{f2}/\partial p_x > 0$ by equation (25) since $\partial X/\partial p_x|p_{f2} < 0$ and $\partial X/\partial p_{f2} > 0$). If the shadow price of food rises in period 2, then $F_L$ decreases by equation (10a) (middle part). This implies that $L_f$ has increased, since the nondecrease in $X$ leads to a nondecrease in $F_L$ without any change in $L_f$ (since $F_{LX} \geq 0$) and since $F_{LL} < 0$. An increase in $L_f$ and nondecrease in $X$ implies that $Y_f$ (and therefore $C_{f2}$) has increased. An increase in $C_{f2}$ will tend to reduce the shadow price of food in period 2, unless $C_{n2}$ has also increased. An increase in $C_{f2}$ also implies that $C_{f1}$ and $C_{n1}$ must have increased, assuming these are net substitutes for $C_{f2}$, since the shadow price of $C_{f2}$ has increased. But an increase in all consumption goods and inputs and in the price of inputs is inconsistent with the combined budget constraint (equation [13]). Hence, we have a contradiction, and $X$ must have decreased. A similar argument can be used to show that food production declines as $p_x$ increases. If $Y_f$ does not decline, $L_f$ must have increased as $X$ decreased. This, together with the fact that $X$ has decreased, implies that $F_L$ has decreased. Then by equation (10a), the shadow price of food in period 2 ($p_{n2}U_{2f}/U_{2n}$) must have increased. As above, if $C_{f2}$ has not decreased (since $Y_f$ has not decreased) and the shadow price of food has increased, this implies that $C_{n2}$ has increased and, if $C_{f1}$ and $C_{n1}$ are net substitutes for $C_{f2}$, these must also have increased. The cost of production must also have increased since $Y_f$ has not decreased and the increase in $p_x$ increases the cost function $C(p_x, w_1, Y_f)$. Again we have a contradiction with equation (13), since all consumption goods and the cost of production cannot increase within the household's budget constraint.

*Implications of a Binding Credit Constraint*

Using a similar approach to that used in the case of autarky in the food market, we assess the implications of a binding credit constraint by replacing exogenous $r_1$ by an endogenously determined shadow price of credit ($r_1^s$), where $r_1^s$ equates credit demand and supply:

$$B_1(r_1^s, Z) = \underline{B}_1 \qquad (27)$$

Then the effects of a change in any exogenous variable ($Z_i$) on endogenous variable $y_j$ in the context of a binding credit constraint can be determined in a fashion analogous to equation (25):

$$\frac{dy_j}{dZ_i} = \frac{\partial y_j}{\partial Z_i}\Big|_{r_1^s} + \frac{\partial y_j}{\partial r_1}\frac{\partial r_1^s}{\partial Z_i} \qquad (28)$$

where $\partial y_j/\partial Z_i|r_1^s$ refers to the effect of $Z_i$ on $y_j$, taking $r_1$ as fixed and borrowing as endogenous, while the second term is the effect of $Z_i$ via its effect on the shadow price of credit. Note that equation (28) can be used to determine impacts irrespective of market regime, as long as the partial effects used in equation (28) ($\partial y_j/\partial Z_i|r_1^s$ and $\partial y_j/\partial r_1$) are the ones relevant to the market regime being considered.

We obtain the impacts of changes in $Z_i$ on the shadow price of credit by total differentiation of equation (27):

$$\frac{dr_1^s}{dZ_i} = -\frac{\frac{\partial B_1}{\partial Z_i}}{\frac{\partial B_1}{\partial r_1}} \qquad (29)$$

As shown previously, $\partial B_1/\partial r_1 < 0$ for market participants. Thus, for market participants, the sign of $\partial r_1^s/\partial Z_i$ is the same as the sign of $\partial B_1/\partial Z_i$. We use this fact, together with equation (28) and the implications already derived for unconstrained households, to derive implications for credit constrained market participants (Table 2).

For autarkic households, the sign for $\partial B_1/\partial r_1$ is ambiguous, as discussed earlier. Hence, the implications of changes in $Z_i$ on $y_j$ for credit-constrained autarkic households are generally ambiguous. One exception is the effects of changes on $C_{n2}$. With borrowing constrained, the second-period budget constraint for an autarkic household becomes $p_{n2}C_{n2} = w_2\underline{L}_2 + T_2 - (1+r_1)\underline{B}_1$ (B2′) .

$C_{n2}$ is completely determined by the exogenous variables in constraint (B2′) ($p_{n2}$, $w_2$, $\underline{L}_2$, $T_2$, $r_1$, and $\underline{B}_1$) for a credit-constrained autarkic household. Thus, an increase in $w_2$, $\underline{L}_2$, or $T_2$ would increase $C_{n2}$, while an increase in $p_{n2}$, $r_1$, or $\underline{B}_1$ would decrease $C_{n2}$, and changes in other exogenous variables have no effect on $C_{n2}$.

**Table 2. Summary of model implications, borrowing constraint binding**

| Exog. variable | Food market position in period 2 | $L_f$ | $L_{o1}$ | X | Y | $C_{f1}$ | $C_{n1}$ | $C_{f2}$ | $C_{n2}$ | $r_1^s$ | $S_{f2}$ | $P_{f2}$ | Utility |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\underline{B}_1$↑ | S/B | + | - | + | + | + | + | ? | ? | - | ? | ? | + |
| | A | ? | ? | ? | ? | ? | ? | ? | - | ? | ? | ? | + |
| $p_{f2}$↑ | S | ? | ? | ? | ? | ? | ? | ? | ? | + | ? | 0 | + |
| | B | ? | ? | ? | ? | ? | ? | ? | ? | ? | 0 | ? | - |
| | A | 0/? | 0/? | 0/? | 0/? | 0/? | 0/? | 0/? | 0 | 0/? | 0/? | 0/? | 0/+ |
| $p_{f1}$↑ | S/B | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | - |
| | A | ? | ? | ? | ? | ? | ? | ? | 0 | ? | ? | ? | - |
| $p_{n1}$↑ | S/B | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | - |
| | A | ? | ? | ? | ? | ? | ? | ? | 0 | ? | ? | ? | - |
| $p_{n2}$↑ | S/B | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | - |
| | A | ? | ? | ? | ? | ? | ? | ? | - | ? | ? | ? | - |
| $p_x$↑ | S/B | ? | ? | ? | ? | ? | ? | ? | ? | ?$^{(-)}$ | ? | ? | - |
| | A | ? | ? | ? | ? | ? | ? | ? | 0 | ? | ? | ? | - |
| $w_1$↑ | S/B | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | + |
| | A | ? | ? | ? | ? | ? | ? | ? | 0 | ? | ? | ? | + |
| $r_1$↑ | S/B | + | - | + | + | - | - | - | - | - | + | - | - |
| | A | ? | ? | ? | ? | ? | ? | ? | - | ? | ? | ? | - |
| K↑ | S/B | ? | ? | ? | + | ? | ? | + | + | + | + | - | + |
| | A | ? | ? | ? | ? | ? | ? | ? | 0 | ? | ? | ? | + |
| $\underline{L}_1$↑ | S/B | + | + | + | + | + | + | + | + | - | + | - | + |
| | A | ? | ? | ? | ? | ? | ? | ? | 0 | ? | ? | ? | + |
| $\underline{L}_2$↑ | S/B | - | + | - | - | + | + | + | + | + | - | + | + |
| | A | ? | ? | ? | ? | ? | ? | ? | + | ? | ? | ? | + |
| $T_1$↑ | S/B | + | - | + | + | + | + | + | + | - | + | - | + |
| | A | ? | ? | ? | ? | ? | ? | ? | 0 | ? | ? | ? | + |
| $T_2$↑ | S/B | - | + | - | - | + | + | + | + | + | - | + | + |
| | A | ? | ? | ? | ? | ? | ? | ? | + | ? | ? | ? | + |

Symbols: S = seller, B = buyer, S/B = seller or buyer, A = autarkic
\+ = positive impact, – = negative impact, 0 = no impact, 0/+ = no or positive impact, ? = ambiguous impact
$^n$ means $C_{f1}$, $C_{n1}$, $C_{f2,}$ and $C_{n2}$ are assumed to be net substitutes for each other for these results.
$^{(-)}$ means effect is negative if $\varepsilon_{x,px} < -1$.
$^{(+)}$ means effect is positive if $\varepsilon_{x,px} < -1$.

Qualitative impacts on household utility are unambiguous in general and the same as without a binding borrowing constraint. For example, an increase in the household's exogenous income, labor endowment, or productive capital will increase utility by increasing full income, regardless of whether credit is constrained. An increase in a price of a good or input that the household buys will decrease real income and hence utility, while an increase in the price of food or labor (if the household sells food or labor) will increase real income and utility.

Impacts on other endogenous variables are ambiguous, however. In the remainder of this subsection we discuss the impacts of exogenous changes, assuming that the household is a market participant.

An increase in the amount of credit available to a credit-constrained market participant ($\underline{B}_1$) reduces the shadow price of credit. The qualitative effects of this are the same as reducing $r_1$ for nonconstrained households.

An increase in $p_{f2}$ (or reduction in $t_{s2}$) increases the shadow price of credit for a food-selling household, since this increases the demand for credit by such households (recall the results in Table 1). The resulting effects on input use, production, and consumption are ambiguous, however, since the increase in $p_{f2}$ tends to increase use of inputs, food production, and consumption of all goods, but the increase in the shadow price of credit tends to reduce these (or has ambiguous effects in the case of $C_{f2}$ and $C_{n2}$).

An increase in $p_{f2}$ for food buyers, or an increase in other good or factor prices ($p_{f1}$, $p_{n1}$, $p_{n2}$, $p_x$, or $w_1$) have ambiguous effects on all endogenous variables except utility. This is because changes in these prices have ambiguous effects on credit demand, as shown in Table 1.

An increase in $K$ has ambiguous impacts on input and labor use in food production and on first-period consumption if credit is constrained. Without any change in input use or first-period consumption, the increase in $K$ would result in an increase in $Y_{f2}$ and second-period income, which would be used to increase both $C_{f2}$ and $C_{n2}$. Since the increase in $K$ increases the marginal productivity of inputs in food production, the household would want to increase both labor and input use in period 1, if borrowing were allowed at the initial shadow cost of credit. It would also want to increase $C_{f1}$ and $C_{n1}$ to smooth the increase in consumption between periods. It would not be able to do all of this, however, since credit is constrained. In order to increase consumption in the first period, it would have to reduce use of labor and inputs; conversely, to increase labor and input use, it would have to reduce first-period consumption. The net impact of these tendencies is an ambiguous change in use of inputs and first-period consumption.

However, $Y_f$, $C_{f2}$ and $C_{n2}$ will unambiguously increase.[17] Since increased consumption of both food and nonfood goods in the second period is financed only by the increased value of food production

[17] *Proof*: Suppose that $Y_f$ does not increase as a result of an increase in $K$, which implies that neither $C_{f2}$ nor $C_{n2}$ increase, since both are normal goods. If $Y_f$ did not increase, the cost of food production ($w_1L_f + p_xX$) would decrease, since increasing $K$ increases productivity and hence reduces the cost function. Since the cost of food production has decreased, more income is available for consumption in period 1, and both $C_{f1}$ and $C_{n1}$ increase. If first-period consumption increases while second-period consumption does not, the shadow price of credit would decrease, since this reflects the marginal rate of substitution between first- and second-period consumption, which decreases in this case. However, this contradicts the fact that the demand for credit increases if $K$ increases (shown in Table 1), which implies that the shadow price of credit must increase (equation [29]). Hence we have a contradiction, and $Y_f$, $C_{f2}$, and $C_{n2}$ increase as a result of increased $K$.

(since borrowing is fixed), the increase in $Y_f$ must be greater than the increase in $C_{f2;}$ food sales increase if the household is a food seller, or food purchases decrease if the household is a food buyer in period 2.

An increase in $\underline{L}_1$ or $T_1$ will reduce the demand for credit in the first period and thus reduce the shadow price of credit. Although these variables would not influence labor or input use in food production if credit were unconstrained (Table 1), the relaxation of the borrowing constraint and reduced shadow price of credit leads to an increase in $L_f$ and $X$, according to equation (28). This leads to an increase in $Y_f$, which increases second-period income, resulting in an increase in $C_{f2}$ and $C_{n2}$. $C_{f1}$ and $C_{n1}$ also increase in equation (28), since these rise when the interest rate is fixed (Table 1), and the reduction in the shadow price of credit contributes further to increased first-period consumption. Since the increase in second-period food and nonfood consumption is financed entirely out of the value of increased food production, the increase in $Y_f$ must be greater than the increase in $C_{f2}$: either food sales increase or food purchases decrease.

Changes in $\underline{L}_1$ or $T_1$ have different impacts on $L_{o1}$, however. An increase in $\underline{L}_1$ increases $L_{o1}$, since additional cash income from off-farm employment is needed to finance increased purchases of $X$, $C_{f1,}$ and $C_{n1}$ if credit is constrained. Thus, even though $L_f$ increases, the increase is not as large as that in $\underline{L}_1$. An increase in $T_1$ reduces $L_{o1}$ since $L_f$ increases and $\underline{L}_1$ is assumed to be fixed in this case.

An increase in $\underline{L}_2$ or $T_2$ increases the demand for credit in the first period and hence increases the shadow price of credit. According to equation (28), this reduces $L_f$, $X$, and $Y_f$. $L_{o1}$ increases since $L_f$ declines (assuming $\underline{L}_1$ is unchanged) and this, together with reduced $X$, means cash available to finance consumption in period 1 has increased, leading to an increase in $C_{f1}$ and $C_{n1}$. Second-period consumption must also increase, since otherwise the shadow price of credit would have decreased. Thus, the value of the decline in $Y_f$ must be less than the increase in $w_2\underline{L}_2$ or in $T_2$. Since $Y_f$ declines and $C_{f2}$ increases, food sales decline or food purchases increase.

An increase in the market interest rate has the same impact as a reduction in $T_2$ when credit is constrained. This is because the market interest rate is not relevant to the household's first-period decisions with a binding credit constraint (what matters is the shadow price of credit), and the increase in $r_1$ simply reduces second-period income by the amount $B_1dr_1$. Thus, when credit is constrained, an increase in $r_1$ causes a reduction in the shadow price of credit, increased use of labor and inputs in food production, reduced off-farm labor supply, reduced consumption of all goods, and increased food sales or reduced food purchases, just as a reduction in $T_2$ would. Hence, for credit-constrained households, increasing the interest rate can induce them to produce and sell more food, although this reduces their consumption and welfare—an interesting implication. If the increase in $r_1$ and reduction in the shadow price of credit are sufficiently large that the shadow price falls below $r_1$ (assuming the same level of $B_1$), the demand for credit will fall below $\underline{B}_1$ and the credit constraint will no longer be binding.

### *Effects of Production Credit Usable Only for Purchased Inputs*

The discussion above assumes that credit is provided in cash and can be used to purchase consumption goods as well as inputs. In Ethiopia, production credit is most often provided in kind and tied to purchase of inputs. If credit use is restricted to purchasing inputs, we have $B_1 \leq p_X X$. If the credit constraint is binding (before and after the marginal increase in credit availability), then $dB_1 = p_X\, dX$; that is, all of the increase in $B_1$ is used to purchase increased amounts of $X$. Because $X$ and $L_f$ are normal inputs and their prices are unchanged, $L_f$ will also increase, implying that $Y$ increases and $L_{o1}$ decreases. Budget constraint (C1) implies that the value of consumption in period 1 must therefore decrease, and since food and nonfood are normal goods and their prices are unchanged, both decrease. In this case, the use of inputs and production increases more than if credit were more flexible, while consumption in period 1 declines, causing the household's discount rate to be even higher and the credit constraint to be even more binding. Although such a policy of restricting the use of credit for purchasing inputs can be effective in promoting increased use of purchased inputs and production, it worsens the problem of constrained credit and reduces farmers' profits and welfare, compared to a more flexible credit policy. Promoting increased food production and commercialization through restrictive policy measures is not necessarily desirable.

The impacts in period 2 are less ambiguous in this case than if more flexible credit is provided in period 1. In this case, the value of farm production in the second period net of loan repayment costs will increase, since increased labor is attracted into food production by use of increased inputs. Thus, net income is increased in period 2 and consumption of both food and nonfood will increase in period 2 if the household is a buyer or seller (implying a fixed price relationship between food and nonfood).

### *Summary of Model Implications*

These results demonstrate that the implications of many exogenous factors depend upon the position of the household in the commodity market as well as on the functioning of the factor markets (credit in this case, though labor market constraints would also change the results). For example, an increase in the market price of food will improve household welfare if the household is a food seller but reduce welfare if the household is a food buyer; it may have no effect on an autarkic household. Reducing marketing transaction costs increases the household's use of inputs and production if the household is not credit-constrained and is a seller, but it will reduce input use and production if the household's credit is unconstrained and it is a food buyer; it may have no effect if the household is autarkic. These effects become more ambiguous if the household is credit-constrained. The effects of an increased interest rate are dramatically different between households where credit is constrained and those where it is not: in the former case, input use and production increases, while in the latter case, use of inputs and production are reduced.

Despite these varying and often ambiguous implications, several robust implications are derived. Household welfare is generally improved by increases in productive endowments or income and reduced by increases in the price of goods or factors that the household purchases. Increases in productive capital in agricultural production lead to increased production in most cases. Increased labor endowment or exogenous income (in either period) lead to increased consumption in both periods in most cases.

These results also demonstrate that changes that increase (reduce) food production and sales need not increase (reduce) household consumption and welfare (for example, reducing the wage rate of net labor suppliers). If the objective of policymakers is to improve the welfare of smallholder farmers, and not simply to increase commercialization, such distinctions and trade-offs need to be taken into account.

## 3. EMPIRICAL APPROACH

Empirical investigation of the hypotheses, generated by the theory in the previous section, requires specification of the functional forms of the relationships to be estimated and specification of the econometric models used to estimate these relationships. We assume that the utility function is log-linear (Cobb-Douglas):

$$U(C_{f1}, C_{n1}, C_{f2}, C_{n2}) = \gamma_{f1} \ln C_{f1} + \gamma_{n1} \ln C_{n1} + \gamma_{f2} \ln C_{f2} + \gamma_{n2} \ln C_{n2}. \quad (30)$$

Since utility maximization is unaffected by a positive monotonic transformation of the utility function, for simplification and without loss of generality, we set $\gamma_{f1} + \gamma_{n1} + \gamma_{f2} + \gamma_{n2} = 1$.

We assume that the production function for the food crop is Cobb-Douglas:

$$Y_f = K^{\alpha_k} L_f^{\alpha_l} X^{\alpha_x}, \quad (31)$$

where $\alpha_k + \alpha_l + \alpha_x = 1$ (constant returns to scale).

