The Welfare Impacts of Price Stabilization: Evidence from Rural Ethiopian Households*

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Abstract

Many governments have tried to stabilize staple commodity prices based on the widespread belief that households, especially the poor, value price stability. We extend the existing microeconomic literature to derive an estimable matrix of coefficients of price risk aversion and associated willingness to pay measures over multiple commodities. Using longitudinal household-level data from rural Ethiopia, we then estimate that the average household would be willing to pay a statistically significant share of its income to stabilize at their means the prices of the eight most important commodities in household budgets. We further show that the welfare gains from price stabilization would be concentrated in the upper half of the income distribution.

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1. Introduction

Throughout history and all over the world, governments have treated commodity price stability as a policy objective. Commodity price volatility over the past three years has rekindled widespread government interest in the use of any of a host of policy instruments – from buffer stocks to administrative pricing to variable tariffs to marketing boards – to stabilize the prices of food and energy commodities in particular. State intervention with respect to domestic staples prices commonly arises because households are widely believed to value price stability, because the poor are widely perceived to suffer disproportionately from food price instability, and because futures and options markets for hedging against price risk are commonly unavailable to consumers and poor producers given the minimum scale of transactions required by the relevant exchanges (Newbery, 1989; Timmer, 1989). Given the policy importance of the topic, and even though economists have commonly questioned the net economic benefit of government price stabilization interventions (Newbery and Stiglitz, 1981; Krueger et al., 1988; Knudsen and Nash, 1990), the theoretical and empirical toolkit for understanding how household welfare is affected by price fluctuations seems limited and somewhat dated.

The effects of price fluctuations (or price risk) on producer behavior and welfare have been well-explored in the theoretical literature. Output price uncertainty generally causes firms to employ fewer inputs, foregoing expected profits as a hedge against price fluctuations (Baron, 1970; Sandmo, 1971). The analysis of commodity price fluctuations has been extended theoretically to individual consumers (Deschamps, 1973; Hanoch, 1977; Turnovsky et al., 1980; Newbery and Stiglitz, 1981; Newbery, 1989) and to agricultural households both theoretically (Finkelshtain and Chalfant, 1991 and 1997) and empirically (Barrett, 1996). These analyses have, however, focused largely on a single staple commodity, and although Turnovsky et al. (1980) did consider the price fluctuations of multiple commodities, they did so only theoretically. Given that indirect utility functions – the usual measure of welfare in microeconomic theory – are defined over both income and a vector of prices, the literature's heavy focus on income risk, at most extended to a single stochastic price, paints a very incomplete picture of attitudes to risk.

The central contribution of this paper is thus to combine the empirical framework of Finkelshtain and Chalfant (1991, 1997) and Barrett (1996) and the theoretical framework of Turnovsky et al. (1980) to derive an estimable matrix of coefficients of price risk aversion and associated willingness to pay (WTP) measures for price stabilization over multiple commodities, and then to demonstrate the empirical implications of the theory as it applies to rural Ethiopian households that both produce and consume several commodities characterized by stochastic prices.

The matrix of price risk aversion coefficients we derive and estimate reflects price risk premia with respect to the covariance matrix of prices faced by the household, yielding not only the usual own-price risk aversion coefficients on the diagonal (i.e., the effect of price variance on household welfare), but also the off-diagonal cross-price risk aversion coefficients (i.e., the effect of the price covariances on household welfare). To the best of our knowledge, these off-diagonal terms have so far been overlooked in the literature, although they have an intuitive interpretation and are necessary to understanding behavior and welfare with respect to multivariate price risk. Indeed, even when focusing on price risk for a single commodity, ignoring cross-price risk aversion coefficients leads to biased estimates of the effect of the price risk, given that staple prices rarely fluctuate independently of one another. Based on the matrix of price risk aversion coefficients, we then derive formulae for the household's WTP to stabilize both the price of individual commodities and the prices of a set of commodities.

Using data from a panel of Ethiopian households, we then estimate the matrix of price risk aversion, find empirical support for the theory, and compute WTP estimates. These estimates show that, assuming a standard Arrow-Pratt coefficient of relative risk aversion in the population equal to 2, households are willing to give up 34 percent of their income to stabilize the price of the eight most important commodities in the sample (i.e., maize, coffee, barley, cooking oil, teff, wheat, and beans). Nonparametric regression analysis indicates that, contrary to conventional wisdom, the welfare gains of price stabilization would accrue to upper half of the income distribution in these data.

The rest of this paper is organized as follows. Based on the theoretical work of Turnovsky et al. (1980) we extend Barrett's (1996) empirical approach to the estimation of price risk aversion coefficients to the multiple commodity case. We then derive the matrix of price risk aversion as well as its properties in section 2. In section 3, we present the data. We then develop a reduced form empirical framework to estimate the matrix of price risk aversion coefficients and discuss identification in section 4. In section 5 we estimate own- and cross-price risk aversion coefficients, construct the matrix of price risk aversion coefficients, test the restrictions of the theory by progressively imposing more structure as a way of conducting robustness checks, and compute and analyzehousehold willingness to pay estimates for price stabilization. We conclude by discussing the research and policy implications of our findings in section 6.

2. Theoretical Framework

This section develops a simple two-period agricultural household model (AHM) and derives the household's matrix of own- and cross-price risk aversion coefficients for the multiple commodity case. This is the most parsimonious model possible, as we need a framework that encompasses both consumer and producer behavior – hence the AHM – while an interest in price instability requires, at a minimum, a two period model, with at least one period in which agents make decisions subject to uncertainty with respect to prices, both in levels and in relation to incomes and other prices. We then derive some key properties of the price risk aversion matrix and relate it to the Slutsky matrix, which yields implications that we test in section 5. Lastly, and more importantly, we analytically derive measures of household willingness to pay to stabilize the prices of one or more commodities.

2.1 Agricultural Household Model

The derivations in this section closely follow those in Barrett (1996), who in turn builds on Turnovsky et al.'s (1980) work on individual consumers and Finkelshtain and Chalfant's (1991) work on price risk in the context of the AHM. In what follows in this subsection, we report the basics of the model. Readers interested in more detailed explanations and derivations of these findings should consult those prior works.

Consider an agricultural household whose preferences are represented by a von Neumann-Morgenstern utility function $U(\cdot)$ defined over consumption of a vector $c_o = (c_{o1}, c_{o2}, ..., c_{oK})$ of all goods whose consumption and/or production is observed by the econometrician; a composite c_u of all goods whose consumption and/or production is unobserved by the econometrician, and leisure ℓ. Assume function $U(\cdot)$ is quasiconcave but concave in each of its arguments, and that the Inada condition $\frac{\partial U}{\partial x}\Big|_{x=0} = \infty$ applies with respect to each argument *x*. All *K* observed goods and the unobserved good can, in principle, be produced or consumed by the household, which draws on its endowments of labor time and land and an exogenously given production technology defined over land, labor and a composite of other variable inputs. The household faces the usual cash and time budget constraints and may receive some unearned income.

The household maximizes its welfare over two periods, making production decisions in the first period, when all product prices are unknown but input prices *z* are known. While Turnovsky (1978) noted how different qualitative results obtain depending on whether price uncertainty arises due to an additive or multiplicative error term, our framework allows us to assume nothing about the shape of price uncertainty and let the data speak for themselves.

By Epstein's (1975) duality result, we can use the household's expected indirect utility function $V(\cdot)$, which is homogeneous of degree zero in prices and income, to solve the household's optimization problem. We thus set the price of the unobserved commodity as numéraire. Lastly, we assume that the household is (income) risk-averse, in the sense that $\frac{\partial^2 V}{\partial y^2} = V_{yy} < 0$, where *y* represents household total income.

Using the household's expected indirect utility function, Barrett (1996) then solves the household's maximization problem and derives an expression of household price risk aversion in the case of a single commodity. We now extend that framework to the case of multiple commodities whose prices are stochastic and derive the household's matrix of own- and cross-price risk aversion coefficients.

2.2 Price Risk Aversion over Multiple Commodities

Let $V(p, y)$ denote the household's indirect utility function. The vector $p = (p_1,..., p_K)$ is the vector of commodity prices faced by the household over the observed commodities, while the scalar y denotes household income. Let p_i denote the price of commodity *i* and p_j denote the price of commodity *j*, without any loss of generality. We know from Barrett (1996) that

$$\text{sign}[Cov(V_y, p_i)] = \text{sign}(V_{yp_i}) . \qquad (1)$$

Moreover, let $M_i = s_i(z, p) - x_i(p, y) = M_i(z, p, y)$ be the marketable surplus of commodity *i*, where $s_i(\cdot)$ is the household supply of commodity *i*, which depends on input and commodity prices, and $x_i(\cdot)$ is its Marshallian demand for commodity *i*, which depends on commodity prices and income. By Roy's identity, i.e., $M_i = -\frac{\partial V / \partial p_i}{\partial V / \partial y}$,[5] we have that

$$V_y = -\frac{V_{p_i}}{M_i} = -\frac{V_{p_j}}{M_j}, \qquad (2)$$

where M_j is the marketable surplus of commodity *j*. Additionally,

$$V_{yp_j} = \left(\frac{V_{p_i p_j}}{M_i} - \frac{V_{p_i}}{M_i^2} \frac{\partial M_i}{\partial p_j} \right) = \frac{1}{M_i} \left\{ V_{p_i p_j} - \frac{\partial M_i}{\partial p_j} V_y \right\}. \qquad (3)$$

We also have that

$$M_i = \frac{V_{p_i}}{V_y} \Leftrightarrow V_{p_i} = M_i V_y, \qquad (4)$$

[5] One can apply Roy's identity to the marketable surplus equation given that it is both additive and convex. See also Finkelshtain and Chalfant (1991).

which implies that

$$V_{p_i p_j} = M_i V_{yp_j} + V_y \frac{\partial M_i}{\partial p_j}, \tag{5}$$

which, in turn, implies that

$$V_{p_i y} = M_i V_{yy} + V_y \frac{\partial M_i}{\partial y} = V_{yp_i}, \tag{6}$$

where the last equation is the result of applying Young's theorem on the symmetry of second derivatives, which requires that (i) $V(\cdot)$ be a differentiable function over (p, y); and (ii) its cross-partials exist and be continuous at all points on some open set.

