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# The Welfare Impacts of Commodity Price Fluctuations: Evidence from Rural Ethiopia\*

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## Abstract

Many governments try to stabilize commodity prices based on the widespread belief that households value price stability and that the poor especially benefit from food price stabilization. We derive an exact measure of multivariate price risk aversion and of associated household willingness to pay for price stabilization across multiple commodities. Using data from a panel of Ethiopian households, we estimate that the average household would be willing to pay 6-32 percent of its income to eliminate fluctuations in the prices of the seven primary food commodities. But not everyone benefits from price stabilization. Contrary to conventional wisdom, the welfare gains from eliminating price fluctuations would be concentrated in the upper 40 percent of the income distribution, making food price stabilization a distributionally regressive policy in this context.

*JEL* Classification Codes: D13, D80, E64, O12, Q12

Keywords: Price Fluctuations, Price Stabilization, Price Risk, Risk and Uncertainty.

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## 1. Introduction

How do commodity price fluctuations affect the welfare of individuals and households in developing countries? And when governments intervene to stabilize commodity prices, who benefits and who suffers? Such questions arise because, throughout history and all over the world, governments have frequently treated commodity price stability as an important goal of economic policy. Using a host of policy instruments, from buffer stocks to administrative pricing and from variable tariffs to marketing boards, governments have tried to stabilize prices. These efforts have typically met with, at best, only very limited success. As a result, price stabilization fell off the policy agenda by the early 1990s.

Since the mid-1990s, however, commodity prices have been on a roller coaster ride (Cashin and McDermott, 2002; Jacks et al., 2009), as food price 10-year volatility reached its highest level in almost 30 years in 2009 (Roache, 2010). Market volatility over the past decade or so, punctuated by the food crisis of 2007-2008 and the biggest one-month jump in wheat prices in more than three decades, in summer 2010, has rekindled widespread popular interest in commodity price stabilization. A simple literature search finds more than five times as many media articles on the topic in the past five years as in the preceding five years.<sup>4</sup> Even the World Bank's flagship *World Development Report* (World Bank, 2008, pp.121-122) discusses various policy options for price stabilization.

The political impulse toward state interventions to stabilize domestic food prices commonly arises because (i) households are widely believed to value price stability; (ii) the poor are widely perceived to suffer disproportionately from food price instability; and (iii) futures and options markets for hedging against food price risk are commonly inaccessible to consumers and poor producers in developing countries (Newbery, 1989; Timmer, 1989). Given the policy importance of the topic, and although economists have commonly questioned the net economic benefit of government price stabilization interventions (Newbery and Stiglitz, 1981; Krueger et al., 1988; Knudsen and Nash,

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<sup>4</sup> An August 13, 2010, LexisNexis search turned up just 51 articles, 2000-2005, on "commodity price stabilization," or variants replacing "commodity" with "food" or "stabilization" with "stability" or "volatility", but 266 articles on the same search terms over the (slightly shorter) 2006-10 period.

1990), it is puzzling that the theoretical and empirical toolkits available to economists for understanding the relationship between price fluctuations – what we will also refer to as “price risk” in this paper – and household welfare is both dated and limited. Although few experts would dispute claim (iii), rigorous, convincing empirical tests of claims (i) and (ii) are noticeably absent from the published literature. Indeed, up to this point there was not an established theory and empirical method for conducting such tests.

In this paper, we address that gap by studying whether (i) households value price stability; and (ii) the poor suffer disproportionately from food price instability. The effects of price fluctuations 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 in order to 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), who are generally thought to be price risk-loving given the quasiconvexity of the indirect utility function. Because agricultural households can be both producers as well as consumers of the same commodities, however, it is entirely possible for some households to be price risk-averse, for others to be price risk-neutral, and for yet others to be price risk-loving (Finkelshtain and Chalfant 1991, 1997; Barrett, 1996), although prior empirical analyses have focused on just a *single* commodity. Although Turnovsky et al. (1980) considered the price fluctuations of multiple commodities, they did so only theoretically. But 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, extended at most to a single stochastic price, paints a very incomplete picture of total (i.e., income and prices) attitudes toward risk and the impacts thereof. The literature is not very useful for informing the growing popular debates that surround food price stabilization policies.

In order to study whether households value multi-commodity price stability and whether the poor suffer disproportionately from food price instability, we combine the theoretical framework of Turnovsky et al. (1980) with the empirical framework

developed by Finkelshtain and Chalfant (1991, 1997) and extended by Barrett (1996). This allows us to derive an exact measure of multivariate price risk aversion – more precisely, an estimable matrix of price risk aversion over multiple commodities – and its associated willingness to pay (WTP) measures for price stabilization. We then apply this measure to estimate the heterogeneous welfare effects of food price volatility among rural Ethiopian households who both produce and consume several commodities characterized by stochastic prices. Indeed, using the standard deviation—mean ratio (i.e., a measure which, for each price, expresses the standard deviation as a percentage of the mean) for each commodity price retained for analysis in this paper as a rough measure of the importance of price fluctuations, the lowest (highest) such ratio is equal to 14 percent (33 percent). Intuitively, this means that in our data, the least variable price will on average rise or fall by one seventh, and the most variable price will on average rise or fall by one third.

Each element of the matrix of price risk aversion coefficients we derive and estimate reflects the risk premium associated with the covariance between two prices faced by the household. On the diagonal, this yields familiar own-price risk aversion coefficients (Barrett 1996). These measure the *direct* impacts on welfare of the fluctuations in each price, i.e., the impact on welfare of the variance of each price, holding everything else constant. But because a price almost never fluctuates alone given that different commodities are typically substitutes for or complements to one another, the off-diagonal elements of the matrix of price risk aversion measure the *indirect* impacts on welfare of the fluctuations in a each price, i.e., the impacts on welfare of the covariance between a given price and the prices of all the other commodities considered, holding everything else constant. Of course, the indirect welfare impact of the covariance between the price of one commodity and the price of another must be symmetric. The symmetry implied by the theory offers a convenient test of the core microeconomic behavioral assumptions.

To obtain the total welfare impacts of price vector fluctuations, one thus needs to consider both (i) the variance in each commodity price series as well as (ii) the covariances among them. Ignoring the covariances between prices leads to a biased

estimate of the *total* welfare impact of price vector fluctuations unless the very strong assumption that commodities are neither complements nor substitutes holds, although the sign of the bias is impossible to determine *ex ante*. The off-diagonal terms (i.e., the indirect effects of price risk, or price covariance effects) of the matrix of price risk aversion have so far been ignored by applied economists. Our analysis is the first to quantify their importance relative to the diagonal terms (i.e., the direct effects of price risk, or price variance effects) of the matrix of price risk aversion.

Based on the matrix of price risk aversion coefficients, we further show how to derive the household's WTP to stabilize at their means the prices of a set of commodities. Using panel data from rural Ethiopian households, we then estimate these measures, finding that the average household is willing to give up 6-32 percent of its income to stabilize the price of the seven most important food commodities. Nonparametric analysis further suggests that in these data, contrary to conventional wisdom, the welfare gains of price stabilization are concentrated among the upper 40 percent of the income distribution, while more than 30 percent of the (poorer) population would suffer statistically significant losses from price stabilization, although the magnitude of per capita losses among the latter subpopulation is much smaller than the magnitude of estimated gains among the wealthier winners. Hence the average net gains, as wealthier households who are largely net sellers of these food commodities benefit at the expense of poorer, largely net buyers. Given the strong political pressures to tackle food price volatility, we conclude with a simple thought experiment. We show that an alternative to strict price stabilization policy, one in which the households who are price risk-averse receive a transfer payment to compensate them for the loss they suffer due to price risk exposure, but which leaves households who benefit from price fluctuations unaffected, may be Pareto superior to fixing prices.

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 in section 2. In section 3, we present the data and descriptive statistics. 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, test the symmetry restrictions of the theory, compute and analyze household WTP estimates for price stabilization, and casually explore a price risk compensation scheme as an alternative to pure price stabilization policy. We conclude in section 6.

## **2. Theoretical Framework**

This section develops a simple two-period agricultural household model (AHM) and derives the household's matrix of price risk aversion coefficients. This is the most parsimonious model possible, as we need a framework that encompasses both consumer and producer behavior 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.<sup>5</sup> After deriving the household's price risk aversion matrix, we show that it is symmetric – an implication which we test for in section 5 – and relate it to the Slutsky matrix. Lastly, we analytically derive measures of household willingness to pay to stabilize the prices of one or more commodities, which allow quantifying the welfare impacts of price fluctuations in section 5.

### **2.1. Agricultural Household Model**

The derivations in this section closely follow those in Barrett (1996), who 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 are encouraged to consult those prior works.

Consider a representative agricultural household whose preferences are represented by a von Neumann-Morgenstern utility function  $U(\cdot)$  defined over consumption of a

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<sup>5</sup> In what follows, we abstract from credit market, storage, and informal transfer considerations. While incorporating these aspects of household behavior would undoubtedly make for a more realistic model of household behavior, we opt for a simpler specification so as to focus on the behavior of households in the face of price risk. In reality, households adopt a host of measures to manage the risks they face. We focus purely on the effect of multicommodity price risk precisely because it has been seriously understudied.

vector  $c_o = (c_{o1}, c_{o2}, \dots, c_{oK})$  of  $K$  goods whose consumption and/or production is observed and whose associated stochastic price vector is  $p_o = (p_{o1}, p_{o2}, \dots, p_{oK})$ ; a composite  $c_u$  of all goods whose consumption and/or production is unobserved by the econometrician and whose associated stochastic composite price is  $p_u$ ; <sup>6</sup> and leisure  $\ell$ . The function  $U(\cdot)$  is concave in each of its arguments, with the Inada condition  $\frac{\partial U}{\partial x} \Big|_{x=0} = \infty$  with respect to each argument  $x$ .

All  $K$  goods observed and the unobserved good can, in principle, be produced and consumed by the household.<sup>7</sup> The household has an endowment  $E^L$  of time and an endowment  $E^A$  of land. The production of each of the  $K$  observed commodities is denoted by

$$F_{oi}(L_{oi}, A_{oi}), \quad i \in \{1, \dots, K\}, \quad (1)$$

where  $L_{oi}$  denotes the amount of labor used in producing observed commodity  $i$  and  $A_{oi}$  denotes the amount of cultivable land used in producing observed commodity  $i$ . The production of the unobserved good is denoted by

$$F_u(L_u, A_u), \quad (2)$$

where  $L_u$  and  $A_u$  denote the amount of labor and cultivable land, respectively, used in producing the unobserved commodity. Both  $F_{oi}$  and  $F_u$  are strictly increasing but weakly concave in each argument.

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<sup>6</sup> In order simplify the exposition, we refer to the vector of commodities whose consumption and production is unobserved by the econometrician as “the unobserved good” in what follows.

<sup>7</sup> For example, it is quite common in developing countries for rural household to grow a staple crop (e.g., barley, wheat, maize, etc.) and many other non-staple crops (e.g., coffee, beans, etc.) For a specific crop, it is also common for some households to be net buyers of it, for some households to be autarkic with respect to it, and for some households to be net sellers of it. Finally, households may switch from one category – net buyer, autarkic, or net seller – to another from one period to the next (Bellemare and Barrett, 2006).