### Implications of the Cobb-Douglas Model

The implications of this Cobb-Douglas model are less ambiguous than the more general model discussed in section 2. Using the above assumptions and the first-order conditions and constraints specified earlier, we can derive closed-form solutions for production, input demands, profit, and consumption:

$$Y_f = [\frac{p_{f2}^{\ s}}{(1+r_1^s)}]^{\frac{\alpha_l+\alpha_x}{1-\alpha_l-\alpha_x}} K^{\frac{\alpha_k}{1-\alpha_l-\alpha_x}} [\frac{\alpha_l}{w_1}]^{\frac{\alpha_l}{1-\alpha_l-\alpha_x}} [\frac{\alpha_x}{p_x}]^{\frac{\alpha_x}{1-\alpha_l-\alpha_x}}, \quad (32)$$

$$L_f = (\frac{\alpha_l}{w_1})\frac{p_{f2}^{\ s} Y_f}{(1+r_1^s)} = ([\frac{p_{f2}^{\ s}}{(1+r_1^s)}]^{\frac{1}{1-\alpha_l-\alpha_x}} K^{\frac{\alpha_k}{1-\alpha_l-\alpha_x}} [\frac{\alpha_l}{w_1}]^{\frac{1-\alpha_x}{1-\alpha_l-\alpha_x}} [\frac{\alpha_x}{p_x}]^{\frac{\alpha_x}{1-\alpha_l-\alpha_x}}, \quad (33)$$

$$X = (\frac{\alpha_x}{p_x})\frac{p_{f2}^{\ s} Y_f}{(1+r_1^s)} = ([\frac{p_{f2}^{\ s}}{(1+r_1^s)}]^{\frac{1}{1-\alpha_l-\alpha_x}} K^{\frac{\alpha_k}{1-\alpha_l-\alpha_x}} [\frac{\alpha_l}{w_1}]^{\frac{\alpha_l}{1-\alpha_l-\alpha_x}} [\frac{\alpha_x}{p_x}]^{\frac{1-\alpha_l}{1-\alpha_l-\alpha_x}}, \quad (34)$$

$$\pi = (1-\alpha_l-\alpha_x)\frac{p_{f2}^{\ s} Y_f}{(1+r_1^s)} = (1-\alpha_l-\alpha_x)[\frac{p_{f2}^{\ s}}{(1+r_1^s)}]^{\frac{\alpha_l+\alpha_x}{1-\alpha_l-\alpha_x}} K^{\frac{\alpha_k}{1-\alpha_l-\alpha_x}} [\frac{\alpha_l}{w_1}]^{\frac{\alpha_l}{1-\alpha_l-\alpha_x}} [\frac{\alpha_x}{p_x}]^{\frac{\alpha_x}{1-\alpha_l-\alpha_x}}, \quad (35)$$

$$C_{f1} = \gamma_{f1}\frac{FI}{p_{f1}^{\ n}}, \quad (36)$$

$$C_{n1} = \gamma_{n1}\frac{FI}{p_{n1}}, \quad (37)$$

$$C_{f2} = \gamma_{f2}\frac{(1+r_1^s)FI}{p_{f2}^{\ s}}, \text{ and} \quad (38)$$

$$C_{n2} = \gamma_{n2} \frac{(1+r_1^s)FI}{p_{n2}}, \tag{39}$$

where $p_{f2}^s$ is the shadow price of food in the second period, which equals $p_{f2} - t_{s2}$ if the household is a food seller and $p_{f2} + t_{b2}$ if the household is a food buyer, falling between these values if the household is autarkic; $r_1^s$ is the shadow price of credit, which equals $r_1$ if the household is not credit-constrained and is greater than $r_1$ if it is credit constrained; and *FI* is the household's discounted full income, which is equal to the sum of its full endowment income (FEI) and profit from food production:

$$FI = w_1\underline{L}_1 + T_1 + \frac{w_2\underline{L}_2 + T_2}{1+r_1^s} + \pi = FEI + \pi \tag{40}$$

Setting food production equal to consumption and solving for $p_{f2}^s$, we can derive an expression for the shadow price of food in autarky:

$$p_{f2}^s = (1+r_1^s)[\frac{\gamma_{f2}FEI}{1-\gamma_{f2}(1-\alpha_l-\alpha_x)}]^{1-\alpha_l-\alpha_x} K^{-\alpha_k}[\frac{w_1}{\alpha_l}]^{\alpha_l}[\frac{p_x}{\alpha_x}]^{\alpha_x} \tag{41}$$

The comparative statics of the shadow price of food in this case can be readily determined from equations (41) and the definition of FEI in equation (40), assuming the household is not credit constrained. An increase in $r_1$, $w_1$, $\underline{L}_1$, $T_1$, $w_2$, $\underline{L}_2$, $T_2$, or $p_x$ leads to an increase in the shadow price of food, while an increase in *K* reduces the shadow price of food.[18] These implications are consistent with the results in Table 1 (although the impacts of $p_x$ and $r_1$ are ambiguous in the more general case). These results imply that an autarkic, credit-unconstrained household will be more likely to buy food if $r_1$, $w_1$, $\underline{L}_1$, $T_1$, $w_2$, $\underline{L}_2$, $T_2$, or $p_x$ are increased and more likely to sell food if *K* is increased.

The comparative statics for a credit-constrained market participant can also be readily derived for this model. Substituting for $L_f$, *X*, $C_{f1}$, and $C_{n1}$ in the first-period budget constraint (B1) using equations (33), (34), (36), and (37), and taking into account that $B_1 = \underline{B}_1$ in this case, we can show that

$$\underline{B}_1 = (\gamma_{f1}+\gamma_{n1})\frac{(w_2\underline{L}_2+T_2)}{1+r_1^s} + [\gamma_{f1}+\gamma_{n1}+(\gamma_{f2}+\gamma_{n2})(\alpha_l+\alpha_x)][\frac{p_{f2}^s}{(1+r_1^s)}]^{\frac{\alpha_l+\alpha_x}{1-\alpha_l-\alpha_x}} K^{\frac{\alpha_k}{1-\alpha_l-\alpha_x}}[\frac{\alpha_l}{w_1}]^{\frac{\alpha_l}{1-\alpha_l-\alpha_x}}[\frac{\alpha_x}{p_x}]^{\frac{\alpha_x}{1-\alpha_l-\alpha_x}}$$
$$-(\gamma_{f2}+\gamma_{n2})(w_1\underline{L}_1+T_1) \tag{42}$$

Using $r_1^s$ as implicitly determined by equation (42) (no explicit solution is possible in general) in equations (32) to (40), we determine the solution to the problem with a binding credit constraint. Equation (42) implies that $r_1^s$ decreases with increases in $w_1$, $p_x$, $\underline{L}_1$, and $T_1$, since these reduce credit demand, and increases with increases in $w_2$, $\underline{L}_2$, $T_2$, $p_{f2}^s$, and *K*, since these increase credit demand. Note that these

[18] Although an increase in $r_1$ reduces FEI, differentiation of $(1+r_1)FEI^{1-\alpha l-\alpha x}$ with respect to $r_1$ shows that this quantity increases with an increase in $r_1$, implying that $p_{f2}^s$ increases with an increase in $r_1$.

implications are consistent with the implications for $r_1^s$ shown in Table 2, although some of the results are ambiguous in the more general case.

For a credit-constrained autarkic household, the shadow prices of food and of credit are determined jointly by equations (41) and (42). The comparative statics of these shadow prices are determined by the following equations, which result from total differentiation of the equations $Y_f(p_{f2}^s, r_1^s, Z) = C_{f2}(p_{f2}^s, r_1^s, Z)$ and $B_1(p_{f2}^s, r_1^s, Z) = \underline{B}_1$:

$$\frac{dp_{f2}^{\ s}}{dZ_i} = \frac{-\frac{\partial(Y_f - C_{f2})}{\partial Z_i}\frac{\partial B_1}{\partial r_1} + \frac{\partial(Y_f - C_{f2})}{\partial r_1}\frac{\partial B_1}{\partial Z_i}}{\frac{\partial(Y_f - C_{f2})}{\partial p_{f2}}\frac{\partial B_1}{\partial r_1} - \frac{\partial(Y_f - C_{f2})}{\partial r_1}\frac{\partial B_1}{\partial p_{f2}}}, \text{ and} \tag{43}$$

$$\frac{dr_1^s}{dZ_i} = \frac{-\frac{\partial(Y_f - C_{f2})}{\partial p_{f2}}\frac{\partial B_1}{\partial Z_i} + \frac{\partial(Y_f - C_{f2})}{\partial Z_i}\frac{\partial B_1}{\partial p_{f2}}}{\frac{\partial(Y_f - C_{f2})}{\partial p_{f2}}\frac{\partial B_1}{\partial r_1} - \frac{\partial(Y_f - C_{f2})}{\partial r_1}\frac{\partial B_1}{\partial p_{f2}}} \tag{44}$$

The comparative statics for credit-constrained autarkic households are ambiguous even in this Cobb-Douglas case, because the sign of the denominator in equations (43) and (44) cannot be determined.

## Econometric Specification and Issues

We seek to estimate the determinants of the household's market position for the food crop, which is determined by the relationship between the household's shadow price in autarky and the market price net of selling or buying transactions costs. Conditional upon the market position, we want to estimate the determinants of food-crop production (for all market positions) and sales or purchases (for market participants). We can derive the econometric specification to be estimated from equations (31) to (41).

### *Determinants of Food Crop Market Position*

Taking logarithms of equation (41), we have

$$\ln(p_{f2}^{\ s}) = \beta_{p0} + \ln(1 + r_1^s) + \beta_{pI}\ln(FEI) + \beta_{pk}\ln K + \beta_{pw}\ln w_1 + \beta_{px}\ln p_x, \tag{45}$$

where the βs are transformations of the parameters in equation (41).[19] These transformations and the assumptions of the theory imply that $0<\beta_{pI}<1$, $-1<\beta_{pk}<0$, $0<\beta_{pw}<1$, and $0<\beta_{px}<1$, while the sign of $\beta_{p0}$ is ambiguous.

We assume that ln*K* is measured with error:

$$\ln K = \ln K_m + u_k, \tag{46}$$

[19] $\beta_{p0} = (1-\alpha_l-\alpha_x)\ln(\gamma_{f2}/[1-\gamma_{f2}(1-\alpha_l-\alpha_x)]- \alpha_l\ln(\alpha_l)- \alpha_x\ln(\alpha_x)$, $\beta_{pI} = 1-\alpha_l-\alpha_x$, $\beta_{pk} = -\alpha_k$, $\beta_{pw} = \alpha_l$, $\beta_{px} = \alpha_x$.

where $K_m$ is the measured value of $K$ and $u_k$ is an unobserved error, which we assume is normally distributed. Substituting equation (46) into (45), we have

$$\ln(p_{f2}{}^{s}) = \beta_{p0} + \ln(1+r_1^{s}) + \beta_{pI}\ln(FEI) + \beta_{pk}\ln K_m + \beta_{pw}\ln w_1 + \beta_{px}\ln p_x + \beta_{pk}u_k\,. \qquad (47)$$

One problem in using equation (47) as the basis for estimation is that we do not have data for $w_1$, $w_2$, $T_1$, or $T_2$, or separate estimates of $\underline{L}_1$ and $\underline{L}_2$, affecting our ability to estimate FEI.[20] Furthermore, FEI depends on $r_1^s$, which is also not observed for credit-constrained households. For simplification, we assume that $T_1$ and $T_2$ are negligible relative to $w_1\underline{L}_1$ and $w_2\underline{L}_2$, that $w_1$=$w_2$=$w$, and that $\underline{L}_1 = \underline{L}_2 = \underline{L}$. These simplifications imply that ln(FEI) ≈ ln($w$) + ln($\underline{L}$) + ln(2+$r_1^s$) – ln(1+$r_1^s$). Substituting these into equation (47), we have

$$\ln(p_{f2}{}^{s}) = \beta_{p0} + (1-\beta_{pI})\ln(1+r_1^{s}) + \beta_{pI}\ln(2+r_1^{s}) + \beta_{pI}\ln\underline{L} + \beta_{pk}\ln K_m + (\beta_{pI}+\beta_{pw}) \ln w + \beta_{px}\ln p_x + \beta_{pk}u_k\,. \qquad (48)$$

Equation (48) could be used as the basis for estimation for credit-unconstrained households, for whom $r_1^s = r_1$. Since we don't know which households are credit-constrained or $r_1^s$ for those that are constrained, we have to approximate $r_1^s$. Equation (42) implicitly defines $r_1^s$ as a function of $w$, $\underline{L}$, $p_{f2}^s$, $K$, $p_x$, and $\underline{B}_1$, as noted earlier. Using first-order translogarithmic functions to approximate 1 + $r_1^s$ and 2 + $r_1^s$ and assuming that available credit ($\underline{B}_1$) is determined by the household's endowment of productive capital ($K$), including the quantity and quality of land owned, and membership in credit and savings organizations ($C$), we have[21]

$$\ln(1+r_1^{s}) = \chi_0 + \chi_w\ln w + \chi_l\ln\underline{L} + \chi_k\ln K + \chi_{pf}\ln p_{f2} + \chi_{px}\ln p_x + \chi_c C + u_{r1} \text{ and} \qquad (49)$$

$$\ln(2+r_1^{s}) = \theta_0 + \theta_w\ln w + \theta_l\ln\underline{L} + \theta_k\ln K + \theta_{pf}\ln p_{f2} + \theta_{px}\ln p_x + \theta_c C + u_{r2}\,. \qquad (50)$$

Households' wage rates were also not observed. We assume that these are determined by the same factors that determine food production (and hence the value of labor in food production), as well as by the household's endowment of human capital ($HC$):

$$\ln(w) = \lambda_0 + \lambda_l\ln\underline{L} + \lambda_k\ln K + \lambda_{pf}\ln p_{f2} + \lambda_{px}\ln p_x + \lambda_{hc}HC + u_w\,. \qquad (51)$$

Substituting equations (49), (50), and (51) into equation (48), solving for ln($p_{f2}^s$), redefining the βs and defining $u_p$, we have

$$\ln(p_{f2}{}^{s}) = \beta_{p0} + \beta_{pl}\ln\underline{L} + \beta_{pk}\ln K_m + \beta_{px}\ln p_x + \beta_{pc}C + \beta_{ph}HC + u_p \equiv \beta_{p0} + \beta_p Z_p + u_p\,, \qquad (52)$$

[20] We attempted to measure exogenous income $T_1$ and $T_2$ in the survey, but the data are beset by serious measurement problems, undermining their reliability.

[21] The logarithm of $C$ is not used in equations (49) and (50) because C is a dummy variable.

where $Z_p = [\ln(\underline{L}), \ln(K_m), \ln(p_x), C, HC]$, $\beta_p = (\beta_{pl}, \beta_{pk}, \beta_{px}, \beta_{pc}, \beta_{ph})$ and $u_p$ is a linear combination of $u_k$, $u_{r1}$, $u_{r2}$, and $u_w$. Assuming that these error terms are normally distributed, $u_p$ will also be normally distributed. We assume that $u_p \sim N(0,\sigma_p)$.

The household will be a food seller if $p_{f2}^s < p_{f2}^m - t_{s2}$, a buyer if $p_{f2}^s > p_{f2}^m + t_{b2}$, and autarkic in the food market if $p_{f2}^m - t_{s2} \le p_{f2}^s \le p_{f2}^m + t_{b2}$. We assume that buying and selling transaction costs are proportional to the market price (that is, $t_{s2} = \tau_{s2} p_{f2}^m$ and $t_{b2} = \tau_{b2} p_{f2}^m$) and that $\tau_{s2}$ and $\tau_{b2}$ are determined by the household's ownership of transportation assets such as vehicles and pack animals, access to roads and markets, social relationships with traders, and membership in a cooperative ($Z_m$):[22]

$$\ln(p_{f2}{}^m - t_{s2}) = \ln(p_{f2}{}^m) + \ln(1-\tau_{s2}) = \ln(p_{f2}{}^m) - \beta_{s0} - \beta_s Z_m \text{ and} \tag{53}$$

$$\ln(p_{f2}{}^m + t_{b2}) = \ln(p_{f2}{}^m) + \ln(1+\tau_{b2}) = \ln(p_{f2}{}^m) + \beta_{b0} + \beta_b Z_m\,. \tag{54}$$

Combining equations (52), (53), and (54), we have the empirical model that determines the household's choice of market position:

$$\text{Seller: } u_p < \ln(p_{f2}{}^m) - \beta_{s0} - \beta_s Z_m - \beta_{p0} - \beta_p Z_p \equiv c_s\,, \tag{55}$$

$$\text{Buyer: } u_p > \ln(p_{f2}{}^m) + \beta_{b0} + \beta_b Z_m - \beta_{p0} - \beta_p Z_p \equiv c_b\,, \text{ and} \tag{56}$$

$$\text{Autarky: } c_s \le u_p \le c_b\,. \tag{57}$$

We estimate the parameters in inequalities (55), (56), and (57), using maximum likelihood estimation, assuming that $u_p$ is normally distributed with zero mean and standard deviation of $\sigma_p$. The log likelihood function (LL) is given by

$$LL = \sum_{i \in sellers} \ln[\Phi(\frac{c_{si}}{\sigma_p})] + \sum_{i \in buyers} \ln[1-\Phi(\frac{c_{bi}}{\sigma_p})] + \sum_{i \in autarky} \ln[\Phi(\frac{c_{bi}}{\sigma_p}) - \Phi(\frac{c_{si}}{\sigma_p})]\,, \tag{58}$$

where Φ( ) is the standard normal distribution function.

This model is like an ordered probit model, although $\sigma_p$ can potentially be identified in this model (unlike an ordered probit) because $\ln(p_{f2}{}^m)$ is observed and the ratio $\ln(p_{f2}{}^m)/\sigma_p$ is a part of the likelihood function. However, if the estimated value of $\sigma_p$ is large, the term $\ln(p_{f2}{}^m)/\sigma_p$ (which enables identification of $\sigma_p$) becomes small, and has little influence on the likelihood function. In this case, $\sigma_p$ may not be identified. We found this to be the case in estimating the model for maize market position (but not for teff). Thus, the coefficients in the maize market position model reported in the results are ratios of $\beta/\sigma_p$, as in an ordered probit model.

[22] For continuous elements of $Z_p$ and $Z_m$ (such as value of assets and distance to the nearest road), we use logarithmic transformations. Otherwise these are vectors of dummy variables.

*Marginal Effects*

To facilitate interpretation of the parameters estimated using the likelihood function in equation (58), we estimate the marginal effects of each variable on the probability of a household being a seller, buyer, or autarkic:

$$\frac{dP(sell)}{dZ_{mj}} = -\varphi(c_s)\frac{\beta_{sj}}{\sigma_p} \; , \tag{59}$$

$$\frac{dP(sell)}{dZ_{pj}} = -\varphi(c_s)\frac{\beta_{pj}}{\sigma_p}, \tag{60}$$

$$\frac{dP(buy)}{dZ_{mj}} = -\varphi(c_b)\frac{\beta_{bj}}{\sigma_p}, \qquad 61)$$

$$\frac{dP(buy)}{dZ_{pj}} = \varphi(c_b)\frac{\beta_{pj}}{\sigma_p}, \qquad 62)$$

$$\frac{dP(autarky)}{dZ_{mj}} = \frac{\varphi(c_b)\beta_{bj} + \varphi(c_s)\beta_{sj}}{\sigma_p}, \text{ and} \tag{63}$$

$$\frac{dP(autarky)}{dZ_{pj}} = [\varphi(c_s) - \varphi(c_b)]\frac{\beta_{pj}}{\sigma_p}, \tag{64}$$

where $Z_{mj}$ is the *j*th variable in $Z_m$, $Z_{pj}$ is the *j*th variable in $Z_p$, $\beta_{sj}$ is the *j*th coefficient in $\beta_s$, $\beta_{bj}$ is the *j*th coefficient in $\beta_b$, and $\beta_{pj}$ is the *j*th coefficient in $\beta_p$. Note that since $c_s$ and $c_b$ vary across households, depending upon the values of $p_{f2}{}^m$, $Z_m$, and $Z_p$, these marginal effects vary across households. We estimate these at the means of $p_{f2}{}^m$, $Z_m$, and $Z_p$.

*Determinants of Food Crop Production*

Taking logarithms of equation (32), substituting for $\ln(1+r_1{}^s)$ from equation (49), $\ln(K)$ from equation (46), $\ln(w)$ from equation (51), and $\ln(p_{f2}{}^s)$ from equation (53) (for food sellers) or (54) (for food buyers), we have the specification for food-crop production of sellers and buyers:

$$\text{Sellers:} \quad Y_f = \beta^s{}_{y0} + \beta^s{}_{yp}\ln(p_{f2}{}^m) + \beta^s{}_{ys}Z_m + \beta^s{}_{yp}Z_p + u^s{}_y, \text{ and} \tag{65}$$

$$\text{Buyers:} \quad Y_f = \beta^b{}_{y0} + \beta^b{}_{yp}\ln(p_{f2}{}^m) + \beta^b{}_{ys}Z_m + \beta^b{}_{yp}Z_p + u^b{}_y, \tag{66}$$

where $Z_m$ and $Z_p$ are as defined earlier, and $u^s{}_y$ and $u^b{}_y$ are linear combinations of $u_{r1}$, $u_k$, and $u_w$.

For autarkic households, we substitute for $\ln(p_{f2}{}^s)$, using equation (52) to obtain:

$$\text{Autarky:} \quad Y_f = \beta^a{}_{y0} + \beta^a{}_{yp}Z_p + u^a{}_y\,. \tag{67}$$

In this case $u^a{}_y$ is a linear combination of $u_p$, $u_{r1}$, $u_k$, and $u_w$.