Replacing V_{yp_i} by equation 6 in equation 5 yields

$$V_{p_i p_j} = M_i \left\{ M_j V_{yy} + V_y \frac{\partial M_j}{\partial y} \right\} + V_y \frac{\partial M_i}{\partial p_j}. \tag{7}$$

Then, we have that

$$V_{p_i p_j} = M_i M_j V_{yy} + M_i V_y \frac{\partial M_j}{\partial y} + V_y \frac{\partial Mi}{\partial p_j}. \tag{8}$$

Multiplying the first term by $V_y y / V_y y$ yields (9)

$$V_{p_i p_j} = -\frac{M_i M_j R V_y}{y} + M_i V_y \frac{\partial M_j}{\partial y} + V_y \frac{\partial Mi}{\partial p_j}, \tag{10}$$

where R is the household's Arrow-Pratt coefficient of relative risk aversion. Multiplying the second term by $M_j y / M_j y$ and the third term by $M_i p_j / M_i p_j$ yields

$$V_{p_i p_j} = -\frac{M_i M_j R V_y}{y} + M_i V_y \eta_j \frac{M_j}{y} + V_y \varepsilon_{ij} \frac{M_i}{p_j}, \tag{11}$$

where η_j is the income-elasticity of the marketable surplus of commodity *j* and ε_{ij} is the elasticity of commodity *i* with respect to the price of commodity *j*. Equation 11 is thus equivalent to

$$V_{p_i p_j} = M_i V_y \left[-\frac{M_j R}{y} + \eta_j \frac{M_j}{y} + \varepsilon_{ij} \frac{1}{p_j} \right]. \tag{12}$$

Multiplying the first two terms in the bracketed expression by p_j / p_j yields

$$V_{p_i p_j} = \frac{M_i V_y}{p_j}\left[-R\beta_j + \eta_j \beta_j + \varepsilon_{ij}\right], \tag{13}$$

where β_j is the budget share of commodity *j*. When simplified, equation 13 is such that

$$V_{p_i p_j} = \frac{M_i V_y}{p_j}\left[\beta_j(\eta_j - R) + \varepsilon_{ij}\right]. \tag{14}$$

Consequently, if $M_i = 0$, the household is indifferent to fluctuations in the price of good *i* and to cofluctuations in the prices of goods *i* and *j* since its autarky from the market leaves it unaffected at the margin by price volatility. Applying Young's theorem again yields the following equation:

$$V_{p_i p_j} = \frac{M_i V_y}{p_j}\left[\beta_j(\eta_j - R) + \varepsilon_{ij}\right] = \frac{M_j V_y}{p_i}\left[\beta_i(\eta_i - R) + \varepsilon_{ji}\right] = V_{p_j p_i}. \tag{15}$$

In other words, the V_{pp} matrix, which is such that

$$V_{pp} = \begin{bmatrix} V_{p_1 p_1} & V_{p_1 p_2} & \cdots & V_{p_1 p_K} \\ V_{p_2 p_1} & V_{p_2 p_2} & \cdots & V_{p_2 p_K} \\ \vdots & \vdots & \ddots & \vdots \\ V_{p_K p_1} & V_{p_K p_2} & \cdots & V_{p_K p_K} \end{bmatrix}, \tag{16}$$

is symmetric. From the V_{pp} matrix, we can derive matrix A of price risk aversion coefficients, which is as follows:

$$\mathrm{A} = -\frac{1}{V_y}\cdot V_{pp} = -\frac{1}{V_y}\cdot \begin{bmatrix} V_{p_1 p_1} & V_{p_1 p_2} & \cdots & V_{p_1 p_K} \\ V_{p_2 p_1} & V_{p_2 p_2} & \cdots & V_{p_2 p_K} \\ \vdots & \vdots & \ddots & \vdots \\ V_{p_K p_1} & V_{p_K p_2} & \cdots & V_{p_K p_K} \end{bmatrix}$$

$$= \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1K} \\ A_{21} & A_{22} & \cdots & A_{2K} \\ \vdots & \vdots & \ddots & \vdots \\ A_{K1} & A_{K2} & \cdots & A_{KK} \end{bmatrix}, \tag{17}$$

where

$$A_{ij} = -\frac{M_i}{p_j}\left[\beta_j(\eta_j - R) + \varepsilon_{ij}\right]. \tag{18}$$

Matrix A has a straightforward interpretation, as developed in the scalar stochastic price case (Barrett 1996). The diagonal elements are analogous to Pratt's (1964) coefficient of absolute (income) risk aversion with respect to income variability, but here with respect to prices. Thus, $A_{ii} > 0$ implies that welfare is decreasing in the volatility of the price of *i*, i.e., that the household is price risk-averse (or a hedger) over *i*; $A_{ii} = 0$ implies that welfare is unaffected by the volatility of the price of *i*, i.e., that the household is price risk-neutral; and $A_{ii} < 0$ implies that welfare is increasing in the volatility of the price of *i*, i.e., that the household is price risk-loving (or a speculator) over *i*.[6] Price risk-aversion is the classic concern of the literature on commodity price stabilization (Deschamps, 1973; Hanoch, 1974, Turnovsky, 1978; Turnovsky et al., 1980; Newbery and Stiglitz, 1981).

The off-diagonals, meanwhile, reflect how variation in one good's price affects the household's marginal utility with respect to variation in the other good's price. Consequently, $A_{ij} >$ (<) 0 implies that greater volatility in price *j* reduces (increases) welfare associated with the net consumption of good *i*, or that the household stands to gain from hedging against (speculating over) covariance in the prices of goods *i* and *j*. The price risk aversion coefficient matrix thus speaks directly to the welfare effects of and household preferences with respect to multivariate price risk. Intuitively, the diagonal terms can be interpreted as the (direct) effect on household welfare of the variance in the price of a single good, and the off-diagonal terms can be interpreted as the (indirect) effect on household welfare of the covariance between the prices of two goods.

Perhaps more importantly, there is no theoretical restriction on the sign of any element of *A*. The theory, however, implies a testable symmetry restriction on the estimated price risk aversion coefficients. With adequate data, one can test the following null hypothesis:

$$H_0 : A_{ij} = A_{ji} \text{ for all } i \neq j, \tag{19}$$

[6] The hedger-speculator terminology is from Hirshleifer and Riley (1992), who apply it to the Keynes-Hicks theory of futures markets.

which represents $K(K-1)/2$ testable restrictions. The next section characterizes the relationship between the price risk aversion matrix A and the Slutsky matrix and shows how a test of the symmetry of A is thus a test of the rationality of the household.

2.3 Relationship between the Price Risk Aversion and Slutsky Matrices

The derivations above raise a natural question: What is the relationship between the price risk aversion matrix and the Slutsky matrix? Let $M_i(z,p,y)$ be the household's marketable surplus of commodity *i* as a function of the prices the household faces and its income. We know from first principles that the Slutsky matrix *S* is such that (Mas-Colell et al., 1995)

$$S_{ij}(p,y) = \frac{\partial M_i}{\partial p_j} + \frac{\partial M_i}{\partial y} M_j = B_{ij} + C_{ij}\,, \tag{20}$$

where $B_{ij} \equiv \frac{\partial M_i}{\partial p_j}$ and $C_{ij} \equiv \frac{\partial M_i}{\partial y} M_j$. Based on the derivations of the previous section, we can show that

$$A_{ij} = M_i \left[\frac{1}{M_j} C_{jj} - \frac{R}{y} + B_{ij} \right]. \tag{21}$$

That is, a household's marginal utility with respect to a change in the price of good i varies as a result of a change in the price of good j (i.e., $V_{p_i p_j}$), and this change is a function of the commodity's own-income effect as well as the cross-price effect between goods i and j. In this sense, since the cross-price risk aversion between goods i and j is linked to both S_{jj} and S_{ij}, there does not exist a one-to-one correspondence between the elements of matrices *A* and *S*. This can be seen by rewriting the last expression as

$$A = \begin{pmatrix} M_1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & M_K \end{pmatrix} \left[\begin{pmatrix} \frac{\partial M_1}{\partial y} & \cdots & \frac{\partial M_K}{\partial y} \\ \vdots & \ddots & \vdots \\ \frac{\partial M_1}{\partial y} & \cdots & \frac{\partial M_K}{\partial y} \end{pmatrix} + \begin{pmatrix} \frac{\partial M_1}{\partial p_1} & \cdots & \frac{\partial M_1}{\partial p_K} \\ \vdots & \ddots & \vdots \\ \frac{\partial M_K}{\partial p_1} & \cdots & \frac{\partial M_K}{\partial p_K} \end{pmatrix} \right.$$

$$-\begin{pmatrix} \frac{R}{y} & \cdots & \frac{R}{y} \\ \vdots & \ddots & \vdots \\ \frac{R}{y} & \cdots & \frac{R}{y} \end{pmatrix} \Bigg] . \qquad (22)$$

In other words, one cannot recover the Slutsky matrix from the matrix of price risk aversion coefficients. The two, however, are related, and the derivations above lead to the following result.

