The Welfare Impacts of Commodity Price Volatility: Evidence from Rural Ethiopia

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How does commodity price volatility affect the welfare of rural households in developing countries, for whom hedging and consumption smoothing are often difficult? When governments choose to intervene in order to stabilize commodity prices, as they often do, who gains the most? This article develops an analytical framework and an empirical strategy to answer those questions, along with illustrative empirical results based on panel data from rural Ethiopian households. Contrary to conventional wisdom, we find that the welfare gains from eliminating price volatility are increasing in household income, making food price stabilization a distributionally regressive policy in this context.

Key words: commodity prices, Ethiopia, price risk, price stabilization, price volatility, risk, uncertainty.

JEL codes: D13, D80, O12, Q12.

Throughout history and all over the world, governments have frequently considered commodity price stability—the reduction of price fluctuations around a mean price level—to be an important goal of economic policy. Governments have tried to stabilize prices using a host of policy instruments, from buffer stocks to administrative pricing, and from variable tariffs to marketing boards. These efforts have typically been met with limited success. There was a period of significant policy research on the topic in the 1970s (Newbery and Stiglitz 1981), but by the early 1990s, price stabilization had largely fallen off the policy research agenda.

Since the mid-1990s, however, commodity prices have been on a rollercoaster ride (Cashin and McDermott 2002; Jacks et al. 2009; Roache 2010). Food price ten-year volatility reached its highest level in almost 30 years in December 2010 (Food and Agriculture Organization 2010). Over the past decade, food price volatility—what we will also refer to as "price uncertainty" or "price risk" throughout this article—punctuated by the food crises of 2008 and of 2010–2011, as well as by the biggest one-month jump in wheat prices in more than three decades in the summer of 2010, has rekindled widespread popular interest in commodity price stabilization. Several governments have recently reintroduced food price stabilization schemes. A simple search finds more than five times as many articles on the topic in the media over the last five years than in the preceding five years.[1] Meanwhile, major international agencies such as the Food and Agriculture Organization (FAO) of the United Nations, the International Fund for Agricultural Development (IFAD), and the World Bank (WB) have prominently discussed policy options for food price stabilization for the first time in years (WB 2008; Food and Agriculture Organization 2010; IFAD 2011).

The impulse toward state interventions to stabilize domestic food prices commonly arises because (1) households are widely believed to value price stability, (2) the poor are widely perceived to suffer disproportionately from

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[1] An August 13, 2010, LexisNexis search turned up just 51 articles from 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) 2006-2010 time period.

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food price instability, and (3) futures and options markets for hedging against food price risk are commonly inaccessible to consumers and most producers in developing countries (Newbery 1989; Timmer 1989). Although few experts would dispute claim (3) above, convincing empirical tests of claims (1) and (2) are noticeably absent from the published literature. Indeed, given the importance of the topic to policy-makers, as well as economists' past skepticism about the net economic benefit of government price stabilization interventions (Newbery and Stiglitz 1981; Krueger et al. 1988; Knudsen and Nash 1990), our theoretical and empirical toolkits for understanding the relationship between price volatility and household welfare remain puzzlingly dated and limited, especially when it comes to empirical applications.

In this article, we address that important gap in the literature by studying whether (1) households value price stability and (2) the poor suffer disproportionately from food price instability. These are empirical questions that require household-level data and a clear, rigorous strategy for relating a measure of household welfare to a measure of food price volatility. A simple regression of household welfare indicators (e.g., income, wealth, expenditures) on food price variance is infeasible for several reasons.[2] We therefore utilize the established theoretical literature on price risk to derive an estimable measure of multi-commodity price risk aversion and the associated willingness to pay for price stabilization.[3] We then use a well-respected household panel data set from rural Ethiopia with controls for household and district-round fixed effects to generate illustrative estimates of multiple commodity price risk aversion across the household income distribution.[4] As Sarris et al. (2011) note in their investigation of potential policy responses to food price volatility in low-income countries, "the main problem is not price or quantity variations *per se*, but rather unforeseen and undesirable departures from expectations" regarding commodity prices.

More precisely, we combine the theoretical frameworks of Turnovsky et al. (1980) and Schmitz et al. (1981) with the empirical framework developed by Finkelshtain and Chalfant (1991), and extended by Barrett (1996). Turnovsky et al. showed how a consumer's preference for price stability depended on only a handful of parameters, and the authors then derived a similar measure for multiple commodities. Our analysis extends this approach by examining agricultural households—who are not pure consumers, as they can *both* consume and produce a number of commodities—and by deriving a measure of willingness to pay for price stabilization as a proportion of household income. Specifically, we derive an estimable matrix of price risk aversion over multiple commodities. Based on that matrix of price risk aversion coefficients, we further show how to derive household willingness to pay (WTP) to stabilize the prices of a set of commodities at their means. As we show in the empirical results, the largest net producers exhibit the greatest WTP for price stabilization, underscoring the practical importance of this extension.

We then apply our 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. Prices in our data are highly variable: the coefficients of variation (i.e., standard deviation/mean) range from 18% to 39% among the commodity prices we study. We find that the average household is willing to give up 18% of its income to fully stabilize the price of the seven most important food commodities in the data. We also find that ignoring the covariances between prices would lead to very slightly underestimating household WTP to stabilize prices in this context. Finally, nonparametric analysis suggests that in the rural Ethiopian context, the welfare gains of price stabilization increase as household income levels increase, which is contrary to conventional wisdom. In other words, although

[2] For example, note that there is no unique "food price." Although there exist food price indices (e.g., the FAO's Food Price Index), any index necessarily aggregates prices and suppresses variance using an arbitrary weighting scheme that almost surely does not match that of the households under study. See Tveterås et al. (2012) for a recent discussion of the issues surrounding the aggregation of prices into a single index.

[3] Throughout this article, we assume away fluctuations in income (and thus in output) to focus on price risk aversion. Looking at both price and income risk aversion simultaneously would allow us to study risk aversion in multiple dimensions, that is, attitudes with respect to uncertainty over both prices and income. That topic is left for further research.

[4] The issue of commodity price volatility is often inextricably linked in the public's mind with the more directly observable issue of rising commodity prices. This article sets aside the issue of rising commodity prices (i.e., increases in the mean of the distribution of commodity prices) to focus on the volatility of commodity prices (i.e., the variance of the distribution of commodity prices). Economists have had a solid understanding of how changes in mean food prices affect welfare ever since Deaton's (1989) seminal work on the topic.

virtually everyone benefits from price stabilization, wealthier households benefit more than poorer households. This mirrors recent findings by Mason and Myers (2013), who find that the Zambian Food Reserve Agency, whose goal was to stabilize maize prices, largely benefited relatively wealthy producers without having any noticeable effect on poor households.

Our empirical estimates are merely a first, necessarily imperfect contribution that we hope reignites empirical economic research on pressing policy questions concerning commodity price stabilization. This question is intrinsically problematic for empirical research because it requires plausible statistical exogeneity of both incomes and multiple commodities' price distributions. Joint randomization of, or instrumentation for, the full vector is infeasible in our context. Below we argue that our identification strategy—which relies on longitudinal data, household fixed effects, and location-time fixed effects—is the best one can do, at least with these data, and perhaps with any existing household data set. But we emphasize the importance of careful attention to and forthright declaration of likely sources of bias in estimation. This is far too important an economic policy question to ignore out of concern for statistical perfection that is intrinsically unattainable in general equilibrium problems such as those associated with nonseparable agricultural household models of the sort we employ.

Theoretical Framework

This section explores the welfare implications of multiple commodity price volatility by specifying a two-period unitary agricultural household model (see supplementary appendix A online for the basic model), and then deriving the household's matrix of price risk aversion coefficients. The agricultural household model framework (Singh, Squire, and Strauss 1986) encompasses households' dual roles as both consumers and producers of the considered commodities. This allows us to summarize demand and supply-side factors in a single variable—marketable surplus (i.e., the difference between production and consumption). Households can be net buyers, net sellers, or autarkic, and can switch among these positions over time.