Since $u^s{}_y$, $u^b{}_y$, and $u^a{}_y$ are linear combinations of many of the same variables as $u_p$ (and since $u^a{}_y$ is a linear combination of $u_p$ with these other variables), all of these error terms are likely to be correlated with $u_p$. This creates a potential selection bias if equations (65), (66), and (67) were estimated using ordinary least squares (OLS).

To address this endogenous selection issue, we estimate these equations using a switching regression framework. Taking conditional expectations of equations (65) to (67), we have

$$\text{Sellers: } E(Y_f \mid u_p < c_s) = \beta^s{}_{y0} + \beta^s{}_{yp} \ln(p_{f2}{}^m) + \beta^s{}_{ys} Z_m + \beta^s{}_{yp} Z_p + E(u^s{}_y \mid u_p < c_s), \tag{68}$$

$$\text{Buyers: } E(Y_f \mid u_p > c_b) = \beta^b{}_{y0} + \beta^b{}_{yp} \ln(p_{f2}{}^m) + \beta^b{}_{ys} Z_m + \beta^b{}_{yp} Z_p + E(u^b{}_y \mid u_p > c_b), \text{ and} \tag{69}$$

$$\text{Autarky: } E(Y_f \mid c_s \le u_p \le c_b) = \beta^a{}_{y0} + \beta^a{}_{yp} Z_p + E(u^a{}_y \mid c_s \le u_p \le c_b). \tag{70}$$

Assuming that $u_p$ and each of $u^s_y$, $u^b_y$, and $u^a_y$ are pairwise bivariate normally distributed, with standard deviations of $\sigma^s_y$, $\sigma^b_y$, and $\sigma^a_y$, respectively, and correlations with $u_p$ of $\rho^s_{yp}$, $\rho^b_{yp}$, and $\rho^a_{yp}$, respectively, we can derive the selection bias correction terms in equations (68), (69), and (70):

$$\text{Sellers: } E(u^s{}_y \mid u_p < c_s) = -\sigma^s{}_y \rho^s{}_{yp} \frac{\varphi(\frac{c_s}{\sigma_p})}{\Phi(\frac{c_s}{\sigma_p})}, \tag{71}$$

$$\text{Buyers: } E(u^b{}_y \mid u_p > c_b) = \sigma^b{}_y \rho^b{}_{yp} \frac{\varphi(\frac{c_b}{\sigma_p})}{1 - \Phi(\frac{c_b}{\sigma_p})}, \text{ and} \tag{72}$$

$$\text{Autarky: } E(u^a{}_y \mid c_s \le u_p \le c_b) = \sigma^a{}_y \rho^a{}_{yp} \frac{\varphi(\frac{c_b}{\sigma_p}) - \varphi(\frac{c_s}{\sigma_p})}{\Phi(\frac{c_b}{\sigma_p}) - \Phi(\frac{c_s}{\sigma_p})}, \tag{73}$$

where φ( ) is the standard normal density function and Φ( ) is the standard normal distribution function.

We estimate the switching regression model by including the selection correction terms from equations (71), (72), and (73), respectively, in the corresponding regression equations (68), (69), and (70). The parameters estimated in the maximum likelihood estimation for determinants of market position (βs and $\sigma_p$) are used to calculate $c_b$ and $c_s$ and the inverse Mills type ratios in equations (71) to (73) for each observation. Since these parameters are estimated values, this two-stage procedure does not produce a consistent estimate of the covariance matrix. To produce consistent estimates of the standard errors, we use bootstrapping (resampling from the first stage of the estimation).

### *Determinants of the Level of Sales and Purchases*

Using equations (35), (38) and (40), we can show that for a seller of food

$$S_{f2} = Y_f - C_{f2} = [1 - \gamma_{f2}(1 - \alpha_l - \alpha_x)] Y_f - \frac{\gamma_{f2}(1 + r_1{}^s)}{p_{f2}{}^s} FEI, \tag{74}$$

where $p_{f2}^s = p_{f2}^m(1-\tau_{s2})$.

Equation (74) shows that sales are positively linearly related to production and negatively linearly related to FEI. Unfortunately, as noted earlier, FEI is not directly observed and depends on variables that are not observed (such as $r_1^s$, $w_1$, $w_2$, $\underline{L}_1$, $\underline{L}_2$, $T_1$, $T_2$). Using the assumptions made earlier that $w_1 = w_2 = w$, $\underline{L}_1 = \underline{L}_2 = \underline{L}$, and $T_1 = T_2 = 0$, we find (as before) that $FEI = w\underline{L}(2 + r_1^s)/(1 + r_1^s)$. Substituting from equations (49), (50), (51), and (53), we can show that

$$S_{f2} = [1-\gamma_{f2}(1-\alpha_l-\alpha_x)]Y_f - \exp(\delta^s{}_0 + \delta^s{}_{pf}\ln p_{f2}{}^m + \delta^s{}_{Zp}Z_p + \delta^s{}_{Zm}Z_m + u_s). \tag{75}$$

Similarly, for households that are food buyers:

$$P_{f2} = \exp(\delta^b{}_0 + \delta^b{}_{pf}\ln p_{f2}{}^m + \delta^b{}_{Zp}Z_p + \delta^b{}_{Zm}Z_m + u_b) - [1-\gamma_{f2}(1-\alpha_l-\alpha_x)]Y_f, \tag{76}$$

where we assume that $u_s \sim N(0,\sigma_s^2)$ and $u_b \sim N(0,\sigma_b^2)$. The assumption that $u_s$ and $u_b$ are normally distributed is consistent with the fact that these error terms are linear combinations of $u_w$ and $u_{r2}$, which we have assumed to be normally distributed.

Equations (75) and (76) are the basis for econometric estimation of the determinants of the level of food sales and purchases, conditional on the household being a food seller or buyer. As with the production regressions for sellers and buyers, there is a potential selection bias in estimating equations (75) and (76). Taking conditional expectations of equation (75) and substituting for $Y_f$ using equation (59), we have

$$\begin{aligned} E(S_{f2} \mid u_p < c_s) &= [1-\gamma_{f2}(1-\alpha_l-\alpha_x)][Y_f{}^p + E(u^s{}_y \mid u_p < c_s)] \\ &- \exp(\delta^s{}_0 + \delta^s{}_{pf}\ln p_{f2}{}^m + \delta^s{}_{Zp}Z_p + \delta^s{}_{Zm}Z_m)E[\exp(u_s) \mid u_p < c_s], \end{aligned} \tag{77}$$

where $Y_f^p = \beta^s{}_{y0} + \beta^s{}_{yp}\ln(p_{f2}{}^m) + \beta^s{}_{ys}Z_m + \beta^s{}_{yp}Z_p$; that is, the nonstochastic part of $Y_f$ in equation (59). $E(u^s{}_y \mid u_p < c_s)$ is given by equation (71). Assuming that $u_p$ and $u_s$ are bivariate normal (*BN*), with $(u_p, u_s) \sim BN(0,0,\sigma_p, \sigma_s, \rho_{ps})$, it can be shown that $E(\exp(u_s) \mid u_p < c_s)$ is equal to[23]

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[23] *Sketch of proof*: The conditional expectation in equation (78) is given by

$$E(e^{u_s} \mid u_p < c_s) = E(e^{\sigma_s\varepsilon_s} \mid \varepsilon_p < \frac{c_s}{\sigma_p}) = \frac{\int_{-\infty}^{c_s/\sigma_p} [\int_{-\infty}^{\infty} e^{\sigma_s\varepsilon_s} f(\varepsilon_s \mid \varepsilon_p)d\varepsilon_s] f(\varepsilon_p)d\varepsilon_p}{\int_{-\infty}^{c_s/\sigma_p} f(\varepsilon_p)d\varepsilon_p},$$

where $\varepsilon_p = u_p/\sigma_p$ and $\varepsilon_s = u_s/\sigma_s$, implying that $(\varepsilon_p, \varepsilon_s) \sim BN(0,0,1,1,\rho_{ps})$. $f(\varepsilon_s|\varepsilon_p)$ is the conditional density of $\varepsilon_s$ given $\varepsilon_p$, and $f(\varepsilon_p)$ is the standard univariate normal density function. The denominator in the expression above is $\Phi(c_s/\sigma_p)$. Amemiya (1988) proved that

$$f(\varepsilon_s \mid \varepsilon_p) = \frac{1}{\sqrt{2\pi(1-\rho_{ps}{}^2)}} e^{-\frac{1}{2}(\frac{\varepsilon_s - \rho_{ps}\varepsilon_p}{1-\rho_{ps}{}^2})}.$$

By substituting this expression into the above equation, carrying out the double integration, and simplifying, we obtain equation (78). To the best of the authors' knowledge, this result has not appeared before in the literature on selection models.

$$E[\exp(u_s) \mid u_p < c_s] = \exp(\frac{\sigma_s^{\ 2}}{2}) \frac{\Phi(\frac{c_s}{\sigma_p} - \sigma_s \rho_{ps})}{\Phi(\frac{c_s}{\sigma_p})} . \quad (78)$$

Note that $E[\exp(u_s)| \ u_p < c_s]$ equals $\exp(\sigma_s^2/2)$ if $\rho_{ps} = 0$, which is the unconditional expectation of $\exp(u_s)$ for normally distributed $u_s$ (that is, there is no selection bias in this case, but the variance of $u_s$ affects the estimated coefficients since the error term $\exp(u_s)$ is multiplicative), and equals 1 if $\sigma_s = 0$. For positive values of $\sigma_s$ and $\rho_{ps}$, the selection bias term in equation (78) is less than $\exp(\sigma_s^2/2)$ and is decreasing with increases in $\rho_{ps}$. Equation (77) can be estimated using nonlinear least squares. For $Y_f^p + E(u^s_y| \ u_p < c_s)$, we use the predicted value of $Y_f$ from estimating equation (68) (including the selection correction term). We identify only the total coefficient of $Y_f$ in equation (75), and not the separate values of $\gamma_{f2}$, $\alpha_{1,}$ and $\alpha_x$. We use estimated values of $c_s$ and $\sigma_p$ from the maximum likelihood estimation given in equation (58). Nonlinear estimation is required because equations (77) and (78) depend nonlinearly on the parameters $\delta^s{}_0$, $\delta^s{}_{pf}$, $\delta_{Zp}$, $\delta_{Zm}$, $\sigma_{,s,}$ and $\rho_{ps}$. We use bootstrapping to compute the standard errors because of the two-stage nature of the estimation.

The counterpart to equation (77) for purchases is

$$\begin{aligned} &E(P_{f2} \mid u_p > c_b) = \exp(\delta^b{}_0 + \delta^b{}_{pf} \ln p_{f2}{}^m + \delta^b{}_{Zp} Z_p + \delta^b{}_{Zm} Z_m) E[\exp(u_b) \mid u_p > c_b] \\ &-[1 - \gamma_{f2}(1 - \alpha_l - \alpha_x)][Y_f{}^p + E(u^b{}_y \mid u_p > c_b)] \end{aligned} . \quad (79)$$

The expression $E(u^b{}_y| \ u_p > c_b)$ is given by equation (72). The counterpart to equation (78) for purchases is

$$E[\exp(u_b) \mid u_p > c_b] = \exp(\frac{\sigma_b^{\ 2}}{2})(\frac{1 - \Phi(\frac{c_b}{\sigma_p} - \sigma_b \rho_{pb})}{1 - \Phi(\frac{c_b}{\sigma_p})}) , \quad (80)$$

where we have assumed that $(u_p, u_b) \sim BN(0,0,\sigma_p,\sigma_b, \rho_{pb})$. Equations (79) and (80) are used to estimate determinants of the level of purchases.

## Explanatory Variables and Hypotheses

The explanatory variables used in the estimations include measures of factors determining sellers' and buyers' transaction costs ($Z_m$) and factors determining the shadow price of food crops ($Z_p$). The measured variables reflecting these factors in the estimations and their hypothesized impacts on transaction costs or shadow prices (based on unconstrained borrowing model results in Table 1) include the following.

### *Determinants of Transaction Costs*

- Distance to the nearest sales market for cereals (+)

- Distance to the nearest all-weather road (+)
- Value of transportation assets owned (such as vehicles, pack animals) (–)
- Number of traders known by the household outside of the Peasant Association (PA)(–)24
- Household membership in a cooperative (–)

*Determinants of Food Shadow Price*

- Price of diammonium phosphate (DAP) fertilizer ($p_x$) (?)
- Number of workers in the household ($\underline{L}$) (+)
- Share of household members whose primary occupation is (compared to crop production)[25]:
  - Livestock production (?)
  - Domestic activities (–, due to lower expected wage and income)
  - Nonfarm activities (?)
- Share of labor force that is (compared to men) (part of HC):
  - Women (–, due to lower expected wage)
  - Children (–, due to lower expected wage)
- Male head of household (part of *HC*) (+, due to higher expected wage and income)
- Age of head of household (part of *HC*) (+, due to higher expected wage and income)
- Primary or secondary education of men and women (part of *HC*) (+, due to higher expected income)
- Area of land operated (part of *K*) (–)
- Quality of land operated (part of *K*), measured by
  - Slope (share gently or steeply sloping or mixed slopes) (+)
  - Altitude (shares in medium- altitude *woina dega* or high-altitude *dega* zones) (+)
  - Soil type (share of high-quality *lem* soil or low-quality *teuf,* or mixed soil types) (– for *lem* and + for *teuf*, relative to mixed)
  - Distance of operated land from residence (share more than one hour's walk from residence) (+)
  - Access to irrigation (–)
- Value of livestock owned (part of *K*) (–)
- Value of farm equipment owned (part of *K*) (–)
- Membership in a credit or savings organization (*C*) (?)

The hypotheses concerning the impacts of most of these measured variables are self-explanatory. For example, variables such as distance to markets and roads are expected to increase transaction costs, while ownership of transportation assets, relationships with traders, and membership in a cooperative are

[24] A Peasant Association is the lowest administrative level in the system of government in Ethiopia, usually consisting of several villages.

[25] These variables are considered part of human capital (HC) and may affect the opportunity cost of labor (w).

expected to reduce transaction costs. Ownership of productive capital such as land, better-quality land, livestock, and equipment are expected to increase production potential and thus reduce the shadow price of food. In the case of measures of human capital, the expected impacts depend upon whether and how these variables affect wage levels and income. We expect older households, more educated households, households with a male head or more male workers to have higher wages and income, and thus to have a higher shadow price of food due to greater effective demand. We expect households having more members involved in domestic activities to have lower incomes than those more involved in crop production, and therefore lower effective food demand and shadow prices. Involvement in other livelihood activities has ambiguous impacts on food shadow prices, since the effects of these activities on income are more ambiguous. We expect membership in a credit or savings institution to reduce the interest rate that the household must pay or to increase the household's access to credit (the latter effect if borrowing is constrained), or both, but these effects have an ambiguous impact on the shadow price of food (see Table 1).

The hypothesized impacts of these variables on food production, sales, and purchases follow from their relationships to the underlying factors included in the theoretical model and their hypothesized impacts as summarized in Tables 1 and 2. As these tables show, the expected impacts of many factors are more ambiguous for autarkic households than for buyers or sellers and more ambiguous if credit is constrained.

# 4. DATA AND DESCRIPTIVE RESULTS

## Data Source and Sample

The empirical analysis in this paper is based upon a nationally representative survey of 7,186 households and 293 communities conducted by IFPRI and the Central Statistics Authority (CSA) of Ethiopia during June and July 2005. A stratified two-stage cluster sample design was used to select the sample. Enumeration areas (EAs) were taken as primary sampling units and agricultural households as secondary sampling units. Sample EAs from each stratum were subsamples of the 2004/05 (1997 Ethiopian Calendar (EC)) Annual Agricultural Sample Survey of CSA. EAs were selected using systematic sampling based on probability proportional to size, size being the number of agricultural households obtained from the 1994 Population and Housing Census, adjusted for the subsampling effect. The 25 agricultural households randomly selected from each sample EA for the 2004/05 Annual Agricultural Sample Survey were also directly taken to be the secondary sampling units for this survey.

The sample size was determined taking into consideration the resources allocated for the survey and the precision desired for total cereal crop production and cattle population, using the results of the 2004/05 CSA Annual Agricultural Sample Survey to estimate precision. A total of 293 EAs and 7,325 agricultural households were found to be sufficient to achieve a coefficient of variation (CV) of 15 percent in estimating household cereal production and livestock population. For the purpose of the survey, the country was divided into five strata. The first four strata consist of the four major rural regions: Tigray, Amhara, Oromia, and Southern Nations, Nationalities and People's (SNNP) regions. The fifth stratum includes all regions other than the four named. Each of the four major regions was considered to be the domain of estimation or a stratum for which major findings of the survey are reported. Findings for all of rural Ethiopia were also obtained by combining the results of each of the stratum. To distribute the sample EAs among the strata, we implemented a power allocation technique.

The study covered all rural areas of the country except Gambella Region (all zones), and the nonsedentary population of three zones of Afar and six zones of Somali regions. The survey also included rural parts of Harari, Addis Ababa, Dire Dawa, and 58 additional zones / special *weredas* (districts) (that are treated as zones) of other regions.

The data were collected using household and community questionnaires, translated into Amharic, that were pretested three times in different agro-ecological locations. . CSA enumerators with statisticians and branch officers were trained regarding the questionnaires and overall data collection. The household questionnaire included questions on the demographic and socioeconomic characteristics of the household and its members (such as gender, age, marital status, education, and primary and secondary activities); income from different sources (crop production, livestock production, off-farm employment, nonfarm activities, and other income); land tenure, land use, and characteristics of agricultural parcels; land investments, land management practices, agricultural inputs, and outputs by plot; household-level supply, use and marketing (sales and purchases) of agricultural commodities (crops, livestock, and livestock products) by type of commodity and period (between June 2004 and May 2005); purchases of agricultural inputs; output marketing arrangements ( use of regular buyers or sellers, intermediaries, and contracts); transaction costs for a single transaction; household assets; access and use of credit; social capital (membership in local organizations and associations, informal contacts, and networks); access to public goods and services ( such as agricultural extension, market information, infrastructure, health services, and schools); and food security and income shocks. The community questionnaire included questions on the population of the Peasant Association (PA) and its ethnic and religious composition; major income sources of households; access to infrastructure and social services; access to markets and economic services; contracting and dispute-resolution mechanisms; sources of technologies; cooperatives and other local organizations; agro-ecological characteristics of the PA; land use; agricultural products produced and inputs used; disease and pest problems; marketing and prices of agricultural commodities; marketing problems; presence of traders; and others.

### Descriptive Results

In this section we present descriptive results concerning the nature and extent of commercialization of food crops by smallholder farmers in Ethiopia, based on analysis of the IFPRI/CSA survey. We present results on the percentage of producing farmers participating in crop sales markets by type of crop and season, the extent of commercialization (share of production sold) by type of crop, the net market positions of producers of different types of crops, and the extent of diversification of production, sales, and purchases of cereals.

### Crop Market Participation

On average, 57 percent of the crop farmers in the sample sold crops in one or more crop markets during the 2004/05 crop year, ranging from 43 percent in Tigray to 67 percent in Amhara (Table 3). A larger proportion of farmers participated in these markets during the postharvest period than in the preharvest period. Overall market participation is the highest for producers of cereal crops (42 percent), followed by producers of pulses (16 percent), oil crops (14 percent), and horticultural crops (13 percent).

**Table 3. Percentage of farmers participating in crop markets by season, 2004/05**

| Crop category | Seasons | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Cereal crops | Pre-harvest (June to Nov ’04) | 9 | 19 | 12 | 10 | 12 |
| | Post-harvest ( Dec to May ’05) | 24 | 45 | 42 | 40 | 39 |
| | Annual | 25 | 48 | 45 | 46 | 42 |
| Pulse crops | Pre-harvest (June to Nov ’04) | 3 | 6 | 3 | 3 | 4 |
| | Post-harvest ( Dec to May ’05) | 9 | 18 | 13 | 12 | 13 |
| | Annual | 10 | 22 | 15 | 15 | 16 |
| Oil crops | Pre-harvest (June to Nov ’04) | 4 | 4 | 1 | 0 | 2 |
| | Post-harvest ( Dec to May ’05) | 12 | 15 | 14 | 2 | 12 |
| | Annual | 6 | 21 | 12 | 15 | 14 |
| Horticultural crops | Pre-harvest (June to Nov ’04) | 3 | 10 | 5 | 9 | 7 |
| | Post-harvest (Dec to May ’05) | 5 | 15 | 9 | 12 | 10 |
| | Annual | 13 | 17 | 15 | 2 | 13 |
| All crops | Annual | 43 | 67 | 59 | 57 | 57 |

Source: IFPRI/CSA Survey 2005.
Note: The different crops were aggregated using values calculated based on the price at which the farmer sold.