Proposition 1: Under the preceding assumptions and if the cross-partials of the household's indirect utility function exist and are continuous at all points on some open set, symmetry of the matrix of price risk aversion coefficients is equivalent to symmetry of the Slutsky matrix.

Proof: Symmetry of the Slutsky matrix implies that

$$\frac{\partial M_i}{\partial p_j} + \frac{\partial M_i}{\partial y} M_j = \frac{\partial M_j}{\partial p_i} + \frac{\partial M_j}{\partial y} M_i . \qquad (23)$$

By Roy's Identity, the above statement can be rewritten as

$$\frac{\partial}{\partial p_j}\left(-\frac{V_{p_i}}{V_y}\right) + \frac{\partial}{\partial y}\left(-\frac{V_{p_i}}{V_y}\right) \cdot \left[-\frac{V_{p_j}}{V_y}\right] = \frac{\partial}{\partial p_i}\left(-\frac{V_{p_j}}{V_y}\right) + \frac{\partial}{\partial y}\left(-\frac{V_{p_j}}{V_y}\right) \cdot \left[-\frac{V_{p_i}}{V_y}\right], \qquad (24)$$

which, once the second-order partials are written explicitly, is equivalent to

$$-\left(\frac{V_{p_i p_j} V_y - V_{yp_j} V_{p_i}}{V_y^2}\right) + \left(\frac{V_{p_i y} V_y - V_{yy} V_{p_i}}{V_y^2}\right) \cdot \left[\frac{V_{p_j}}{V_y}\right] =$$

$$-\left(\frac{V_{p_j p_i} V_y - V_{yp_i} V_{p_j}}{V_y^2}\right) + \left(\frac{V_{p_j y} V_y - V_{yy} V_{p_j}}{V_y^2}\right) \cdot \left[\frac{V_{p_i}}{V_y}\right]. \qquad (25)$$

This last equation can then be arranged to show that

$$\left(V_{p_i p_j} - V_{p_j p_i}\right) V_y = V_{yp_j} V_{p_i} - V_{p_j y} V_{p_i} - V_{yp_i} V_{p_j} + V_{p_i y} V_{p_j} . \qquad (26)$$

By Young's Theorem, we know that $V_{p_i p_j} = V_{p_j p_i}$, that $V_{yp_i} V_{p_j} = V_{p_i y} V_{p_j}$, and that $V_{yp_j} = V_{p_j y}$, so both sides of the previous equation are identically equal to zero. In other words, symmetry of the Slutsky matrix implies and is implied by symmetry of the matrix A of price risk aversion coefficients.■

The symmetry of the Slutsky matrix and the symmetry of the matrix of price risk aversion coefficients have the same empirical content in that they both embody the rationality of the household. But symmetry of the Slutsky matrix should be easier to reject than symmetry of the matrix of price risk aversion given that it imposes much more structure on the data than symmetry of the matrix of price risk aversion. Indeed, symmetry of the matrix A of price risk aversion coefficients only requires that $V_{p_i p_j}$ not be statistically significantly different from $V_{p_j p_i}$. Symmetry of the Slutsky matrix, however, requires (i) that $V_{p_i p_j}$ not be statistically significantly different from $V_{p_j p_i}$; (ii) that $V_{yp_i}V_{p_j}$ not be statistically significantly different from $V_{p_i y}V_{p_j}$; and (iii) that V_{yp_j} not be statistically significantly different from $V_{p_j y}$. As a result, it should be easier to reject symmetry of the Slutsky matrix than it is to reject symmetry of the matrix of price risk aversion coefficients, simply because the former imposes more restriction on the data.

2.4 Willingness to Pay for Price Stabilization

Policymakers routinely try to stabilize one or more staple good prices, but what are the welfare effects of such efforts? This subsection derives the appropriate WTP measures necessary to establish the welfare gains from partial price stabilization, i.e., from stabilizing one or more commodity prices.[7]

In order to tackle this question with respect to *K* prices, one first needs to compute the total WTP, i.e., the WTP for *K* commodities. Then,

$$WTP = \frac{V(E(p), y) - E(V(p, y))}{V_y} = \frac{E[V(E(p), y) - V(p, y)]}{V_y}. \qquad (27)$$

[7] The measures derived in this section are partial in the sense that they only stabilize prices for a subset of the (potentially infinite) set of commodities consumed and produced by the household, as it is essentially impossible to stabilize prices completely since the costs of stabilization increase exponentially with the degree of stabilization pursued (Knudsen and Nash, 1990).

A Taylor series approximation around $V\left(E\left(p\right),y\right)$ yields

$$WTP \approx \frac{E\left[-V_p\left(E(p),y\right)\left(p-E(p)\right)-\frac{1}{2}\left(p-E(p)\right)'V_{pp}\left(E(p),y\right)\left(p-E(p)\right)\right]}{V_y}. \tag{28}$$

In other words,

$$WTP \approx -\frac{1}{2}\frac{E\left[\left(p-E(p)\right)\left(p-E(p)\right)'V_{pp}\left(E(p),y\right)\left(p-E(p)\right)\right]}{V_y} \tag{29}$$

and so

$$WTP \approx -\frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K}\sigma_{ij}\frac{V_{p_i p_j}}{V_y} = \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K}\sigma_{ij}A_{ij}\ , \tag{30}$$

where σ_{ij} is the covariance between prices *i* and *j* and A_{ij} is the coefficient of price risk aversion, as defined above. By symmetry of matrix A, the above is equivalent to

$$WTP \approx \frac{1}{2}\sum_{i=1}^{K}\sum_{j=1}^{K}\sigma_{ji}A_{ji}\ . \tag{31}$$

These derivations provide the transfer payment a policymaker would need to make to the household in order to compensate it for the uncertainty over $(p_1,...,p_K)$. If instead one wishes to stabilize only one price *i*, the above derivations reduce to

$$WTP_i \approx \frac{1}{2}\left[\sigma_{ii}A_{ii} + \sum_{j\neq i}^{K}\sigma_{ij}A_{ij}\right], \tag{32}$$

and, by symmetry of matrix A and of the price covariance matrix, the above is equivalent to

$$WTP_i \approx \frac{1}{2}\left[\sigma_{ii}A_{ii} + \sum_{j\neq i}^{K}\sigma_{ji}A_{ji}\right]. \tag{33}$$

Because equations 32 and 33 are equivalent, the WTP for commodity *i* can be computed in two ways, i.e., via either the rows or the columns of matrix A. This provides the transfer payment a policymaker would need to make to the household in order to compensate it for the uncertainty over p_i. Finkelshtain and Chalfant (1997) introduced a similar measure, but their framework considered only one stochastic price, *de facto* ignoring the covariances between prices. Realistically, however, even the WTP for a single commodity *i* depends on the covariance between the price *i* and the prices of other commodities *j*. In other words, a price stabilization policy focusing solely on the price of commodity *i* would bias the estimated WTP for commodity *i*, unless $\sigma_{ij} = 0$ or $A_{ij} = 0$ for all $i \neq j$.

3. Data and Descriptive Statistics

We estimate the price risk aversion coefficient matrix as an empirical demonstration of the core theory developed in the preceding section. In order to do so, we use data from the publicly-available Ethiopian Rural Household Survey (ERHS),[8] which includes results from four rounds: 1994a, 1994b, 1995, and 1997.

The ERHS data record both household consumption and production decisions over multiple years. ERHS has a low attrition rate as well as a standardized survey instrument across the rounds we retain for analysis. The sample includes a total of 1471 households across 16 districts (*woredas*) with an attrition rate of only 2 percent across the four rounds selected for analysis (Dercon and Krishnan, 1998).[9] The average household in our sample was observed 5.9 times over four rounds and three seasons;[10] only 57 households appear only once in the data.

Given that many of the households in our data were autarkic with respect to several commodities, for every time period in which a household is neither a net buyer nor a net seller of a given commodity, this household has a marketable surplus of zero for that

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[8] These data are made available by the Department of Economics at Addis Ababa University (AAU), the Centre for the Study of African Economies (CSAE) at Oxford University, and the International Food Policy Research Institute (IFPRI). Funding for data collection was provided by the Economic and Social Research Council (ESRC), the Swedish International Development Agency (SIDA) and the US Agency for International Development (USAID). The preparation of the public release version of the ERHS data was supported in part by the World Bank, but AAU, CSAE, IFPRI, ESRC, SIDA, USAID, and the World Bank are not responsible for any errors in these data or for their use or interpretation.

[9] Ethiopia is subdivided into eleven zones subdivided into *woredas*, which are roughly equivalent to US districts.

[10] Within-round variation in seasons occurred only in 1995. The 1995 round includes data for the *meher* (Autumn) and *belg* (Spring) seasons, but the 1989 round also included data for which the season was unspecified. Likewise, season was *belg* for the 1994a (January-March) and *meher* for the 1994b (August-October) rounds. The presence in the data of observations for which the season was not specified prevents the use of season dummies in the empirical analysis of section 5.

particular commodity. In what follows, we focus on maize, coffee, barley, cooking oil, teff, wheat, beans, and sorghum, i.e., the top eight commodities when considering the proportion of observations with a nonzero marketable surplus.

Table 1 presents descriptive statistics for these eight commodities. A positive (negative) mean marketable surplus indicates that the average household is a net seller (buyer) of a commodity. The average household is a net seller of maize, coffee, barley, teff, wheat, beans, and sorghum. No household in our data is a net seller of cooking oil, a manufactured commodity not produced by rural Ethiopian households. Table 2 further characterizes the dependent variables by focusing solely on the nonzero marketable surplus observations for each commodity. For the seven unprocessed commodities, there are many households in both the net buyer and net seller categories, reflecting potentially heterogeneous welfare effects with respect to commodity prices in rural Ethiopia.