The effects of price volatility on producer behavior and profit have been well-explored in the theoretical literature. Output price uncertainty generally causes firms to employ fewer inputs, forgoing expected profits in order to hedge against price volatility (Baron 1970; Sandmo 1971; Schmitz et al. 1981).[5] The analysis of commodity price risk has been theoretically extended to individual consumers (Deschamps 1973; Hanoch 1977; Turnovsky et al. 1980; Newbery and Stiglitz 1981) who, given the quasi-convexity of the indirect utility function, are generally thought to be price risk loving for a specific commodity when the budget share of that commodity is not too large. But because agricultural households can be both producers and consumers of the same commodities, 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, although prior empirical analyses have focused on just a single commodity (Finkelshtain and Chalfant 1991, 1997; Barrett 1996). And while Turnovsky et al. (1980) considered the price volatility of multiple commodities, they only did so theoretically and for pure consumers. 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 focus on income risk, extended at most to a single stochastic price, paints an incomplete picture of attitudes toward risk, as well as the impacts thereof. More concretely, the literature is of limited usefulness in informing the growing popular debates that surround food price volatility and food price stabilization policies, especially in developing countries where many households both consume and produce the commodities in question.

Our interest in price instability requires at minimum a two-period model,[6] with at least one period in which agents make decisions subject to temporal uncertainty with respect to prices. In what follows, we assume away other sources of volatility (e.g., output and income volatility, the impacts of which are well-documented in the literature), so as to focus solely on the impacts of price volatility on household welfare. A simpler, single commodity version of this framework was used by Barrett (1996) to explain the existence of the inverse farm size-productivity relationship as

[5] In Sandmo's (1971) case, this is due to the risk aversion of the firm's owner.

[6] We caution the reader against interpreting our model as dynamic. This is because the "dynamic" aspect lies, with respect to the resolution of uncertainty, with expectations denoting "first-period" (i.e., *ex ante*) variables. Inversely, the absence of expectations denotes "second-period" (i.e., *ex post*) variables.

a result of staple food crop price risk. In what follows, we extend Barrett's framework to the case of multiple goods with stochastic prices.

We abstract from credit market, storage, and informal transfer considerations; while incorporating the credit and informal transfer aspects of household behavior would undoubtedly make for a more realistic model of household behavior, we opt for a simpler specification to focus on the behavior of households in the face of temporal price risk. Regarding storage, Tadesse and Guttormsen (2011) note that in Ethiopia, "smallholder farmers sell the bulk of their produce right after harvest to pay taxes and loans and to meet their cash requirements for social services, … few farmers store grain for long periods in order to benefit from temporal arbitrage," and also that "… storage cost is generally very high in Ethiopia." Enhancements to our admittedly parsimonious framework, which will have to be combined with more detailed empirical data, are thus left for future research.

Price Risk Aversion over Multiple Commodities

Suppose a household maximizes their utility of consumption subject to a budget constraint that reflects production decisions made subject to uncertainty about the vector $\boldsymbol{p} = (p_1, \ldots, p_k)$ of commodity prices faced by the household in a subsequent period. The household can both consume and produce each commodity, thus yielding a vector of marketable surplus (production less consumption) of the observed commodities, $\boldsymbol{x} = (x_1, \ldots, x_k)$. Negative (positive) values of any x indicate net consumption (surplus). The household receives income y from a number of sources: the crops it sells, its labor endowment, its endowment of other inputs, and transfers (e.g., remittances). As demonstrated in the more detailed model found in online appendix A, this model implies a variable indirect utility function, $EV(p, y)$, where E is the expectation operator. Let p_i denote the price of commodity i, and p_j denote the price of commodity j. Likewise, let V_y denote the first derivative of the indirect utility function with respect to income, let $\boldsymbol{V}_{pp}$ denote the matrix of second derivatives of the indirect utility function with respect to prices, and let $\boldsymbol{V}_{yp}$ denote the vector of second derivatives of the indirect utility function with respect to income and prices, respectively.

We start from the matrix of second derivatives of the household's indirect utility function relative to the vector of prices faced by the household, i.e., $\boldsymbol{V}_{pp}$, which is such that:

$$(1) \qquad \begin{bmatrix} V_{p_1p_1} & \cdots & V_{p_1p_K} \\ \vdots & \ddots & \vdots \\ V_{p_Kp_1} & \cdots & V_{p_Kp_K} \end{bmatrix}$$

and derive the following matrix $\boldsymbol{A}$ of price risk aversion coefficients in online appendix B:

$$\begin{aligned} (2) \qquad A &= -\frac{1}{V_y} \cdot V_{pp} \\ &= -\frac{1}{V_y} \cdot \begin{bmatrix} V_{p_1p_1} & \cdots & V_{p_1p_K} \\ \vdots & \ddots & \vdots \\ V_{p_Kp_1} & \cdots & V_{p_Kp_K} \end{bmatrix} \\ &= \begin{bmatrix} A_{11} & \cdots & A_{1K} \\ \vdots & \ddots & \vdots \\ A_{K1} & \cdots & A_{KK} \end{bmatrix}, \end{aligned}$$

where

$$(3) \qquad A_{ij} = -\frac{M_i}{p_j}[\beta_j(\eta_j - R) + \varepsilon_{ij}]$$

and where M_i is the marketable surplus of commodity i (i.e., the household's net supply of commodity i, or the quantity supplied, minus the quantity demanded by the household of commodity i), p_j is the price of commodity j, β_j is the budget share of the marketable surplus of commodity j (i.e., $\beta_j = p_j M_j / y$), η_j is the income elasticity of marketable surplus of commodity j, R is the Arrow-Pratt coefficient of relative risk aversion of the household, and ε_{ij} is the cross-price elasticity of the marketable surplus of commodity i relative to the price of commodity j. The elements of the matrix $\boldsymbol{A}$ vary among households, leading to heterogeneity of price risk preferences in the population.

There are no theoretical restrictions on the sign of any of the elements of $\boldsymbol{A}$. Indeed, the sign of A_{ij} depends on: (i) whether the household is a net buyer or a net seller of commodity i, that is, on the sign of M_i; (ii) the sign of the budget share of the marketable surplus of commodity j, that is, β_j; (iii) whether the household's coefficient of relative risk aversion R is less than or greater than the income elasticity of the marketable surplus of commodity j, that is, η_j; and (iv) the sign and magnitude of the elasticity of the marketable surplus of commodity i with respect to price j, that is, ε_{ij}.

Nevertheless, matrix $\boldsymbol{A}$ has a straightforward interpretation: the diagonal elements are analogous to Pratt's (1964) coefficient of absolute (income) risk aversion, but with respect to individual prices instead of income. Therefore:

1. $A_{ii} > 0$ implies that welfare is decreasing in the volatility of the price of i, that is, that the household is price risk averse over i.
2. $A_{ii} = 0$ implies that welfare is unaffected by the volatility of the price of i, that is, that the household is price risk neutral.
3. $A_{ii} < 0$ implies that welfare is increasing in the volatility of the price of i, that is, that the household is price risk loving over i.

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 diagonal elements, A_{ii}, measure the *direct* impacts on welfare of the volatility in each price, i.e., the impact on welfare of the variance of each price, holding everything else constant. However, prices almost never fluctuate alone—commodities are, to varying degrees, typically substitutes for or complements to one another.[7] Interpreting the off-diagonal terms is a bit trickier. Because prices commonly co-vary, the off-diagonal elements of the matrix of price risk aversion measure the *indirect* impacts on welfare of the volatility in each price, that is, they measure the impacts on welfare of the covariance between a given price and the prices of all the other commodities considered, holding everything else constant. This reflects the impact on welfare of changes in covariation within a portfolio.

To obtain the welfare impacts of price volatility, one thus needs to consider both (i) the variance in each commodity price series and (ii) the covariances among these price series. Ignoring the covariances between prices leads, in principle, to a biased estimate of the *total* (i.e., direct and indirect) welfare impacts of price vector volatility, 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 thus far been ignored in the literature. 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. Taken as a whole, the matrix A of the price risk aversion coefficient thus speaks directly to household preferences with respect to multivariate price risk.

Although there are no restrictions on the sign of the elements of matrix A, the theory implies a testable symmetry restriction on the estimated price risk aversion coefficients. With adequate data, one can test the null hypothesis:

$$(4) \qquad H_0 : A_{ij} = A_{ji} \quad \text{for all } i \neq j$$

which, for a matrix of price risk aversion defined over K commodities, represents $K(K-1)/2$ testable restrictions. Intuitively, the empirical content of equation (4) 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 the symmetry of the Slutsky matrix; the following proposition summarizes this result.