Among producers of cereal crops, teff and wheat producers had the highest market participation: 48 percent of farmers producing teff and 37 percent producing wheat participated in the markets at the national level (Table 4). Among regions, the highest proportion of producing farmers participated in the teff market in SNNP (67 percent), followed by Oromiya (50 percent), Amhara (45 percent), and Tigray (18 percent). Most farmers sold cereals during the postharvest period (December to May).

**Table 4. Percentage of farmers participating in cereal crop markets by season, 2004/05**

| Cereal crop | Season | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Teff | Pre-harvest (June to Nov ’04) | 6 | 16 | 12 | 16 | 14 |
| | Post-harvest (Dec to May ’05) | 17 | 40 | 47 | 56 | 43 |
| | Annual | 18 | 45 | 50 | 67 | 48 |
| Barley | Pre-harvest (June to Nov ’04) | 4 | 7 | 5 | 4 | 5 |
| | Post-harvest (Dec to May ’05) | 14 | 14 | 27 | 21 | 19 |
| | Annual | 15 | 17 | 30 | 24 | 21 |
| Wheat | Pre-harvest (June to Nov ’04) | 5 | 7 | 9 | 4 | 7 |
| | Post-harvest (Dec to May ’05) | 20 | 25 | 40 | 43 | 35 |
| | Annual | 23 | 26 | 44 | 46 | 37 |
| Maize | Pre-harvest (June to Nov ’04) | 4 | 6 | 4 | 5 | 5 |
| | Post-harvest (Dec to May ’05) | 6 | 19 | 16 | 18 | 16 |
| | Annual | 8 | 20 | 18 | 21 | 18 |
| Sorghum | Pre-harvest (June to Nov ’04) | 5 | 13 | 4 | 1 | 5 |
| | Post-harvest (Dec to May ’05) | 17 | 31 | 21 | 10 | 20 |
| | Annual | 18 | 34 | 22 | 11 | 22 |

Source: IFPRI/CSA Survey 2005.

Next to cereals, pulses are the second most produced crop in Ethiopia. Different levels of market participation are observed among producers of pulses (Table 5). Producers of grass pea were most likely to sell some of their production in 2004/05 (43 percent), followed by producers of lentils (41 percent), chickpeas (38 percent), horse beans (28 percent), field peas (28 percent), and haricot beans (15 percent). As with cereals, most farmers sold during the postharvest period.

**Table 5. Percentage of farmers participating in pulse crop markets by season, 2004/05**

| Pulse crop | Season | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Horse beans | Pre-harvest (June to Nov ’04) | 8 | 6 | 2 | 5 | 6 |
| | Post-harvest ( Dec to May ’05) | 23 | 22 | 24 | 29 | 24 |
| | Annual | 23 | 33 | 25 | 19 | 28 |
| Lentils | Pre-harvest (June to Nov ’04) | 6 | 19 | 9 | 4 | 13 |
| | Post-harvest ( Dec to May ’05) | 15 | 39 | 26 | 18 | 31 |
| | Annual | 15 | 54 | 34 | 21 | 41 |
| Chickpea | Pre-harvest (June to Nov ’04) | 15 | 2 | 5 | 4 | 6 |
| | Post-harvest ( Dec to May ’05) | 15 | 28 | 39 | 17 | 37 |
| | Annual | 23 | 29 | 39 | 17 | 38 |
| Field pea | Pre-harvest (June to Nov ‘04 | 6 | 7 | 4 | 8 | 6 |
| | Post-harvest ( Dec to May ’05) | 15 | 13 | 33 | 33 | 23 |
| | Annual | 17 | 19 | 36 | 41 | 28 |
| Haricot beans | Pre-harvest (June to Nov ’04) | | 9 | 9 | 4 | 7 |
| | Post-harvest ( Dec to May ’05) | | 18 | 7 | 7 | 9 |
| | Annual | | 25 | 16 | 9 | 15 |
| Grass pea | Pre-harvest (June to Nov ’04) | 0 | 9 | 4 | | 9 |
| | Post-harvest ( Dec to May ’05) | 20 | 30 | 49 | | 41 |
| | Annual | 20 | 33 | 51 | | 43 |

Source: IFPRI/CSA survey 2005.

The major oil crops produced in the country are linseed, groundnut, sesame, sunflower, and Niger seed (*nueg*). The highest market participation is observed for sesame, with 74 percent of the producers selling, followed by groundnuts (71 percent), *nueg* (70 percent), linseed (50 percent), and sunflower seeds (23 percent) (Table 6). Most farmers sell during the postharvest period.

**Table 6. Percentage of farmers participating in oil crop markets by season, 2004/05**

| Oil crop | Market Position | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Linseed | Pre-harvest (June to Nov ’04) | 8 | 6 | 9 | 17 | 8 |
| | Post-harvest ( Dec to May ’05) | 16 | 24 | 65 | 39 | 44 |
| | Annual | 21 | 29 | 72 | 56 | 50 |
| Groundnut | Pre-harvest (June to Nov ’04) | 50 | 0 | 13 | 0 | 9 |
| | Post-harvest ( Dec to May ’05) | 50 | 0 | 27 | 17 | 67 |
| | Annual | 50 | 0 | 40 | 17 | 71 |
| Sesame | Pre-harvest (June to Nov ’04) | 19 | 21 | 2 | 0 | 14 |
| | Post-harvest ( Dec to May ’05) | 71 | 57 | 78 | 0 | 66 |
| | Annual | 76 | 70 | 80 | 0 | 74 |
| Sunflower | Pre-harvest (June to Nov ’04) | | 5 | | 0 | 4 |
| | Post-harvest ( Dec to May ’05) | | 24 | | 20 | 21 |
| | Annual | | 27 | | 20 | 23 |
| Nueg | Pre-harvest (June to Nov ’04) | 6 | 12 | 2 | 20 | 8 |
| | Post-harvest ( Dec to May ’05) | 33 | 57 | 69 | 80 | 64 |
| | Annual | 39 | 65 | 71 | 100 | 70 |

Source: IFPRI/CSA Survey, 2005

Following the expansion of irrigation schemes, which are associated with production of high-value horticultural crops, the production of horticultural crops has been increasing in the country. Among horticultural crop producers, the highest proportion of producing farmers sold tomatoes (71 percent) and carrots (70 percent), followed by onions (49 percent) and beetroots (49 percent) (Table 7). Unlike other crops, the timing of horticultural crop sales is more mixed because irrigated crops produced during the prior dry postharvest season are sold during the preharvest season.

**Table 7. Percentage of farmers participating in horticultural crop markets by season, 2004/05**

| Horticultural crop | Season | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Potato | Pre-harvest (June to Nov '04) | 27 | 22 | 17 | 1 | 16 |
| | Post-harvest ( Dec to May '05) | 27 | 19 | 11 | 3 | 13 |
| | Annual | 41 | 31 | 27 | 4 | 23 |
| Onion | Pre-harvest (June to Nov '04) | 24 | 34 | 19 | 31 | 26 |
| | Post-harvest ( Dec to May '05) | 35 | 24 | 29 | 47 | 33 |
| | Annual | 50 | 52 | 35 | 69 | 49 |
| Tomato | Pre-harvest (June to Nov '04) | 67 | 40 | 0 | – | 18 |
| | Post-harvest ( Dec to May '05) | 67 | 40 | 40 | – | 63 |
| | Annual | 100 | 53 | 40 | – | 71 |
| Sweet potato | Pre-harvest (June to Nov '04) | – | 0 | 8 | 12 | 10 |
| | Post-harvest ( Dec to May '05) | – | 29 | 14 | 19 | 17 |
| | Annual | – | 29 | 21 | 23 | 22 |
| Cabbage | Pre-harvest (June to Nov '04) | – | 7 | 7 | 16 | 12 |
| | Post-harvest ( Dec to May '05) | – | 32 | 8 | 12 | 13 |
| | Annual | – | 36 | 13 | 17 | 18 |
| Beet root | Pre-harvest (June to Nov '04) | – | 60 | 24 | 25 | 37 |
| | Post-harvest ( Dec to May '05) | – | 20 | 20 | 25 | 17 |
| | Annual | – | 60 | 44 | 25 | 49 |
| Carrot | Pre-harvest (June to Nov '04) | 43 | 27 | 55 | 25 | 52 |
| | Post-harvest ( Dec to May '05) | 71 | 27 | 9 | 25 | 23 |
| | Annual | 100 | 45 | 64 | 50 | 70 |
| Ginger | Pre-harvest (June to Nov '04) | – | – | 25 | 33 | 28 |
| | Post-harvest ( Dec to May '05) | – | – | 17 | 50 | 28 |
| | Annual | – | – | 33 | 67 | 44 |
| Garlic | Pre-harvest (June to Nov '04) | 7 | 4 | 13 | 26 | 11 |
| | Post-harvest ( Dec to May '05) | 37 | 15 | 18 | 18 | 18 |
| | Annual | 37 | 19 | 26 | 42 | 26 |
| Pepper | Pre-harvest (June to Nov '04) | 13 | 4 | 2 | 9 | 4 |
| | Post-harvest ( Dec to May '05) | 6 | 10 | 21 | 40 | 17 |
| | Annual | 19 | 11 | 22 | 49 | 20 |

Source: IFPRI/CSA survey 2005.

Consistent with these results, data on the timing of sales show that the amount of cereals, pulses, and oil crops sold is much greater during the December to May period than in the preharvest season (June to November) (Figures 1 to 3). The pattern of sales varies somewhat across the regions and by type of crop, with cereal sales peaking earlier and having a higher level (per household) in higher-rainfall SNNP and Oromia than in lower-rainfall Tigray and Amhara. Pulse sales per household are largest in the Amhara region, while oil crop sales per household are largest in Tigray.

**Figure 1. Timing of cereal sales (birr)**

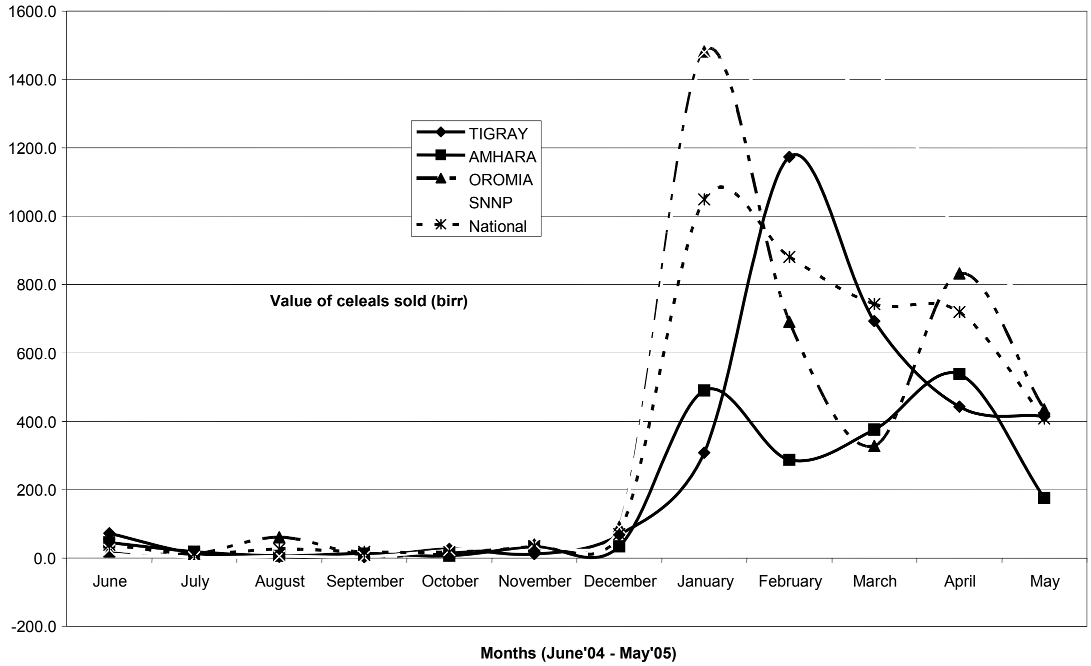



**Figure 2. Timing of pulse sales (birr)**

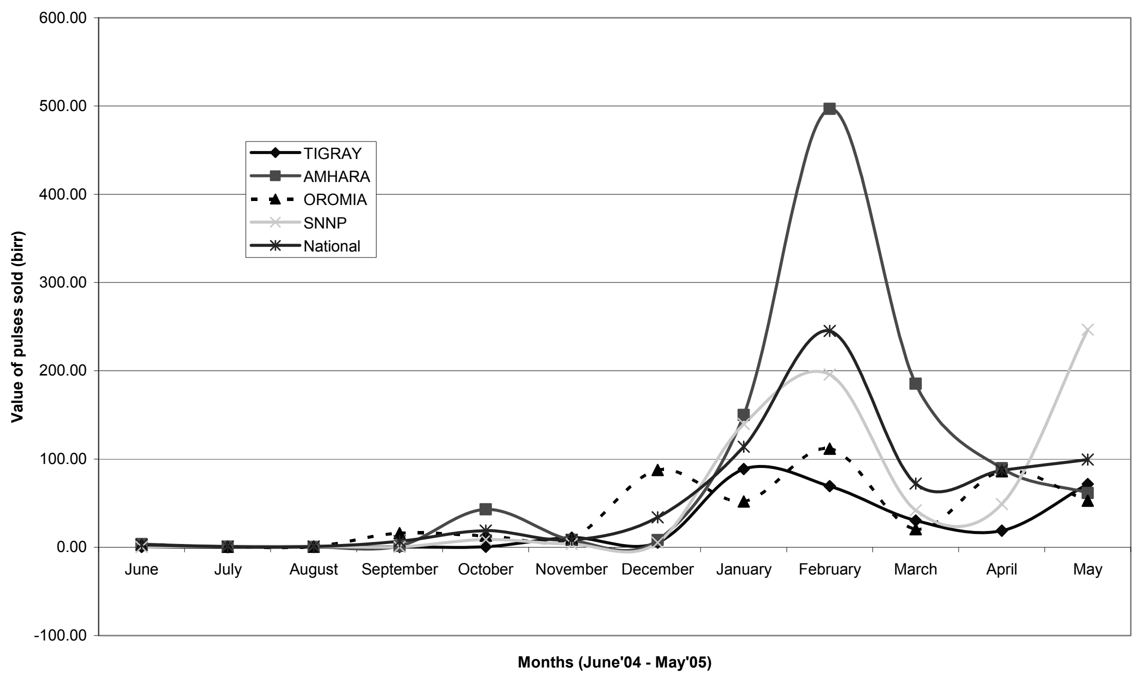
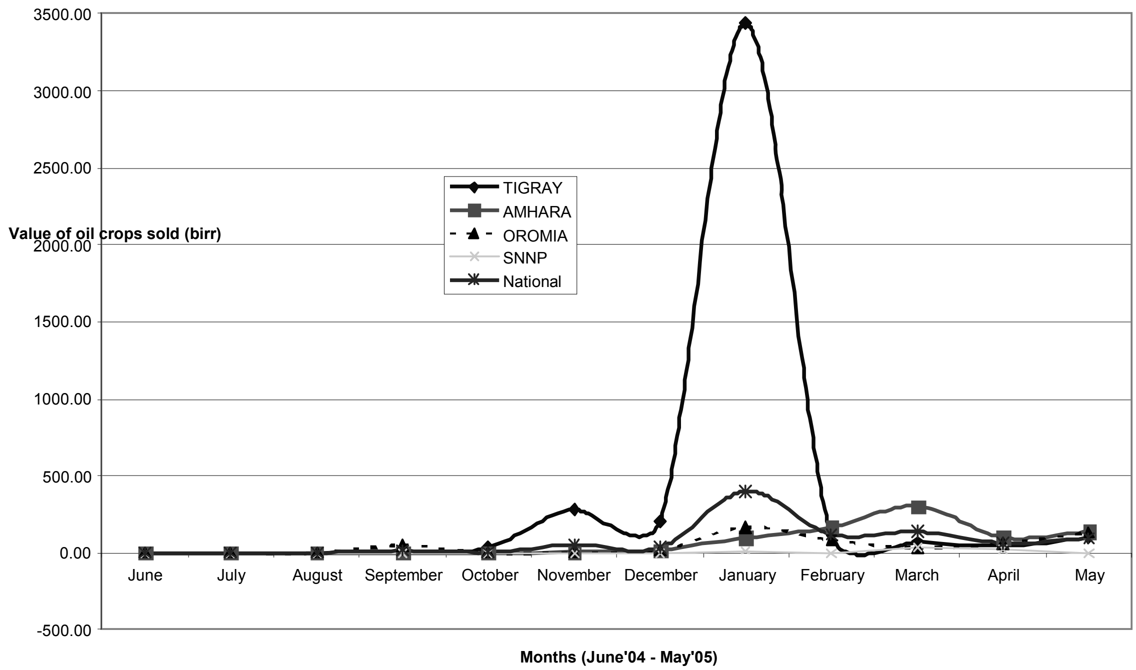


**Figure 3. Timing of oil crop sales (birr)**




## Share of Crop Production Sold

Teff is the most commercialized cereal. Nationally, teff producers sold an average of about 24 percent of their production (Table 8). There was considerable variability among regions, with 49 percent of teff production sold on average in SNNP but only about 8 percent sold in Tigray. For wheat, 17 percent of production was sold on average nationally, with the largest proportion (27 percent) sold in SNNP and the smallest (8 percent) in Amhara. For barley, only 10 percent of production was sold nationally, with the largest proportion (16 percent) sold in SNNP and the smallest proportion (5 percent) in Amhara. For maize, on average, 8 percent of production was sold nationally, with the largest proportion (12 percent) sold in SNNP and the smallest proportion (4 percent) in Tigray. For sorghum, 9 percent of production on average was sold nationally, with the largest proportion (10 percent) in Oromia and the smallest proportion (7 percent) in SNNP.

**Table 8. Commercialization level of cereal crops (% sold)**

| Cereal crop | Indicator | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Teff | Mean | 8 | 18 | 21 | 49 | 24 |
| | Standard deviation (Std) | 19 | 27 | 27 | 36 | 31 |
| Barley | Mean | 9 | 5 | 14 | 16 | 10 |
| | Std | 22 | 16 | 26 | 30 | 23 |
| Wheat | Mean | 9 | 8 | 20 | 27 | 17 |
| | Std | 21 | 16 | 27 | 29 | 25 |
| Maize | Mean | 4 | 6 | 9 | 12 | 8 |
| | Std | 16 | 15 | 19 | 25 | 20 |
| Sorghum | Mean | 9 | 8 | 10 | 7 | 9 |
| | Std | 20 | 19 | 20 | 20 | 19 |

Source: IFPRI/CSA survey 2005.

Among the pulse crops, 38 percent of lentils, 22 percent of grass peas, and 20 percent of horse beans were sold, with considerable variability among regions (Table 9). On average, 18 percent of field pea production, 17 percent of chickpeas, and 13 percent of haricot beans were sold.

**Table 9. Commercialization level of pulse crops (% sold)**

| Pulses | Indicators | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Horse beans | Mean | 13 | 14 | 18 | 38 | 20 |
| | Standard deviation (Std) | 15 | 25 | 34 | 44 | 33 |
| Lentils | Mean | 19 | 45 | 29 | 25 | 36 |
| | Std | 36 | 41 | 39 | 43 | 41 |
| Chickpea | Mean | 20 | 12 | 17 | 11 | 17 |
| | Std | 31 | 21 | 26 | 27 | 25 |
| Field pea | Mean | 11 | 11 | 22 | 29 | 18 |
| | Std | 23 | 24 | 33 | 37 | 31 |
| Haricot beans | Mean | | 14 | 20 | 6 | 13 |
| | Std | | 25 | 36 | 18 | 27 |
| Grass pea | Mean | 8 | 13 | 31 | | 22 |
| | Std | 16 | 25 | 37 | | 31 |

Source: IFPRI/CSA survey 2005.