Table 3 lists the mean price in Ethiopian birr for each of the eight commodities we study,[11] the average income in the full sample, the average nonzero income, and the mean budget share for each commodity. The income measure used in this paper is the sum of proceeds from crop revenues, off-farm income, and livestock sales. That said, average income from the aforementioned sources is different from zero in about 65 percent of cases, which explains why the average seasonal income of about $53 may seem low. When focusing on nonzero income, the average seasonal income increases to about $82. Table 3 also presents the average budget share for each commodity, which encompasses both sellers (positive budget shares) and buyers (negative budget shares). In these data, the average household is a net seller of all the commodities retained for analysis except cooking oil, with maize, barley, teff, and sorghum having the highest budget shares. Finally, because price covariances will play an important role in computing household WTP for price stabilization, table 4 reports the variance-covariance matrix for the prices of the eight commodities retained for analysis.

[11] As of writing, US$1 ≈ Birr 9.43.

4. Empirical Framework

As defined previously, a household's marketable surplus of a given commodity *i*, $M_i(z, p, y)$, is the quantity harvested of that commodity net of the quantity purchased and the household's consumption of its own harvest, a reduced form function of input and output prices and household income. Our data include commodity prices and allow us to compute household income, but include only village-level average wage as an input price. Given that all households in an area face common market prices at the same time, however, we use *woreda*-round fixed effects to control for the vector of input prices faced by each household in each location in each period. Time invariant household fixed effects provide further control for household-specific transactions costs related to distance from the main *woreda* market, social relationships that may confer preferential pricing, etc.

We estimate the following marketable surplus functions for the eight commodities *i* discussed in the previous section:

$$M_{ik\ell t} = \alpha_i + \delta_i \ln y_{ik\ell t} + \phi_i \ln p_{ik\ell t} + \varphi_i \ln p_{jkt} + \lambda_{ik\ell} + \tau_{i\ell t} + \nu_{ik\ell t}\,, \qquad (34)$$

where *i* denotes a specific commodity,[12] *k* denotes the household, ℓ denotes the *woreda*, and *t* denotes the round; y denotes household income net of income from commodity *i*; p_i is a measure of the price of commodity *i*; p_j is a vector of measures of the prices of all (observed) commodities other than *i*; λ is a household-*woreda* fixed effect; τ is a *woreda*-round fixed effect that controls for, among other things, the price of the unobservable composite consumer good as well as for input prices; and ν is a mean zero, iid error term.[13,14]

[12] Subscripts on coefficients thus denote coefficients from specific commodity equations.

[13] We also add 0.001 to each observation for the variables for which logarithms are taken so as to not drop observations in a nonrandom fashion and introduce selection bias (MaCurdy and Pencavel, 1986). Robustness checks were conducted during preliminary empirical work, adding 0.1 and 0.000001 instead of 0.001 with no significant change to the empirical results.

[14] We do not estimate the marketable surplus equations using seemingly unrelated regression (SUR) since SUR estimation brings no efficiency gain over estimating the various equations in the system separately when the dependent variables are all regressed on the same set of regressors.

We estimate equation 34 over 1,471 households across four rounds and three seasons, clustering the standard errors at the *woreda* level. No household was observed over all four rounds and three seasons; the number of observations per household ranged from one to eight.[15] We also include as explanatory variables all commodity prices available in our data (i.e., maize, coffee, barley, cooking oil, teff, wheat, beans, sorghum, potatoes, onions, cabbage, milk, *tella*, and sugar.)[16]

Computation of own- and cross-price elasticities, of the income-elasticity, and of the budget share of marketable surplus follows directly from equation 34. For example, to derive the estimated cross-price risk aversion coefficient $\hat{A}_{ij}$, one first computes budget share $\hat{\beta}_j = M_j p_j / y$ from the data; income elasticity $\hat{\eta}_j = \hat{\delta}_j / M_j$ from the data and the marketable surplus equation parameter estimate for commodity *j*; and cross-price elasticity $\hat{\varepsilon}_{ij} = \hat{\varphi}_i / M_i$ from the data and the marketable surplus equation parameter estimate for commodity *i*. One then combines these estimates to obtain the point estimate

$$\hat{A}_{ij} = \frac{M_i}{p_j}[\hat{\beta}_j(\hat{\eta}_j - R) + \hat{\varepsilon}_{ij}]. \tag{35}$$

Given that marketable surplus is often zero, we use the mean of M_j and M_i so as to compute elasticities *at means*. Although it would be preferable to use mean elasticities, it is simply not possible to do so in these data.[17] The coefficient of relative risk aversion *R* can either be directly estimated, if the data allow, or assumed equal to a certain value. Given that our data do not allow direct estimation of *R*, we estimate the A_{ij} coefficients for $R = 1$, $R = 2$, and $R = 3$, which covers the range of credible values found in the literature (Friend and Blume, 1975; Hansen and Singleton, 1982; Chavas and Holt, 1993; and Saha et al., 1994). This variation provides additional robustness checks on our empirical results.

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[15] By controlling for household unobservables, the use of fixed effects controls for the possible selection problem posed by households for which we only have one observation through time (Verbeek and Nijman, 1992).

[16] *Tella* is a traditional Ethiopian beer made from teff and maize.

[17] Likewise, given that we use the household's income from non-agricultural sources as a proxy for total income *y* so as to avoid endogeneity problems, many households have a residual income of zero. In this case, we compute the estimated budget share by dividing by *y* + 0.001 (MaCurdy and Pencavel, 1986).

4.1 Identification

Identification of ϕ and φ comes from the variation in own-price both within each household over time, since each household retained in the estimation is observed more than once, and between *woreda*-round, since prices are common to all households in the same region within the same *woreda* in the same round. Identification of δ comes from the intertemporal variation in income both within each household and between households within a round and *woreda*.

Since households are price takers for all commodities, all prices are exogenous in equation 34. Income, however, is likely endogenous, if only because a positive marketable surplus implies an additional source of revenue for the household. Unfortunately, the data do not include a credible instrument for income. Including both household and *woreda*-round fixed effects should purge the error term of a great deal of its prospective correlation with income, however, since a household's status as a net seller is primarily driven by preferences and by the transactions costs it faces (de Janvry et al., 1991; Goetz, 1992; Bellemare and Barrett, 2006), which are accounted for by the household fixed effect, as well as by climatic and other environmental fluctuations that effect production (Sherlund et al., 2002), which are largely accounted for by the woreda-round fixed effect. Finally, as discussed above, the potential endogeneity problem caused by the absence of input prices from the data is accounted for by our inclusion of *woreda*-round fixed effects, which control for local market conditions.[18]

Because many households have a marketable surplus of zero for several commodities, we test several estimates of the matrix of price risk aversion coefficients. We first test the A sub-matrix for the top three commodities consumed and produced by the households in our data (i.e., maize, coffee, and barley), and then test the sub-matrices defined by the top four, five, six, seven, and eight commodities. With three different assumptions on relative risk aversion *R* and six different sub-matrices in each case, we conduct a total of 18 tests of the null hypothesis of symmetry of the matrix of price risk aversion. The consistency

[18] Alternatively, input prices are predetermined in the theoretical model of section 2.

of results – which is mirrored by associated qualitative consistency in estimated WTP for price risk stabilization – provides some assurance of the robustness of the empirical findings.

5. Estimation Results and Hypothesis Tests

This section first presents estimation results for the marketable surplus equations. Given that these results are ancillary, we only briefly discuss them so as to devote the bulk of our analysis to the estimated matrix of price risk aversion and, more importantly, to the estimates of household willingness to pay to stabilize prices.

Table 5 presents estimation results for the eight marketable surplus equations. Intuitively, one would expect the ϕ_i (i.e., own-price) coefficients to be positive. That is, as the price of commodity *i* increases, the household buys less or sells more of the same commodity. Indeed, own price has a positive and statistically significant effect on the marketable surplus of all commodities except coffee and teff, for which the point estimate is negative. This is likely due to a profit effect within the household (Singh et al., 1986), although testing for such a profit effect would require a more structural empirical framework. As regards the relationships between commodities, while the results are not everywhere consistent (e.g., the coffee equation indicates that coffee and cooking oil are substitutes, but the cooking oil equation indicates they are complements), the results that are consistent indicate that some goods are substitutes for one another (e.g., maize and sorghum; barley and wheat) while others are complements (e.g., wheat and maize; coffee and barley; barley and beans).

5.1 Price Risk Aversion Matrix

We use the results of table 5 to compute coefficients of own- and cross-price risk aversion and use these coefficients to construct sub-matrices A_3 to A_8 of price risk aversion.[19] Looking at table 6a, the households in our data are significantly own-price risk-averse over most commodities except wheat and beans, for which estimated own-

[19] We use the term “sub-matrix” given that the number of commodities produced and consumed by the household in theory goes to infinity. This is similar to Turnovsky et al. (1980), who only consider a subset of commodities in their theoretical analysis.

price risk aversion coefficients are positive but not statistically significant. In addition, the average household is most significantly own-price risk-averse over teff, maize and sorghum – the staples for which net buyers' net purchase volumes are greatest (table 2) – and least price risk-averse over coffee and cooking oil.[20]

The off-diagonal elements of the estimated A matrix underscore the importance of estimating price risk aversion in a multivariate context. Seventeen of the 56 point estimates are statistically significantly different from zero, all of them positive, indicating aversion to positive cofluctuations in commodity prices. Single price approaches to estimating price risk aversion would neglect these effects, leading to biased estimates of own-price risk aversion.