Agricultural labor is a function of household labor on the farm  $L^f$  and of hired labor  $L^h$ , but note that those are imperfect substitutes given that monitoring of hired workers may be imperfect, with the usual moral hazard consequence (Feder, 1985; Frisvold, 1994). A general function  $h(\cdot)$  maps hired labor into family labor equivalent units. The household can also sell a quantity  $L^m$  of labor on the market at parametric wage rate  $w$ , but the market for credit is assumed missing.

The household's time constraint is such that  $L^m + \ell + \sum_i L_{oi}^f + L_u^f \leq E^L$ , where  $\ell$  is the household's leisure time;  $L_{oi}^f$  is the amount of household labor devoted to production of observed commodity  $i$  and  $L_u^f$  is the amount of household labor devoted to production of the unobserved good. The household's land constraint is such that  $A^m + A^f \leq E^A$ , where  $A^m$  is the amount of household land leased out on the tenancy market at parametric rental rate  $r$ ; and  $A^f \equiv \sum_i A_{oi}^f + A_u^f$  is the amount of household land devoted to the production of the observable and unobservable commodities, respectively. Likewise,  $A_{oi}^h$  and  $A_u^h$  are the amounts of leased in land devoted to the production of the observable and unobservable commodities, respectively, so that  $A_{oi} \equiv A_{oi}^f + A_{oi}^h$  and  $A_u \equiv A_u^f + A_u^h$  are the total amounts of land allocated to the production of the observable and unobservable commodities. Finally, let  $I$  denote the household's unearned income, i.e., income from transfers or remittances.

In what follows, we consider a two-period model. That is, all (stochastic) product prices are unknown when labor allocation decisions are made, but post-harvest prices are revealed before consumption decisions are made. The household's problem is thus to

$$(3) \quad \max_{\{A_{oi}^h, A_u^h, A_{oi}^f, L^m, L_{oi}^h, A_{oi}^f, L_{oi}^h, L_u^h, L_u^f, A^m, \ell\}} E \max_{\{c_o, c_u\}} U(c_o, c_u, \ell)$$

subject to

$$p_o c_o + p_u c_u \leq Y^*, \quad (4)$$

$$Y^* \equiv w[L^m - \sum_{oi} L_{oi}^h - L_u^h] + r[A^m - \sum_{oi} A_{oi}^h - A_u^h] \\ + \sum_i p_{oi} F_{oi}(L_{oi}, A_{oi}) + p_u F_u(L_u, A_u) + I, \quad (5)$$

$$L_{oi} \equiv h(L_{oi}^h) + L_{oi}^f \quad \forall i, \quad (6)$$

$$L_u \equiv h(L_u^h) + L_u^f, \quad (7)$$

$$L^m + \ell + \sum_i L_{oi}^f + L_u^f \leq E^L, \quad (8)$$

$$A^f \equiv \sum_i A_{oi}^f + A_u^f \quad (9)$$

$$A^h \equiv \sum_i A_{oi}^h + A_u^h \quad (10)$$

$$A^m + A^f \leq E^A \quad (11)$$

$$h(L_{oi}^h) \in [0, L_{oi}^h], \text{ and} \quad (12)$$

$$h(L_u^h) \in [0, L_u^h]. \quad (13)$$

Given that the household's utility function is strictly increasing, preferences are locally non-satiated and so the constraints in equations (4), (8) and (11) bind. The household allocates labor and land conditional on its expectations regarding its *ex post* optimal choices of  $c_o$ ,  $c_u$ , and  $\ell$ .

By Epstein's (1975) duality result, we can use the household's variable indirect utility function  $V(\cdot)$ , which is homogeneous of degree zero in prices and income, i.e., the measurement unit chosen to measure prices and income do not matter. Thus, we can set the price of the unobserved commodity  $p_u$  as numéraire, so that  $p_i = p_{oi}/p_u$  and  $y = Y^*/p_u$ . Finally, assume that the household is income risk-averse, in the sense that

$$\frac{\partial^2 V}{\partial y^2} = V_{yy} < 0.^8$$

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<sup>8</sup> In a slight abuse of notation, we use subscripts not only to denote commodities but also the partial derivatives of the function  $V(\cdot)$  in what follows.

Using the household's (variable) indirect utility function, we can rewrite the household's maximization problem as

$$\max_{\{A_{oi}^h, L_{oi}^h, A_{oi}^f, L_{oi}^f, L_u^h, L_u^f, A^m, \ell\}} EV(\ell, p_i, y) \quad (14)$$

subject to

$$\begin{aligned} Y = w[E^L - \ell - \sum_i L_{oi}^f - \sum_i L_{oi}^h - L_u^f - L_u^h] + r[E^A - \sum_i A_{oi}^f - \sum_i A_{oi}^h - A_u^f - A_u^h] \\ + \sum_i p_i F_{oi}(L_{oi}, A_{oi}) + F_u(L_u, A_u) + I. \end{aligned} \quad (15)$$

The first-order necessary conditions (FONCs) for this problem are then:

$$\text{with respect to } L_{oi}^h : E \left\{ V_y \left( p_i \frac{\partial F_{oi}}{\partial L_{oi}^h} - w \right) \right\} \leq 0 \quad (= 0 \text{ if } L_{oi}^h > 0), \quad (16)$$

$$\text{with respect to } A_{oi}^h : E \left\{ V_y \left( p_i \frac{\partial F_{oi}}{\partial A_{oi}^h} - r \right) \right\} \leq 0 \quad (= 0 \text{ if } A_{oi}^h > 0), \quad (17)$$

$$\text{with respect to } L_{oi}^f : E \left\{ V_y \left( p_i \frac{\partial F_{oi}}{\partial L_{oi}^f} - w \right) \right\} \leq 0 \quad (= 0 \text{ if } L_{oi}^f > 0), \quad (18)$$

$$\text{with respect to } A_{oi}^f : E \left\{ V_y \left( p_i \frac{\partial F_{oi}}{\partial A_{oi}^f} - r \right) \right\} \leq 0 \quad (= 0 \text{ if } A_{oi}^f > 0), \text{ and} \quad (19)$$

$$\text{with respect to } \ell : E \{ V_\ell - V_y w \} \leq 0 \quad (= 0 \text{ if } \ell > 0). \quad (20)$$

Intuitively, the terms in parentheses in equations (16) to (19) mean that the household is a profit maximizer (i.e., it sets the value of its marginal product of labor equal to the wage rate, and the value of its marginal product of land equal to the rental rate), and equation (20) means that the household will set its (expected) marginal utility of leisure equal to the marginal cost of leisure. This set of FONCs is similar to what is usually derived from the basic agricultural household model (Singh et al., 1986; Bardhan and Udry, 1999).

A slightly similar version of this framework was used by Barrett (1996) to explain the existence of the inverse farm size–productivity relationship as a result of staple food crop price risk. We now extend this framework to the case of multiple goods with stochastic prices. As such, the next subsection shows how to 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  $p = (p_1, \dots, p_K)$  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

$$\text{sign}[\text{Cov}(V_y, p_i)] = \text{sign}(V_{yp_i}). \quad (21)$$

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.,  $M_i = \frac{\partial V / \partial p_i}{\partial V / \partial y}$ ,<sup>9</sup> we have that

$$V_y = \frac{V_{p_i}}{M_i} = \frac{V_{p_j}}{M_j}, \quad (22)$$

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

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<sup>9</sup> 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).

$$V_{yp_j} = \left( \frac{V_{p_i p_j}}{M_i} - \frac{V_{p_i}}{M_i^2} \frac{\partial M_i}{\partial p_j} \right) = \frac{1}{M_i} \left\{ V_{p_i p_j} - \frac{\partial M_i}{\partial p_j} V_y \right\}. \quad (23)$$

We also have that

$$M_i = \frac{V_{p_i}}{V_y} \Leftrightarrow V_{p_i} = M_i V_y, \quad (24)$$

which implies that

$$V_{p_i p_j} = M_i V_{yp_j} + V_y \frac{\partial M_i}{\partial p_j}, \quad (25)$$

which, in turn, implies that

$$V_{p_i y} = M_i V_{yy} + V_y \frac{\partial M_i}{\partial y} = V_{yp_i}, \quad (26)$$

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

$$V_{p_i p_j} = M_i \left\{ M_j V_{yy} + V_y \frac{\partial M_j}{\partial y} \right\} + V_y \frac{\partial M_i}{\partial p_j}. \quad (27)$$

Then, we have that

$$V_{p_i p_j} = M_i M_j V_{yy} + M_i V_y \frac{\partial M_j}{\partial y} + V_y \frac{\partial M_i}{\partial p_j}. \quad (28)$$

Multiplying the first term by  $V_{yy}/V_{yy}$  yields

$$V_{p_i p_j} = -\frac{M_i M_j R V_y}{y} + M_i V_y \frac{\partial M_j}{\partial y} + V_y \frac{\partial M_i}{\partial p_j}, \quad (30)$$

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

$$V_{p_i p_j} = -\frac{M_i M_j R V_y}{y} + M_i V_y \eta_j \frac{M_j}{y} + V_y \varepsilon_{ij} \frac{M_i}{p_j}, \quad (31)$$

where  $\eta_j$  is the income-elasticity of the marketable surplus of commodity  $j$  and  $\varepsilon_{ij}$  is the elasticity of commodity  $i$  with respect to the price of commodity  $j$ . Equation 31 is thus equivalent to

$$V_{p_i p_j} = M_i V_y \left[ -\frac{M_j R}{y} + \eta_j \frac{M_j}{y} + \varepsilon_{ij} \frac{1}{p_j} \right]. \quad (32)$$

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

$$V_{p_i p_j} = \frac{M_i V_y}{p_j} \left[ -R \beta_j + \eta_j \beta_j + \varepsilon_{ij} \right], \quad (33)$$

where  $\beta_j$  is the budget share of commodity  $j$ . When simplified, equation 33 is such that

$$V_{p_i p_j} = \frac{M_i V_y}{p_j} \left[ \beta_j (\eta_j - R) + \varepsilon_{ij} \right]. \quad (34)$$

Consequently, if  $M_i = 0$ , the household is indifferent to fluctuations in the price of good  $i$  (i.e., the variance in the price of good  $i$ ) and to fluctuations in the prices of goods  $i$  and  $j$  (i.e., the covariance between the prices of good  $i$  and  $j$ ) since its autarky from the market leaves it unaffected at the margin by price volatility.