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

Proof. See online appendix C. ■

Moreover, 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 household rationality. Thus, this offers a useful alternative path to testing canonical neoclassical assumptions of household behavior that are often difficult to test using Slutsky matrices.

Willingness to Pay for Price Stabilization

As discussed in the introduction, policy-makers routinely try to stabilize one or more commodity prices. But what are the welfare effects of such efforts, if and when they are successful? This subsection derives the WTP measures necessary to establish the welfare gains

[7] Commodity prices can also fluctuate in tandem because they are subjected to correlated shocks. In this article, we abstract from studying the impacts of such shocks.

from partial price stabilization, that is, from stabilizing one or more commodity prices.[8]

We model risky choice as a two-period model in which decisions are made in the first period, that is, before the realization of price uncertainty, and prices (and thus utility) are realized in the second period. We can then define the WTP to eliminate all price risk as the amount of money which, when subtracted from wealth given expected price levels $E(p)$, results in the individual being indifferent to the random prices p and income y, or,

$$E[V(E(p), y - WTP)] = E[V(p, y)] \tag{5}$$

where income y may be random. Following the standard procedure in the literature, we approximate the left-hand side of this equation using a first-order Taylor series expansion in directions of certainty around the mean price and income, and using a second-order Taylor series expansion around mean price and income in all dimensions involving risk (e.g., Arrow's (1971) derivation of the coefficient of absolute risk aversion). Following the derivations in online appendix D, we ultimately obtain the following measure of WTP to stabilize the prices of all K commodities:

(6)

$$WTP = \frac{1}{2}\left[\sum_{j=1}^{k}\sum_{i=1}^{k}\sigma_{ij}\frac{V_{p_j p_i}}{V_y} + 2\sum_{i=1}^{k}\frac{V_{yp_i}}{V_y}\sigma_{yi}\right].$$

Assuming that income (which is likely to be locally determined) is uncorrelated with prices (which are likely to be globally determined),[9] this simplifies to:

$$WTP = \frac{1}{2}\left[\sum_{j=1}^{k}\sum_{i=1}^{k}\sigma_{ij}A_{ij}\right]. \tag{7}$$

Thus, WTP is just the sum of the covariances of prices weighted by the money metric impact of price variation on indirect utility. If instead one is interested in stabilizing only the price of a single commodity, i, WTP simplifies to:

$$WTP_i = -\frac{1}{2}\sigma_{ii}\frac{V_{p_i p_i}}{V_y} - \sum_{j \neq i}\sigma_{ji}\frac{V_{p_j p_i}}{V_y}. \tag{8}$$

The WTP figures derived above provide the transfer payment that a policy-maker would need to make to the household to compensate that household for the uncertainty it bears over p. Finkelshtain and Chalfant (1997) introduced a similar measure, but their framework considered only one stochastic price, which necessarily ignored the covariance between prices.

Equation (8), however, indicates that even WTP_i (i.e., the WTP to stabilize the price of a single commodity i) depends on the covariance between the price, i, and the prices of other commodities, j. Stabilizing the price of one commodity would have implications for the production and consumption of substitutes and complements that can impact welfare through portfolio effects. 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 $i \neq j$. It is impossible to determine *a priori* the sign of the bias, which depends on the sign of the covariances, and on the sign of the off-diagonal terms of the matrix of price risk aversion.

Below, WTP is always expressed as a proportion of household income so as to make WTP comparable across households. Therefore, the remainder of this article discusses WTP/y rather than WTP.

Data and Descriptive Statistics

We empirically illustrate the theory developed in the previous section by estimating the price risk aversion coefficient matrix and household WTP for price stabilization using the 1994a, 1994b, 1995, and 1997 rounds of the widely-used and well-respected Ethiopian Rural Household Survey (ERHS) data. Tadesse and Guttormsen (2011) note that, in Ethiopia, "[a] rise or decline in price trend is not as bad as its variability. … [P]rice volatility and, more recently, food price inflation remain the overriding national concerns. Post-reform grain prices are subject to significant and continuing interannual price volatility that ranks among the highest in the developing world."

[8] 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.

[9] The assumption that income is statistically independent of commodity prices holds in the data used in this article, where the bivariate correlation coefficients between income and any of the commodity prices varies only between −0.029 and 0.023, and none is significant at the 10% level.

Table 1. Seasonal Descriptive Statistics for Crop Marketable Surplus (Full Sample, in Kilograms) ($n = 8,518$)

Crop	Mean (kg)	(Std. Dev.)	Median (kg)	Min.	Max.	Nonzero Observations
Coffee	−13.36	(87.36)	−6.53	−2662.20	1200.00	6744
Maize	−121.57	(364.54)	0.00	−3915.00	3208.50	3966
Beans	−40.39	(95.63)	0.00	−717.75	600.00	3030
Barley	−88.76	(367.04)	0.00	−3915.00	3050.00	2825
Wheat	−64.82	(279.28)	0.00	−3915.00	5000.00	2796
Teff	−100.92	(335.37)	0.00	−3593.03	3225.69	2666
Sorghum	−38.82	(204.00)	0.00	−1688.00	1600.00	1712

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 1,494 households across 16 districts (*woreda*) with an attrition rate of only 2% across the four rounds selected for analysis (Dercon and Krishnan 1998).[10] The average household in the data was observed 5.7 times over four rounds and three seasons (i.e., three-month periods),[11] with just seven households appearing only once in the data. The estimations in this article thus rely on a sample of 8,518 observations.[12]

In what follows we focus on coffee, maize, beans, barley, wheat, teff, and sorghum, which are the seven most important commodities in the data when considering the fraction of households producing or consuming them. Table 1 presents descriptive statistics: a positive mean marketable surplus indicates that the average household is a net seller of a commodity, and a negative mean marketable surplus indicates that the average household is a net buyer of a commodity, so the average household is a net buyer of every commodity. For each commodity, a significant number of households have a marketable surplus of zero, however, because they neither bought nor sold that commodity.[13] Per equation (3), a household is price risk neutral for any commodity for which its net marketable surplus equals zero. If a household neither buys nor sells off a given commodity, it is unaffected by fluctuations in the price of that commodity.

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,[14] the average seasonal household income, and the average seasonal nonzero household income in the full sample. The income measure used in this article is the sum of proceeds from labor income (both off-farm employment and non-farm self-employment), crop sales, remittances, sales of assets, including livestock, and sales of animal products for each period. Average income from the aforementioned sources is different from zero in only about 82% 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

[10] Ethiopia is subdivided into eleven zones, which are further subdivided into districts, which are roughly equivalent to counties in the United States.

[11] 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 our empirical analysis.

[12] The original data included several outliers with respect to 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% interval. As a remedy, for each of the seven marketable surpluses used below, we kept only the 99% confidence interval (i.e., ±2.576 standard deviations) around the median, the mean being too sensitive to outliers. We thus dropped 188 observations. Generally, those outliers were households whose net purchases (rather than net sales) were excessively large, suggesting either measurement error or the inclusion of purchases that were for multiple household groups, or as inputs into household food processing enterprises, and not for single household consumption. For each crop, we dropped only one or two observations due to excessively large net sales.

[13] There were no cases where a household bought and sold a commodity in the exact same quantities.

[14] At the time of writing, US\$1 ≈ Birr 9.43.