Recall that the theory developed in section 2 implies symmetry of the A matrix. Consistent with the theory, we cannot reject the null hypothesis of symmetry for sub-matrices A_3 to A_8, as shown in table 6b under the assumption that $R = 2$. Even though the test of symmetry has low power because most of the probability mass rests on non-rejection of the null hypothesis, the result is robust across the range of commodities studied and to alternative assumptions about the coefficient of income risk aversion, R (see Appendix A). These results are not due to the fact that the coefficients included in matrices A_3 to A_8 are not themselves statistically significant; the null hypotheses that all coefficients equal zero and that all off-diagonal coefficients equal zero are rejected with *p*-values of 0.00, and well over a third of the coefficients in matrix A_8 are statistically significant.

Having discussed the link between the matrix of price risk aversion coefficients and the Slutsky substitution matrix, it is only natural to wish to compare the two, given our earlier point that symmetry of the former imposes a weaker rationality assumption than symmetry of the latter, i.e., symmetry of the matrix of price risk aversion imposes less structure on the data than does Slutsky symmetry. Table 7a shows the estimated Slutsky

[20] The coefficients in table 6a are directly comparable between one another given that the marketable surpluses are all expressed in kilograms, and prices are all expressed in Ethiopian birr. Should either measurement unit differ between commodities, these coefficients would no longer be comparable.

matrix for the households in our data based on the marketable surplus equation estimates in table 5. All but two of the own-price Slutsky substitution terms are significant and negative.

The evidence gets more interesting in table 7b, which presents tests of symmetry of the various Slutsky sub-matrices. In every case, symmetry of the Slutsky matrix is rejected, and each individual restriction was found not to hold in the data. This implies rejection of the rationality of the household, a result that does not obtain when looking at the directly related but less restrictive price risk aversion matrix (table 6b). Deaton and Muellbauer (1980), among many studies, also rejected symmetry of the Slutsky matrix.

Our results so far thus indicate that the households in our data (i) are significantly risk averse over the own prices of specific commodities; (ii) are significantly risk averse over cofluctuations in the prices of many specific pairs of commodities; and (iii) behave as theory predicts, in the sense that their risk preferences over co-movements in the prices of specific pairs of commodities are symmetric, even if the more restrictive, estimated Slutsky matrix does not imply such symmetry.

5.2 Willingness to Pay Estimates for Price Stabilization

Recall from section 2.4 that the WTP for stabilization of a single commodity price can be estimated by considering either the rows or columns of matrix A of price risk aversion, but that both values coincide by construction for total WTP. For our three relative risk aversion assumptions (i.e., $R \in \{1,2,3\}$), tables 8a and 8b show the estimated average household WTP, expressed as a proportion of household income, to stabilize the prices of individual commodities as well as to stabilize the prices of all eight commodities considered in this paper. In what follows, we only discuss the results for R = 2, but the interpretation of the results in tables 8a and 8b for R = 1 or R = 3 is straightforward. The WTP measures below rely on mean income (498.52 birr) in the data both for the estimation of the price risk aversion coefficients as well as for expressing the WTP measures as proportions of household income. We do this because many of the households in our data were autarkic with respect to all the commodities considered in our analysis, and even for the households whose marketable surplus was non-zero for one commodity, their marketable surplus of other commodities was often equal to zero. Thus we had to rely on elasticities at means rather than on mean elasticities when computing coefficients of price risk aversion, and so the variation exploited in computing the typical coefficient of price risk aversion came from marketable surplus, price, and budget share, rather than from the same variables augmented with price elasticity, and income elasticity. A high prevalence of zero marketable surpluses is the defining feature of developing countries, however, since markets often fail for specific households (de Janvry et al., 1991). As such, it would be extremely difficult if not impossible to find a developing-country data set for which most households are net buyers or net sellers of almost all commodities.

Estimating WTP with the rows of A in table 8a, the average WTP estimates are all statistically significantly different from zero. The commodities for which the average household would be willing to pay a higher proportion of its budget to stabilize prices are maize (15 percent), barley (9 percent) and sorghum (5 percent), the three commodities with the largest mean marketable surplus in sample (Table 1). Alternatively, estimating WTP with the columns of A in table 8b, the average WTP estimates are all statistically significant, but the commodities for which the average household would be willing to pay a higher proportion of its budget to stabilize prices are maize (14 percent), teff (8 percent) and barley (6 percent).

By way of comparison, we compute the WTP measures derived by Finkelshtain and Chalfant (1997) in the case of a single stochastic commodity price. Table 8c thus presents WTP estimates that ignore the covariances between prices. Testing the null hypothesis that either of our total WTP measures (i.e., the last rows of tables 8a and 8b) is equal to a similar measure ignoring the covariance between prices, however, leads to a rejection of the null hypothesis with a *p*-value of 0.00. It thus seems that in these data, covariances between prices matter in that ignoring them leads one to underestimate the average welfare gain to stabilizing the prices of the eight most important commodities in the data.

The average household's WTP estimate to stabilize the prices of these eight commodities is about 34 percent of its income (11 percent for R = 1; 57 percent for R = 3), a proportion that is statistically significant at the one percent level. In order to be more specific about the distribution of the welfare gains from price stabilization, however, figure 1 plots the results of a nonparametric regression of the household-specific WTP for all eight commodities on household income using Hastie and Tibshirani's (1990) generalized additive model smoother, along with the associated 95 percent confidence band. Figure 1 indicates that households in the upper half of the income distribution, above roughly 1400 birr benefit significantly from price stabilization, poorer households (i.e., households whose total income lies between roughly 400 and 900 birr) are actually slightly hurt by price stabilization.[21] Thus, contrary to conventional wisdom, price stabilization appears to be a regressive policy in these data, benefiting disproportionately the better off, potentially at the expense of poorer households.

While Turnovsky (1978) discussed various theoretical predictions regarding who are the winners and losers from price stabilization between consumers and producers, his results depended on whether price uncertainty stems from random fluctuations in supply or in demand, on whether price uncertainty is additive or multiplicative, and on whether supply and demand functions are linear. Our approach, which is free from such assumptions and lets the data speak for themselves, finds that total welfare is increased by price stabilization, albeit regressively so among households arrayed by income.

6. Conclusion

This paper has modestly extended microeconomic theory so as to enable the study of price risk aversion over multiple commodities. Specifically, we have derived a matrix measuring the curvature of the indirect utility function in the hyperspace defined by the vector of all commodity prices faced by agricultural households. Then we have estimated this matrix of price risk aversion coefficients using well-known survey data on a panel of

[21] The nonparametric regression in figure 1 was run on a truncated sample of households whose income did not exceed 5000 birr. The 91 households whose income exceeded 5000 had a mean income of 13644 birr, and we chose to drop these outliers so as to present a more refined picture of the nonparametric regression in figure 1.

rural Ethiopian households. We find these households are significantly risk averse over the own prices of specific commodities and over cofluctuations in the prices of many specific pairs of commodities. We further find behavior consistent with microeconomic theory, in that risk preferences over co-movements in the prices of specific pairs of commodities are symmetric, even though the more restrictive, estimated Slutsky matrix does not imply such symmetry. We show how testing for the symmetry of the matrix of price risk aversion coefficients is equivalent to, but imposes less structure than, testing the symmetry of the Slutsky matrix.

Our results have important policy implications. Under the assumption that the coefficient of relative risk aversion is such that $R = 2$, we find that the average WTP for price stabilization of individual commodities is highest for maize, and that the average WTP to stabilize the prices of all eight commodities we consider is 34 percent of household income. Under other assumptions (R=1 or R=3), estimated WTP for multivariate price stabilization range from 11 to 57 percent of household income. Hence governments' interest in price stabilization; on average, households stand to benefit from it. However, nonparametric regression analysis of household-specific WTP estimates finds that the bulk of the welfare gains from stabilizing prices at their means would accrue to households with relatively high incomes, suggesting regressive benefit incidence from price stabilization policy. Although price stability is often deemed especially important for the poor, in these data and using this new, exact method of computing WTP for price stability, the better off seem to benefit most from price stabilization policy.

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Table 1: Descriptive Statistics for the Dependent Variables (Full Sample)

Crop	Mean	(Std. Dev.)	Observations	Nonzero Observations
Maize Marketable Surplus (Kg)	63.83	(895.00)	8722	1763
Coffee Marketable Surplus (Kg)	1.08	(44.70)	8722	1534
Barley Marketable Surplus (Kg)	87.33	(553.69)	8722	1504
Cooking Oil Marketable Surplus (Kg)	-4.41	(21.77)	8722	1333
Teff Marketable Surplus (Kg)	8.58	(311.05)	8722	1089
Wheat Marketable Surplus (Kg)	33.57	(325.15)	8722	993
Beans Marketable Surplus (Kg)	4.37	(178.43)	8722	733
Sorghum Marketable Surplus (Kg)	59.15	(503.34)	8722	625

Table 2: Descriptive Statistics for the Dependent Variables (Nonzero Observations)

Crop	Net Buyer Mean Marketable Surplus	(Std. Dev.)	Net Buyer Observations	Net Seller Mean Marketable Surplus	(Std. Dev.)	Net Seller Observations
Maize (Kg)	-309.48	(738.52)	895	960.46	(2552.17)	868
Coffee (Kg)	-16.96	(24.75)	1194	87.31	(201.53)	340
Barley (Kg)	-236.06	(869.29)	518	896.56	(1245.50)	986
Cooking Oil (Kg)	-28.87	(48.96)	1333	–	–	0
Teff	-261.41	(605.65)	667	590.53	(983.70)	422
Wheat (Kg)	-90.29	(173.222)	664	1072.07	(1269.221)	329
Beans (Kg)	-108.19	(246.32)	576	639.98	(1049.71)	157
Sorghum (Kg)	-452.64	(703.63)	236	1600.95	(1667.06)	389