Oil crop production is more commercialized than cereals and pulses (Table 10). Sesame and *nueg* are the most commercialized of the oil crops, with about 61 percent of sesame production and 56 percent of *nueg* production sold in markets nationally, followed by groundnuts (48 percent), linseed (47 percent), and sunflower seed (16 percent). As for other crops, commercialization levels of oil crops vary considerably across regions.

**Table 10. Commercialization level of oil crops (% sold)**

| Oil crop | Indicators | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Linseed | Mean | 36 | 24 | 59 | 51 | 47 |
| | Standard deviation (Std) | 40 | 37 | 40 | 48 | 42 |
| Groundnut | Mean | 50 | | 41 | 17 | 48 |
| | Std | 71 | | 43 | 29 | 32 |
| Sesame | Mean | 61 | 49 | 63 | | 61 |
| | Std | 36 | 39 | 36 | | 38 |
| Sunflower | Mean | | 19 | | 25 | 16 |
| | Std | | 33 | | 50 | 31 |
| Nueg | Mean | 55 | 48 | 57 | 95 | 56 |
| | Std | 48 | 39 | 42 | 15 | 41 |

Source: IFPRI/CSA Survey 2005.

Among horticultural crops, tomatoes, carrots, beet roots and onions are the most commercialized nationally, with 65 percent of the tomatoes produced, 62 percent of the carrots, 47 percent of the beet roots and 42 percent of the onions sold nationally but with considerable variability across regions (Table 11). Other horticultural crops appear to be produced primarily for home consumption.

**Table 11. Commercialization of horticultural crops (% sold)**

| Horticultural crop | | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Potato | Mean | 46 | 12 | 15 | 2 | 13 |
| | Standard deviation(Std) | 44 | 22 | 28 | 12 | 26 |
| Onion | Mean | 37 | 43 | 29 | 64 | 42 |
| | Std | 42 | 43 | 41 | 44 | 44 |
| Tomato | Mean | 67 | 44 | 46 | – | 65 |
| | Std | 29 | 45 | 47 | – | 40 |
| Sweet potato | Mean | – | 35 | 37 | 14 | 19 |
| | Std | – | 48 | 40 | 26 | 31 |
| Beet root | Mean | – | 40 | 47 | 14 | 47 |
| | Std | – | 42 | 45 | 24 | 43 |
| Cabbage | Mean | – | 41 | 12 | 14 | 17 |
| | Std | – | 46 | 28 | 29 | 33 |
| Carrot | Mean | 87 | 36 | 67 | 50 | 62 |
| | Std | 19 | 45 | 47 | 58 | 43 |
| Ginger | Mean | – | – | – | 44 | 8 |
| | Std | – | – | – | 50 | 26 |
| Pepper | Mean | 19 | 10 | 23 | 38 | 19 |
| | Std | 39 | 27 | 39 | 43 | 36 |
| Garlic | Mean | 36 | 14 | 22 | 41 | 22 |
| | Std | 44 | 29 | 38 | 47 | 37 |

Source: IFPRI/CSA survey 2005.

## Net Market Positions

Subsistence production is quite common among cereal crop producers, with more than half of barley, maize, and sorghum producers and nearly half of teff and wheat producers nationwide being autarkic in these crops (Table 12).

**Table 12. Market position of cereal crop producers (% of producing farmers)**

| Cereal crop | Market position | TIGRAY | AMHARA | OROMIA | SNNP | National |
|---|---|---|---|---|---|---|
| Teff | Autarky | 68.2 | 50.4 | 44.0 | 36.9 | 47.3 |
| | Only seller | 14.7 | 39.1 | 38.6 | 51.1 | 38.9 |
| | Net seller | 1.1 | 1.7 | 4.5 | 6.7 | 3.4 |
| | Only buyer | 15.0 | 8.2 | 12.2 | 5.3 | 9.8 |
| | Net buyer | 1.1 | 0.7 | 0.6 | 0.0 | 0.6 |
| Maize | Autarky | 57.1 | 62.4 | 49.7 | 46.0 | 52.2 |
| | Only seller | 5.3 | 16.8 | 10.6 | 10.9 | 12.0 |
| | Net seller | 0.9 | 0.9 | 2.7 | 3.7 | 2.4 |
| | Only buyer | 35.8 | 19.7 | 36.0 | 37.4 | 32.3 |
| | Net buyer | 0.8 | 0.2 | 0.9 | 2.0 | 1.1 |
| Wheat | Autarky | 41.9 | 57.0 | 48.8 | 39.2 | 49.1 |
| | Only seller | 14.9 | 22.8 | 33.5 | 36.0 | 29.1 |
| | Net seller | 0.9 | 1.1 | 3.6 | 2.5 | 2.4 |
| | Only buyer | 39.1 | 17.7 | 13.5 | 21.4 | 18.2 |
| | Net buyer | 3.3 | 1.5 | 0.6 | 0.8 | 1.1 |
| Barley | Autarky | 63.6 | 38.3 | 57.6 | 58.0 | 62.7 |
| | Only seller | 14.0 | 15.2 | 24.7 | 21.3 | 19.2 |
| | Net seller | 0.3 | 1.0 | 3.0 | 2.8 | 1.9 |
| | Only buyer | 21.0 | 14.9 | 14.3 | 16.9 | 15.6 |
| | Net buyer | 1.0 | 0.6 | 0.5 | 0.9 | 0.6 |
| Sorghum | Autarky | 47.2 | 42.4 | 56.0 | 38.7 | 54.4 |
| | Only seller | 16.8 | 26.1 | 15.1 | 6.4 | 16.2 |
| | Net seller | 1.4 | 1.1 | 0.6 | 0.8 | 0.9 |
| | Only buyer | 34.2 | 27.3 | 26.9 | 19.6 | 26.9 |
| | Net buyer | 0.4 | 3.2 | 1.4 | 0.6 | 1.6 |

Source: IFPRI/CSA survey 2005.

Autarkic production of teff is most common in Tigray and least in SNNP. About two-fifths of teff producers were sellers of teff in 2004/05; some both bought and sold teff but the vast majority only sold. Teff sales are most common in the SNNP region and least common in Tigray. About 10 percent of teff producers were buyers, with only a few of these both selling and buying teff. Teff buyers are most common in Tigray and Oromia.

Autarkic production of maize is most common in Amhara and Tigray. Maize buyers are more common than sellers, with about 33 percent of maize producers being buyers, while only 14 percent are sellers (net and only combined). As with teff, few households both buy and sell maize. Maize sellers are most common in Amhara and least in Tigray, while maize buyers are most common in SNNP, Oromia, and Tigray and least common in Amhara.

Autarkic production of wheat is most common in Amhara and least in SNNP. Nearly one-third of wheat producers are sellers, while about one-fifth are buyers. Few households both sell and buy wheat. Selling wheat is most common in SNNP and least in Tigray, while buying wheat is most common in Tigray and least in Oromia.

Autarkic production of barley is most common in Tigray and least in Amhara. About one-fifth of barley producers are sellers, with the largest proportion in Oromia and the smallest in Tigray. About 16 percent of barley producers are buyers, with the largest proportion in Tigray and the smallest in Oromia. Few households are both buyers and sellers of barley.

Autarkic production of sorghum is most common in Oromia and least common in SNNP. About 17 percent of sorghum producers are sellers, with the largest proportion in Amhara and the smallest in SNNP. About 28 percent of sorghum producers are buyers of sorghum, with the largest proportion in Tigray and the smallest in SNNP. Few households both buy and sell sorghum.

In general, teff and wheat are less often produced for subsistence alone and more commonly sold than other cereals, while maize and sorghum are more commonly purchased than other cereals. Barley is often produced by autarkic households, but autarky is common for all cereals. Cereal producers are generally more likely to engage in selling in higher rainfall areas such as SNNP and Oromia (except for sorghum) and least likely to be sellers in Tigray, where production is more marginal. Few households both buy and sell any type of cereal.

### *Differences across Households by Market Positions*

Statistics describing the net market positions of producers of teff and maize are presented in Table 13, using the dependent and explanatory variables of the econometric analysis.[26] As expected, sellers of teff and maize produce the largest quantities of these cereals, followed by autarkic households, with buying households producing the least.

[26] In Table 13 and the remainder of the paper, we combine sellers only and net sellers into one category of net sellers, and buyers only and net buyers into one category of net buyers, recognizing that the vast majority of net sellers are sellers only and the vast majority of net buyers are buyers only.

**Table 13. Descriptive statistics by net market position of teff and maize producers**

| Variable | Teff market position | | | | | | Maize market position | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Autarky | | Net Seller | | Net Buyer | | Autarky | | Net Seller | | Net Buyer | |
| | Mean | Standard Deviation | Mean | Std Dev. | Mean | Std Dev. | Mean | Std Dev. | Mean | Std Dev. | Mean | Std Dev. |
| **Dependent variables** | | | | | | | | | | | | |
| Teff/maize net market position among producers (number) | 1256 | | 1091 | | 271 | | 2302 | | 618 | | 1438 | |
| Teff/maize production (kg) | 195.4 | 233.5 | 476.1 | 521.8 | 174.7 | 219.5 | 240.1 | 386.5 | 766.5 | 710.4 | 210.2 | 327.9 |
| Teff/maize sold after harvest (kg.) | 0.0 | 0.0 | 143.2 | 201.7 | 21.2 | 74.4 | 0.0 | 0.0 | 190.0 | 275.4 | 8.4 | 33.0 |
| Teff/maize purchased after harvest (kg.) | 0.0 | 0.0 | 10.8 | 93.6 | 78.1 | 395.0 | 0.0 | 0.0 | 13.7 | 50.5 | 156.5 | 562.6 |
| Explanatory variables | | | | | | | | | | | | |
| Local teff/maize harvest price(EB/quintal(qq))[27] | 207.3 | 49.3 | 205.8 | 41.7 | 205.1 | 49.1 | 102.1 | 38.2 | 94.0 | 31.8 | 116.5 | 40.8 |
| Local price of DAP (Ethiopian Birr (EB)/kg) | 3.227 | 0.486 | 3.263 | 0.477 | 3.234 | 0.442 | 3.277 | 0.468 | 3.320 | 0.467 | 3.198 | 0.488 |
| **Value of assets owned (EB)** | | | | | | | | | | | | |
| - Livestock | 3305.3 | 3481.6 | 3434.8 | 3035.8 | 2752.6 | 2401.9 | 3471.0 | 6651.5 | 3448.2 | 4063.0 | 2811.1 | 5173.8 |
| - Farm equipment | 252.0 | 1894.7 | 146.6 | 829.6 | 131.5 | 220.4 | 191.4 | 1425.5 | 137.2 | 555.2 | 122.4 | 776.8 |
| - Transportation assets | 6.8 | 99.8 | 6.7 | 83.1 | 13.7 | 159.6 | 30.9 | 949.7 | 222.7 | 5229.8 | 11.5 | 117.1 |
| Distance to nearest (km) | | | | | | | | | | | | |
| - All-weather road | 12.82 | 19.78 | 8.97 | 8.50 | 9.06 | 9.37 | 11.98 | 15.24 | 10.69 | 11.50 | 11.01 | 13.24 |
| - Sales market (km) | 9.17 | 8.29 | 9.23 | 9.30 | 10.61 | 9.11 | 10.13 | 13.23 | 9.41 | 8.88 | 10.68 | 12.05 |
| Number of traders known outside PA | 4.70 | 13.60 | 7.11 | 21.51 | 5.65 | 13.27 | 5.86 | 19.15 | 5.42 | 7.92 | 5.30 | 13.20 |
| Member of a cooperative | 0.135 | 0.342 | 0.154 | 0.361 | 0.148 | 0.355 | 0.093 | 0.290 | 0.129 | 0.336 | 0.081 | 0.272 |
| Member of a credit or savings institution | 0.425 | 0.495 | 0.604 | 0.489 | 0.421 | 0.495 | 0.447 | 0.497 | 0.542 | 0.499 | 0.476 | 0.500 |
| **Proportion of adults with primary activity:** | | | | | | | | | | | | |
| - Crop production | 0.516 | 0.322 | 0.508 | 0.315 | 0.462 | 0.331 | 0.475 | 0.332 | 0.502 | 0.321 | 0.430 | 0.323 |
| - Livestock production | 0.083 | 0.163 | 0.072 | 0.141 | 0.075 | 0.139 | 0.081 | 0.174 | 0.065 | 0.148 | 0.101 | 0.196 |
| - Domestic activities | 0.158 | 0.220 | 0.190 | 0.228 | 0.207 | 0.271 | 0.199 | 0.247 | 0.190 | 0.238 | 0.223 | 0.251 |
| - Non-farm activities | 0.017 | 0.083 | 0.016 | 0.080 | 0.010 | 0.057 | 0.021 | 0.109 | 0.012 | 0.073 | 0.024 | 0.108 |

[27] 1 quintal (qq) = 100 kg.

**Table 13. Continued**

| Variable | Teff market position | | | | | | Maize market position | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Autarky | | Net Seller | | Net Buyer | | Autarky | | Net Seller | | Net Buyer | |
| | Mean | Standard Deviation | Mean | Std Dev. | Mean | Std Dev. | Mean | Std Dev. | Mean | Std Dev. | Mean | Std Dev. |
| **Proportion of labor force that is** | | | | | | | | | | | | |
| - Women | 0.441 | 0.203 | 0.438 | 0.202 | 0.491 | 0.245 | 0.456 | 0.218 | 0.456 | 0.204 | 0.479 | 0.223 |
| - Children | 0.149 | 0.198 | 0.141 | 0.190 | 0.133 | 0.192 | 0.140 | 0.197 | 0.139 | 0.200 | 0.149 | 0.202 |
| Male head of household | 0.855 | 0.352 | 0.859 | 0.348 | 0.801 | 0.400 | 0.828 | 0.377 | 0.851 | 0.356 | 0.801 | 0.399 |
| Age of household head | 45.7 | 15.0 | 43.3 | 14.9 | 46.2 | 15.7 | 44.5 | 15.3 | 41.9 | 14.5 | 44.6 | 15.0 |
| Number of working age family members | 2.779 | 1.262 | 2.853 | 1.370 | 2.657 | 1.272 | 2.695 | 1.331 | 2.715 | 1.276 | 2.685 | 1.277 |
| Area of land operated (ha) | 1.813 | 1.426 | 2.057 | 1.564 | 1.587 | 1.240 | 1.542 | 1.367 | 1.772 | 1.407 | 1.121 | 0.998 |
| Primary or secondary education of | | | | | | | | | | | | |
| - Women in household | 0.192 | 0.271 | 0.187 | 0.277 | 0.224 | 0.304 | 0.178 | 0.270 | 0.205 | 0.289 | 0.169 | 0.261 |
| - Men in household | 0.340 | 0.338 | 0.349 | 0.344 | 0.355 | 0.343 | 0.335 | 0.345 | 0.379 | 0.349 | 0.339 | 0.346 |
| Proportion of operated land that is | | | | | | | | | | | | |
| - Gently sloping | 0.356 | 0.389 | 0.251 | 0.341 | 0.322 | 0.373 | 0.321 | 0.392 | 0.306 | 0.392 | 0.328 | 0.407 |
| - Steeply sloping | 0.046 | 0.156 | 0.043 | 0.150 | 0.035 | 0.124 | 0.061 | 0.195 | 0.026 | 0.121 | 0.044 | 0.170 |
| - Mixed slopes | 0.048 | 0.172 | 0.057 | 0.204 | 0.062 | 0.190 | 0.061 | 0.213 | 0.034 | 0.161 | 0.045 | 0.180 |
| - *Lem* (high quality) soil | 0.427 | 0.422 | 0.439 | 0.415 | 0.323 | 0.384 | 0.503 | 0.444 | 0.645 | 0.416 | 0.457 | 0.452 |
| - *Teuf* (low quality) soil | 0.156 | 0.303 | 0.096 | 0.220 | 0.195 | 0.339 | 0.085 | 0.231 | 0.048 | 0.160 | 0.107 | 0.269 |
| - In *dega* (high altitude) zone | 0.182 | 0.366 | 0.092 | 0.267 | 0.334 | 0.461 | 0.135 | 0.327 | 0.164 | 0.354 | 0.135 | 0.332 |
| - In *woina dega* (medium altitude) zone | 0.478 | 0.476 | 0.570 | 0.470 | 0.424 | 0.475 | 0.501 | 0.482 | 0.513 | 0.483 | 0.538 | 0.485 |
| - Irrigable | 0.017 | 0.082 | 0.019 | 0.084 | 0.026 | 0.091 | 0.030 | 0.133 | 0.032 | 0.145 | 0.039 | 0.153 |
| - Far (> 1 hour walk) from residence | 0.078 | 0.195 | 0.070 | 0.191 | 0.082 | 0.217 | 0.072 | 0.198 | 0.048 | 0.166 | 0.048 | 0.166 |
| Proportion of households by region | | | | | | | | | | | | |
| - Tigray | 0.212 | 0.409 | 0.053 | 0.224 | 0.221 | 0.416 | 0.084 | 0.278 | 0.036 | 0.185 | 0.099 | 0.299 |
| - Amhara | 0.361 | 0.480 | 0.333 | 0.471 | 0.284 | 0.452 | 0.234 | 0.424 | 0.241 | 0.428 | 0.118 | 0.323 |
| - Oromia | 0.299 | 0.458 | 0.354 | 0.478 | 0.417 | 0.494 | 0.354 | 0.478 | 0.361 | 0.481 | 0.397 | 0.489 |
| - SNNP | 0.110 | 0.313 | 0.208 | 0.406 | 0.077 | 0.268 | 0.220 | 0.414 | 0.246 | 0.431 | 0.304 | 0.460 |
| - Addis Ababa | 0.001 | 0.028 | 0.028 | 0.166 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.026 |

Average local harvest prices for teff vary little across households with different market positions for teff, while local maize harvest prices are lowest for sellers, intermediate for autarkic households, and highest for buying households, as would be expected. Fertilizer (DAP) prices vary little across these groups but are slightly higher for sellers of both teff and maize, perhaps reflecting greater fertilizer demand in communities where there are more cereal sales.

As expected, buyers of both teff and maize have less land area than sellers or autarkic households, while sellers farm the most land. Teff sellers also tend to farm better quality land—more *lem* or mixed soils—with a smaller proportion of their land on slopes or in the high altitude *dega* zone. The situation is similar for maize sellers, except that maize sellers have a higher proportion of their land in the *dega* zone than autarkic or buying households. Teff sellers have a smaller proportion of the land far from their residences than do buyers or autarkic households, while a smaller share of the land of both maize buyers and sellers is far from their residences than is the case for autarkic households. Interestingly, a somewhat larger share of land of teff and maize buyers is irrigable (has access to irrigation but may not be irrigated in any given year) than that of sellers or autarkic households, although the irrigable share of land is small (only about 2 to 4 percent) for all groups. Perhaps cereal buyers use irrigation for producing other higher-value crops, rather than for irrigating maize.

Teff buyers are poorer on average than teff sellers or autarkic households in terms of ownership of livestock and farm equipment, though they own slightly more transportation assets. Maize buyers are poorer than maize sellers or autarkic households in terms of transportation assets as well as livestock and equipment.

As expected, teff and maize sellers and buyers live closer to an all-weather road on average than autarkic households. Maize sellers also live closer to the nearest sales market than other maize producers, while teff sellers and autarkic households live somewhat closer to the nearest market than buyers on average.

Teff sellers know more traders outside of their PA than either buyers or autarkic households, on average, and are more likely to be members of a cooperative (followed in both cases by teff buyers). Maize sellers are also more likely to be members of a cooperative than autarkic households or buyers, but know fewer traders than autarkic households. Both teff and maize sellers are more likely to be members of a credit or savings institution than buyers or autarkic households.