Table 2. Seasonal Descriptive Statistics for Crop Marketable Surplus (Nonzero Observations, in Kilograms)

Crop	Net Buyer Mean Marketable Surplus (kg)	(Std. Dev.)	Number of Net Buyer Observations	Net Seller Mean Marketable Surplus (kg)	(Std. Dev.)	Number of Net Seller Observations
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 = 8,518)

Crop	Mean	Std. Dev.	Median	Min.	Max.
Real Prices					
Coffee (Birr/kg)	13.32	(5.20)	11.96	3.58	26.69
Maize (Birr/kg)	1.29	(0.38)	1.25	0.66	2.86
Beans (Birr/kg)	1.88	(0.43)	1.86	1.03	3.15
Barley (Birr/kg)	1.50	(0.41)	1.48	0.66	2.53
Wheat (Birr/kg)	1.74	(0.33)	1.70	0.92	2.48
Teff (Birr/kg)	2.28	(0.40)	2.36	1.03	3.26
Sorghum (Birr/kg)	1.52	(0.42)	1.40	0.72	2.61
Potatoes (Birr/kg)	1.52	(0.74)	1.63	0.27	4.14
Onion (Birr/kg)	1.97	(0.78)	2.03	0.41	4.14
Cabbage (Birr/kg)	0.92	(0.68)	0.95	0.14	5.06
Milk (Birr/kg)	2.09	(0.88)	1.91	0.87	6.32
Tella (Birr/kg)	0.69	(0.25)	0.57	0.27	1.63
Sugar (Birr/kg)	5.85	(2.08)	5.64	1.27	10.87
Salt (Birr/kg)	1.70	(1.02)	1.41	0.69	5.86
Cooking Oil (Birr/kg)	9.14	(2.60)	8.79	3.26	15.25
Income					
Income (Birr)	886.17	(9869.70)	271.62	0.00	820625.80
Nonzero Income (Birr)	1087.35	(10922.88)	403.32	0.64	820625.80
Budget Shares of Marketable Surpluses					
Budget Share of Coffee	−0.15	(1.07)	−0.09	−0.99	0.99
Budget Share of Maize	−0.13	(0.41)	0.00	−1.00	0.99
Budget Share of Beans	−0.07	(0.17)	0.00	−1.00	0.91
Budget Share of Barley	−0.12	(0.53)	0.00	−1.00	0.99
Budget Share of Wheat	−0.11	(0.44)	0.00	−0.99	0.96
Budget Share of Teff	−0.21	(0.70)	0.00	−0.99	0.99
Budget Share of Sorghum	−0.06	(0.33)	0.00	−1.00	1.00

Note: Because prices were measured once per season at the district level rather than at the household level, there are fewer than 8,518 price observations.

increases to about $106 ($424 annually). These figures, while seemingly low, encompass all the sources of income available in the data and reflect the extreme poverty prevalent in rural Ethiopia.

Table 3 also presents the budget share of each staple commodity. Food, at 85%, represents the overwhelming majority of rural Ethiopian household expenditures. This falls at 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 our inability to impute the value of land rental income and expenditure in the ERHS data. Purchases of teff and coffee represent the largest household expenditures, with 21% and 15% percent of the average budget being devoted to them, respectively. Although a budget share of 15% may seem very high

Table 4. Seasonal Variance-Covariance Matrix of Commodity Prices over the Four Rounds Retained for Analysis

	Coffee	Maize	Beans	Barley	Wheat	Teff	Sorghum
Coffee	27.05						
Maize	0.46	0.15					
Beans	0.25	0.05	0.19				
Barley	0.29	0.03	−0.04	0.17			
Wheat	0.13	0.04	0.05	0.05	0.11		
Teff	0.00	0.06	0.06	0.06	0.06	0.16	
Sorghum	0.18	0.05	0.00	0.06	0.06	0.03	0.17

Note: All covariances are measured in monetary terms (i.e., birr).

for coffee, recall that coffee plays an important role in Ethiopian culture, where the coffee ceremony is culturally central (Pankhurst 1997). Note that households both purchase and sell green coffee beans, so that the same commodity is being compared as part of the marketable surplus of coffee.

Finally, because price variances and 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. Coffee exhibits by far the most price volatility. Since coffee is also one of only two crops (along with wheat) 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 stabilizing coffee prices is more likely to generate welfare gains than would stabilizing other commodity prices. But that remains an empirical question, and our estimation results actually suggest otherwise.

Empirical Framework

For each commodity, we estimate a reduced form regression of the marketable surplus of that commodity as a function of output prices and household income with controls for a range of observables and unobservables. We use district-round fixed effects to control for the input prices and weather conditions faced by each household in each district in each round, as well as for macroeconomic factors such as inflation, interest rates, the international price of commodities, etc. Time-invariant household fixed effects provide further control for household-specific preferences, production skill, transactions costs and biophysical conditions related to location and social relationships that may confer preferential pricing or access to income-earning opportunities, 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; Bellemare and Barrett 2006). The use of household and district-round fixed effects also controls for access to storage, so that our estimates should largely account for what little commodity storage there is in rural Ethiopia (Tadesse and Guttormsen 2011).

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

$$M^{*}_{ik\ell t} = \alpha_i + \eta_i y^{*}_{k\ell t} + \sum_{j=1}^{7} \varepsilon_{ij} p^{*}_{j\ell t} + \lambda_i d_k + \tau_i d_{\ell t} + \upsilon_{ik\ell t} \tag{9}$$

where an asterisk (*) denotes a variable transformed using the inverse hyperbolic sine transformation—a logarithmic-like transformation that allows us to keep negative as well as zero-valued observations and which allows us to interpret coefficients as elasticities as suggested by Burbidge et al. (1988) and used by MacKinnon and Magee (1990), Moss and Shonkwiler (1993), and Pence (2006).[15] Moreover, i denotes a specific commodity (i.e., coffee, maize, beans, barley, wheat, teff, or

[15] Under the IHS transformation, each variable, $x^* = \ln(x_{ijk} + (x^2_{ijk} + \theta)^{1/2})$, where $\theta = 1$, as is the custom in the existing literature that employs IHS. The advantage of the IHS transformation is that it retains the desirable properties of the log transformation while allowing us to keep negative and zero-valued observations rather than simply drop them.

sorghum),[16] k denotes the household, ℓ denotes the district, and t denotes the round; y denotes household income, $\boldsymbol{p}_j$ is a vector of the prices of all (observed) commodities (including i), $\boldsymbol{d}_k$ is a vector of household dummies, $\boldsymbol{d}_{\ell t}$ is a vector of district-round dummies, and υ is a mean zero, iid error term.

The estimated coefficient on household income y in equation (9) is the income elasticity of the marketable surplus of commodity i, or η_i in the notation of equation (3) in our theoretical framework. Likewise, the estimated coefficient on price $\boldsymbol{p}_j$ in equation (9) is the elasticity of the marketable surplus of commodity i with respect to price j, or ε_{ij} in the notation of our theoretical framework.

We estimate equation (9) by seemingly unrelated regressions (SUR), since SUR estimation brings an efficiency gain over estimating the various equations in the system separately when the dependent variables are all regressed on the same set of regressors. We estimate equation (9) over 1,494 households across seven periods (i.e., four rounds and three seasons), clustering standard errors at the district level. No household was observed over all four rounds and three seasons; the number of observations per household ranged from one to six.[17] We also include all commodity prices available in the data (i.e., coffee, maize, beans, barley, wheat, teff, sorghum, potatoes, onions, cabbage, milk, *tella*,[18] sugar, salt, and cooking oil) as explanatory variables.

Computation of own- and cross-price elasticities (i.e., the ε terms), as well as of income elasticities (i.e., the η terms) is straightforward, as the estimated coefficients on own- and cross-price, as well as on income in equation (9) are elasticities given the inverse hyperbolic sine transformation. We then combine these estimates to obtain the point estimate

$$(10) \qquad \hat{A}_{ij} = -\frac{M_i}{p_j}[\hat{\beta}_j(\hat{\eta}_j - R) + \hat{\varepsilon}_{ij}],$$

whose standard error is obtained by the delta method. Given that marketable surplus is often zero, we use the means of the M_ι and M_j variables to compute budget shares.[19] Because our data do not allow us to directly estimate R, the coefficient of relative risk aversion, we estimate the A_{ij} coefficients for $R = 1$, which is well within 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).

What would the ideal data set for estimating equation (9) look like? Ideally, one would want to ensure statistical independence of prices and income from the error term in the marketable surplus equation, and thereby obtain causal estimates of the η, and ε elasticity parameters. Randomizing over a multi-dimensional vector of prices and income is practically infeasible, however, as is any other approach for generating a vector of valid instrumental variables for price and income regressors that could otherwise be endogenous.