Table 3: Descriptive Statistics for the Independent Variables

Crop	Mean	(Std. Dev.)
Commodity Prices		
Maize (Birr/Kg)	1.22	(0.34)
Coffee (Birr/Kg)	12.21	(4.95)
Barley (Birr/Kg)	1.43	(0.37)
Cooking Oil (Birr/Kg)	1.65	(1.00)
Teff (Birr/Kg)	2.18	(0.39)
Wheat (Birr/Kg)	1.66	(0.31)
Beans (Birr/Kg)	1.80	(0.42)
Sorghum (Birr/Kg)	1.46	(0.40)
Potatoes (Birr/Kg)	1.45	(0.71)
Onions (Birr/Kg)	1.86	(0.71)
Cabbage (Birr/Kg)	0.86	(0.66)
Milk (Birr/Liter)	1.96	(0.82)
Tella (Birr/Liter)	0.67	(0.25)
Sugar (Birr/Kg)	5.71	(1.98)
Income		
Income (Birr)	498.52	(2633.17)
Nonzero Income (Birr)	773.00	(3246.47)
Budget Shares		
Budget Share of Maize	0.17	(2.66)
Budget Share of Coffee	0.06	(0.69)
Budget Share of Barley	0.21	(1.59)
Budget Share of Cooking Oil	0.00	(0.01)
Budget share of Teff	0.07	(1.16)
Budget Share of Wheat	0.04	(0.48)
Budget Share of Beans	0.02	(0.50)
Budget Share of Sorghum	0.12	(1.01)

Note: Income (i.e., the sum of off-farm income, all crop revenues, and livestock sales) was different from zero for only 5625 observations, so budget shares are computed for that sub-sample.

Table 4: Variance-Covariance Matrix of Commodity Prices

	Maize	Coffee	Barley	Cooking Oil	Teff	Wheat	Beans	Sorghum
Maize	**0.119**							
Coffee	0.354	**24.483**						
Barley	0.022	0.413	**0.135**					
Cooking Oil	0.092	0.150	-0.009	**0.999**				
Teff	0.059	0.257	0.048	0.077	**0.151**			
Wheat	0.024	0.277	0.044	-0.045	0.060	**0.098**		
Beans	0.043	0.466	-0.023	0.090	0.069	0.049	**0.177**	
Sorghum	0.039	0.306	0.057	-0.046	0.033	0.056	-0.003	**0.164**

Table 5: Marketable Surplus Equations

	(1)		(2)		(3)		(4)	
Dependent Variable:	**Maize Marketable Surplus**		**Coffee Marketable Surplus**		**Barley Marketable Surplus**		**Cooking Oil Marketable Surplus**	
Coefficients	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**
Maize Price	**614.339*** **	**(66.688)**	6.117***	(1.334)	8.853	(29.045)	-9.582***	(0.316)
Coffee Price	40.263	(38.249)	**-1.535***	**(0.765)**	65.276***	(16.659)	18.474***	(0.181)
Barley	547.540***	(45.723)	23.150***	(0.914)	**163.460*** **	**(19.914)**	12.156***	(0.217)
Cooking Oil	-353.931***	(24.672)	-9.810***	(0.493)	-51.275***	(10.745)	**9.960*****	**(0.117)**
Teff	-1108.400***	(122.434)	-37.909***	(2.449)	-132.848**	(53.324)	5.458***	(0.580)
Wheat Price	690.525***	(69.849)	-10.140***	(1.397)	-253.167***	(30.422)	6.708***	(0.331)
Beans Price	954.924***	(45.381)	24.339***	(0.908)	133.773***	(19.765)	1.094***	(0.215)
Sorghum Price	-192.849***	(20.413)	8.250***	(0.408)	73.293***	(8.891)	3.117***	(0.097)
Potatoes Price	344.191***	(18.544)	3.663***	(0.371)	1.253	(8.077)	3.636***	(0.088)
Onions Price	-610.746***	(25.347)	-1.651***	(0.507)	-0.796	(11.040)	4.383***	(0.120)
Cabbage Price	27.609**	(11.174)	5.072***	(0.223)	12.501**	(4.867)	6.864***	(0.053)
Milk Price	213.934***	(6.545)	-0.128	(0.131)	48.718***	(2.850)	15.354***	(0.031)
Tella Price	590.423***	(29.976)	4.132***	(0.600)	-42.076***	(13.056)	-15.625***	(0.142)
Sugar Price	-47.083***	(10.360)	-2.782***	(0.207)	-127.536***	(4.512)	1.289***	(0.049)
Soap Price	-586.104***	(13.483)	-12.928***	(0.270)	-2.947	(5.872)	-6.661***	(0.064)
Income	15.529	(10.212)	0.394*	(0.204)	7.600	(4.448)	0.113**	(0.048)
Intercept	1567.124***	(264.288)	53.062***	(5.286)	245.842*	(115.107)	-75.436***	(1.251)
N	8722		8722		8722		8722	
p-value (All Coefficients)	0.00		0.00		0.00		0.00	
R^2	0.23		0.23		0.28		0.21	
Household FEs	Yes		Yes		Yes		Yes	
Woreda-Round FEs	Yes		Yes		Yes		Yes	

Note: *, **, and *** denote significance at the 90, 95, and 99 percent levels. Bolded coefficients and standard errors are for own-price effects.

Table 5 (continued): Marketable Surplus Equations

	(4)		(5)		(6)		(7)	
Dependent Variable:	**Teff Marketable Surplus**		**Wheat Marketable Surplus**		**Beans Marketable Surplus**		**Sorghum Marketable Surplus**	
Variable	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**	**Coefficient**	**(Std. Err.)**
Maize Price	-19.249	(11.432)	28.263***	(7.494)	9.639**	(4.378)	-98.175***	(28.812)
Coffee Price	25.810***	(6.557)	-28.382***	(4.298)	10.658***	(2.511)	115.243***	(16.525)
Barley Price	51.799***	(7.838)	-33.614***	(5.138)	51.544***	(3.001)	81.645***	(19.755)
Cooking Oil Price	29.680***	(4.229)	-22.803***	(2.772)	1.953	(1.620)	131.742***	(10.659)
Teff Price	**-90.251*** **	**(20.988)**	19.760	(13.758)	-69.096***	(8.037)	-214.291***	(52.897)
Wheat Price	-105.942***	(11.973)	**46.257*** **	**(7.849)**	-45.251***	(4.585)	-222.446***	(30.178)
Beans Price	178.874***	(7.779)	-66.741***	(5.100)	**45.876*** **	**(2.979)**	488.607***	(19.607)
Sorghum Price	3.225	(3.499)	6.160**	(2.294)	9.493***	(1.340)	**56.605*****	**(8.820)**
Potatoes Price	-14.761***	(3.179)	15.191***	(2.084)	-3.049**	(1.217)	4.022	(8.012)
Onions Price	10.506***	(4.345)	-24.088***	(2.848)	10.678***	(1.664)	38.583***	(10.951)
Cabbage Price	-20.467***	(1.915)	18.444***	(1.256)	4.263***	(0.734)	-62.949***	(4.828)
Milk Price	-18.296***	(1.122)	-0.881	(0.735)	1.099**	(0.430)	12.643***	(2.828)
Tella Price	-13.154**	(5.139)	41.982***	(3.369)	-3.505*	(1.968)	-2.879	(12.951)
Sugar Price	-149.198***	(1.776)	91.166***	(1.164)	-38.322***	(0.680)	-426.212***	(4.476)
Soap Price	20.405***	(2.311)	-25.683***	(1.515)	-1.788*	(0.885)	-14.208**	(5.825)
Income	4.371**	(1.751)	2.901**	(1.148)	1.212*	(0.670)	7.411	(4.412)
Intercept	157.638***	(45.304)	81.555**	(29.699)	60.964***	(17.349)	363.492***	(114.185)
N	8722		8722		8722		8722	
p-value (All Coefficients)	0.00		0.00		0.00		0.00	
R^2	0.25		0.29		0.21		0.32	
Household FEs	Yes		Yes		Yes		Yes	
Woreda-Round FEs	Yes		Yes		Yes		Yes	

Note: *, **, and *** denote significance at the 90, 95, and 99 percent levels. Bolded coefficients and standard errors are for own-price effects.