There are also differences in human capital across these groups. Maize-selling households have a larger share of members with formal (primary or secondary) education than autarkic or buying households, while teff buyers have a slightly larger share of educated members on average than the other two groups. Teff and maize-selling households are somewhat more likely to be headed by males than the other groups; they have more working- age adults, have a slightly larger share of men in the household labor force, and the head tends to be younger. Maize-selling households tend to be more focused on crop production and less on livestock production, domestic activities, or nonfarm activities than other maize producers. Teff sellers also tend to be more oriented toward crop production than teff buyers, while autarkic teff producers have a similar degree of focus on crop production as the primary activity.

These descriptive results suggest that teff and maize sellers tend to have several advantages, compared with buyers and autarkic households, particularly in terms of access to and quality of land, endowments of physical and financial capital and some types of social and human capital, and access to roads and markets. These differences have important implications for policies that affect cereal crop production and prices. For example, policies that increase cereal productivity and reduce cereal prices should unambiguously benefit net buyers of cereals, who tend to be poorer than sellers in many respects. The effects of improvements in productivity are also likely to be favorable for the large share of producers who are autarkic, while market price declines are irrelevant to autarkic households unless they are large enough to induce such households to become net buyers (which would benefit autarkic households ). The impacts of increased productivity and lower prices on sellers are more ambiguous, as they depend on the price elasticity of demand (in other words, sellers revenues may fall as a result of increased production if demand is price-inelastic) and the extent to which sellers' costs of production fall. Thus, policies to promote increased cereal productivity and hence lower prices are likely to have beneficial distributional as well as efficiency effects, although some cereal-selling households may be worse off as a result.

In order to draw further policy-relevant implications, we need to assess the extent to which the factors discussed here affect farmers' production and marketing decisions, accounting for the simultaneous influence of multiple factors. That is the objective of the econometric analysis presented in the next section.

# 5. ECONOMETRIC RESULTS

In this section we discuss the econometric results for teff and maize, including the determinants of market position, production, and the amount of sales or purchases of each crop. Teff and maize were selected for this analysis because they are the two most important crops in Ethiopia in terms of area planted and the value of production. For this analysis, we have 1,635 teff-producing households and 2,072 maize-producing households with a complete set of data for all variables. Here we have combined sellers only and net sellers and buyers only and net buyers to reduce the number of categories, and because few households in the sample both sell and buy teff or maize. Nearly half of the teff producers in the sample are teff sellers and only a tenth are buyers, with the remainder autarkic. By contrast, only about one-fifth of the maize producers are sellers, nearly half of which are autarkic, with the remaining third being buyers. To be consistent with the empirical model, the analysis focuses on crop sales and purchases during the postharvest period only.

## Econometric Results for Teff

### *Determinants of Teff Market Position*

The estimation results for determinants of market position for teff are reported in Table 14. The model predicts the mean probabilities of the different market positions quite well. For example, the mean predicted probability of being a seller or a buyer is 0.4895 and 0.1016, respectively; quite close to the mean proportions of sellers and buyers in the sample of 0.4887 and 0.1011, respectively. However, the ability of the model to discriminate different probabilities for households that take different market positions is limited. For example, among teff-selling households, the predicted probability of selling teff is 0.5670, while it is 0.3595 among buying households and 0.4294 among autarkic households. Thus, the discriminating power or “fit” of the model is far from perfect. Nevertheless, the model does reveal several factors that significantly affect households’ market position for teff.

Variables found to significantly affect sellers’ transaction costs (at the 5 percent level) include distance to an all-weather road (positive effect [+]) and the number of traders outside the PA known by the respondent (negative effect [–]). Both of these impacts are as hypothesized. None of the explanatory variables have a statistically significant impact on buyers’ transaction costs. This may be due to the weaker statistical power of the model and data to identify these effects, given the relatively small number of teff buyers in the estimation sample (165).

**Table 14. Determinants of market position for teff**

| Variable | Coefficient | Std. Err. | Marginal effects | | |
|---|---|---|---|---|---|
| | | | P(seller)[28] | P(buyer) | P(autarky) |
| Sellers' transaction costs ($\beta_s$) | | | | | |
| Ln (value of transportation assets) | -0.002 | 0.110 | 0.0006 | 0.1023 | -0.1029 |
| Ln (distance to all-weather road) | 0.166** | 0.072 | -0.0451 | 0.0483 | -0.0032 |
| Ln (minimum distance to sales market) | -0.146 | 0.091 | 0.0397 | 0.0883 | -0.1280 |
| Ln (number of traders known outside PA) | -0.153** | 0.071 | 0.0414 | 0.0544 | -0.0959 |
| Member of a cooperative | -0.048 | 0.191 | 0.0130 | -0.1909 | 0.1779 |
| Constant ($\beta_{s0}$) | 3.457*** | 1.040 | | | |
| | | | | | |
| Buyers' transaction costs ($\beta_b$) | | | | | |
| Ln(value of transportation assets) | -0.200 | 0.143 | | | |
| Ln(distance to all-weather road) | -0.094 | 0.073 | | | |
| Ln(minimum distance to sales market) | -0.172 | 0.109 | | | |
| Ln(number of traders known outside PA) | -0.106 | 0.084 | | | |
| Member of a cooperative | 0.373 | 0.311 | | | |
| | | | | | |
| Shadow price of teff ($\beta_p$) | | | | | |
| Ln(price of DAP) | -1.271*** | 0.468 | 0.3446 | -0.6505 | 0.3059 |
| Proportion of adults in household with primary activity (cf., proportion of crop producers) | | | | | |
| - Livestock production | 0.252 | 0.390 | -0.0684 | 0.1292 | -0.0607 |
| - Domestic activities | 0.491* | 0.291 | -0.1331 | 0.2513 | -0.1181 |
| - Nonfarm enterprise | 0.534 | 0.634 | -0.1448 | 0.2733 | -0.1285 |
| Ln(total number of workers in household) | 0.017 | 0.211 | -0.0046 | 0.0086 | -0.0041 |
| Proportion of labor force (cf., men) | | | | | |
| - Women | 0.659* | 0.388 | -0.1788 | 0.3375 | -0.1587 |
| - Children | 0.090 | 0.347 | -0.0243 | 0.0459 | -0.0216 |
| Male head of household | 0.415* | 0.216 | -0.1125 | 0.2123 | -0.0998 |
| Ln(age of household head) | 0.556** | 0.226 | -0.1507 | 0.2845 | -0.1338 |
| Primary or secondary education of women | 0.481* | 0.259 | -0.1306 | 0.2464 | -0.1159 |
| Primary or secondary education of men | 0.289 | 0.189 | -0.0783 | 0.1477 | -0.0695 |
| Ln(area of land operated) | -0.228** | 0.116 | 0.0619 | -0.1168 | 0.0549 |
| Land quality characteristics | | | | | |
| Slope of land (cf., flat land) | | | | | |
| - Proportion of land gently sloping | 0.515** | 0.226 | -0.1396 | 0.2635 | -0.1239 |
| - Proportion of land steeply sloping | -0.068 | 0.387 | 0.0184 | -0.0347 | 0.0163 |

[28] P(seller) means probability of being a seller, etc.

**Table 14. Continued**

| Variable | Coefficient | Std. Err. | Marginal effects P(seller)[29] | P(buyer) | P(autarky) |
|---|---|---|---|---|---|
| Soil quality | | | | | |
| - Proportion of land with *lem* soil | 0.052 | 0.148 | -0.0140 | 0.0265 | -0.0125 |
| - Proportion of land with *teuf* soil | 0.318 | 0.266 | -0.0862 | 0.1626 | -0.0765 |
| Agroecology (altitude zone) | | | | | |
| - Proportion of land in *dega* (high alt.) zone | 1.258*** | 0.463 | -0.3412 | 0.6440 | -0.3028 |
| - Proportion of land in *woina dega* (medium alt.) | 0.064 | 0.149 | -0.0174 | 0.0329 | -0.0155 |
| Proportion of land with access to irrigation | 0.737 | 0.758 | -0.1999 | 0.3774 | -0.1775 |
| Proportion of land far from residence | -0.459 | 0.439 | 0.1245 | -0.2351 | 0.1105 |
| Other productive assets | | | | | |
| Ln(value of livestock) | -0.086** | 0.043 | 0.0232 | -0.0439 | 0.0206 |
| Ln(value of equipment) | -0.316*** | 0.118 | 0.0858 | -0.1619 | 0.0761 |
| Member of credit or savings institution | -0.134 | 0.140 | 0.0363 | -0.0685 | 0.0322 |
| Region (cf., Tigray) | | | | | |
| - Amhara | -1.185*** | 0.369 | 0.3214 | -0.6067 | 0.2853 |
| - Oromia | -1.291*** | 0.379 | 0.3501 | -0.6609 | 0.3107 |
| - SNNP | -2.035*** | 0.565 | 0.5518 | -1.0416 | 0.4898 |
| - Addis Ababa | -4.070*** | 1.389 | 1.1039 | -2.0837 | 0.9798 |
| Constant ($\beta_{p0}$) | 3.493*** | 1.071 | | | |
| $\sigma_p$ | 1.810*** | 0.529 | | | |
| Number of observations | 1635 | | 795 | 165 | 675 |
| Proportion of observations | | | 0.4887 | 0.1011 | 0.4102 |
| Mean predicted probability (entire estimation sample) | | | 0.4895 | 0.1016 | 0.4089 |
| Mean predicted probability (selling households) | | | 0.5670 | 0.0707 | 0.3624 |
| Mean predicted probability (buying households) | | | 0.3595 | 0.1848 | 0.4556 |
| Mean predicted probability (autarkic households) | | | 0.4294 | 0.1178 | 0.4528 |

*, **, *** mean that the coefficient is statistically significant at the 10%, 5% or 1% levels, respectively.

Explanatory variables having a statistically significant impact (5 percent level, or less) on the shadow price of teff include the price of DAP (–), the age of the household head (+), the area of land operated (–), the proportion of land that is gently sloping (+), the proportion of land in the *dega* (high-altitude) zone (+), the value of livestock (–) and equipment (–) owned by the household, and the region (lower in all regions than in Tigray). Other variables having a weak statistically significant impact (10 percent level) on the teff shadow price include the proportion of adults pursuing domestic activities (+),

[29] P(seller) means probability of being a seller, etc.

the proportion of women in the household labor force (+), male head of household (+), and primary or secondary education of women in the household (+).

Most of these results are consistent with the hypotheses from our theoretical model discussed in section 2. Productive assets that increase potential production of teff, such as a larger operated land area and ownership of livestock and equipment, lead to lower shadow prices, while factors that reduce teff productivity, such as sloping lands, higher elevation, and lower rainfall (as in Tigray), lead to higher shadow prices (see Table 1 and equation [41]). Factors that increase the opportunity costs of labor, such as the age of the household head and women's education, also increase shadow prices.

One unexpected finding is that a higher price of DAP fertilizer is associated with a lower shadow price of teff. This contradicts our hypothesis that higher input prices will increase crop shadow prices (see equation 41),[30] and suggests that other factors that are correlated with the DAP price may be responsible. For example, if the price of DAP is higher in more productive environments due to higher fertilizer demand in these environments, and the productivity of the environment is not adequately reflected by the agro-ecological variables included in the model, this omitted variable bias could explain why we find this unexpected result. Further research is needed to investigate this issue.

Two other unexpected findings are that domestic work and women's share of the household labor force have a statistically weak  but positive impact on the shadow price. If domestic work and women laborers are associated with lower wages and income, these would be expected to reduce teff consumption demand and hence reduce the shadow price of teff. However, if labor markets are not perfect (as assumed in the theoretical models) but rather segmented, involvement in domestic work and women's share of the labor force could reduce the labor supply available for food production, effectively increasing the labor opportunity cost in food production and the shadow price of food. An alternative explanation is that women are more concerned with household food security and therefore have a greater demand for food than male household members, so that the demand for teff is greater in households with more female members, other factors being equal. Further research is necessary to assess the plausibility of either of these (or other) explanations for these results.

To facilitate interpretation of the estimation results, the marginal effects of each variable on the predicted probability of households taking different market positions (evaluated at the means of the explanatory variables) are also reported in Table 14. We focus here on the marginal effects of selected variables that are statistically significant (at the 5 percent level). Increasing the distance to an all-weather road by 1 percent reduces the probability that a household with average characteristics is a seller by

[30] Note that the relationship between the price of inputs and the shadow price of food is ambiguous in the more general theoretical model summarized in Table 1, so this result does not contradict a more general specification of the model.

0.00045.[31] Increasing the number of traders known outside the PA by 1 percent increases the probability of being a seller by 0.00041. Increasing the area of land operated by the household by 1 percent increases the probability that it is a seller by 0.00062 and that it is autarkic by 0.00055, while reducing the probability that it is a buyer by 0.00117. Increasing the value of livestock owned by 1 percent increases the probability of being a seller or autarkic by 0.00020 each, while reducing the probability of being a buyer by 0.00040. Increasing the value of equipment owned by 1 percent has qualitatively similar but stronger impacts, increasing the probability of being a seller or autarkic by about 0.00080 each and reducing the probability of being a buyer by 0.00160.

These results suggest that to promote more households to become sellers of teff, we should increase smallholders' access to roads, land, equipment, livestock, and social connections with traders. However, the impacts of such improvements on teff commercialization would not be very large, unless the magnitude of improvements in access to these forms of capital is quite large.

### *Determinants of Teff Production*

The determinants of teff production, estimated separately for sellers, buyers, and autarkic households, are reported in Table15. The models for sellers and buyers explain a substantial share of the variance in teff production (45 percent for sellers and 49 percent for buyers), despite using a relatively small number of explanatory variables, compared with the number of observations. The model for production by autarkic households does not fit the data as well, but still explains 28 percent of the variance in teff production. In the models for sellers and buyers, the selectivity correction term is highly statistically significant, indicating the importance of including this correction for these models to avoid selectivity bias.

The factors found to significantly influence teff production by teff sellers (at the 5 percent level) include the market price of teff (+), distance to an all-weather road (-), the number of traders known outside the PA (+), the importance of domestic activities in the household allocation of labor (-), the proportion of women in the household labor force (-), the age of the household head (-), the area of land operated (+), the proportion of land with gentle or mixed slopes (compared with flat land) (-), the proportion of land in the high-altitude *dega* zone (–), the value of livestock (+) and equipment (+) owned, and the region (higher in all regions than Tigray). Most of these results are consistent with our hypotheses; for example, the positive effects of market price, factors reducing transaction costs, productive capital, and agro-ecological potential (higher outside of Tigray, on flatter land, and at lower elevation). The age of the household head probably has a negative impact because older household heads

[31] As defined in equations (59) to (64), the marginal effect (M) measures dP/dZ, where P is the probability of the market position (teff seller in this case) and Z is the explanatory variable (ln(distance to an all-weather road in this case). Defining the distance to an all-weather road as X, we have M = dP/dlnX, which implies dP = M dlnX = M dX/X. If M = 0.045 (the marginal effect of ln(distance to an all weather road) on P(teff seller) in Table 14), then a 1 percent change in X (dX/X = 0.01) implies dP = 0.045 x 0.01 = 0.00045.

have higher labor opportunity costs,  which is consistent with the finding discussed above that older household heads have a higher shadow price of teff. The negative impacts of domestic activities and the share of women in the household labor force on teff production are also consistent with the positive impact that these factors have on the shadow price of teff and supports the explanation that these factors reduce the effective labor supply in teff production in the context of an imperfect labor market, resulting in higher labor opportunity costs, lower teff production, and a higher shadow price of teff.

**Table 15. Determinants of teff production, dependent variable ln(teff production)**

| Variable | Sellers | | Buyers | | Autarkic | |
|---|---|---|---|---|---|---|
| | Coefficient | Std. Err.[a] | Coefficient | Std. Err.[a] | Coefficient | Std. Err.[a] |
| Ln (market price of teff) | 1.372*** | 0.437 | -3.341* | 1.754 | | |
| Ln (value of transportation assets) | 0.066 | 0.094 | 0.613 | 0.694 | | |
| Ln (distance to all-weather road) | -0.167** | 0.071 | 0.392 | 0.328 | | |
| Ln (minimum distance to sales market) | 0.112 | 0.080 | 0.397 | 0.387 | | |
| Ln (number of traders known outside PA) | 0.152*** | 0.052 | 0.571* | 0.307 | | |
| Member of a cooperative | 0.033 | 0.160 | -1.484 | 1.312 | | |
| Ln (price of DAP) | 0.699 | 0.529 | -4.123* | 2.493 | -0.014 | 0.304 |
| Proportion of adults in household with primary activity (cf. crop producers) | | | | | | |
| - Livestock production | -0.460 | 0.392 | 1.614 | 1.822 | 0.351 | 0.296 |
| - Domestic activities | -0.773*** | 0.258 | 2.174** | 1.063 | -0.157 | 0.237 |
| - Nonfarm enterprise | -1.124 | 0.699 | 1.854 | 2.775 | -0.377 | 0.488 |
| Proportion of labor force (cf., men) | | | | | | |
| - Women | -0.798** | 0.343 | 3.616** | 1.522 | -0.295 | 0.307 |
| - Children | -0.290 | 0.334 | 0.992 | 1.442 | -0.171 | 0.300 |
| Male head of household | -0.319* | 0.192 | 1.776** | 0.890 | 0.123 | 0.173 |
| Ln (age of household head) | -0.590** | 0.252 | 2.102** | 0.885 | -0.030 | 0.159 |
| Ln (total number of workers) | 0.064 | 0.201 | 0.388 | 0.858 | 0.005 | 0.142 |
| Ln (area of land operated) | 0.468*** | 0.133 | -0.489 | 0.407 | 0.339*** | 0.091 |
| Member of credit or savings institution | 0.224* | 0.128 | -0.568 | 0.641 | 0.022 | 0.103 |
| Primary or secondary education of women | -0.501* | 0.263 | 1.793* | 0.930 | 0.096 | 0.169 |
| Primary or secondary education of men | -0.127 | 0.213 | 1.371* | 0.814 | -0.243 | 0.163 |
| Land quality characteristics | | | | | | |
| Slope of land (cf., flat land) | | | | | | |
| - Proportion of land gently sloping | -0.740*** | 0.239 | 1.170 | 0.867 | -0.351** | 0.165 |
| - Proportion of land steeply sloping | 0.310 | 0.339 | -1.357 | 1.581 | 0.334 | 0.269 |
| - Proportion of land with mixed slopes | -0.821** | 0.387 | 2.471 | 1.824 | -0.222 | 0.311 |
| Soil quality | | | | | | |
| - Proportion of land with *lem* soil | -0.043 | 0.141 | 0.362 | 0.669 | 0.058 | 0.122 |
| - Proportion of land with *teuf* soil | -0.318 | 0.272 | 1.717 | 1.046 | 0.375** | 0.160 |
| Agroecology (altitude zone) | | | | | | |

**Table 15. Continued**

| Variable | Sellers | | Buyers | | Autarkic | |
|---|---|---|---|---|---|---|
| | Coefficient | Std. Err.[a] | Coefficient | Std. Err.[a] | Coefficient | Std. Err.[a] |
| - Proportion of land in *dega* (high alt.) zone | -1.306*** | 0.491 | 4.091** | 1.938 | -0.491* | 0.283 |
| - Proportion of land in *woina dega* (medium) | -0.072 | 0.138 | 0.620 | 0.727 | -0.064 | 0.104 |
| Proportion of land with access to irrigation | -1.048 | 0.857 | 1.601 | 3.228 | 0.523 | 0.577 |
| Proportion of land far from residence | 0.416 | 0.410 | -3.237 | 2.030 | -0.515 | 0.359 |
| Other productive assets | | | | | | |
| Ln (value of livestock) | 0.170*** | 0.064 | -0.167 | 0.171 | 0.084*** | 0.031 |
| Ln (value of equipment) | 0.515*** | 0.125 | -1.051** | 0.467 | 0.124 | 0.079 |
| Region (cf., Tigray) | | | | | | |
| - Amhara | 2.172*** | 0.543 | -3.859** | 1.897 | 1.114*** | 0.216 |
| - Oromia | 2.497*** | 0.587 | -4.301** | 1.991 | 1.043*** | 0.231 |
| - SNNP | 2.413*** | 0.828 | -7.678*** | 2.964 | 0.243 | 0.337 |
| - Addis Ababa | 3.913*** | 0.975 | (dropped) | | 1.742* | 0.987 |
| Selectivity correction | -2.684*** | 0.999 | 7.751** | 3.395 | 0.485 | 0.398 |
| Intercept | -7.164* | 3.678 | 6.754 | 7.487 | 3.382*** | 0.654 |
| Number of observations | | 795 | | 165 | | 675 |
| $R^2$ | | 0.4474 | | 0.4893 | | 0.2811 |

[a] Based on 100 bootstrap replications.
*, **, *** mean the coefficient is statistically significant at the 10%, 5% or 1% levels, respectively.