Applying Young's theorem once again, we obtain the following equation:

$$V_{p_i p_j} = \frac{M_i V_y}{P_j} [\beta_j (\eta_j - R) + \varepsilon_{ij}] = \frac{M_j V_y}{P_i} [\beta_i (\eta_i - R) + \varepsilon_{ji}] = V_{p_j p_i}. \quad (35)$$

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

$$V_{pp} = \begin{bmatrix} V_{p_1 p_1} & V_{p_1 p_2} & \cdots & V_{p_1 p_K} \\ V_{p_2 p_1} & V_{p_2 p_2} & \cdots & V_{p_2 p_K} \\ \vdots & \vdots & \ddots & \vdots \\ V_{p_K p_1} & V_{p_K p_2} & \cdots & V_{p_K p_K} \end{bmatrix}, \quad (36)$$

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

$$\begin{aligned} A &= -\frac{1}{V_y} \cdot V_{pp} = -\frac{1}{V_y} \cdot \begin{bmatrix} V_{p_1 p_1} & V_{p_1 p_2} & \cdots & V_{p_1 p_K} \\ V_{p_2 p_1} & V_{p_2 p_2} & \cdots & V_{p_2 p_K} \\ \vdots & \vdots & \ddots & \vdots \\ V_{p_K p_1} & V_{p_K p_2} & \cdots & V_{p_K p_K} \end{bmatrix} \\ &= \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1K} \\ A_{21} & A_{22} & \cdots & A_{2K} \\ \vdots & \vdots & \ddots & \vdots \\ A_{K1} & A_{K2} & \cdots & A_{KK} \end{bmatrix}, \end{aligned} \quad (37)$$

where

$$A_{ij} = -\frac{M_i}{p_j} [\beta_j (\eta_j - R) + \varepsilon_{ij}]. \quad (38)$$

Matrix A has a relatively straightforward interpretation. The diagonal elements are analogous to Pratt's (1964) coefficient of absolute (income) risk aversion, but 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 (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 (a speculator) over  $i$ .<sup>10</sup> 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 interpretation of the off-diagonal terms is a bit trickier in that those reflect how variations in the price of one good due to variations in the price of another good affect household welfare. Put simply, if  $A_{ii}$  captures the welfare impact of the variance of the price of commodity  $i$  holding other prices constant, the off-diagonal elements capture the impacts of price covariances. Consequently,  $A_{ij} > (<) 0$  implies that for an indirect increase in the volatility of price  $i$  attributable to an increase in the volatility of price  $j$ , household welfare decreases (increases), i.e., the household stands to gain from hedging against (speculating over) covariance in the prices of goods  $i$  and  $j$ .

Taken as a whole, the price risk aversion coefficient matrix thus speaks directly to the total 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, *ceteris paribus*. Similarly, the off-diagonal terms can be interpreted as the (indirect) effect on household welfare of the covariance between the prices of two goods, *ceteris paribus*.

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<sup>10</sup> The hedger-speculator terminology is from Hirshleifer and Riley (1992), who apply it to the Keynes-Hicks theory of futures markets.



Perhaps more importantly, there is no theoretical restriction on the sign of any element of  $A$ . As per equation 38, the sign of  $A_{ij}$  depends on (i) whether the household is a net buyer or a net seller of commodity  $i$ , i.e., on the sign of  $M_i$ ; (ii) the sign of the budget share of the marketable surplus of commodity  $j$ , i.e.,  $\beta_j$ ; (iii) whether the household's coefficient of relative risk aversion  $R$  is less or greater than the income elasticity of the marketable surplus of commodity  $j$ , i.e.,  $\eta_j$ ; and (iv) the sign and magnitude of the elasticity of the marketable surplus of commodity  $i$  with respect to price  $j$ , i.e.  $\varepsilon_{ij}$ . The theory, however, implies a testable symmetry restriction on the estimated price risk aversion coefficients. With adequate data, one can test the null hypothesis

$$H_0 : A_{ij} = A_{ji} \text{ for all } i \neq j, \quad (39)$$

which, if the matrix of price risk aversion is defined over  $K$  commodities, represents  $K(K-1)/2$  testable restrictions. In other words, the empirical content of equation 39 is simply that the impact on household welfare of the covariance between prices  $i$  and  $j$  should be the same as the impact on household welfare of the covariance between prices  $j$  and  $i$ . This is analogous to symmetry of the Slutsky matrix. 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 a test of household rationality.

### 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  $i$  expressed as a function of the vector of input prices  $z$  and the vector of commodity prices  $p$  the household faces as well as its income  $y$ . We know the Slutsky matrix  $S$  is such that

$$S_{ij}(p, y) = \frac{\partial M_i}{\partial p_j} + \frac{\partial M_i}{\partial y} M_j = B_{ij} + C_{ij}, \quad (40)$$

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

$$A_{ij} = M_i \left[ \frac{1}{M_j} C_{ij} - \frac{R}{y} + B_{ij} \right]. \quad (41)$$

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  $A_{ij}$  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

$$A = \begin{pmatrix} M_1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & M_K \end{pmatrix} \left[ \begin{pmatrix} \frac{\partial M_1}{\partial y} & \dots & \frac{\partial M_K}{\partial y} \\ \vdots & \ddots & \vdots \\ \frac{\partial M_1}{\partial y} & \dots & \frac{\partial M_K}{\partial y} \end{pmatrix} + \begin{pmatrix} \frac{\partial M_1}{\partial p_1} & \dots & \frac{\partial M_1}{\partial p_K} \\ \vdots & \ddots & \vdots \\ \frac{\partial M_K}{\partial p_1} & \dots & \frac{\partial M_K}{\partial p_K} \end{pmatrix} \right. \\ \left. - \begin{pmatrix} \frac{R}{y} & \dots & \frac{R}{y} \\ \vdots & \ddots & \vdots \\ \frac{R}{y} & \dots & \frac{R}{y} \end{pmatrix} \right]. \quad (42)$$

In other words, one cannot recover the Slutsky matrix from the matrix of price risk aversion coefficients. The two matrices, 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

$$\frac{\partial M_i}{\partial p_j} + \frac{\partial M_i}{\partial y} M_j = \frac{\partial M_j}{\partial p_i} + \frac{\partial M_j}{\partial y} M_i. \quad (43)$$

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

$$\frac{\partial}{\partial p_j} \left( -\frac{V_{p_i}}{V_y} \right) + \frac{\partial}{\partial y} \left( -\frac{V_{p_i}}{V_y} \right) \cdot \left[ -\frac{V_{p_j}}{V_y} \right] = \frac{\partial}{\partial p_i} \left( -\frac{V_{p_j}}{V_y} \right) + \frac{\partial}{\partial y} \left( -\frac{V_{p_j}}{V_y} \right) \cdot \left[ -\frac{V_{p_i}}{V_y} \right], \quad (44)$$

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

$$\begin{aligned} -\left( \frac{V_{p_i p_j} V_y - V_{y p_j} V_{p_i}}{V_y^2} \right) + \left( \frac{V_{p_i y} V_y - V_{y y} V_{p_i}}{V_y^2} \right) \cdot \left[ \frac{V_{p_j}}{V_y} \right] = \\ -\left( \frac{V_{p_j p_i} V_y - V_{y p_i} V_{p_j}}{V_y^2} \right) + \left( \frac{V_{p_j y} V_y - V_{y y} V_{p_j}}{V_y^2} \right) \cdot \left[ \frac{V_{p_i}}{V_y} \right]. \end{aligned} \quad (45)$$

This last equation can then be arranged to show that

$$\left( V_{p_i p_j} - V_{p_j p_i} \right) V_y = V_{y p_j} V_{p_i} - V_{p_j y} V_{p_i} - V_{y p_i} V_{p_j} + V_{p_i y} V_{p_j}. \quad (46)$$

By Young's Theorem, we know that  $V_{p_i p_j} = V_{p_j p_i}$ , that  $V_{y p_i} V_{p_j} = V_{p_i y} V_{p_j}$ , and that  $V_{y p_j} = V_{p_j y}$ , 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  $V_{y p_i} V_{p_j}$  not be statistically significantly different from  $V_{p_i y} V_{p_j}$ ; and (iii) that  $V_{y p_j}$  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.<sup>11</sup>

In order to tackle this question with respect to the prices of  $K$  observable commodities, one first needs to compute the total WTP for those  $K$  commodities, which is obtained by computing the difference between (i) the consumer's utility if prices were held fixed at their respective expectations (i.e., the first term in the numerator below); and

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<sup>11</sup> 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).

(ii) the expected utility of the consumer in the face of stochastic prices (i.e., the second term in the numerator below), such that

$$WTP = \frac{V(E(p), y) - E(V(p, y))}{V_y} = \frac{E[V(E(p), y) - V(p, y)]}{V_y}. \quad (47)$$

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

$$WTP \approx \frac{E\left[-V_p(E(p), y)(p - E(p)) - \frac{1}{2}(p - E(p))^2 V_{pp}(E(p), y)(p - E(p))\right]}{V_y}. \quad (48)$$

In other words,

$$WTP \approx -\frac{1}{2} \frac{E[(p - E(p))(p - E(p))^2 V_{pp}(E(p), y)(p - E(p))]}{V_y} \quad (49)$$

and so

$$WTP \approx -\frac{1}{2} \sum_{i=1}^K \sum_{j=1}^K \sigma_{ij} \frac{V_{p_i p_j}}{V_y} = \frac{1}{2} \sum_{i=1}^K \sum_{j=1}^K \sigma_{ij} A_{ij}, \quad (50)$$

where  $\sigma_{ij}$  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

$$WTP \approx \frac{1}{2} \sum_{i=1}^K \sum_{j=1}^K \sigma_{ji} A_{ji}. \quad (51)$$

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

$$WTP_i \approx \frac{1}{2} \left[ \sigma_{ii} A_{ii} + \sum_{j \neq i}^K \sigma_{ij} A_{ij} \right], \quad (52)$$

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

$$WTP_i \approx \frac{1}{2} \left[ \sigma_{ii} A_{ii} + \sum_{j \neq i}^K \sigma_{ji} A_{ji} \right]. \quad (53)$$

Because equations 52 and 53 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  $i \neq j$ .

Lastly, we note that it is impossible to determine *a priori* whether  $WTP$  or  $WTP_i$  will be biased upward or downward when the covariance terms are ignored as in Finkelshtain and Chalfant (1997). This is because the direction of the bias will depend on the sign of the covariances and on the sign of the off-diagonal terms of the matrix of price risk aversion that are involved in computing  $WTP$  or  $WTP_i$ .

### 3. Data and Descriptive Statistics

We empirically demonstrate the theory developed in the previous section by estimating the price risk aversion coefficient matrix and household WTP for price stabilization using four rounds of the Ethiopian Rural Household Survey (ERHS) data<sup>12</sup> (1994a, 1994b, 1995, and 1997). The ERHS recorded both household consumption and production decisions using a standardized survey instrument across the rounds we retain for analysis. The sample includes a total of 1494 households across 16 districts (*woredas*) with an attrition rate of only 2 percent across the four rounds selected for analysis (Dercon and Krishnan, 1998).<sup>13</sup> The average household in the data was observed 5.7 times over four rounds and three seasons,<sup>14</sup> with only 7 households appearing only once in the data. The estimations in this paper thus rely on a sample of 8556 observations.<sup>15</sup>

Many households were autarkic with respect to several commodities (i.e., they neither bought or sold those commodities). For every season (i.e., the time period we consider in these data; each seasons lasts three months) 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 particular commodity. In what follows, we focus on coffee, maize, horse beans, barley, wheat, teff, and sorghum, i.e., the top seven staple commodities when considering the proportion of observations with a nonzero marketable surplus.

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<sup>12</sup> 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.

<sup>13</sup> Ethiopia is subdivided into eleven zones subdivided into *woredas*, which are roughly equivalent to counties in the United Kingdom or United States.

<sup>14</sup> Within-round variation in seasons occurred only in 1994a and 1997. Because the season was not specified for the 1994b and 1995 rounds, we cannot control for seasonality in the empirical analysis of section 5.