Table 6a: Matrix of Price Risk Aversion for *R* = 2

	Maize	Coffee	Barley	Cooking Oil	Teff	Wheat	Beans	Sorghum
Maize	**167.217****	0.244**	2.688	0.483	9.971	0.510	0.055	8.815**
	(83.096)	(0.088)	(2.690)	(0.343)	(10.623)	(0.351)	(0.041)	(4.332)
Coffee	0.080	**0.316***	0.126	0.077**	0.072*	0.036**	0.115**	0.311
	(0.061)	**(0.163)**	(0.123)	(0.018)	(0.040)	(0.017)	(0.057)	(0.244)
Barley	-0.007	0.018	**25.298****	0.107*	-0.837	14.244	-1.675	-6.459
	(0.007)	(0.012)	**(8.154)**	(0.059)	(11.443)	(16.293)	(1.667)	(4.547)
Cooking Oil	0.729**	0.089**	0.435	**0.363****	0.124	0.233**	0.244**	0.168
	(0.336)	(0.024)	(0.411)	**(0.090)**	(0.079)	(0.091)	(0.117)	(0.123)
Teff	0.068	0.166	-0.323	0.016	**171.446***	-0.005	2.828	-0.210
	(0.108)	(0.111)	(0.345)	(0.011)	**(51.901)**	(0.114)	(2.019)	(0.164)
Wheat	-1.348	0.033**	0.038**	0.087	-20.811	**12.858**	0.052**	-0.015
	(1.903)	(0.015)	(0.018)	(0.073)	(13.363)	**(8.977)**	(0.021)	(0.047)
Beans	0.084	0.107**	0.151*	0.331	-27.089	0.227*	**30.148**	0.376
	(0.054)	(0.039)	(0.084)	(0.238)	(26.016)	(0.124)	**(25.628)**	(0.303)
Sorghum	0.385	0.106	9.764	0.004	0.600	0.181	-36.009	**67.222****
	(0.257)	(0.078)	(9.764)	(0.004)	(4.736)	(0.179)	(31.754)	**(27.269)**

Note: Standard errors are in parentheses, and *, **, and *** denote significance at the 90, 95, and 99 percent levels. Bolded coefficients are own-price risk aversion coefficients.

Table 6b: Tests of Symmetry of the Matrix of Price Risk Aversion for *R* = 2

Sub-Matrix	Test Statistic	*p*-value
A_3 (Maize, …, Barley)	$F(3, 8719) = 1.64$	0.18
A_4 (Maize, …, Cooking Oil)	$F(6, 8716) = 1.28$	0.26
A_5 (Maize, …, Teff)	$F(10, 8712) = 1.06$	0.39
A_6 (Maize, …, Wheat)	$F(15, 8707) = 1.00$	0.45
A_7 (Maize, …, Beans)	$F(21, 8701) = 0.96$	0.52
A_8 (Maize, …, Sorghum)	$F(28, 8694) = 1.05$	0.39
Joint Significance (All Coefficients)	$F(64, 8658) = 2.23$	0.00
Joint Significance (Diagonal Coefficients)	$F(8, 8714) = 6.78$	0.00
Joint Significance (Off-Diagonal Coefficients)	$F(56, 8666) = 1.94$	0.00

Table 7a: Slutsky Matrix

	Maize	Coffee	Barley	Cooking Oil	Teff	Wheat	Beans	Sorghum
Maize	**-1605.534********* (148.824)**	-57.091*** (7.432)	-1903.805*** (92.069)	422.441*** (3.621)	975.136*** (51.723)	-1211.781*** (54.067)	-1022.864*** (29.670)	-725.793*** (83.697)
Coffee	-31.275*** (3.777)	**1.108*** (0.189)**	-57.574*** (2.337)	11.549*** (0.092)	34.527*** (1.313)	-3.090** (1.372)	-26.064*** (0.753)	-31.566*** (2.124)
Barley	-493.932*** (72.832)	-73.511*** (3.637)	**-827.199*** (45.057)**	84.803*** (1.772)	67.630*** (25.313)	-1.929 (26.460)	-167.022*** (14.520)	-522.864*** (40.960)
Cooking Oil	2.359** (1.085)	-18.597*** (0.054)	-22.039*** (0.671)	**-9.461*** (0.026)**	-6.429*** (0.377)	-10.507*** (0.394)	-1.589*** (0.216)	-9.812*** (0.610)
Teff	-259.712*** (41.885)	-30.546*** (2.092)	-433.505*** (25.912)	-10.398*** (1.019)	**52.745*** (14.557)**	-40.760*** (15.216)	-197.995*** (8.350)	-261.766*** (23.556)
Wheat	-213.405*** (27.798)	25.239*** (1.388)	-219.719*** (17.197)	35.600*** (0.676)	-44.652*** (9.661)	**-143.621*** (10.099)**	54.050*** (5.542)	-177.751*** (15.634)
Beans	-87.016*** (11.618)	-11.971*** (0.580)	-157.420*** (7.187)	3.395*** (0.283)	58.693*** (4.038)	4.560 (4.221)	**-51.180*** (2.316)**	-81.207*** (6.534)
Sorghum	-374.851*** (71.023)	-123.274*** (3.547)	-728.893*** (43.938)	-99.047*** (1.728)	150.693*** (24.684)	-26.312 (25.802)	-521.030*** (14.160)	**-495.007*** (39.943)**

Note: Standard errors are in parentheses, and *, **, and *** denote significance at the 90, 95, and 99 percent levels. Bolded coefficients are own-price risk aversion coefficients.

Table 7b: Tests of Slutsky Symmetry

Sub-Matrix	Test Statistic	*p*-value
A_3 (Maize, …, Barley)	$F(2, 8720) = 72.29$	0.00
A_4 (Maize, …, Cooking Oil)	$F(3, 8719) = 4664.88$	0.00
A_5 (Maize, …, Teff)	$F(4, 8718) = 3534.58$	0.00
A_6 (Maize, …, Wheat)	$F(5, 8717) = 2924.14$	0.00
A_7 (Maize, …, Beans)	$F(6, 8716) = 2640.24$	0.00
A_8 (Maize, …, Sorghum)	$F(7, 8715) = 2281.87$	0.00
Joint Significance (All Coefficients)	$F(8, 8714) = 2104.78$	0.00
Joint Significance (Diagonal Coefficients)	$F(8, 8714) = 1.63e^4$	0.00
Joint Significance (Off-Diagonal Coefficients)	$F(8, 8714) = 2094.86$	0.00

Table 8a: WTP as Proportion of Household Income (Rows)

	R **= 1**		***R*** **= 2**		***R*** **= 3**	
Commodity	**WTP**	**(Std. Err)**	**WTP**	**(Std. Err)**	**WTP**	**(Std. Err)**
Maize	0.035	(0.027)	0.152**	(0.069)	0.269**	(0.111)
Coffee	0.000	(0.003)	0.013***	(0.004)	0.026***	(0.007)
Barley	0.039***	(0.013)	0.090***	(0.027)	0.142***	(0.042)
Cooking Oil	-0.008	(0.001)	-0.008***	(0.000)	-0.008	(0.000)
Teff	0.010***	(0.005)	0.029**	(0.014)	0.048**	(0.024)
Wheat	0.003**	(0.001)	0.007***	(0.002)	0.011***	(0.003)
Beans	0.001	(0.001)	0.006**	(0.003)	0.012**	(0.005)
Sorghum	0.028***	(0.004)	0.051***	(0.008)	0.074***	(0.012)
All Commodities	0.107***	(0.031)	0.340***	(0.076)	0.574***	(0.121)

Note: Standard errors are in parentheses, and *, **, and *** denote significance at the 90, 95, and 99 percent levels.

Table 8b: WTP as Proportion of Household Income (Columns)

	R **= 1**		***R*** **= 2**		***R*** **= 3**	
Commodity	***R*** **= 1**	**(Std. Err)**	***R*** **= 2**	**(Std. Err)**	***R*** **= 3**	**(Std. Err)**
Maize	0.026	(0.026)	0.143**	(0.068)	0.260**	(0.110)
Coffee	0.005*	(0.003)	0.018***	(0.005)	0.031***	(0.008)
Barley	0.012	(0.014)	0.064**	(0.028)	0.115***	(0.042)
Cooking Oil	0.013***	(0.003)	0.013***	(0.003)	0.013***	(0.003)
Teff	0.060***	(0.008)	0.079***	(0.016)	0.097***	(0.026)
Wheat	0.013***	(0.003)	0.018***	(0.004)	0.022***	(0.004)
Beans	-0.036	(0.006)	-0.029***	(0.006)	-0.022	(0.007)
Sorghum	0.013***	(0.004)	0.035***	(0.008)	0.057***	(0.012)
All Commodities	0.107***	(0.031)	0.340***	(0.076)	0.574***	(0.121)

Note: Standard errors are in parentheses, and *, **, and *** denote significance at the 90, 95, and 99 percent levels.

Table 8c: WTP as Proportion of Household Income Ignoring Covariances

	R **= 1**		***R*** **= 2**		***R*** **= 3**	
Commodity	***R*** **= 1**	**(Std. Err)**	***R*** **= 2**	**(Std. Err)**	***R*** **= 3**	**(Std. Err)**
Maize	0.023	(0.026)	0.140**	(0.068)	0.256***	(0.110)
Coffee	0.012***	(0.003)	0.025***	(0.005)	0.038***	(0.008)
Barley	0.032**	(0.013)	0.082***	(0.027)	0.132**	(0.042)
Cooking Oil	-0.009	(0.001)	-0.009***	(0.001)	-0.009	(0.001)
Teff	0.017	(0.006)	0.035**	(0.016)	0.053***	(0.025)
Wheat	0.000***	(0.001)	0.003**	(0.002)	0.006**	(0.002)
Beans	-0.002	(0.002)	0.004	(0.003)	0.010***	(0.004)
Sorghum	0.013***	(0.003)	0.034***	(0.007)	0.056***	(0.011)
All Commodities	0.085***	(0.030)	0.314***	(0.075)	0.543***	(0.121)

Note: These measures are derived following Finkelshtain and Chalfant (1997). Standard errors are in parentheses, and *, **, and *** denote significance at the 90, 95, and 99 percent levels.