The best feasible option for this problem is therefore panel data analysis, which allows us to control for unobservable household, district, and period characteristics. Household fixed effects should control for the systematic way in which each household forms its price expectations, and district-round fixed effects should control for departures from the systematic way in which each household forms its price expectations by accounting for the price information available to each household in a given district in a given time period. Likewise, if a household's status as a net buyer, autarkic, or a net seller with respect to a given commodity is primarily driven by its preferences for producing and consuming that specific commodity, by innate skill, by location-specific endowments, or by the household-specific transactions costs it faces (de Janvry et al. 1991; Goetz 1992; Bellemare and Barrett 2006), these factors are accounted for by the household fixed effect. While this panel data approach does not purge the error term of all prospective correlations with the explanatory variables in equation (9), it surely purges much of it, and is ultimately the best one can do in terms of empirical identification on this important empirical question, as we discuss in greater detail in online appendix E. Still, we caution the reader against either interpreting our estimates for the coefficients in equation (9) as strictly causal, or ignoring crucial policy questions for which ironclad identification is inherently elusive. We subject

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

[17] 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).

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

[19] Many households have a reported income of zero, so we compute budget shares using the average income in the data rather than household-specific income measures.

our estimates to a range of robustness tests as a check on our findings. The core, qualitative findings prove invariant to a range of robustness checks.

In the empirical work below, the ε parameters—the price elasticities of marketable surplus—are identified by: (i) the variation in prices within each household over time (given our use of household fixed effects); and (ii) the between-district variation within a given round and over time for each district (given our use of district-round fixed effects). For example, the price of maize is common to all the households in a given district in a given round, so controlling for the unobserved heterogeneity between households and the unobserved heterogeneity between district-round, the vector of coefficients $\boldsymbol{\varepsilon}$—the vector of price elasticities of marketable surplus—is identified because prices vary over time for each household and because prices also vary between each district-round both across space and over time. The identification of η—the income elasticity of marketable surplus—is more straightforward given that income varies both within households over time and between households in a given district within a given round.

Conditional on a household's status as a net buyer, autarkic, or a net seller of a given commodity, its purchases or sales of that commodity is driven by its preferences and by the household-specific transactions costs it faces, but also by climatic and other environmental fluctuations that affect production (Sherlund et al. 2002), which are largely accounted for by the district-round fixed effect, and by prices and income, for which we control. See online appendix E for an extended discussion of our identification strategy and of prospective sources of bias in estimation.

Estimation Results and Hypothesis Tests

This section first presents estimation results for the marketable surplus equation (9) for all seven commodities retained for analysis. Given that these results are ancillary, we only 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 WTP for price stabilization.

Table 5 presents estimation results for the seven marketable surplus equations. One would expect the own-price elasticity coefficients, ε_{ii}, to be positive. That is, as the price of commodity i increases, households buy less or sell more of that same commodity, depending on whether they are net buyers or net sellers to begin with. In six cases out of seven (coffee, maize, beans, barley, teff, and sorghum), estimated own-price elasticities of marketable surplus are positive, and those coefficients are statistically significant in three of those six cases (coffee, maize, and barley). Only one estimated own-price elasticity (wheat) is negative, which is likely due to the profit effect identified by Singh et al. (1986). The profit effect concerns the added impact on demand of the income the household enjoys from the higher price for the commodity it grows; for net sellers with a relatively high income elasticity of demand (as distinct from marketable surplus) for the commodity, one can obtain this result. This seems plausible for wheat in this setting.

Similarly, estimated income elasticity coefficients are positive and statistically significant in six out of seven cases (coffee, maize, barley, wheat, teff, and sorghum), and the income elasticity of the remaining marketable surplus is not significantly different from zero. This could partly reflect residual endogeneity of income as a function of marketable surplus, but almost surely reflects the crucial role that cash income plays in financing productivity-enhancing inputs in this setting, such that higher income is routinely causally associated with higher output because it relaxes the liquidity constraint that producers face in financing the purchase of inputs such as fertilizer and improved seeds, which offer high marginal returns (Dercon and Christiaensen 2011).

We can illustrate the interpretation of coefficients in table 5 by taking coffee as an example. In that case, for a 1% increase in the price of coffee, the marketable surplus of coffee increases by 0.5% on average as a result of net buyers of coffee purchasing less coffee, and of net sellers of coffee selling more coffee. Likewise, for a 1% increase in household income, the marketable surplus of coffee increases by 0.1%.

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 the matrix A of price risk aversion in table 6a.

Table 5. Seasonal Marketable Surplus Equation Estimates (n = 8,518)

Variables	(1) Coffee	(2) Maize	(3) Beans	(4) Barley	(5) Wheat	(6) Teff	(7) Sorghum
Dependent Variables: Marketable Surplus of Each Commodity							
Price of Coffee	**0.536****	3.340***	0.656**	−1.692***	0.191	1.210***	0.428
	(**0.230**)	(0.444)	(0.290)	(0.417)	(0.385)	(0.362)	(0.325)
Price of Maize	−0.330	**4.330*****	0.545	0.316	−5.131***	3.472***	0.300
	(0.460)	(**0.889**)	(0.581)	(0.835)	(0.771)	(0.725)	(0.651)
Price of Beans	−0.697	−4.414***	**0.933**	2.571**	−1.304	−0.105	−0.595
	(0.578)	(1.117)	(**0.731**)	(1.049)	(0.969)	(0.911)	(0.818)
Price of Barley	−2.013***	0.365	0.361	**1.835****	−1.138	−0.478	2.878***
	(0.469)	(0.905)	(0.592)	(**0.850**)	(0.785)	(0.738)	(0.663)
Price of Wheat	−1.469***	−4.009***	5.147***	3.758***	**−1.368**	1.065	−2.961***
	(0.525)	(1.015)	(0.664)	(0.953)	(**0.880**)	(0.827)	(0.743)
Price of Teff	5.880***	3.268*	−1.649	−3.468**	7.600***	**0.092**	−0.587
	(0.905)	(1.748)	(1.143)	(1.641)	(1.516)	(**1.425**)	(1.280)
Price of Sorghum	−2.432***	2.415**	−3.625***	−6.457***	2.097**	−2.544***	**0.370**
	(0.549)	(1.060)	(0.693)	(0.995)	(0.920)	(0.864)	(**0.776**)
Price of Potatoes	−0.198	−1.187***	1.053***	−0.332	1.107***	0.013	−1.178***
	(0.143)	(0.277)	(0.181)	(0.260)	(0.240)	(0.226)	(0.203)
Price of Onions	0.357	3.730***	−1.587***	−2.661***	−0.592	1.877***	0.959
	(0.460)	(0.889)	(0.581)	(0.835)	(0.771)	(0.725)	(0.651)
Price of Cabbage	−0.569***	0.036	−0.481**	−0.094	0.354	0.340	0.709***
	(0.192)	(0.370)	(0.242)	(0.348)	(0.321)	(0.302)	(0.271)
Price of Tella	0.006	7.005***	0.014	−1.249	−4.136***	2.479***	0.643
	(0.436)	(0.843)	(0.551)	(0.791)	(0.731)	(0.687)	(0.617)
Price of Milk	1.254*	−2.919**	3.358***	4.615***	0.443	4.714***	−1.815*
	(0.698)	(1.348)	(0.882)	(1.266)	(1.170)	(1.099)	(0.987)
Price of Sugar	0.178	0.558*	0.536**	−0.385	1.215***	−2.474***	−0.572**
	(0.170)	(0.328)	(0.215)	(0.308)	(0.285)	(0.267)	(0.240)
Price of Salt	0.102	2.759***	−1.175***	−0.660	−0.169	0.965*	−0.356
	(0.345)	(0.667)	(0.436)	(0.626)	(0.578)	(0.543)	(0.488)
Price of Cooking Oil	0.447	−0.216	−2.624***	−2.498***	1.610**	−0.469	1.372**
	(0.443)	(0.855)	(0.559)	(0.803)	(0.742)	(0.697)	(0.626)
Household Income	**0.115*****	**0.180*****	**0.015**	**0.215*****	**0.016**	**0.143*****	**0.111*****
	(**0.009**)	(**0.017**)	(**0.011**)	(**0.016**)	(**0.014**)	(**0.013**)	(**0.012**)
Constant	−0.000	−0.000	0.000	0.000	0.000	−0.000	−0.000
	(0.016)	(0.030)	(0.020)	(0.028)	(0.026)	(0.024)	(0.022)
Observations	8,518	8,518	8,518	8,518	8,518	8,518	8,518
R-squared	0.174	0.171	0.098	0.157	0.091	0.197	0.126

Notes: Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Estimated intercepts are equal to zero due to the centering of data necessary to account for household fixed effects. Own price and income elasticities are in bold.