Other factors having a statistically weak (10 percent level) impact on sellers' teff production include the gender of the household head (– for male headed households), membership in a credit or savings institution (+), and education of women (–). The negative effects of male-headed households and education of women may be due to such factors causing higher labor opportunity costs, while the positive impact of membership in a credit or savings institution may be because such organizations provide credit at a lower rate of interest (Table 1) or relax binding credit constraints (Table 2).

There are many differences between the factors influencing teff production by teff sellers and those influencing production by teff buyers. For buyers, factors having a statistically significant impact on production include the importance of domestic activities (+), share of women in the household labor supply (+), male head of household (+), age of the household head (+), share of land in the *dega* zone (+), the value of equipment owned (–), and the region (greater production by buyers in Tigray than in other regions). Factors having a weakly significant (10 percent level) impact include the market price of teff (–), the number of traders known outside the PA (+), the price of DAP (–), education of women (+), and education of men (+). Most of these factors have an opposite effect on production by sellers: teff price, domestic activities, share of women in the labor force, gender and age of the household head, education of women, altitude, ownership of equipment, and the region are all opposite signs from those for the buyers , and many of these impacts are contrary to our expectations.

These results confirm our assertion that the same factors can have different impacts on production incentives for buyers versus sellers. However, we expected this only for factors that influence transaction costs, assuming that higher transaction costs would give sellers less incentive to produce but buyers more incentive. Although some of the factors found to have differential effects on production of buyers versus sellers could influence transaction costs (education of women, for example), most are not clearly related to transaction costs. Moreover, the variables that we expected to be most directly related to transaction costs—such as distance to the nearest market or road, ownership of transportation assets, number of traders known, or membership in a cooperative—had either insignificant effects on buyers or the same impacts on buyers and sellers (the number of traders known, for example). It may be that teff buyers are motivated to produce teff primarily for subsistence motives, and that these motives are stronger for poorer and more vulnerable households who have a larger share of women in the labor force, are more involved in domestic activities, whose head is older, who live at higher elevations, or in lower rainfall regions, or who own less equipment. By contrast, among households who produce enough teff for their own subsistence and a surplus for sales, such poverty-related factors have the more expected negative effects. Further research to investigate the robustness of these findings and probe the reasons behind these unexpected differences would be useful.

For households that are autarkic in teff production and consumption, the factors found to significantly affect teff production include the area of land operated (+), the proportion of land that is sloping (–), the proportion of land with *teuf* (low quality) soil (+), the proportion of land in the *dega* zone (–, weakly significant), the value of livestock owned (+), and the region (greater production in Amhara, Oromia, and Addis Ababa (weakly significant) than in Tigray). These results are similar to many of the results for households selling (but not buying) teff. As expected, we find that factors that increase potential production, such as the amount and quality of land owned, livestock ownership, and rainfall, contribute to greater teff production and consumption by autarkic households. The positive coefficient for lower-quality *teuf* soil is unexpected, however.

### *Determinants of Teff Sales and Purchases*

The nonlinear least-squares-regression results for teff sales and purchases are reported in Table 16. We were unable to estimate the model for purchases including the selectivity correction term and several explanatory variables (the model failed to converge), so these were dropped from this model. The fit of these regressions is fairly high, especially for purchases ($R^2 = 0.91$).

The only variable found to have a statistically significant impact in the sales regression was teff production. The coefficient of this variable (0.818) indicates that teff sellers consume less that 20 percent of each additional unit of teff production and sell more than 80 percent of additional production. This emphasizes the market orientation of teff sellers. Factors expected to affect household demand for teff (controlling for teff production), such as the size and composition of the household, have insignificant impacts. These findings suggest that the most effective way to increase teff commercialization by households who are already selling teff is to increase their productivity.

**Table 16. Determinants of teff sales and purchases, nonlinear least squares estimation**

| Variable | Sales | | Purchases (without selectivity correction)[a] | |
|---|---|---|---|---|
| | Coeff. | Std. error[b] | Coeff. | Std. error[b] |
| Teff production | 0.818*** | 0.301 | -0.176*** | 0.040 |
| Ln (market price of teff) | 0.585 | 108.078 | -8.971 | 47.138 |
| Ln (value of transportation assets) | | | | |
| Ln (dist to all weather road) | -0.087 | 17.291 | 21.517 | 14.038 |
| Ln (minimum distance to sales market) | -0.066 | 47.662 | | |
| Ln (number of traders known outside PA) | 0.154 | 63.400 | -3.526 | 12.748 |
| Member of a cooperative | -0.114 | 3337.688 | -28.445 | 147.928 |
| Ln (price of DAP) | 0.125 | 355.659 | -31.687 | 60.291 |
| Proportion of adults in household with primary activity (cf. crop producers) | | | | |
| - Livestock production | -0.343 | 95.898 | 99.737 | 79.333 |
| - Domestic activities | -1.104 | 230.593 | -15.989 | 43.255 |
| - Non-farm enterprise | | | | |
| Proportion of labor force (cf., men) | | | | |
| - Women | -1.119 | 153.921 | -19.720 | 92.244 |
| - Children | -1.106 | 166.491 | 107.412 | 75.056 |
| Male head of household | -0.235 | 45.359 | 22.582 | 30.003 |
| Ln (age of household head) | -0.547 | 77.264 | -103.95*** | 40.184 |
| Ln (total number of workers) | 0.371 | 19.092 | 57.280 | 45.157 |
| Ln (area of land operated) | 0.455 | 16.674 | 23.093 | 14.910 |
| Member of credit or savings institution | 0.075 | 91.388 | 28.896 | 28.657 |
| Primary or secondary education of women | -0.219 | 44.527 | 55.551 | 37.345 |
| Primary or secondary education of men | -0.379 | 180.319 | 20.890 | 38.880 |
| Land quality characteristics | | | | |
| Slope of land (cf., flat land) | | | | |
| - Proportion of land gently sloping | -0.327 | 31.128 | | |
| - Proportion. of land steeply sloping | 0.708 | 6530.796 | | |
| - Proportion of land with mixed slopes | -0.209 | 1.584E+06 | | |
| Soil quality | | | | |
| - Proportion of land with *lem* soil | -0.147 | 41.093 | 26.693 | 25.363 |
| - Proportion of land with *teuf* soil | -0.310 | 213.307 | -32.901 | 49.086 |
| Agroecology (altitude zone) | | | | |
| - Proportion of land in *dega* (high alt.) zone | -0.727 | 1.261E+05 | 53.816* | 30.428 |

**Table 16. Continued**

| Variable | Sales | | Purchases (without selectivity correction)[a] | |
|---|---|---|---|---|
| | Coeff. | Std. error[b] | Coeff. | Std. error[b] |
| - Proportion of land in *woina dega* (medium) | -0.147 | 101.174 | 20.262 | 29.628 |
| - Proportion of land with access to irrigation | | | | |
| - Proportion of land far from residence | 0.164 | 468.308 | -84.086 | 9.896E+06 |
| Other productive assets | | | | |
| Ln (value of livestock) | 0.107 | 1.479E+05 | -5.875 | 8.387 |
| Ln (value of equipment) | 0.445 | 82.088 | 12.324* | 6.987 |
| Region (cf., Tigray) | | | | |
| - Amhara | 1.469 | 216.622 | -14.932 | 40.023 |
| - Oromia | 1.528 | 235.361 | -1.519 | 31.449 |
| - SNNP | | | | |
| - Addis Ababa | 2.566 | 449.544 | | |
| Selectivity correction ($\sigma_s\rho_{ps}$) | -18.457 | 3.440E+10 | [a] | [a] |
| Intercept ($\delta_0$) | -0.359 | 444.688 | 211.459 | 270.492 |
| Number of observations | | 728 | | 102 |
| $R^2$ | | 0.3384 | | 0.9067 |

[a] Nonlinear least squares model for purchases failed to converge after 4000 iterations with selectivity correction included, so this parameter was dropped from the estimation.
[b] Based on 100 bootstrap replications.
*, **, *** mean the coefficient is statistically significant at the 10%, 5% or 1% levels, respectively.

For teff buyers, the factors significantly influencing the amount purchased include teff production (–), the age of the household head (–), the proportion of land in the *dega* zone (+, weakly significant), and value of equipment owned (+, weakly significant). The coefficient of teff production (–0.176) indicates that increased teff production by teff buyers has only limited impact on teff purchases; households consume more than 80 percent of an increase in production. This is consistent with the argument made above that teff buyers are poorer households facing severe food supply constraints; they consume nearly all of any increase in production..

The negative coefficient of age of household head is unexpected, since we expect older household heads to demand more teff because their wages or other sources of income are higher. The weak positive impact of higher elevation on teff purchases is inconsistent with the earlier finding that teff buyers in the *dega* zone produce more teff, but it is consistent with our expectation of lower productivity in this zone (and the production results for sellers and autarkic households). The (weakly significant) positive impact of value of equipment on purchases is inconsistent with our theoretical predictions (see Tables 1 and 2). We do not have any convincing explanations to offer for these inconsistencies, which may be simply a result of statistical errors.

## Econometric Results for Maize

In this section we discuss the econometric results for maize market position, production, sales, and purchases.

### *Determinants of Maize Market Position*

The determinants of maize market position are reported in Table 17. As for teff, the model accurately predicts the mean probabilities of each market position but is limited in its ability to discriminate different predicted probabilities for households taking different market positions. For example, the mean predicted probability of maize sales among maize sellers is only 0.27, while the predicted probability of maize sales is 0.14 for maize buyers and 0.20 for autarkic households.

**Table 17. Determinants of market position for maize, maximum likelihood estimation**

| | | | Marginal effects | | |
|---|---|---|---|---|---|
| **Variable** | **Coefficient** | **Std. Err.** | **P(seller)** | **P(buyer)** | **P(autarky)** |
| Sellers' transaction costs ($\beta_s$) | | | | | |
| Ln (value of transportation assets) | -0.047 | 0.036 | 0.008 | 0.023 | -0.031 |
| Ln (dist to all weather road) | 0.047** | 0.022 | -0.008 | -0.010 | 0.017 |
| Ln (minimum distance to sales market) | -0.034 | 0.038 | 0.006 | -0.023 | 0.017 |
| Ln (number of traders known outside PA) | -0.033 | 0.029 | 0.005 | -0.024 | 0.019 |
| Member of a cooperative | -0.227** | 0.115 | 0.037 | -0.122 | 0.085 |
| Constant ($\beta_{s0}$) | 1.336*** | 0.095 | | | |
| | | | | | |
| Buyers' transaction costs ($\beta_b$) | | | | | |
| Ln (value of transportation assets) | -0.034 | 0.037 | | | |
| Ln (dist to all weather road) | 0.014 | 0.021 | | | |
| Ln (minimum distance to sales market) | 0.033 | 0.034 | | | |
| Ln (number of traders known outside PA) | 0.035 | 0.026 | | | |
| Member of a cooperative | 0.181* | 0.110 | | | |
| | | | | | |
| Shadow price of maize ($\beta_p$) | | | | | |
| Ln (price of DAP) | -0.253 | 0.184 | 0.042 | -0.171 | 0.129 |
| Proportion of adults in household with primary activity (cf., proportion crop producers) | | | | | |
| - Livestock production | 0.245 | 0.180 | -0.041 | 0.166 | -0.125 |
| - Domestic activities | 0.223** | 0.108 | -0.037 | 0.151 | -0.114 |
| - Non-farm enterprise | 0.431* | 0.244 | -0.071 | 0.292 | -0.220 |
| Ln (total number of workers in household) | 0.147 | 0.108 | -0.024 | 0.100 | -0.075 |
| Proportion of labor force (cf., men) | | | | | |

**Table 17. Continued**

| Variable | Coefficient | Std. Err. | Marginal effects P(seller) | P(buyer) | P(autarky) |
|---|---|---|---|---|---|
| - Women | 0.154 | 0.168 | -0.025 | 0.104 | -0.079 |
| - Children | 0.088 | 0.176 | -0.015 | 0.059 | -0.045 |
| Male head of household | 0.080 | 0.085 | -0.013 | 0.054 | -0.041 |
| Ln (age of household head) | 0.265*** | 0.084 | -0.044 | 0.179 | -0.135 |
| Primary or secondary education of women | -0.048 | 0.095 | 0.008 | -0.032 | 0.024 |
| Primary or secondary education of men | 0.050 | 0.085 | -0.008 | 0.034 | -0.025 |
| Ln (area of land operated) | -0.301*** | 0.037 | 0.050 | -0.204 | 0.154 |
| Land quality characteristics | | | | | |
| Slope of land (cf., flat land) | | | | | |
| - Proportion of land gently sloping | 0.001 | 0.072 | 0.000 | 0.001 | -0.001 |
| - Proportion of land steeply sloping | 0.248 | 0.165 | -0.041 | 0.168 | -0.127 |
| - Proportion of land with mixed slopes | 0.209 | 0.142 | -0.035 | 0.141 | -0.107 |
| Soil quality | | | | | |
| - Proportion of land with *lem* soil | -0.181*** | 0.067 | 0.030 | -0.123 | 0.093 |
| - Proportion of land with *teuf* soil | 0.664*** | 0.133 | -0.110 | 0.449 | -0.339 |
| Agroecology (altitude zone) | | | | | |
| - Proportion of land in *dega* (high alt.) zone | -0.014 | 0.093 | 0.002 | -0.009 | 0.007 |
| - Proportion of land in *woina dega* (medium alt.) | -0.076 | 0.068 | 0.013 | -0.052 | 0.039 |
| Proportion of land with access to irrigation | 0.750*** | 0.254 | -0.124 | 0.507 | -0.383 |
| Proportion of land far from residence | -0.045 | 0.162 | 0.007 | -0.030 | 0.023 |
| Other productive assets | | | | | |
| Ln (value of livestock) | -0.025* | 0.014 | 0.004 | -0.017 | 0.013 |
| Ln (value of equipment) | -0.039 | 0.027 | 0.006 | -0.026 | 0.020 |
| Member of credit or savings institution | 0.095* | 0.056 | -0.016 | 0.064 | -0.049 |
| Region (cf., Tigray) | | | | | |
| - Amhara | -0.354** | 0.161 | 0.059 | -0.240 | 0.181 |
| - Oromia | 0.016 | 0.155 | -0.003 | 0.011 | -0.008 |
| - SNNP | 0.093 | 0.158 | -0.015 | 0.063 | -0.048 |
| Constant ($\beta_{p0}$) | -1.062** | 0.422 | | | |
| $\sigma_p$ | NE | NE | | | |
| Number of observations | 2072 | | 383 | 714 | 975 |
| Proportion of observations | | | 0.1930 | 0.3341 | 0.4729 |
| Mean predicted probability (entire estimation sample) | | | 0.1925 | 0.3327 | 0.4748 |
| Mean predicted probability (selling households) | | | 0.2707 | 0.2419 | 0.4874 |
| Mean predicted probability (buying households) | | | 0.1414 | 0.4035 | 0.4551 |
| Mean predicted probability (autarkic households) | | | 0.1966 | 0.3198 | 0.4836 |

*, **, *** mean the coefficient is statistically significant at 10%, 5% or 1% levels, respectively.

The factors found to affect sellers' transaction costs, statistically significant at the 5 percent level, include distance to an all-weather road (+) and membership in a cooperative (–). These results are as hypothesized. Membership in a cooperative has an unexpected positive effect on buyers' transaction costs, although this coefficient is only weakly statistically significant (10 percent level).

The factors that significantly affect the shadow price of maize (at the 5 percent level or better) include the importance of domestic activities in household labor allocation (+), age of the household head (+), area of land operated (–), soil quality (– for *lem* soil, + for *teuf* soil), access to irrigation (+), and region (lower in Amhara than Tigray). Variables that have weakly significant impacts (at the 10 percent level) on the shadow price include involvement in nonfarm activities (+), value of livestock owned (–), and membership in a savings or credit institution (+). Many of these results are similar to the results for teff, with factors that increase production potential such as land area operated, better quality soil, more livestock owned, and higher rainfall (which is higher in Amhara than Tigray) contributing to a lower maize shadow price, while factors reflecting labor constraints and higher labor opportunity costs, such as the importance of domestic or nonfarm activities and the age of the household head contributing to a higher shadow price.

The positive coefficient for access to irrigation is a surprise, since we expected irrigation to increase maize productivity. This result could be due to use of irrigation for other higher-value crops, rather than for maize, which could lead to lower maize production among households with access to irrigation, or it could be that households with access to irrigation have a higher demand for maize, as a result of their increased income from irrigating high-value crops. The positive coefficient for membership in a credit or savings institution is also unexpected, but could arise for similar reasons (that is, credit access may facilitate production of other crops of higher value than maize or other economic activities, increasing maize demand by increasing income). We investigate these issues further in the next section, in which we estimate the determinants of maize production.

Considering the marginal effects shown in Table 17, we predict that being 1 percent farther from an all-weather road reduces the probability of a household (at the mean of the data) being a maize seller by 0.00008 and being a maize buyer by 0.00010, while increasing the probability of being autarkic by 0.00017. Being a member of a cooperative is associated with a 0.037 higher probability of being a maize seller, a 0.085 higher probability of being autarkic in maize, and 0.122 lower probability of being a maize buyer. Having 1 percent more land increases the probability of being a maize seller by 0.0005 and the probability of being autarkic by 0.0015, while reducing the probability of being a buyer by 0.0020. Access to irrigation increases the probability of being a maize buyer by 0.507, while reducing the probability of being autarkic by 0.383 and the probability of being a seller by 0.124.

These results suggest that improved access to roads, cooperatives, land, and livestock will tend to increase smallholders' involvement in selling maize, although the impacts are likely to be relatively small without large changes in access to these assets and organizations. In contrast, increased access to irrigation may substantially reduce the likelihood of households selling maize by increasing production of higher-value commodities or households' demand for maize.

### *Determinants of Maize Production*

The determinants of maize production for sellers, buyers, and autarkic households are reported in Table 18. The fit of the models ranges from $R^2$ = 0.21 for autarkic households to 0.39 for sellers. The selectivity correction is significant only in the production model for autarkic households.