<sup>15</sup> The original data included several outliers when considering the marketable surpluses of the seven commodities we study. These outliers caused certain percentage values (e.g., the WTP measures below) to lie far outside the 0 to 100 percent interval. As a remedy, for each of the seven marketable surpluses used below, we kept only the 99 percent confidence interval (i.e.,  $\pm 2.576$  standard deviations) around the median, the mean being too sensitive to outliers. We thus dropped 188 observations.

Table 1 presents descriptive statistics for these seven 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 buyer of every staple. Table 2 further characterizes the dependent variables by focusing on the nonzero marketable surplus observations and by comparing descriptive statistics between net buyers and net sellers. Except for coffee and wheat, the purchases of the average net buyer household exceed the sales of the average net seller household. For every commodity, there are many households in both the net buyer, autarkic, and net seller categories, reflecting potentially heterogeneous welfare effects with respect to commodity price volatility in rural Ethiopia.

Table 3 lists the mean real (i.e., corrected for the consumer price index) price in Ethiopian birr for each of the seven commodities we study,<sup>16</sup> the average seasonal household income, and the average seasonal nonzero household income in the full sample. The income measure used in this paper is the sum of proceeds from crop sales, off-farm income, and livestock sales per period. That said, average income from the aforementioned sources is different from zero in only about 82 percent of cases, which explains why the average seasonal income of about \$94 (\$376 annually) may seem low. When focusing on nonzero income, the average seasonal income increases to about \$106 (\$424 annually).

Table 3 also presents the budget share of each staple commodity. Food represents the overwhelming majority of rural Ethiopian household expenditures, at least 85 percent. This falls on the upper end of global estimates of such budget shares, reflecting the extreme poverty of this population, the conspicuous absence of much other than food to purchase in rural Ethiopia, and the inability to impute the value of home rental income and expenditure in the ERHS data. Purchases of teff and coffee represent the largest budget shares, with 21 and 15 percent of the average household budget, respectively. The purchases of staple crops such as maize, barley, and wheat come close at 13, 12, and 11

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<sup>16</sup> As of writing, US\$1  $\approx$  Birr 9.43.



percent, respectively, of the average household budget. The purchases of beans and sorghum come last, with 7 and 6 percent, respectively, of the average household budget.

Finally, because price covariances play an important role in computing household WTP for price stabilization, table 4 reports the variance-covariance matrix for the prices of the seven staple commodities retained for analysis. Note that coffee exhibits, by far, the most price volatility. Since coffee is also one of only two crops where net sellers' mean net sales volumes exceed net buyers' mean net purchase volumes – recall that net sellers are always price risk averse in the single stochastic price setting (Finkelshtain and Chalfant 1991, Barrett 1996) – these descriptive statistics suggest that stabilization of coffee prices is more likely to generate welfare gains than would stabilization of other commodity prices. The estimates we report in Section 5 corroborate this simple insight.

#### **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 (i.e., household supply, which depends on input prices  $z$ ) net of the quantity purchased and the household's consumption of its own harvest (i.e., household demand, which depends on output prices  $p$  and income  $y$ ), a reduced form function of input and output prices and household income.

##### **4.1. Estimation Strategy**

The ERHS data include commodity prices and allow us to compute household income, but they only include 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 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, and other household-specific transaction costs that determine whether a household is a net buyer of a commodity, autarkic with respect to it, or a net seller of the same commodity (de Janvry et al., 1991).

We estimate the following marketable surplus functions for the seven commodities  $i$  discussed in the previous section:

$$M_{ik\ell t} = \alpha_i + \delta_i \ln y_{k\ell t} + \phi_i \ln p_{i\ell t} + \varphi_i \ln p_{j\ell t} + \lambda_i d_{k\ell} + \tau_i d_{\ell t} + \nu_{ik\ell t}, \quad (54)$$

where  $i$  denotes a specific commodity,<sup>17</sup>  $k$  denotes the household,  $\ell$  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  $i$ ;  $d_{k\ell}$  is a vector of household dummies;  $d_{\ell t}$  is a vector of *woreda*-round dummies that controls for the price of the unobservable composite consumer good as well as for input prices, among other things; and  $\nu$  is a mean zero, iid error term.<sup>18,19</sup>

We estimate equation (54) over 1,494 households across four rounds and three seasons, clustering 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 six.<sup>20</sup> We also include as explanatory variables all commodity prices available in the data (i.e., coffee, maize, beans, barley, wheat, teff, sorghum, potatoes, onions, cabbage, milk, *tella*, sugar, salt, and cooking oil.)<sup>21</sup>

Computation of own- and cross-price elasticities, of the income elasticity, and of the budget share of marketable surplus follows directly from equation 54. As an example, to

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<sup>17</sup> Subscripts on coefficients thus denote coefficients from specific commodity equations.

<sup>18</sup> 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 in which 0.1 and 0.000001 were added instead of 0.001, with no significant change to the empirical results.

<sup>19</sup> 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.

<sup>20</sup> 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).

<sup>21</sup> *Tella* is a traditional Ethiopian beer made from teff and maize.

obtain the estimated cross-price risk aversion coefficient  $\hat{A}_{ij}$ , one first computes budget share  $\hat{\beta}_j = M_j p_j / y$  and income elasticity  $\hat{\eta}_j = \hat{\delta}_j / M_j$  using the estimates of equation for commodity  $j$ ; and cross-price elasticity  $\hat{\epsilon}_{ij} = \hat{\phi}_i / M_i$  using estimates of the equation for commodity  $i$ . The variables  $M_j$ ,  $p_j$ , and  $M_i$  are available in the data. One then combines these estimates to obtain the point estimate

$$\hat{A}_{ij} = -\frac{M_i}{p_j} [\hat{\beta}_j (\hat{\eta}_j - R) + \hat{\epsilon}_{ij}]. \quad (55)$$

Given that marketable surplus is often zero, we use the mean of  $M_j$  and  $M_i$  so as to compute elasticities (and later compute WTP) *at means*. Although it might be preferable to use mean elasticities, it is simply not possible in these data.<sup>22</sup>

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; Saha et al., 1994). This provides additional robustness checks on our empirical results.

## 4.2. Identification Strategy

The identification of  $\phi$  and  $\varphi$  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 *woreda* in the same round. Identification of  $\delta$  comes from the intertemporal variation in income both within and between households within a round and *woreda*.

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<sup>22</sup> 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).

Since households are price takers for all commodities, all prices are exogenous in equation (54). 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 household-specific 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 affect 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.

Because many households have a marketable surplus of zero for several commodities, we estimate several sub-matrices of price risk aversion coefficients.<sup>23</sup> We first test the  $A$  sub-matrix for the top three commodities consumed and produced by the sample households (i.e., coffee, maize, and beans; we label that sub-matrix  $A_3$ ), and then test the sub-matrices defined by the top four, five, six, and seven commodities (we label these sub-matrices  $A_4$  to  $A_7$ ). With three different assumptions on relative risk aversion  $R$  and five different sub-matrices in each case, we generate a range of estimated WTP for incomplete commodity price stabilization and conduct a total of 15 tests of the null hypothesis of symmetry of the matrix of price risk aversion. The consistency of results 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 equation in equation 54 for all seven commodities. Given that these results are ancillary, we only

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<sup>23</sup> 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.

briefly discuss them so as to devote the bulk of our discussion to the estimated matrix of price risk aversion and, more importantly, to our estimates of household willingness to pay for price stabilization.

Table 5 presents estimation results for the seven marketable surplus equations. Intuitively, one would expect the  $\phi_i$  (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 wheat, for which the point estimate is statistically insignificantly different from zero.

The cross-price coefficients whose signs are consistent (i.e., of the same sign) among equations – for example, the coefficient estimate for the price of barley is negative in the coffee equation, and the coefficient estimate for the price of coffee is also negative in the barley equation – indicate that some goods are substitutes for one another (e.g., coffee and barley; maize and sorghum; beans and sorghum; and wheat and sorghum) while others are complements (e.g., coffee and wheat; teff and coffee; beans and barley; barley and teff; wheat and teff). Since these estimates reveal statistically significant complementarities and substitution effects, it looks as though ignoring covariance effects would necessarily bias estimates of price risk aversion, as discussed previously.

### **5.1. Price Risk Aversion Matrix**

We use the estimation results reported in table 5 to compute coefficients of own- and cross-price risk aversion and use these coefficients to construct sub-matrices  $A_3$  to  $A_7$  of price risk aversion. The ERHS households are significantly own-price risk-averse over all commodities. Table 6a reports estimates under the intermediate assumption of  $R=2$ ; Appendix tables A1a and A2a report estimates for  $R=1$  and  $R=3$ , respectively. The average household appears most significantly own-price risk-averse over barley, maize and teff – the commodities with the greatest net purchase volumes – and least price risk-averse over coffee and beans, which have the lowest mean net sales (purchases) volumes

among net sellers (buyers), as reflected in Table 2.<sup>24</sup> Most rural Ethiopians' price risk exposure to these latter commodities is quite modest, hence the relatively low price risk aversion coefficient estimates.

The statistical significance and magnitude of the off-diagonal elements of the estimated A matrix underscore the importance of estimating price risk aversion in a multivariate context. All 42 off-diagonal point estimates are statistically significantly different from zero, all of them positive, indicating aversion to positive co-fluctuations in commodity prices. Looking at either the upper or lower triangle of matrix A in table 6a, households are most price risk-averse over co-fluctuations in the prices of (i) teff and maize; (ii) teff and wheat; (iii) wheat and barley; and (iv) teff and barley. Given that barley, maize, and teff are staples, it is not surprising that households get hurt the most by co-movements between their respective prices. Similarly, households are least price risk-averse over co-fluctuations in the prices of (i) sorghum and coffee; (ii) beans and coffee; and (iii) wheat and coffee. Given that coffee is a nonstaple, it is not surprising that households get hurt the least by co-movements between its price and the prices of other commodities. A single-price approach to estimating price risk aversion would assume these cross-price effects all equal zero, which would bias estimates of own-price risk aversion. In particular, they would fail to capture how households dislike covariation in multiple prices that limits their capacity to substitute among commodities in response to price shocks.

We illustrate the necessity of our approach with the example of teff. First, note that in table 6a, households are risk-averse over the price of teff. This is the *direct* effect of fluctuations in the price of teff. Recall, however, that the covariances between price of teff and the prices of other commodities were all positive in table 4, so that an increase in the volatility of the price of teff is correlated with variation in other food prices, over which households are also risk averse. This generates an *indirect* welfare effect of fluctuations in the price of teff through its covariance with other food prices. To obtain

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<sup>24</sup> 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.

the *total* welfare effect in the price of teff, one needs to consider the coefficient estimates in the “teff” row or the coefficient estimates in the “teff” column of matrix A, as in equations 52 and 53, as we discuss in the next section.

Before discussing welfare effects, however, recall that the theoretical framework in section 2 implied symmetry of the A matrix. Although we reject the null hypothesis of symmetry for sub-matrices  $A_3$  to  $A_7$ , as shown in table 6b under the assumption that  $R = 2$ ,<sup>25</sup> note that each  $\hat{A}_{ij}$  is extremely close to its associated  $\hat{A}_{ji}$ . In fact, computing  $\min\{\hat{A}_{ij}, \hat{A}_{ji}\} / \max\{\hat{A}_{ij}, \hat{A}_{ji}\}$  for all  $i \neq j$  in order to measure the discrepancies between matched off-diagonal terms, the minimum such measure equals just 0.966. In other words, two matched off-diagonal coefficients differ by, at most, by three percent, hardly a substantive deviation from symmetry. Even though the formal statistical test rejects the symmetry hypothesis for the estimated A matrix, households certainly seem to behave remarkably similarly to how the theory developed in section 2 would predict.