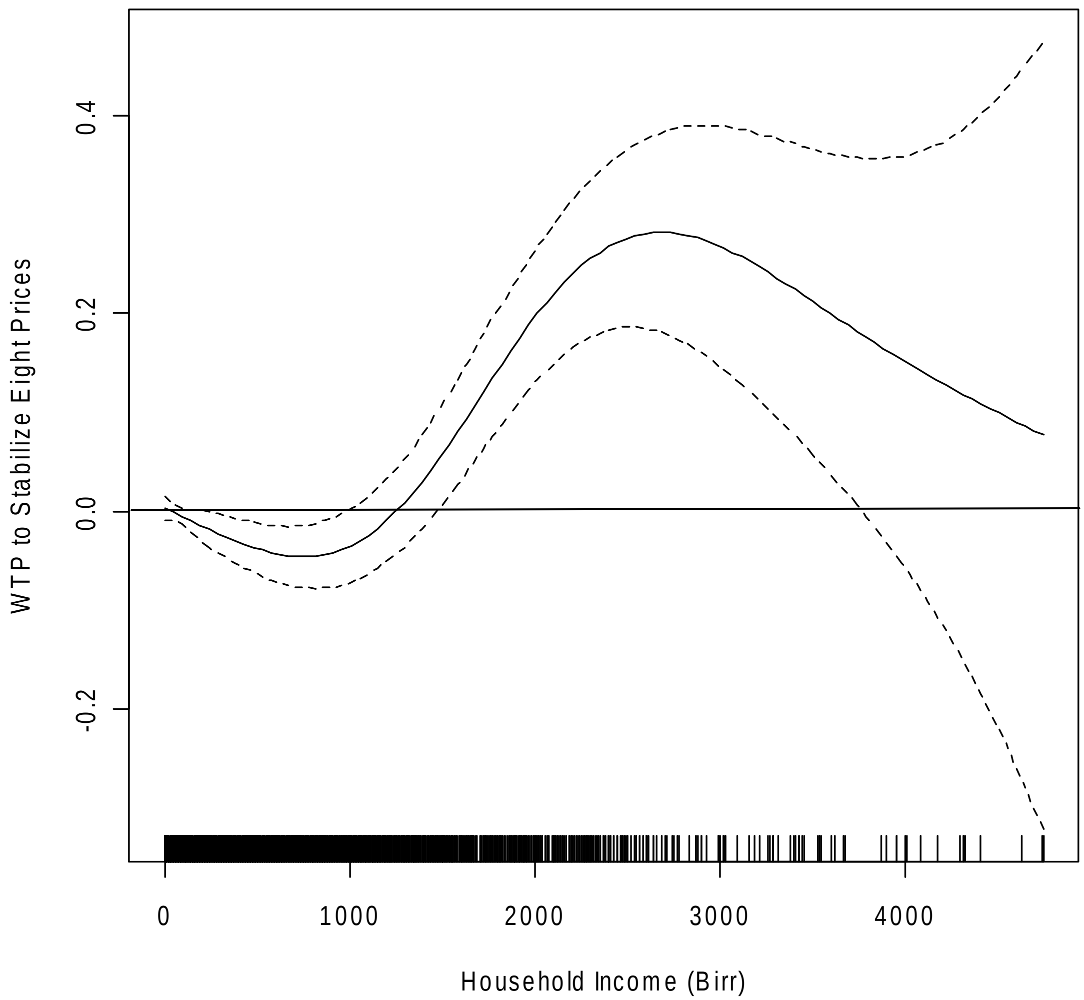

Figure 1: Nonparametric regression of household willingness to pay to stabilize the prices of eight commodities on household income with 95 percent confidence band. The rug plot on the horizontal axis depicts the income distribution in the sample.

Appendix A

Table A1a: Matrix of Price Risk Aversion for *R* = 1

	Maize	Coffee	Barley	Cooking Oil	Teff	Wheat	Beans	Sorghum
Maize	**72.025****	0.095***	1.281	0.246	3.286	0.241	0.020	4.114**
	(35.794)	(0.034)	(1.284)	(0.174)	(3.497)	(0.168)	(0.017)	(2.021)
Coffee	0.035	**0.123***	0.060	0.039***	0.024*	0.017**	0.048**	0.145
	(0.026)	**(0.063)**	(0.059)	(0.009)	(0.013)	(0.008)	(0.024)	(0.114)
Barley	-0.003	0.007	**12.073*****	0.054*	-0.275	6.801	-0.703	-3.014
	(0.003)	(0.005)	**(3.892)**	(0.030)	(3.767)	(7.779)	(0.699)	(2.122)
Cooking Oil	0.314**	0.035***	0.207	**0.184*****	0.041	0.111**	0.102**	0.079
	(0.145)	(0.009)	(0.196)	**(0.046)**	(0.026)	(0.043)	(0.049)	(0.058)
Teff	0.030	0.064	-0.154	0.008	**56.435*****	-0.002	1.186	-0.098
	(0.047)	(0.043)	(0.165)	(0.005)	**(17.084)**	(0.054)	(0.847)	(0.076)
Wheat	-0.581	0.013**	0.018**	0.044	-6.851	**6.138**	0.022**	-0.007
	(0.820)	(0.006)	(0.009)	(0.037)	(4.399)	**(4.286)**	(0.009)	(0.022)
Beans	0.036	0.041***	0.072*	0.168	-8.917	0.109*	**12.649**	0.175
	(0.023)	(0.015)	(0.040)	(0.120)	(8.563)	(0.059)	**(10.753)**	(0.141)
Sorghum	0.166	0.041	4.660	0.002	0.198	0.087	-15.111	**31.365****
	(0.111)	(0.030)	(4.660)	(0.002)	(1.559)	(0.086)	(13.324)	**(12.723)**

Note: Standard errors are in parentheses, and *, **, and *** denote significance at the 90, 95, and 99 percent levels. Bolded coefficients are own-price risk aversion coefficients.

Table A1b: Tests of Symmetry of the Matrix of Price Risk Aversion for *R* = 1

Sub-Matrix	Test Statistic	*p*-value
A_3 (Maize, …, Barley)	$F(3, 8719) = 1.47$	0.22
A_4 (Maize, …, Cooking Oil)	$F(6, 8716) = 1.10$	0.36
A_5 (Maize, …, Teff)	$F(10, 8712) = 0.95$	0.49
A_6 (Maize, …, Wheat)	$F(15, 8707) = 0.93$	0.53
A_7 (Maize, …, Beans)	$F(21, 8701) = 0.93$	0.55
A_8 (Maize, …, Sorghum)	$F(28, 8694) = 1.03$	0.42
Joint Significance (All Coefficients)	$F(64, 8658) = 2.25$	0.00
Joint Significance (Diagonal Coefficients)	$F(8, 8714) = 6.78$	0.00
Joint Significance (Off-Diagonal Coefficients)	$F(56, 8666) = 1.97$	0.00

Table A2a: Matrix of Price Risk Aversion for *R* = 3

	Maize	Coffee	Barley	Cooking Oil	Teff	Wheat	Beans	Sorghum
Maize	**262.409****	0.393***	4.095	0.720	16.656	0.778	0.090	13.517**
	(130.399)	(0.142)	(4.096)	(0.512)	(17.749)	(0.534)	(0.065)	(6.642)
Coffee	0.126	**0.509***	0.192	0.114***	0.121*	0.055**	0.181**	0.476
	(0.095)	**(0.262)**	(0.188)	(0.027)	(0.067)	(0.026)	(0.090)	(0.374)
Barley	-0.012	0.030	**38.522*****	0.160*	-1.400	21.686	-2.647	-9.905
	(0.010)	(0.019)	**(12.417)**	(0.089)	(19.119)	(24.807)	(2.634)	(6.972)
Cooking Oil	1.144**	0.144***	0.662	**0.542*****	0.207	0.354**	0.386**	0.258
	(0.527)	(0.039)	(0.626)	**(0.135)**	(0.132)	(0.138)	(0.185)	(0.189)
Teff	0.107	0.267	-0.492	0.024	**286.456*****	-0.008	4.470	-0.323
	(0.170)	(0.179)	(0.526)	(0.016)	**(86.717)**	(0.174)	(3.191)	(0.251)
Wheat	-2.116	0.052**	0.058**	0.130	-34.772	**19.577**	0.082**	-0.022
	(2.987)	(0.025)	(0.028)	(0.109)	(22.328)	**(13.668)**	(0.033)	(0.071)
Beans	0.132	0.172***	0.229*	0.495	-45.261	0.346*	**47.647**	0.576
	(0.084)	(0.062)	(0.128)	(0.355)	(43.468)	(0.188)	**(40.503)**	(0.464)
Sorghum	0.603*	0.171	14.868	0.007	1.001	0.275	-56.907	**103.080****
	(0.404)	(0.125)	(14.868)	(0.006)	(7.913)	(0.273)	(50.185)	**(41.815)**

Note: Standard errors are in parentheses, and *, **, and *** denote significance at the 90, 95, and 99 percent levels. Bolded coefficients are own-price risk aversion coefficients.

Table A2b: Tests of Symmetry of the Matrix of Price Risk Aversion for *R* = 3

Sub-Matrix	Test Statistic	*p*-value
A_3 (Maize, …, Barley)	$F(3, 8719) = 1.69$	0.17
A_4 (Maize, …, Cooking Oil)	$F(6, 8716) = 1.36$	0.23
A_5 (Maize, …, Teff)	$F(10, 8712) = 1.11$	0.35
A_6 (Maize, …, Wheat)	$F(15, 8707) = 1.03$	0.42
A_7 (Maize, …, Beans)	$F(21, 8701) = 0.97$	0.50
A_8 (Maize, …, Sorghum)	$F(28, 8694) = 1.06$	0.37
Joint Significance (All Coefficients)	$F(64, 8658) = 2.23$	0.00
Joint Significance (Diagonal Coefficients)	$F(8, 8714) = 6.78$	0.00
Joint Significance (Off-Diagonal Coefficients)	$F(56, 8666) = 1.94$	0.00