**Table 18. Determinants of maize production, dependent variable ln(maize production)**

| Variable | Sellers | | Buyers | | Autarkic | |
|---|---|---|---|---|---|---|
| | Coefficient | Std. Err.[a] | Coefficient | Std. Err.[a] | Coefficient | Std. Err.[a] |
| Ln (market price of maize) | 0.421** | 0.182 | 0.143 | 0.162 | | |
| Ln (value of transportation assets) | 0.093 | 0.149 | 0.025 | 0.077 | | |
| Ln (dist to all weather road) | -0.087 | 0.118 | -0.077* | 0.045 | | |
| Ln (minimum distance to sales market) | 0.245** | 0.115 | -0.181** | 0.074 | | |
| Ln (number of traders known outside PA) | 0.078 | 0.096 | 0.046 | 0.061 | | |
| Member of a cooperative | 0.494 | 0.478 | -0.008 | 0.336 | | |
| Ln (price of DAP) | 0.205 | 0.893 | -0.213 | 0.496 | -0.406 | 0.385 |
| Proportion of adults in household with primary activity (cf. crop producers) | | | | | | |
| - Livestock production | -0.450 | 0.755 | 0.542 | 0.489 | 0.639* | 0.366 |
| - Domestic activities | -0.489 | 0.517 | 0.051 | 0.363 | 0.289 | 0.242 |
| - Non-farm enterprise | -0.678 | 1.351 | 0.524 | 0.599 | 0.437 | 0.654 |
| Proportion of labor force (cf., men) | | | | | | |
| - Women | -0.347 | 0.614 | 0.563 | 0.460 | 0.183 | 0.391 |
| - Children | -0.288 | 0.600 | 0.892** | 0.394 | 0.272 | 0.384 |
| Male head of household | -0.068 | 0.294 | -0.060 | 0.223 | 0.092 | 0.186 |
| Ln (age of household head) | -0.541 | 0.499 | -0.419 | 0.381 | 0.511** | 0.219 |
| Ln (total number of workers) | -0.075 | 0.333 | 0.282 | 0.296 | 0.189 | 0.264 |
| Ln (area of land operated) | 0.693 | 0.580 | 0.311 | 0.404 | -0.239 | 0.196 |
| Member of credit or savings institution | 0.242 | 0.232 | 0.019 | 0.188 | 0.220** | 0.110 |
| Primary or secondary education of women | 0.155 | 0.340 | -0.603*** | 0.226 | 0.252 | 0.200 |
| Primary or secondary education of men | 0.043 | 0.281 | -0.100 | 0.202 | 0.141 | 0.158 |
| Land quality characteristics | | | | | | |
| Slope of land (cf., flat land) | | | | | | |
| - Proportion of land gently sloping | -0.635*** | 0.199 | -0.323* | 0.182 | -0.228 | 0.167 |

**Table 18. Continued**

| Variable | Sellers | | Buyers | | Autarkic | |
|---|---|---|---|---|---|---|
| | Coefficient | Std. Err.[a] | Coefficient | Std. Err.[a] | Coefficient | Std. Err.[a] |
| - Proportion of land steeply sloping | -0.312 | 0.792 | -0.384 | 0.475 | 0.524 | 0.338 |
| - Proportion of land with mixed slopes | -0.012 | 0.871 | 0.025 | 0.422 | 0.319 | 0.359 |
| Soil quality | | | | | | |
| - Proportion of land with *lem* soil | 0.081 | 0.354 | 0.254 | 0.257 | 0.191 | 0.161 |
| - Proportion of land with *teuf* soil | -1.856 | 1.313 | -0.088 | 0.787 | 0.826* | 0.486 |
| Agroecology (altitude zone) | | | | | | |
| - Proportion of land in *dega* (high alt.) zone | -0.350 | 0.252 | -0.967*** | 0.220 | -0.522*** | 0.168 |
| - Proportion of land in *woina dega* (medium) | -0.043 | 0.233 | -0.026 | 0.186 | -0.065 | 0.130 |
| Proportion of land with access to irrigation | -0.597 | 1.676 | 0.193 | 1.090 | 0.328 | 0.609 |
| Proportion of land far from residence | -0.172 | 0.528 | -0.274 | 0.420 | 0.272 | 0.342 |
| Other productive assets | | | | | | |
| Ln (value of livestock) | 0.052 | 0.062 | 0.028 | 0.041 | -0.018 | 0.031 |
| Ln (value of equipment) | 0.105 | 0.098 | 0.190** | 0.085 | 0.178*** | 0.063 |
| Region (cf., Tigray) | | | | | | |
| - Amhara | 0.896 | 0.860 | 0.549 | 0.767 | -0.481 | 0.348 |
| - Oromia | 0.517 | 0.609 | 1.656*** | 0.391 | 0.594** | 0.261 |
| - SNNP | 0.167 | 0.634 | 1.512*** | 0.346 | 0.554* | 0.285 |
| Selectivity correction | -1.969 | 2.380 | -0.055 | 1.898 | -1.806*** | 0.695 |
| Intercept | 2.177 | 2.960 | 3.615 | 3.138 | 2.263** | 0.926 |
| Number of observations | 383 | | 714 | | 975 | |
| $R^2$ | 0.3938 | | 0.3162 | | 0.2085 | |

[a] Based on 100 bootstrap replications.
*, **, *** mean the coefficient is statistically significant at 10%, 5% or 1% levels, respectively

For maize sellers, the factors that statistically significantly influence production include the maize market price (+), distance to the nearest market (+), and proportion of land that is gently sloping (–, compared to flat land). For maize buyers, the significant factors include distance to the nearest market (–) or all-weather road (—, weakly significant at the 10 percent level), the proportion of children in the household labor force (+), education of women in the household (–), proportion of land that is gently sloping (–, weakly significant), proportion of land in the *dega* zone (–), the value of equipment (+), and the region (higher in Oromia and SNNP than in Tigray). For autarkic households, significant factors include household involvement in livestock production (+, weakly significant), age of household head (+), membership in a credit or savings institution (+), proportion of land with *teuf* soil (+, weakly significant), proportion of land in the *dega* zone (–), the value of equipment owned (+), and the region (higher in Oromia and SNNP than in Tigray).

Several factors have similar qualitative impacts on maize production by households taking different market positions. Sloping land has a negative impact on maize produced by buyers and sellers, high elevation *dega* land lowers production by both buyers and autarkic households, equipment has a positive impact on production by both buyers and autarkic households, and production is higher in Oromia and SNNP than in Tigray for both buyers and autarkic households. These results are consistent with our expectations.

Some factors have a significant influence only on households with a particular market position. For example, the maize price has a significant positive impact on production by sellers but not by buyers (although the coefficient is also positive as expected for buyers). For maize buyers, the proportion of children in the household has a positive impact on production, while education of women has a negative impact. For autarkic households, the age of the household head and membership in a credit or savings institution are associated with greater maize production. None of these findings is inconsistent with the theory, but it is not clear why these factors have different impacts on households taking different market positions.

Some findings are inconsistent with the theory: (1) that maize sellers produce more and maize buyers produce less the farther they are from a market and (2) that buyers produce less the farther they are from a road. According to the theory presented earlier, we expected that factors that increase transaction costs such as distance to markets and roads would reduce sellers' production incentives while increasing buyers' production incentives. Further research is necessary to investigate the robustness of such unexpected findings, and if they are robust, to explain them.

Relative to the unexpected negative impact of access to irrigation on the shadow price of maize, discussed in the previous section, we find no evidence that irrigation access has a significant impact on maize production. Thus, it appears that if access to irrigation is increasing the shadow price of maize, it must be doing so through demand-side impacts (by increasing household incomes and hence the demand for maize) rather than by directly affecting maize production. Similarly, the positive impact of membership in a credit or savings institution on maize production by autarkic households does not explain why such membership has a (weakly) significant positive impact on the maize shadow price, but again this could be due to the demand-increasing effects of credit access. Further consideration of such demand-side effects, using the regressions for maize sales and purchases (which control for the level of production), is presented in the next section.

*Determinants of Maize Sales And Purchases*

The determinants of maize sales and purchases are reported in Table 19. Neither model fits the data particularly well, especially the model for maize purchases. Nevertheless, several factors are found to have statistically significant impacts in that model.

**Table 19. Determinants of maize sales and purchases, nonlinear least squares estimation**

| Variable | Sales | | Purchases | |
|---|---|---|---|---|
| | Coeff. | Std. error[a] | Coeff. | Std. error[a] |
| Maize production | 0.332*** | 0.030 | -0.217*** | 0.038 |
| Ln (market price of maize) | 1.2 | 21.9 | 165.9* | 88.5 |
| Ln (value of transportation assets) | -8.4 | 16.0 | 422.1 | 7659796.0 |
| Ln (dist to all weather road) | 7.9 | 11.4 | -468.0** | 189.5 |
| Ln (minimum distance to sales market) | -6.8 | 17.4 | 233.7* | 133.4 |
| Ln (number of traders known outside PA) | -6.2 | 8.8 | 310.8** | 135.7 |
| Member of a cooperative | -30.2 | 55.0 | 2173.0** | 894.2 |
| Ln (price of DAP) | -33.3 | 60.9 | 2502.3** | 1036.0 |
| Proportion of adults in household with primary activity (cf. crop producers) | | | | |
| - Livestock production | 56.9 | 86.9 | -2400.0** | 1057.5 |
| - Domestic activities | 48.8 | 88.7 | -2407.8*** | 940.6 |
| - Nonfarm enterprise | 73.1 | 1188.9 | -3516.7** | 1581.4 |
| Proportion of labor force (cf., men) | | | | |
| - Women | 9.7 | 71.2 | -1588.6** | 638.6 |
| - Children | -3.2 | 65.0 | -640.3 | 407.6 |
| Male head of household | -1.1 | 37.2 | -805.1** | 340.3 |
| Ln(age of household head) | 33.9 | 66.2 | -2730.2** | 1076.0 |
| Ln(total number of workers) | 38.2 | 50.6 | -1504.1** | 610.0 |
| Ln(area of land operated) | -42.9 | 64.9 | 2982.2** | 1206.2 |
| Member of credit or savings institution | 21.9 | 18.7 | -895.2** | 406.0 |
| Primary or secondary education of women | -3.4 | 30.1 | 264.7 | 205.8 |
| Primary or secondary education of men | 6.4 | 27.3 | -611.8** | 242.3 |
| Land quality characteristics | | | | |
| Slope of land (cf., flat land) | | | | |
| - Proportion of land gently sloping | -11.0 | 25.9 | 69.3 | 74.2 |
| - Proportion of land steeply sloping | 34.4 | 73.3 | -2455.5 | 2854.4 |
| - Proportion of land with mixed slopes | 36.1 | 83.6 | -2334.8*** | 898.1 |
| Soil quality | | | | |
| - Proportion of land with *lem* soil | -27.7 | 32.4 | 1881.5** | 747.7 |
| - Proportion of land with *teuf* soil | 101.5 | 150.2 | -6634.3** | 2665.1 |

**Table 19. Continued**

| Variable | Sales | | Purchases | |
|---|---|---|---|---|
| | Coeff. | Std. error[a] | Coeff. | Std. error[a] |
| Agroecology (altitude zone) | | | | |
| - Prop. of land in *dega* (high alt.) zone | -8.4 | 32.8 | 265.8* | 155.8 |
| - Prop. of land in *woina dega* (medium) | -14.1 | 47.1 | 760.9** | 320.4 |
| Prop. of land with access to irrigation | 182.8 | 188.4 | -6970.9** | 3084.7 |
| Prop. of land far from residence | -0.7 | 58.1 | 564.0 | 522.9 |
| Other productive assets | | | | |
| Ln(value of livestock) | -4.9 | 5.1 | 253.1*** | 96.9 |
| Ln(value of equipment) | -4.6 | 11.6 | 414.4** | 169.2 |
| Region (cf., Tigray) | | | | |
| - Amhara | -63.3 | 63.5 | 3400.6** | 1421.3 |
| - Oromia | -13.3 | 62.8 | -55.8 | 134.3 |
| - SNNP | 5.3 | 3241.0 | -600.4 | 372.4 |
| Selectivity correction ($\sigma_s\rho_{ps}$) | 200.5 | 256.1 | -12329.1** | 4867.0 |
| Intercept ($\delta_0$) | 227.3 | 289.2 | -11995.3** | 5247.6 |
| Number of observations | 383 | | 714 | |
| $R^2$ | 0.1967 | | -0.0301 | |

[a] Based on 100 bootstrap replications.
*, **, *** mean the coefficient is statistically significant at 10%, 5%, or 1% levels, respectively.

As with the model for teff sales (Table 16), the only factor having a statistically significant impact on maize sales is maize production. The coefficient of maize production (0.332) in this model indicates that an increase in maize production results in an increase of only one-third of that amount in maize sales by maize-selling households. This suggests that maize production is a large component of the income of such households and that an increase in production substantially increases maize demand.

An increase in maize production by maize-buying households results in a reduction of maize purchases of only 22 percent of the increase in production, again reflecting increased demand for maize as a result of increased maize production and income. Other factors significantly affecting maize purchases include the distance to the nearest all-weather road (–), the number of traders known outside the PA (+), membership in a cooperative (+), the price of DAP (+), the importance of occupations other than crop production (–), the proportion of women in the household's labor force (–), male head of household (–), the age of the household head (–), the number of adult workers in the household (–), the area of land operated (+), ownership of livestock (+) and equipment (+), membership in a credit or savings institution (–), education of men in the household (–), the proportion of land with mixed slopes (–), the proportion of land with different soil types (+ for *lem* soil, – for *teuf* soil), the altitude zone (+ in the medium-altitude *woina dega* zone relative to lower-altitude zones), access to irrigation (–), and the region (greater in Amhara than in Tigray).

Most of these results are consistent with the predictions of our theoretical model. For example, greater ownership of land, livestock, and equipment all contribute to greater maize purchases by increasing maize demand, controlling for the level of production; while a larger proportion of women in the labor force (likely associated with lower income) is associated with lower maize purchases.[32] A higher price of DAP is associated with greater maize purchases, consistent with the theoretical prediction discussed in section 2 (if the demand for fertilizer is sufficiently price elastic) (see Table 1). Lower maize purchases by households pursuing primary activities other than crop production may be due in part to differences in income (if such households earn lower incomes, which may be particularly true for households in which domestic activities are more important), or differences in consumption preferences by households with different livelihood strategies (may be particularly true for pastoralist livestock producers and households specializing in nonfarm activities). Some factors likely influence maize purchases by affecting transaction costs; for example, being closer to an all-weather road, knowing more traders, or being a member of a cooperative all may increase maize purchases by reducing costs of buying maize.

The effects of some factors are not consistent with the unconstrained credit model but could be consistent with the model with binding credit constraints. For example, we find that a larger household labor supply is associated with lower maize purchases, which contradicts the predictions of the theoretical model with unconstrained borrowing, as shown in Table 1, but it could be consistent with the model with a binding credit constraint (in which such impacts are ambiguous), as shown in Table 2. The negative impacts of male head of household and male education on maize purchases are also not consistent with the unconstrained-borrowing model, assuming that these factors contribute to higher income, but could be consistent with the more ambiguous predictions of the credit-constrained model in Table 2. The negative impact of membership in a credit or savings institution on purchases also could be consistent with the credit-constrained model, assuming that membership in such organizations increases access to credit (see the ambiguous impact of credit constraint on purchases in Table 2).

The negative impact of access to irrigation on maize purchases (controlling for production level) is not consistent with the predictions of our theoretical model, since access to additional productive assets is expected to increase income and hence consumption demand. This is also not consistent with our findings in Table 17 showing a positive impact of access to irrigation on the shadow price of maize (which we explained as possibly due to demand-increasing effects of irrigation access). We do not have an explanation for this puzzling finding.

[32] Although Tables 1 and 2 show that increasing $K$ is predicted to reduce purchases by food buyers, this is the total effect of the increase in $K$, allowing production to increase. In our regression results, we are controlling for the level of production, so the effects on purchases of increasing productive assets in these results are via the impacts on food demand.

# 6. CONCLUSIONS AND IMPLICATIONS

In this paper we have developed a theoretical farm household model of food crop production and marketing decisions, derived testable hypotheses concerning the determinants of these decisions, and tested these hypotheses using data on cereal production and marketing collected from a nationally representative household survey in Ethiopia.

The household model predicts the standard results of three market regimes in the presence of variable transaction costs (sellers, buyers, and autarkic households); that reduction in transaction costs increases the likelihood of participation in markets and improves the welfare of both sellers and buyers. The model predicts that a change in market prices has opposite effects on the welfare of sellers versus buyers, but no impact on autarkic households' welfare, unless the change is large enough to induce them to participate in markets (in which case formerly autarkic households' welfare increases, regardless of whether they become sellers or buyers). The model also predicts that a change in variable transaction costs has opposite impacts on the production incentives of food sellers versus buyers, with a transaction cost decrease increasing sellers' incentive to produce but reducing buyers' production incentive.

The effects of other factors influencing the household supply and demand for food are also predicted by the theory. For example, endowments of productive quasi-fixed assets such as land, livestock, and equipment are predicted to increase production and the probability and level of food sales by reducing the shadow price of food, while higher prices of inputs and higher wage levels are predicted to reduce production and sales if credit constraints are not binding. Higher input prices and wages have different predicted impacts on consumption and welfare, however, if households are buyers of inputs but net sellers of labor (as is common in Ethiopia). Other demand related factors, such as the household's labor endowment and exogenous income are not expected to influence production by market participants, if credit constraints are not binding and the labor market functions perfectly, but increases in these factors are expected to increase production and consumption by autarkic households by inducing an increase in the shadow price of food. The impacts of most factors are more ambiguous if credit is constrained or other markets operate imperfectly (such as the labor market), especially for autarkic households.

The predictions of the theory demonstrate that the factors that increase commercialization do not necessarily increase smallholders' crop production or welfare, and vice versa. For example, an increase in the market price increases production and sales by sellers but reduces welfare of buyers, and investments in infrastructure or development of market institutions that reduce transaction costs will increase production by food crop sellers but reduce production by food crop buyers, as noted above. Similarly, lower wage levels tend to promote greater crop production and sales, due to lower costs and lower household demand, but they also reduce the welfare of households who are net labor sellers. Hence, if improving the welfare of rural households is of primary concern, promoting commercialization may not always be the most effective way to achieve this, and having too narrow a focus on promoting commercialization could be counterproductive. The implications of particular approaches to promoting commercialization and trade-offs between the objectives of increasing commercialization and improving household welfare should be considered.

The evidence from the household survey indicating that households hold different market positions for teff and maize, the two most important crops for smallholders in Ethiopia, leads to some important policy-relevant implications. We find that most producers of teff and maize are either autarkic or net buyers of these crops, rather than net sellers (net buying is especially common for maize), and that these households are poorer, in many respects, than net sellers. The welfare of both net buyers and autarkic households is improved by increases in food productivity and net buyers benefit from reduced food prices, while the welfare of autarkic households is either unaffected by price decreases or improved if the price decrease is enough to induce them to become net buyers. Therefore, the distributional impacts of policies to promote increased cereal production and reduced prices are generally favorable, although some net sellers may lose as a result. Coupling this favorable distributional impact with the efficiency and economic growth-enhancing impacts of productivity increases strongly supports continued efforts to improve foodcrop productivity in Ethiopia.

Several factors, supported by the theoretical and econometric results of this study, contribute to increased production and sales of teff and maize. Improvements in smallholders' access to roads, land, livestock, farm equipment, and social connections with traders were all found to increase production of teff and the probability of being a teff seller. Increased teff production was the only factor found to significantly increase the level of teff sales by teff sellers. Similarly, improved access to roads, land area and quality, and livestock increase the likelihood of maize selling. Maize production is the only factor significantly increasing maize sales. These results are consistent with the hypotheses and indicate the importance of continued investments in productive infrastructure, assets, and other factors contributing to improved cereal productivity, if the government of Ethiopia is to be successful in promoting greater commercialization of food crops.

Not all of our empirical results are consistent with our theoretical hypotheses (especially for the model with unconstrained borrowing and a perfect labor market). For example, several factors had different and unexpected impacts on teff production by teff buyers than on production by teff sellers; including the price of teff, the gender and age of the household head, ownership of farm equipment, altitude, and the region. Although the model predicts that factors affecting transaction costs will have different impacts on sellers' and buyers' production incentives, most of these factors are not clearly related to transaction costs. It may be that teff buyers, who may be poorer and more likely to have binding credit constraints, are more concerned about risk than teff sellers. For example, this could account for the negative association between teff price and production by teff buyers, since a higher price implies a reduction in real income for teff buyers, which could inhibit their ability or willingness to purchase inputs for teff production. Concerns about food insecurity could also cause teff-buying households in Tigray, where rainfall is lower and more uncertain than in other regions, or households living at higher elevations, to produce more teff than comparable households in other regions, despite lower productivity in these areas.

We also found, contrary to our expectations, that access to irrigation is associated with a higher shadow price of maize and that maize sellers produce more the farther they are from a market, while maize buyers produce more the closer they are to a market. Some of these unexpected findings may result from the effects of access to irrigation and markets on other agricultural crops besides maize and other livelihood options. For example, access to irrigation may increase households' income via increased production of higher-value commodities or higher labor demand and wage levels, hence increasing households' demand and the shadow price of maize. Farmers farther from an urban market may have a comparative advantage in producing and selling maize relative to high-value perishable crops; hence maize sellers who are farther from an urban market may devote more of their land to maize and thus produce more. It is less clear why maize production by maize buyers would decline with distance from markets.

Further research is needed to assess these and alternative explanations for such unexpected findings. Incorporating the effects of risk, imperfections in labor markets, and alternative crops and land uses would be useful directions to take in generalizing the theoretical models developed here and explaining the empirical findings. Nevertheless, the finding that several factors can have differential impacts on production by households taking different market positions is an important result, demonstrating that targeted approaches taking such differences in to account are needed to promote food crop production and commercialization among smallholders in Ethiopia.

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