## 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 7a and 7b 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 seven commodities considered in this paper. In what follows, we only discuss the results for  $R = 2$ , but the interpretation of the results for  $R = 1$  or  $R = 3$  is similar.

Estimating WTP with the rows of A in table 7a, the average WTP estimates are all statistically significantly different from zero. The commodity for which the average household would be willing to pay the highest proportion of its budget to stabilize the price is coffee (14.2 percent). Although the estimated coefficients of own-price risk

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<sup>25</sup> This result is robust to alternative assumptions about the coefficient of income risk aversion  $R$  (see Appendix A).

aversion are greatest for the main staple crops (teff, maize and barley) for which net marketed surplus exposure is greatest – for both net buyers and net sellers – because coffee price volatility is more than two orders of magnitude greater than for any other commodity, WTP for price stabilization is greatest for coffee, nearly an order of magnitude greater than for any grain. WTP for price stabilization is a function of both the magnitude of a commodity’s price volatility and a household’s market exposure, and thus price risk aversion coefficients.

The average household’s WTP estimate to stabilize the prices of these seven commodities is 6-32 percent of its income, depending on one’s assumed income risk aversion (6 percent for  $R = 1$ ; 19 percent for  $R = 2$ ; 32 percent for  $R = 3$ ). That proportion is statistically significant at the one percent level clearly indicating aggregate willingness to pay to stabilize food commodity prices in rural Ethiopia.

By way of comparison, we compute the WTP measures derived by Finkelshtain and Chalfant (1997) in the case of a single stochastic commodity price, ignoring the covariances between prices (Table 7c). We reject the null hypothesis that either of our total WTP measures equals the analog measure ignoring the covariance between prices, with a  $p$ -value of 0.00. Consequently, in these data, covariances between prices matter. Ignoring them significantly underestimates the average welfare loss due to price risk.

In order to be more specific about the distribution of the welfare gains from price stabilization, figure 1 plots the results of a second-degree fractional polynomial regression of the estimated household-specific WTP to stabilize the prices of all seven commodities on household income, along with the associated 95 percent confidence band.<sup>26</sup> Three important features appear in figure 1. First, a significant share (31%) of households are price risk-loving (i.e., the households whose WTP for price stabilization is statistically significantly negative) while a somewhat larger share (39%) are price risk-averse (i.e., the households whose WTP for price stabilization is statistically significantly

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<sup>26</sup> We refer readers interested in using fractional polynomial regressions to Royston and Altman (1997), who prove a good discussion of both the method as well as of its usefulness. See Henley and Peirson (1997) for an economic application.



positive). Thus the population is roughly equally divided among those who favor, oppose or are indifferent about price stabilization.

Second, the significantly price risk-loving households are markedly poorer than the significantly price risk-averse ones. Poorer households are more likely to be net consumers of all goods because they own fewer productive assets on average. And pure consumer theory holds that consumers are generally price risk-loving due to the quasiconvexity of the indirect utility function. Conversely, better-off households are more likely to be producers of all goods because they own more productive assets. Their price risk preferences are therefore more consistent with the predictions of pure producer theory, which holds that firms are generally price risk-averse (Baron, 1970; Sandmo, 1971). Table 8 shows the income percentile ranges for which households are statistically significantly price risk-loving, price risk-neutral, and price risk-averse. Households in the top 39 percent of the income distribution (i.e., the households whose seasonal income lies between 442 and 10,000 birr) are expected to gain from price stabilization, while the poorest 62 percent of the income distribution lose out from price stabilization, on average. This suggests that price stabilization would be a distributionally regressive policy in Ethiopia, benefiting the better off at the expense of poorer households. Turnovsky (1978) discussed various theoretical predictions regarding the winners and losers from price stabilization between consumers and producers. His results, however, depended on whether (i) price uncertainty stems from random fluctuations in supply or in demand; (ii) price uncertainty is additive or multiplicative; and (iii) supply and demand functions are linear. Our empirical approach is free from such assumptions and lets the data speak for themselves.

Third, the magnitude of price risk preferences is far higher among the price risk-averse than among the price risk-loving, hence the sizable average WTP for price risk stabilization even though the population is roughly evenly divided among the price risk-averse, price risk-loving and price risk-neutral subpopulations. Combined with the previous points, this underscores how simple averages may mask essential heterogeneity that is important in both equity and political economy terms.

Given the generally greater political influence of wealthier subpopulations in determining food price policy (Lipton 1977, Bates 1981) and the greater incentives for political mobilization among subgroups with a larger personal stake in the outcome (Olson 1965), the three preceding observations may help partly explain some of the political economy of food price stabilization in spite of heterogeneous preference for food price stability. Indeed, because economic policy is often subject to elite capture (i.e., the wealthy often have more of a say than the poor in the political process), these observations correspond relatively well with the “developmental paradox”, i.e., the empirical regularity according to which the more developed a country, the more its government subsidizes agriculture and favors stabilizing crop prices (Lindert, 1991; Barrett, 1999).

### **5.3. *Ex Ante* Changes in Social Welfare Under Three Stylized Policy Scenarios**

As is well known, pure price stabilization through price fixing regulations or buffer stock management introduces considerable distortions in the economy (Krueger et al., 1988, Williams and Wright 1991). In this subsection we therefore briefly consider an alternative to the laissez-faire and government-imposed price stabilization counterfactuals, a stylized price risk compensation scheme to fully compensate households who incur a welfare loss from price fluctuations, but which offers nothing to households who gain from price fluctuations. Although our previous results clearly indicate that such a policy would be distributionally regressive, as would any price stabilization policy, such a scheme merits consideration as an alternative to full-blown price stabilization if political pressure, perhaps from economic elites, effectively compels the state to act in some fashion so as to reduce food price volatility.

We begin by considering the effects of full price stabilization, i.e., a policy in which households who gain from price fluctuations are, in effect, fully taxed for their gains while households who lose out from price fluctuations are, *de facto*, fully compensated for their losses. This represents the naïve benchmark of pure price stabilization, ignoring (likely important) general equilibrium effects (Acemoglu, 2010). Table 9a characterizes

the (in-sample) winners and losers from such a policy. Under an assumed relative risk aversion  $R = 2$ , in this Ethiopian sample, those who would lose out from price stabilization vastly outnumber those who would gain (5216 versus 3060 households). But those who would lose out would incur a welfare loss from price stabilization that is on average much smaller than magnitude than the welfare gain of those who would benefit from nonstochastic prices (53 birr versus 660 birr). This echoes the point made in the previous section about the logic of collective action among a relatively small number of big winners, even when a majority would lose out from the policy (Olson 1965).

Table 9b then compares the social welfare changes for two policy options, as measured against a *laissez-faire* policy under which nothing is done about commodity price volatility.<sup>27</sup> The first intervention option is the pure price stabilization policy discussed above (column 5). Column (6) reflects a compromise option, a price risk compensation scheme in which those households who are price risk-averse receive full compensation for their exposure to price fluctuations but in which those households who are price risk-neutral and price risk-loving are unaffected. As shown, the change in social welfare is highest under a price risk compensation scheme, with the pure price stabilization policy falling between *laissez-faire* and price risk compensation. Moreover, only the price risk compensation is Pareto-improving, precisely because it leaves price risk-neutral and price risk-loving households unaffected. By contrast, pure price stabilization would make a majority of households worse off, even though average welfare gains are positive because the average gains to the price risk-averse subpopulation are more than an order of magnitude greater than the average losses to the price risk-loving subpopulation.

While this is just a highly stylized example, it serves to underscore how the heterogeneous welfare effects of food price risk exposure may require more nuanced and creative policy responses than are commonly mooted in current popular discussions. This is an area ripe for further research using more realistic general equilibrium models that

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<sup>27</sup> This highly stylized analysis ignores fiscal costs and general equilibrium effects, both of which cannot be quantified with the data at hand.

take into full consideration the distortionary effects of tax policies necessary to raise the resources for compensatory payments.

## **6. Conclusion**

This paper has modestly extended microeconomic theory so as to allow applied economists to study price risk aversion over multiple commodities. Specifically, we first derived a matrix measuring the curvature of the indirect utility function in the hyperspace defined by the prices faced by agricultural households. The elements of this matrix describe own- and cross-price risk aversion, which respectively relate to the direct impacts of a price's volatility (i.e., the variance of the price of each commodity) as well as its indirect impacts through other prices (i.e., the covariance between the prices of all commodities) on household welfare. We have also shown how testing for the symmetry of the matrix of price risk aversion coefficients is equivalent to testing the symmetry of the Slutsky matrix, although the former imposes less structure on the data than the latter and is in principle more likely not to be rejected.

In the empirical portion of the paper, we estimate the matrix of price risk aversion coefficients using well-known survey data on a panel of rural Ethiopian households. We find that these households are on average significantly price risk-averse over the prices of specific commodities as well as over co-fluctuations in the prices of the same commodities. Although we statistically reject the hypothesis that of symmetry in the matrix of price risk aversion, the estimated differences are economically insignificant, lending weak support to the underlying theory. The contrast between the statistical and economic results is likely due to the precision with which we estimate the coefficients in the matrix of price risk aversion.

More importantly, the average household's willingness to pay to fully stabilize commodity prices at their means lies between 6 to 32 percent of household income, depending on one's assumption about Arrow-Pratt relative income risk aversion. This may very well explain governments' frequent interest in price stabilization: on average, households stand to benefit from it. Nonparametric analysis of household-specific WTP

estimates, however, suggests that the welfare gains from stabilizing prices at their means would accrue to households in the upper half of the income distribution and that a significant proportion of the households in the bottom half of the income distribution would actually be hurt by price stabilization, suggesting a distributionally regressive benefit incidence from price stabilization policy.

Finally, if and when the political economy of price stabilization compels a government to intervene to attenuate the impacts of commodity price volatility, we suggest a price risk compensation alternative to outright price stabilization. Holding administrative costs constant and ignoring general equilibrium effects, we demonstrate in a very simplistic illustration that a compensation scheme without market interventions might prove Pareto-superior to pure price stabilization, albeit still distributionally regressive. Given the high-level of renewed interest in this topic, the complex and heterogeneous welfare effects of multivariate commodity price volatility appears a topic that merits further exploration.