Because all prices are measured in birr and all quantities are measured in kilograms, the various coefficients of price risk aversion in table 5 can be compared to one another. Looking at the diagonal elements of matrix A, it appears that households in the data are on average most significantly own-price risk averse over maize (619.379), barley (268.86), and teff (102.842)—the commodities with the greatest net purchase volumes—and least price risk averse over coffee (7.200), wheat (23.787), and beans (31.923). Of the latter three commodities, two—coffee and beans—have the lowest mean net sales volumes among net sellers, and the lowest mean net purchase volumes among net buyers, as reflected in table 2. 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 $\boldsymbol{A}$ matrix underscore the importance of estimating price risk aversion in a multivariate context. Indeed, all 42 off-diagonal elements of $\boldsymbol{A}$ are statistically significant at the 1% level. Regarding specific coefficients, note that when it comes to cross-price risk aversion, the average household in the data is most price risk averse over the prices of maize and

Table 6a. Estimated Matrix of Price Risk Aversion for Relative Risk Aversion $R = 1$ (N = 8, 518)

	Coffee	Maize	Beans	Barley	Wheat	Teff	Sorghum
Coffee	**7.200**	−1.865	−4.854	−17.834	−10.862	38.506	−21.604
	(**1.528**)	(0.229)	(0.306)	(1.607)	(0.829)	(2.544)	(1.709)
Maize	40.283	**619.379**	−291.741	37.066	−269.469	194.685	210.238
	(1.450)	(**20.738**)	(9.414)	(1.810)	(9.594)	(6.615)	(7.506)
Beans	2.951	19.307	**31.923**	18.214	128.988	−22.697	−96.824
	(0.109)	(0.548)	(**0.936**)	(0.750)	(3.363)	(0.714)	(2.471)
Barley	−9.887	27.202	127.682	**227.309**	219.168	−117.312	−372.571
	(0.528)	(1.895)	(5.700)	(**10.612**)	(10.098)	(5.323)	(16.955)
Wheat	2.235	−239.443	−42.106	−37.143	**23.787**	229.359	94.698
	(0.147)	(14.714)	(1.982)	(2.769)	(**5.973**)	(11.204)	(5.048)
Teff	13.812	305.788	2.280	−24.684	81.363	**102.842**	−166.878
	(0.530)	(11.756)	(0.541)	(1.809)	(3.273)	(**5.234**)	(6.243)
Sorghum	2.144	11.641	−9.884	85.849	−62.620	−6.230	**45.352**
	(0.135)	(0.961)	(0.661)	(4.459)	(3.522)	(0.753)	(**2.173**)

Notes: Each cell presents a mean coefficient of price risk aversion for the relevant commodities. Standard errors are in parentheses. Diagonal elements are in bold and denote own-price risk aversion, that is, the welfare impact of variance in the price of a given commodity. Off-diagonal elements denote cross-price risk aversion, that is, the welfare impact of covariance between the prices of two commodities. A positive (negative) coefficient indicates that the average household loses (gains) from variability in the prices of the commodities considered by a given cell. All values are statistically significant at the 1% level.

Table 6b. Mean Coefficient of Price Risk Aversion for Relative Risk Aversion $R = 1$ for Net Buyers and Net Sellers

	Net Sellers		Net Buyers	
	Mean	(Std. Err.)	Mean	(Std. Err.)
Coffee	7.743	(61.032)	9.257	(164.452)
Maize	−834.125	(1323.370)	1928.369	(2594.919)
Beans	−32.239	(24.858)	97.848	(125.645)
Barley	−208.385	(249.934)	996.200	(1756.375)
Wheat	899.277	(2214.627)	−54.926	(436.023)
Teff	196.587	(702.984)	363.186	(844.835)
Sorghum	81.144	(220.140)	270.510	(430.648)

Notes: Each cell presents a mean coefficient of own-price risk aversion for the relevant commodity. Standard errors are in parentheses. A positive (negative) coefficient indicates that the average household loses (gains) from variability in the price of the commodity. Standard errors are in parentheses. All values are statistically significant at the 1% level.

teff (reading coefficients as row-column, given the positive signs on the maize-teff and teff-maize coefficients), and most price risk loving over the prices of maize and wheat (given the negative signs on the maize-wheat and wheat-maize coefficients). In other words, whereas the average household in the data is hurt by covariance in the prices of maize and teff, it benefits from covariance in the prices of maize and wheat. In fact, for maize, those cross-price effects clearly dominate the own-price effect. Indeed, the maize-teff (194.685), teff-maize (305.788), maize-wheat (−269.469), and wheat-maize (−239.443) coefficients of cross-price risk aversion are all much larger in absolute value than the wheat-wheat coefficient of own-price risk aversion (23.787).

We illustrate the necessity of our multi-commodity approach with the example of teff, which has a positive coefficient of own-price risk aversion (102.842). First, note that in table 6a, households are, on average, risk averse over the price of teff; this is the *direct* effect of fluctuations in its price. However, the covariances between the price of teff and the prices of other commodities were all positive in table 4, so an increase in the volatility of the price of teff is correlated with variation in other food prices over which households are either risk averse (coffee, maize, and wheat) or risk loving (beans, barley, and sorghum). This generates an *indirect* welfare effect of volatility in the price of teff through its covariance with other food prices. To obtain the *total* welfare effect in the price of teff, one must consider the coefficient estimates in the "teff" row or the coefficient estimates in the "teff" column of matrix $\boldsymbol{A}$, as discussed in the next section.

In addition, we "unpool" the data and present the diagonal terms of the matrix of coefficients of own-price risk aversion for each commodity by splitting the sample between the net buyers and net sellers in table 6b. In that case, we note that net buyers of all commodities except wheat are, on average, price risk averse; net sellers of coffee, wheat, teff, and sorghum are, on average, price risk averse; and net sellers of maize, beans, and barley appear price risk loving, on average.

The theoretical framework implied symmetry for matrix $\boldsymbol{A}$. We thus conduct a Hotelling (1931) test of multivariate means equality whose null hypothesis of symmetry is such that $H_0 : A_{ij} = A_{ij}$ for all $i \neq j$. Given that there are 21 coefficients on either side of the diagonal of matrix A, the test contains 21 restrictions and is run over all 8,518 observations, so that the F-statistic of 202.91 for the test should be compared with the $F(21,8497)$ critical value. One restriction is dropped due to multicollinearity, however, so we compare the $F(20,8498)$ critical value. As do most other studies concerned with testing household rationality (e.g., Browning and Chiappori 1998), we reject the null hypothesis of household rationality at less than the 1% level.

Willingness to Pay Estimates for Price Stabilization

Recall from above that the WTP for stabilization of single commodity price can be estimated by considering either the rows or columns of matrix $\boldsymbol{A}$ of price risk aversion, but that for total WTP, both values coincide by construction. Table 7 shows the estimated average household WTP (expressed as a proportion of household income) for stabilizing the prices of individual commodities, as well as for stabilizing the prices of all seven commodities considered in this article.

We start by estimating WTP ignoring the covariances between prices (Finkelshtain and Chalfant 1991), an omission that biases downward commodity-specific and total measures of WTP to stabilize prices. In that case, note that the commodity-specific WTP estimates are all statistically significant and that the average household in the data would be willing to give up 17% of its income to stabilize the prices of all seven commodities retained for analysis. Though this may seem a rather high figure, full price stabilization is practically infeasible, so this figure represents an upper bound on the welfare gains associated with price stabilization.

Looking at the WTP derived from the columns of $\boldsymbol{A}$ in the second column of table 7, the average WTP estimates are all statistically significant. The commodity for which the average household would be willing to pay the highest proportion of its budget to stabilize the price of is coffee, with 11%, and the commodity for which the average household would be willing to pay the smallest proportion of its budget is beans, with −2%. In other words, considering the columns of matrix $\boldsymbol{A}$, the average household in the data would be willing to give up 11% of its income to stabilize the price of coffee, but it would need to be paid 2% of its income to accept a stabilization in the price of beans.