## References

- Acemoglu, D. (2010), "Theory, General Equilibrium, Political Economy, and Empirics in Development Economics," *Journal of Economic Perspectives* 24(3): 17-32.
- Baron, D.P. (1970), "Price Uncertainty, Utility, and Industry Equilibrium in Pure Competition," *International Economic Review* 11(3): 463-480.
- Barrett, C.B. (1996), "On Price Risk and the Inverse Farm Size-Productivity Relationship," *Journal of Development Economics* 51(2): 193-215.
- Barrett, C.B. (1999), "The Microeconomics of the Developmental Paradox: On the Political Economy of Food Price Policy," *Agricultural Economics* 20(2): 159-172.
- Bates, R. (1981), *Markets and States in Tropical Africa*, Berkeley: University of California Press.
- Bellemare, M.F., and C.B. Barrett (2006), "An Ordered Tobit Model of Market Participation: Evidence from Kenya and Ethiopia," *American Journal of Agricultural Economics* 88(2): 324-337.
- Browning, M., and P.-A. Chiappori (1998), "Efficient Intrahousehold Allocations: A General Characterization and Empirical Tests," *Econometrica* 66(6): 1241-1278.
- Cashin, P., and J.C. McDermott (2002), "The Long-Run Behavior of Commodity Prices: Small Trends and Big Variability," *IMF Staff Papers*, 49(2): 175-99.
- Chavas, J.-P., and M.T. Holt (1993), "Acreage Decisions under Risk: The Case of Corn and Soybeans," *American Journal of Agricultural Economics* 72(3): 529-538.
- Deaton, A., and J. Muellbauer (1980), "An Almost Ideal Demand System," *American Economic Review*, 70(3): 312-326.
- de Janvry, A., M. Fafchamps, and É. Sadoulet (1991), "Peasant Household Behavior with Missing Markets: Some Paradoxes Explained," *Economic Journal* 101(409): 1400-1417.
- Dercon, S., and P. Krishnan (1998), "Changes in Poverty in Rural Ethiopia 1989-1995: Measurement, Robustness Tests and Decomposition," Working Paper, Centre for the Study of African Economies, Oxford University.
- Deschamps, R. (1973), "Risk Aversion and Demand Functions," *Econometrica* 41(3): 455-465.
- Epstein, L. (1975), "A Disaggregate Analysis of Consumer Choice under Uncertainty," *Econometrica* 43(5-6): 877-892.

- Finkelshtain, I. and J. Chalfant (1991), "Marketed Surplus under Risk: Do Peasants Agree with Sandmo?," *American Journal of Agricultural Economics* 73(3): 557-567.
- Finkelshtain, I. and J. Chalfant (1997), "Commodity Price Stabilization in a Peasant Economy," *American Journal of Agricultural Economics* 79(4): 1208-1217.
- Friend, I. and M.E. Blume (1975), "The Demand for Risky Assets," *American Economic Review* 65(5): 900-922.
- Goetz, S.J. (1992) "A Selectivity Model of Household Food Marketing Behavior in Sub-Saharan Africa," *American Journal of Agricultural Economics* 74(2): 444-452.
- Hanoch, G. (1977), "Risk Aversion and Consumer Preferences," *Econometrica* 45(2): 413-426.
- Hansen, L.P. and K.J. Singleton (1982), "Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns," *Journal of Political Economy* 91(2): 249-265.
- Henley, A. and J. Peirson (1997), "Non-Linearities in Electricity Demand and Temperature: Parametric Versus Non-Parametric Methods," *Oxford Bulletin of Economics and Statistics* 59(1): 149-162.
- Hirshleifer, J. and J.G. Riley (1992), *The Analytics of Uncertainty and Information*, Cambridge: Cambridge University Press.
- Brown, O., A. Crawford, and J. Gibson (2008), "Boom or Bust: How Commodity Price Volatility Impedes Poverty Reduction, and What to Do About It," IISD Policy Report.
- Henley, A., and J. Peirson (1997), "Non-Linearities in Electricity Demand and Temperature: Parametric Versus Non-Parametric Methods," *Oxford Bulletin of Economics and Statistics* 59(1): 149-162.
- Jacks, D.S., K.H. O'Rourke, and J.G. Williamson (2009), "Commodity Price Volatility and World Market Integration since 1700," *NBER Working Paper* 14748.
- Knudsen, O. and J. Nash (1990), "Domestic Price Stabilization Schemes in Developing Countries," *Economic Development and Cultural Change* 38(3): 539-558.
- Krueger, A.O., M. Schiff and A. Valdes (1988), "Agricultural Incentives in Developing Countries: Measuring the Effect of Sectoral and Economywide Policies," *World Bank Economic Review* 2(3): 255-271.
- Lindert, P.H. (1991), "Historical Patterns of Agricultural Policy," in C.P. Timmer, ed., *Agriculture and the State*, Ithaca: Cornell University Press.

- Lipton, M. (1977), *Why poor people stay poor: urban bias in world development* Cambridge, MA: Harvard University Press.
- MaCurdy, T.E., and J.H. Pencavel (1986), "Testing between Competing Models of Wage and Employment Determination in Unionized Markets," *Journal of Political Economy* 94(3): S3-S39.
- Newbery, D.M.G. (1989), "The Theory of Food Price Stabilization," *Economic Journal* 99(398): 1065-1082.
- Newbery, D.M.G, and J.E. Stiglitz (1981), *The Theory of Commodity Price Stabilization*, Oxford, UK: Oxford University Press.
- Olson, M. (1965), *The Logic of Collective Action: Public Goods and the Theory of Groups*, Cambridge, MA: Harvard University Press.
- Pratt, J.W. (1964), "Risk Aversion in the Small and in the Large," *Econometrica* 32(1-2): 122-136.
- Roache, S. (2010), "What Explains the Rise in Food Price Volatility?," Working Paper, International Monetary Fund.
- Royston, P., and D.G. Altman (1997), "Approximating Statistical Functions by Using Fractional Polynomial Regression," *Journal of the Royal Statistical Society: Series D (The Statistician)*, 46(3): 411-422.
- Saha, A., C.R. Shumway, and H. Talpaz (1994), "Joint Estimation of Risk Preference Structure and Technology Using Expo-Power Utility," *American Journal of Agricultural Economics*, 76(2): 173-184.
- Sandmo, A. (1971), "On the Theory of the Competitive Firm under Price Uncertainty," *American Economic Review* 61(1): 65-73.
- Sherlund, S., C.B. Barrett, and A.A. Adesina (2002), "Smallholder Technical Efficiency Controlling for Environmental Production Conditions," *Journal of Development Economics*, 69(1): 85-101.
- Singh, I., L. Squire, and J. Strauss (1986), *Agricultural Household Models*, Baltimore, MD: Johns Hopkins University Press.
- Timmer, C.P. (1989), *Food Price Stabilization: Rationale, Design, and Implementation*, Cambridge, MA: Harvard Institute for International Development.



- Turnovsky, S.J. (1978), "The Distribution of Welfare Gains from Price Stabilization: A Survey of Some Theoretical Issues," in F.G. Adams and S.A. Klein, eds., *Stabilizing World Commodity Markets*, Lexington, MA: Lexington Books.
- Turnovsky, S.J., H. Shalit, and A. Schmitz (1980), "Consumer's Surplus, Price Instability, and Consumer Welfare," *Econometrica* 48(1): 135-152.
- Verbeek, M., and T. Nijman (1992), "Testing for Selectivity Bias in Panel Data Models," *International Economic Review* 33(3): 681-703.
- Williams, J.C., Wright, B.D.(1991), *Storage and Commodity Markets*. Cambridge: Cambridge University Press.
- World Bank (2008), *World Development Report 2008: Agriculture for Development*, Washington, DC: World Bank Publications.

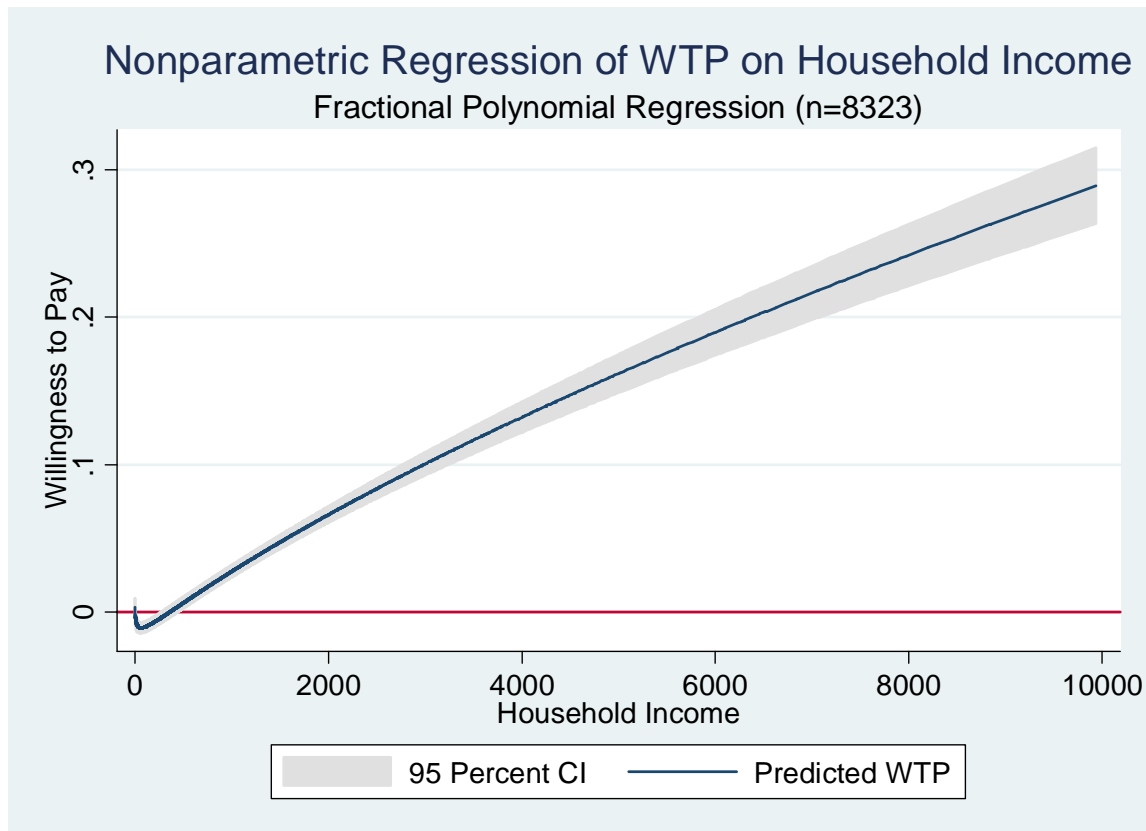


Figure 1: Fractional polynomial regression of household WTP to eliminate price fluctuations among seven staple commodities on household income for households whose seasonal income does not exceed 10,000 birr.