Likewise, looking at the WTP derived from the rows of $\boldsymbol{A}$ in the third column of table 7, the average WTP estimates are again all statistically significant. The commodity for which the average household would be willing to pay the highest proportion of its budget to stabilize the price is again coffee, with 8%, and the commodity for which the average household would be willing to pay the smallest proportion of its budget is barley, with less than 1%.

Ultimately, columns 2 and 3 of table 7 suggest that the average household in the data would be willing to give up 18% of its income to simultaneously and completely stabilize the prices of coffee, maize, beans, barley, wheat, teff, and sorghum. That estimate is statistically significant at the 1% level, which suggests aggregate willingness to pay to stabilize food commodity prices in rural Ethiopia under the assumption that the average household's coefficient of relative risk aversion $R = 1$.

There is a seeming contradiction between the magnitude of the estimate coefficients of price risk aversion in matrix $\boldsymbol{A}$ in table 6a, in which the average household seemed to care most about food staples (i.e., maize, barley, teff) and the magnitude of the estimated WTPs for price stabilization in table 7, in which the average household seems to care most about a nonstaples (i.e., coffee). The discrepancy between the coefficients in matrix $\boldsymbol{A}$ and the WTP measures is due to the fact that while the WTP measures in equations (7) and (8) include prices variances and covariances, the coefficients of price risk aversion in equation (3) do not include these variances and covariances. So although households are *a priori* relatively less risk averse with respect to the price of coffee than they are for other commodities, the fact that

Table 7. Estimated WTP for Price Stabilization

	Ignoring Covariances		Including Covariances, Row-based		Including Covariances, Column-based	
Commodity	WTP	(Std. Err.)	WTP	(Std. Err.)	WTP	(Std. Err.)
Coffee	0.091***	(0.019)	0.107***	(0.019)	0.080***	(0.019)
Maize	0.042***	(0.001)	0.052***	(0.002)	0.058***	(0.002)
Beans	0.003***	(0.000)	−0.019***	(0.001)	0.008***	(0.000)
Barley	0.018***	(0.001)	0.015***	(0.001)	−0.004***	(0.001)
Wheat	0.001***	(0.000)	0.007***	(0.001)	0.007***	(0.000)
Teff	0.008***	(0.000)	0.024***	(0.001)	0.024***	(0.001)
Sorghum	0.004***	(0.000)	−0.008***	(0.001)	0.005***	(0.000)
Total	0.167***	(0.019)	0.179***	(0.019)	0.179***	(0.019)

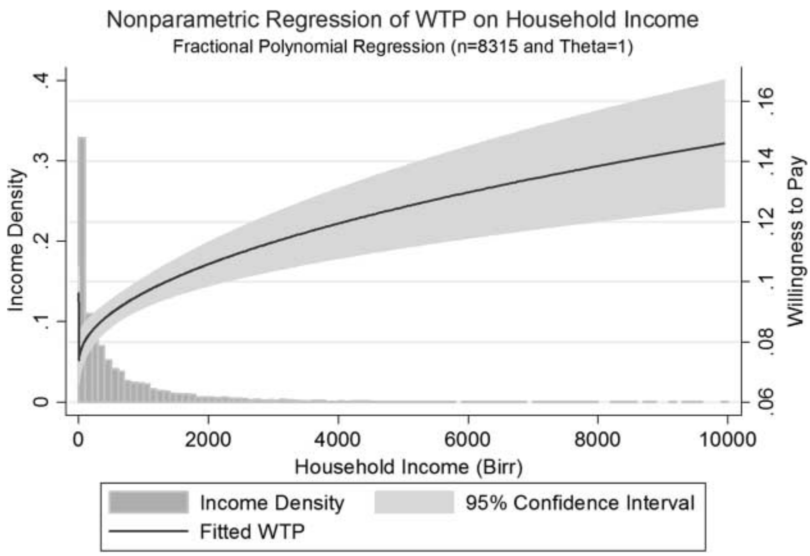

Figure 1. Fractional polynomial regression of household WTP to stabilize at their means the prices of the seven commodities retained for analysis on household income for households whose seasonal income does not exceed 10,000 birr, with 95% confidence interval. The histogram plots the proportion of households falling in each income category

their WTP to stabilize the price of coffee dominates their WTP to stabilize the prices of other commodities is due to the considerably more volatile price of coffee. In other words, whereas equation (3) denotes preferences for marginal tradeoffs in price risk, equations (7) and (8) derive the WTP as a combination of those preferences and the magnitude of the price risks involved.

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% confidence band.[20] Figure 1 indicates that although the average WTP to stabilize the prices of coffee, maize, barley, beans, wheat, teff, and sorghum all at once is positive at all levels of income, households are willing to give up an increasing amount of their income to stabilize prices as they get wealthier. This goes against the conventional wisdom that holds that the poor in developing countries are the ones who are most hurt by price volatility.

[20] We refer readers interested in using fractional polynomial regressions to Royston and Altman (1997), who provide a good discussion of both the method as well as of its usefulness. See Henley and Peirson (1997) for an economic application.

The intuition behind the result in figure 1 is that since producers are more likely to be hurt by price volatility (Sandmo 1971), and since the wealthier households in our data are more likely to be producers, a positive relationship naturally arises between income and WTP to stabilize prices. The fact that relatively wealthier rural households appear to be hurt more by price volatility than poorer rural households may also go a long way toward explaining the political economy of food prices in the developing world, where commodity price stabilization—in the sense of dampening variance, rather than reducing the likelihood of price spikes—is usually a concern of food producers, who tend to be relatively wealthier rural households, rather than of food consumers (Lipton 1977; Bates 1981; Barrett 1999; Lindert 1991; van de Walle 2001).

Limitations

The theoretical derivations and the empirical framework provide a useful methodology with which to study the welfare impacts of price volatility. Likewise, the results in this section illustrate the empirical application of the methodology. Those results, however, suffer from important limitations that must be acknowledged and discussed.

First, we have assumed away other sources of volatility (income, output, etc.) in order to focus solely on price risk aversion, that is, on the welfare impacts of price volatility. But in applied microeconomics, welfare is represented by the indirect utility function, which depends on both the prices faced by the individual or household, as well as on the individual's or the household's income. To present a complete picture of risk aversion, then, one would need to take into consideration the fact that income is also stochastic. As derived in online appendix A and discussed in the theoretical framework, the calculations here are only valid if other stochastic sources of income are uncorrelated with price risk. None of the bivariate correlation coefficients between prices and income in the ERHS data are statistically significantly different from zero at the 10% level, but independence cannot be taken for granted.

Second, in the expected utility (EU) framework that we adopt in this article, the welfare costs of risk generally tend to be of the second order. This leads to well-known issues such as the apparent low welfare cost of macroeconomic volatility. If we take those issues seriously, however, it may mean that the welfare costs of volatility are much higher than normally acknowledged (Grant and Quiggin 2005). So while the EU framework is a convenient tool with which to analyze behavior, it is far from perfect, as the literature on behavioral anomalies with respect to and departures from the EU framework demonstrates. Our rejection of the symmetry implication of the matrix of price risk aversion coefficients reinforces a vast body of literature that questions canonical

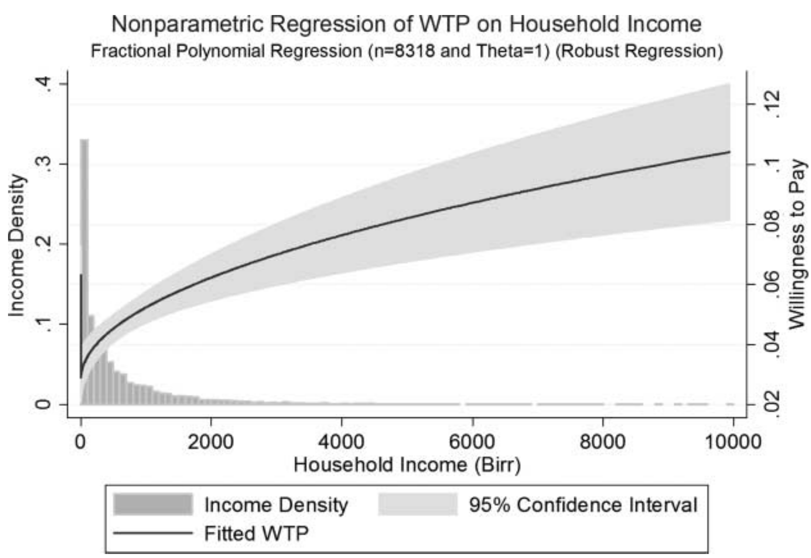

Figure 2. Robustness check for the fractional polynomial regression in figure 1 using robust regression estimates