**Table 1: Seasonal Descriptive Statistics for Crop Marketable Surplus (Full Sample, all in kg)**

<b>Crop</b>	<b>Mean</b>	<b>(Std. Dev.)</b>	<b>Nonzero Observations</b>
Coffee	-13.36	(87.37)	6744
Maize	-121.57	(364.54)	3966
Beans	-40.39	(95.63)	3030
Barley	-88.76	(367.04)	2825
Wheat	-64.82	(279.28)	2796
Teff	-100.92	(335.37)	2666
Sorghum	-38.82	(204.00)	1712

N=8556

**Table 2: Seasonal Descriptive Statistics for Crop Marketable Surplus (Nonzero Observations)**

<b>Crop</b>	<b>Net Buyer Mean Marketable Surplus (kg)</b>	<b>(Std. Dev.)</b>	<b>Net Buyer Observations</b>	<b>Net Seller Mean Marketable Surplus (kg)</b>	<b>(Std. Dev.)</b>	<b>Net Seller Observations</b>
Coffee	-23.44	(95.64)	6206	57.92	(95.02)	538
Maize	-397.18	(438.32)	3115	231.55	(388.10)	851
Beans	-127.14	(122.91)	2848	90.70	(95.32)	182
Barley	-459.27	(553.31)	2097	279.81	(329.47)	728
Wheat	-296.70	(337.00)	2420	434.74	(620.52)	376
Teff	-471.03	(453.10)	2136	269.06	(432.08)	530
Sorghum	-349.56	(320.29)	1313	317.96	(290.27)	399

**Table 3: Seasonal Descriptive Statistics for the Independent Variables (n=8556)**

<b>Crop</b>	<b>Mean</b>	<b>(Std. Dev.)</b>
<i>Real Commodity Prices</i>		
Coffee (Birr/Kg)	13.32	(5.20)
Maize (Birr/Kg)	1.29	(0.38)
Beans (Birr/Kg)	1.88	(0.43)
Barley (Birr/Kg)	1.50	(0.41)
Wheat (Birr/Kg)	1.74	(0.33)
Teff (Birr/Kg)	2.28	(0.40)
Sorghum (Birr/Kg)	1.52	(0.42)
Potatoes (Birr/Kg)	1.52	(0.74)
Onions (Birr/Kg)	1.97	(0.78)
Cabbage (Birr/Kg)	0.92	(0.68)
Milk (Birr/Liter)	2.09	(0.88)
Tella (Birr/Liter)	0.69	(0.25)
Sugar (Birr/Kg)	5.85	(2.08)
Salt (Birr/Kg)	1.70	(1.02)
Cooking Oil (Birr/Liter)	9.14	(2.60)
<i>Income</i>		
Income (Birr)	886.17	(9869.70)
Nonzero Income (Birr)	1087.35	(10922.88)
<i>Budget Shares</i>		
Budget Share of Coffee	-0.15	(1.05)
Budget Share of Maize	-0.13	(0.40)
Budget Share of Beans	-0.07	(0.16)
Budget Share of Barley	-0.12	(0.52)
Budget Share of Wheat	-0.11	(0.43)
Budget Share of Teff	-0.21	(0.69)
Budget Share of Sorghum	-0.06	(0.33)

**Note:** Income (i.e., the sum of off-farm income, all crop revenues, and livestock sales) was different from zero for only 6973 observations, so budget shares are computed for that sub-sample. Because of the presence of zero incomes, budget shares were obtained by dividing marketable surpluses by mean nonzero income.

**Table 4: Seasonal Variance-Covariance Matrix of Commodity Prices**

	Coffee	Maize	Beans	Barley	Wheat	Teff	Sorghum
Coffee	<b>27.05</b>						
Maize	0.46	<b>0.15</b>					
Beans	0.25	0.05	<b>0.19</b>				
Barley	0.29	0.03	-0.04	<b>0.17</b>			
Wheat	0.13	0.04	0.05	0.05	<b>0.11</b>		
Teff	0.00	0.06	0.06	0.06	0.06	<b>0.16</b>	
Sorghum	0.18	0.05	0.00	0.06	0.06	0.03	<b>0.17</b>

**Table 5: Seasonal Marketable Surplus Equation Estimates**

Dependent Variable: Coefficients	(1) Coffee Marketable Surplus		(2) Maize Marketable Surplus		(3) Beans Marketable Surplus		(4) Barley Marketable Surplus	
	Coeff. Est.	(Std. Err.)	Coeff. Est.	(Std. Err.)	Coeff. Est.	(Std. Err.)	Coeff. Est.	(Std. Err.)
Coffee Price	<b>40.273***</b>	<b>(0.092)</b>	96.297***	(0.688)	15.471***	(0.051)	-178.545***	(0.500)
Maize Price	-6.344	(3.703)	<b>389.529***</b>	<b>(27.526)</b>	36.811***	(2.043)	118.277***	(20.027)
Beans Price	-9.567*	(5.359)	-115.378**	(39.841)	<b>39.952***</b>	<b>(2.957)</b>	257.049***	(28.988)
Barley Price	-27.499***	(3.585)	-53.697*	(26.648)	7.396***	(1.978)	<b>305.961***</b>	<b>(19.389)</b>
Wheat Price	30.689***	(5.884)	137.883***	(43.738)	146.613***	(3.246)	254.879***	(31.823)
Teff Price	104.537***	(7.905)	-66.515	(58.761)	-94.449***	(4.361)	-326.964***	(42.754)
Sorghum Price	-68.434***	(2.637)	-73.385***	(19.603)	-95.320***	(1.455)	-445.863***	(14.263)
Potatoes Price	12.659***	(1.007)	7.845	(7.488)	26.723***	(0.556)	37.081***	(5.448)
Onions Price	-24.624***	(3.258)	59.407**	(24.220)	-51.082***	(1.798)	-275.690***	(17.622)
Cabbage Price	-10.344***	(0.563)	52.844***	(4.182)	5.462***	(0.310)	73.095***	(3.043)
Milk Price	-13.161***	(1.182)	290.977***	(8.790)	-26.748***	(0.652)	18.605**	(6.395)
Tella Price	28.556***	(4.217)	131.295***	(31.345)	75.795***	(2.326)	307.160***	(22.806)
Sugar Price	11.445***	(3.310)	-151.995***	(24.602)	5.659***	(1.826)	21.166	(17.901)
Salt Price	6.754***	(1.944)	121.660***	(14.449)	-36.798***	(1.072)	-264.330***	(10.513)
Cooking Oil Price	-5.634**	(2.350)	-15.989	(17.470)	-91.614***	(1.297)	-362.422***	(12.711)
Income	0.721	(0.499)	7.242*	(3.708)	0.302	(0.275)	6.861**	(2.698)
Intercept	-151.799***	(15.180)	-304.647**	(112.841)	187.358***	(8.374)	1448.533***	(82.102)
<i>N</i>	8556		8556		8556		8556	
<i>p</i> -value (All Coefficients)	0.00		0.00		0.00		0.00	
<i>R</i> <sup>2</sup>	0.33		0.44		0.44		0.37	
Household FEs	Yes		Yes		Yes		Yes	
<i>Woreda</i> -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): Seasonal Marketable Surplus Equation Estimates**

Dependent Variable: Variable	(5) Wheat Marketable Surplus		(6) Teff Marketable Surplus		(7) Sorghum Marketable Surplus	
	Coeff. Est.	(Std. Err.)	Coeff. Est.	(Std. Err.)	Coeff. Est.	(Std. Err.)
Coffee Price	2.688***	(0.290)	113.406***	(0.632)	22.879***	(0.369)
Maize Price	-85.971***	(11.603)	48.316*	(25.306)	-36.271**	(14.774)
Beans Price	-35.692**	(16.795)	-63.054	(36.628)	-68.184***	(21.383)
Barley Price	-46.119***	(11.234)	-58.085**	(24.499)	50.331***	(14.303)
Wheat Price	<b>17.469</b>	<b>(18.438)</b>	38.188**	(40.211)	-144.397***	(23.475)
Teff Price	235.372***	(24.771)	<b>123.266**</b>	<b>(54.022)</b>	84.194**	(31.538)
Sorghum Price	-45.547***	(8.263)	3.172	(18.022)	<b>39.693***</b>	<b>(10.521)</b>
Potatoes Price	31.551***	(3.157)	10.700	(6.884)	-34.192***	(4.019)
Onions Price	-64.140***	(10.210)	103.915***	(22.267)	61.417***	(12.999)
Cabbage Price	21.528***	(1.763)	29.668***	(3.845)	8.517***	(2.244)
Milk Price	-134.989***	(3.705)	111.745***	(8.081)	25.431***	(4.718)
Tella Price	106.587***	(13.213)	-0.722	(28.817)	-80.962***	(16.823)
Sugar Price	43.907***	(10.371)	-175.316***	(22.619)	-22.747	(13.205)
Salt Price	-3.396	(6.091)	140.199***	(13.284)	8.750	(7.755)
Cooking Oil Price	8.577	(7.364)	12.020	(16.061)	75.466***	(9.376)
Income	0.626	(1.563)	4.950	(3.409)	2.861	(1.990)
Intercept	-130.943**	(47.568)	-396.577***	(103.741)	-300.241***	(60.564)
<i>N</i>		8556		8556		8556
<i>p</i> -value (All Coefficients)		0.00		0.00		0.02
<i>R</i> <sup>2</sup>		0.39		0.45		0.37
Household FEs		Yes		Yes		Yes
<i>Woreda</i> -Round FEs		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: Estimated Matrix of Price Risk Aversion for Relative Risk Aversion  $R = 2$**

	Coffee	Maize	Beans	Barley	Wheat	Teff	Sorghum
Coffee	<b>18.148***</b> (5.229)	10.091*** (1.983)	3.427*** (0.663)	17.293*** (2.758)	6.894*** (0.997)	11.056*** (1.879)	2.510*** (0.783)
Maize	10.063*** (1.978)	<b>620.421***</b> (72.300)	15.567*** (2.035)	58.287*** (12.732)	45.306*** (11.961)	134.083*** (24.918)	22.676*** (6.237)
Beans	3.507*** (0.679)	15.969*** (2.088)	<b>51.661***</b> (4.387)	96.571*** (10.278)	42.830*** (6.383)	57.995*** (6.444)	10.821*** (1.952)
Barley	17.098*** (2.727)	57.788*** (12.624)	93.324*** (9.933)	<b>893.913***</b> (101.013)	125.214*** (17.033)	112.650*** (19.065)	28.062*** (8.739)
Wheat	7.046*** (1.019)	46.433*** (12.258)	42.785*** (6.376)	129.431*** (17.606)	<b>275.618***</b> (60.152)	136.169*** (26.187)	16.764*** (4.529)
Teff	11.083*** (1.883)	134.770*** (25.046)	56.819*** (6.314)	114.203*** (19.327)	133.552*** (25.684)	<b>514.857***</b> (58.887)	28.438*** (4.839)
Sorghum	2.486*** (0.776)	22.521*** (6.194)	10.476*** (1.889)	28.108*** (8.754)	16.246*** (4.389)	28.099*** (4.781)	<b>94.009***</b> (13.201)

**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 Relative Risk Aversion  $R = 2$**

Sub-Matrix	Test Statistic	$p$ -value
Symmetry of Sub-Matrix $A_3$ (Coffee, ..., Beans)	$F(3, 8553) = 24.48$	0.00
Symmetry of Sub-Matrix $A_4$ (Coffee, ..., Barley)	$F(6, 8550) = 26.53$	0.00
Symmetry of Sub-Matrix $A_5$ (Coffee, ..., Wheat)	$F(9, 8547) = 22.33$	0.00
Symmetry of Sub-Matrix $A_6$ (Coffee, ..., Teff)	$F(14, 8542) = 16.59$	0.00
Symmetry of Sub-Matrix $A_7$ (Coffee, ..., Sorghum)	$F(27, 8529) = 13.61$	0.00
Joint Significance (All Coefficients)	$F(29, 8527) = 18.62$	0.00
Joint Significance (Diagonal Coefficients)	$F(7, 8549) = 47.52$	0.00
Joint Significance (Off-Diagonal Coefficients)	$F(22, 8534) = 22.85$	0.00

**Note:** Constraints were dropped due to collinearity in every test.

**Table 7a: Estimated WTP as Proportion of Household Income (Rows)**

Commodity	R = 1		R = 2		R = 3	
	WTP	(Std. Err)	WTP	(Std. Err)	WTP	(Std. Err)
Coffee	0.052***	(0.019)	0.142***	(0.039)	0.231***	(0.060)
Maize	-0.013***	(0.001)	-0.003***	(0.001)	0.007***	(0.001)
Beans	-0.002***	(0.000)	-0.001***	(0.000)	0.000	(0.000)
Barley	0.005***	(0.001)	0.016***	(0.001)	0.027***	(0.002)
Wheat	0.005***	(0.000)	0.010***	(0.001)	0.016***	(0.001)
Teff	0.007***	(0.000)	0.016***	(0.001)	0.026***	(0.001)
Sorghum	0.003***	(0.000)	0.007***	(0.000)	0.010***	(0.001)
<b>All Commodities</b>	<b>0.056***</b>	<b>(0.019)</b>	<b>0.187***</b>	<b>(0.040)</b>	<b>0.318***</b>	<b>(0.060)</b>

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

**Table 7b: Estimated WTP as Proportion of Household Income (Columns)**

Commodity	R = 1		R = 2		R = 3	
	R = 1	(Std. Err)	R = 2	(Std. Err)	R = 3	(Std. Err)
Coffee	0.045**	(0.019)	0.134***	(0.039)	0.224***	(0.059)
Maize	-0.014***	(0.001)	-0.004***	(0.001)	0.007***	(0.001)
Beans	0.005***	(0.000)	0.006***	(0.000)	0.007***	(0.000)
Barley	-0.002***	(0.001)	0.010***	(0.001)	0.021***	(0.002)
Wheat	-0.001***	(0.000)	0.004***	(0.001)	0.009***	(0.001)
Teff	0.008***	(0.000)	0.018***	(0.001)	0.028***	(0.001)
Sorghum	0.015***	(0.000)	0.019***	(0.001)	0.022***	(0.001)
<b>All Commodities</b>	<b>0.056***</b>	<b>(0.019)</b>	<b>0.187***</b>	<b>(0.040)</b>	<b>0.318***</b>	<b>(0.060)</b>

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

**Table 7c: Estimated WTP as Proportion of Household Income Ignoring Covariances**

Commodity	R = 1		R = 2		R = 3	
	R = 1	(Std. Err)	R = 2	(Std. Err)	R = 3	(Std. Err)
Coffee	0.045**	(0.019)	0.133***	(0.039)	0.222***	(0.059)
Maize	-0.015***	(0.001)	-0.006***	(0.001)	0.003**	(0.001)
Beans	-0.001***	(0.000)	0.000***	(0.000)	0.001***	(0.000)
Barley	-0.007***	(0.001)	0.003***	(0.001)	0.013***	(0.001)
Wheat	0.003***	(0.000)	0.007***	(0.001)	0.011***	(0.001)
Teff	0.005***	(0.000)	0.013***	(0.001)	0.021***	(0.001)
Sorghum	0.001***	(0.000)	0.004***	(0.000)	0.008***	(0.000)
<b>All Commodities</b>	<b>0.030</b>	<b>(0.019)</b>	<b>0.154***</b>	<b>(0.039)</b>	<b>0.278***</b>	<b>(0.059)</b>

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



**Table 8: Estimated WTP for Price Risk Stabilization, By Income Range**

<b>Income Range (Birr)</b>	<b>Income Percentile Range</b>	<b>Sign of Fitted WTP</b>
0.00 - 3.24	0.00 - 18.84	0
3.24 - 267.66	18.84 - 49.82	-
267.66 - 441.92	49.82 - 61.49	0
441.92 - 10,000.00	61.49 - 100.00	+

**Note:** These numbers reflect the regression plotted in figure 1. A negative sign in the third column means that households in this interval are statistically significantly price risk-loving; a 0 means that households in this interval have no statistically significant preference for or against price variability; and a positive sign means that households in this interval are statistically significantly price risk-averse.

**Table 9a: Estimated Welfare Gains and Losses from Eliminating Price Fluctuations**

<b>Coefficient of Relative Risk Aversion</b>	<b>(1) Average Welfare Gain (Birr)</b>	<b>(2) Number of Households Who Would Benefit</b>	<b>(3) Average Welfare Loss (Birr)</b>	<b>(4) Number of Households Who Would Lose Out</b>
<i>R</i> = 1	439.37	2134	67.23	6142
<i>R</i> = 2	660.41	3060	52.96	5216
<i>R</i> = 3	836.28	3778	43.35	4498

**Note:** The average welfare gains and losses are derived from the “All Commodities” estimates in tables 7a and 7b and reflect the effect on household welfare of completely eliminating price fluctuations, i.e., keeping the prices of coffee, maize, beans, barley, wheat, teff, and sorghum fixed at their means.

**Table 9b: *Ex Ante* Marginal Changes in Social Welfare under Three Policy Scenarios**

<b>Coefficient of Relative Risk Aversion</b>	<b>(5) Change in Social Welfare under Price Stabilization (1) x (2) - (3) x (4)</b>	<b>(6) Change in Social Welfare under Compensation (1) x (2)</b>
<i>R</i> = 1	524,689	937,616
<i>R</i> = 2	1,744,615	2,020,855
<i>R</i> = 3	2,964,478	3,159,466

**Note:** Values in columns 5 to 7 are expressed in Ethiopian birr. Column 5 describes the change in social welfare under no policy. Column 6 describes the change in social welfare under a price stabilization policy, i.e., a policy in which prices are kept equal to their means and do not fluctuate, i.e., the product of columns 1 and 2 minus the product of columns 3 and 4. Column 7 describes the change in social welfare under a price risk compensation policy, i.e., a policy in which prices fluctuate but transfers are made to compensate those who suffer from price risk, i.e., the product of columns 1 and 2.

## Appendix A

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

	Coffee	Maize	Beans	Barley	Wheat	Teff	Sorghum
Coffee	4.657*** (1.342)	2.596*** (0.510)	0.860*** (0.166)	4.484*** (0.715)	1.732*** (0.250)	2.830*** (0.481)	0.650*** (0.203)
Maize	2.582*** (0.507)	<b>159.592***</b> (18.598)	3.907*** (0.511)	15.115*** (3.302)	11.381*** (3.005)	34.324*** (6.379)	5.871*** (1.615)
Beans	0.900*** (0.174)	4.108*** (0.537)	<b>12.964***</b> (1.101)	25.043*** (2.665)	10.759*** (1.603)	14.847*** (1.650)	2.802*** (0.505)
Barley	4.387*** (0.700)	14.865*** (3.247)	23.418*** (2.492)	<b>231.808***</b> (26.193)	31.455*** (4.279)	28.840*** (4.880)	7.267*** (2.263)
Wheat	1.808*** (0.261)	11.945*** (3.153)	10.737*** (1.600)	33.564*** (4.565)	<b>69.239***</b> (15.110)	34.858*** (6.703)	4.340*** (1.173)
Teff	2.843*** (0.483)	34.667*** (6.443)	14.259*** (1.584)	29.616*** (5.012)	33.549*** (6.452)	<b>131.799***</b> (15.074)	7.362*** (1.253)
Sorghum	0.638*** (0.199)	5.794*** (1.593)	2.629*** (0.474)	7.288*** (2.270)	4.082*** (1.103)	7.193*** (1.224)	<b>24.339***</b> (3.418)

**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 Relative Risk Aversion  $R = 1$**

Sub-Matrix	Test Statistic	$p$ -value
Symmetry of Sub-Matrix $A_3$ (Coffee, ..., Beans)	$F(3, 8553) = 24.44$	0.00
Symmetry of Sub-Matrix $A_4$ (Coffee, ..., Barley)	$F(6, 8550) = 26.55$	0.00
Symmetry of Sub-Matrix $A_5$ (Coffee, ..., Wheat)	$F(9, 8547) = 22.24$	0.00
Symmetry of Sub-Matrix $A_6$ (Coffee, ..., Teff)	$F(14, 8542) = 16.58$	0.00
Symmetry of Sub-Matrix $A_7$ (Coffee, ..., Sorghum)	$F(20, 8536) = 13.65$	0.00
Joint Significance (All Coefficients)	$F(33, 8523) = 88.54$	0.00
Joint Significance (Diagonal Coefficients)	$F(7, 8549) = 47.52$	0.00
Joint Significance (Off-Diagonal Coefficients)	$F(26, 8530) = 110.23$	0.00

**Note:** Constraints were dropped due to collinearity in every test.

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

	Coffee	Maize	Beans	Barley	Wheat	Teff	Sorghum
Coffee	<b>13.493***</b> (3.887)	7.496*** (1.473)	2.567*** (0.497)	12.809*** (2.043)	5.162*** (0.746)	8.226*** (1.398)	1.860*** (0.581)
Maize	7.482*** (1.470)	<b>460.839***</b> (53.702)	11.661*** (1.524)	43.174*** (9.431)	33.926*** (8.956)	99.761*** (18.539)	16.806*** (4.622)
Beans	2.607*** (0.505)	11.862*** (1.551)	<b>38.699***</b> (3.286)	71.534*** (7.613)	32.072*** (4.779)	43.151*** (4.795)	8.020*** (1.446)
Barley	12.712*** (2.027)	42.924*** (9.376)	69.909*** (7.440)	<b>662.159***</b> (74.820)	93.766*** (12.754)	83.822*** (14.184)	20.798*** (6.477)
Wheat	5.239*** (0.757)	34.490*** (9.105)	32.050*** (4.776)	95.875*** (13.041)	<b>206.392***</b> (45.042)	101.315*** (19.484)	12.424*** (3.357)
Teff	8.240*** (1.400)	100.104*** (18.603)	42.563*** (4.729)	84.598*** (14.316)	100.007*** (19.232)	<b>383.074***</b> (43.813)	21.077*** (3.586)
Sorghum	1.848*** (0.577)	16.729*** (4.601)	7.847*** (1.415)	20.819*** (6.484)	12.166*** (3.287)	20.907*** (3.557)	<b>69.675***</b> (9.783)

**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 Relative Risk Aversion  $R = 3$**

Sub-Matrix	Test Statistic	<i>p</i> -value
Symmetry of Sub-Matrix $A_3$ (Coffee, ..., Beans)	$F(3, 8553) = 24.44$	0.00
Symmetry of Sub-Matrix $A_4$ (Coffee, ..., Barley)	$F(6, 8550) = 26.55$	0.00
Symmetry of Sub-Matrix $A_5$ (Coffee, ..., Wheat)	$F(9, 8547) = 22.24$	0.00
Symmetry of Sub-Matrix $A_6$ (Coffee, ..., Teff)	$F(14, 8542) = 16.58$	0.00
Symmetry of Sub-Matrix $A_7$ (Coffee, ..., Sorghum)	$F(20, 8536) = 13.65$	0.00
Joint Significance (All Coefficients)	$F(29, 8527) = 18.61$	0.00
Joint Significance (Diagonal Coefficients)	$F(7, 8549) = 47.52$	0.00
Joint Significance (Off-Diagonal Coefficients)	$F(22, 8534) = 18.38$	0.00

**Note:** Constraints were dropped due to collinearity in every test.