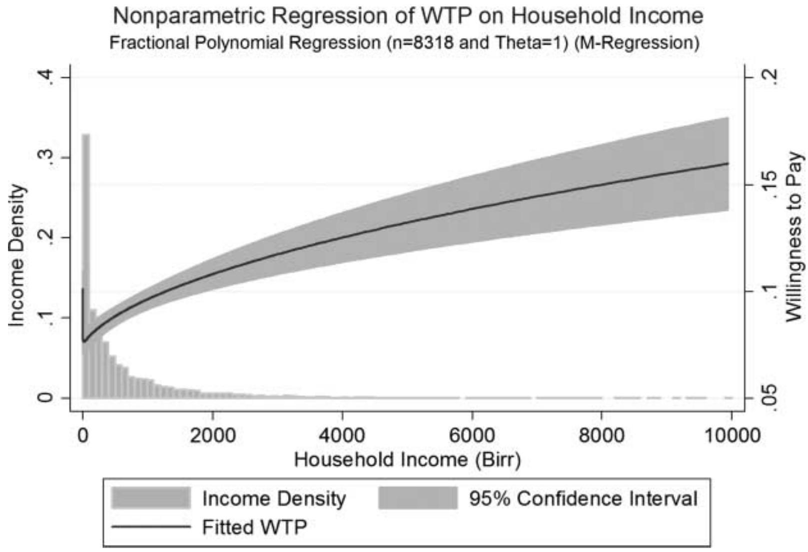

Figure 3. Robustness check for the fractional polynomial regression in figure 1 using M-regression estimates

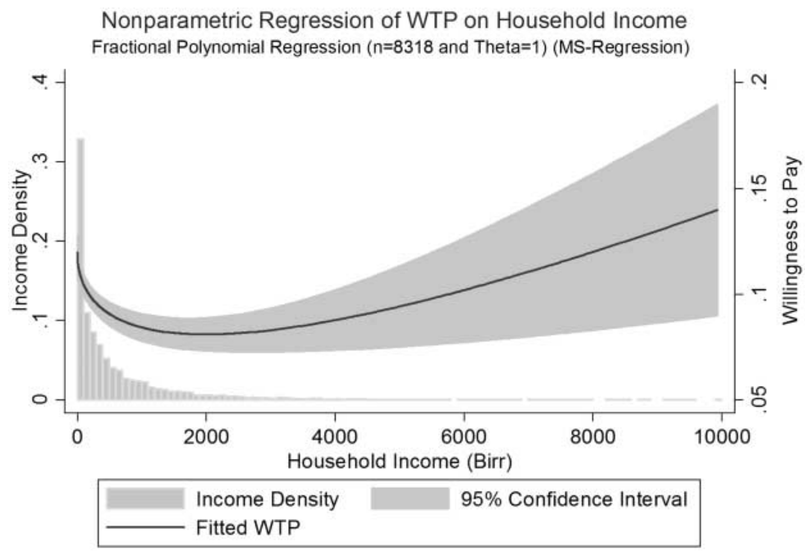

Figure 4. Robustness check for the fractional polynomial regression in figure 1 using MS-regression estimates

assumptions of neoclassical consumer and producer theory. Extending the analysis of price risk aversion to more general models of behavior is an interesting topic for future research.

Third, the methodology developed in this article only accounts for the static costs of volatility, but there are also dynamic costs that may be much more important. For example, households may decide to withdraw their children from school, forgo some investments in health, or draw down their assets to maintain a specific level of consumption after food price shocks (Carter and Barrett 2006). These coping behaviors may have long-term consequences on household welfare, which our methodology cannot capture. So while our empirical results provide a glimpse of the generally negative impacts that food price volatility can have on welfare, they nevertheless provide an incomplete picture. Nesting analysis of the welfare effects of price volatility within a structural dynamic model—especially one with prospective nonlinearities that might give rise to poverty traps—would represent an important extension of the current model.

Lastly, we return to the empirical concerns identified in the empirical framework. While our use of panel data allows us to control for much prospective statistical endogeneity, and is ultimately the best one can do in this class of problem, we once again caution the reader against interpreting table 5's estimates for the coefficients in equation (9) as strictly causal. Rather, focus should be less on the precise quantitative estimates than on the core qualitative findings: the average rural Ethiopian household is price risk averse over these seven commodities, but the welfare loss due to commodity price volatility increases with increasing levels of income.

Robustness Checks

An anonymous reviewer and the editor in charge encouraged us to discuss the robustness of our results. In a previous version, instead of applying the inverse hyperbolic sine transformation to all marketable surpluses, prices, and incomes, we regressed marketable surpluses in levels on the logarithms of prices and incomes. Doing so led to results that were somewhat similar to those in figure 1, with the exception that, on average, households in the left tail of the income distribution appeared price risk loving (i.e., they had a negative WTP for price stabilization) rather than price risk averse, as in figure 1. The findings that average WTP for price stabilization is positive and on the order of 15-20%, and that it increases with income, however, were present even in that previous version.

Figures 2 to 4 show the results of additional robustness checks that were conducted using robust regression techniques: robust regression using iteratively reweighted least squares (Li 1985); Huber's M-regression (Huber 1973); and Rousseuw and Yohai's MS-regression (Rousseuw and Yohai 1987). In every case our core qualitative results remain, that is, WTP for price stabilization is everywhere positive and increasing as income levels increase.

Table 8. Robustness Checks on Average WTP

Price Covariances	WTP (Proportion of Income)	(Std. Err.)
Huber's M-Estimator		
Ignoring Covariances	0.193	(0.020)
Including Covariances	0.184	(0.020)
Rousseuw and Yohai's MS-Estimator		
Ignoring Covariances	0.144	(0.022)
Including Covariances	0.218	(0.022)
Robust Regression		
Ignoring Covariances	0.172	(0.019)
Including Covariances	0.127	(0.018)

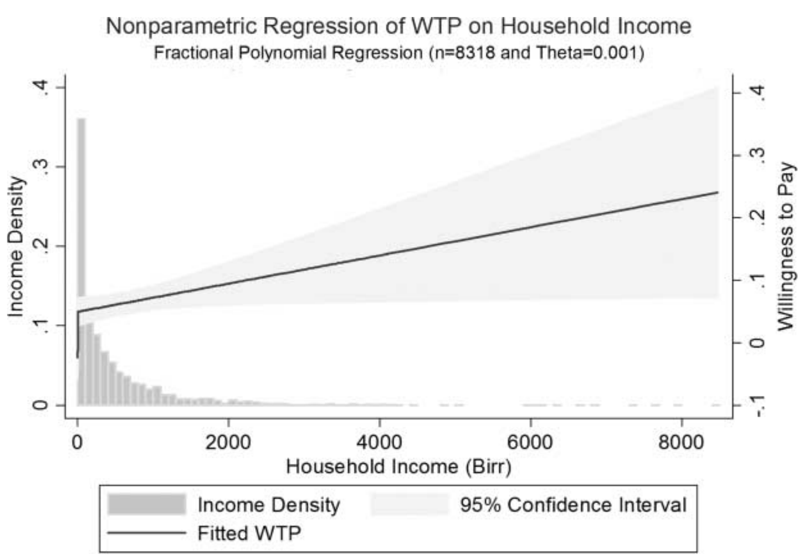

Figure 5. SUR Estimation of OLS Specifications with θ = 0.001

Table 8 summarizes average WTPs to stabilize all seven prices across those regression methods, both ignoring and including covariances.

Lastly, the inverse hyperbolic sine transformation includes a scale parameter $\theta = 1$, which we had set equal to 1 everywhere. We conduct additional robustness checks by re-estimating everything for $\theta \in \{0.001, 0.01, 0.1, 0.05, 2\}$, and present the results of those robustness checks in figures 5 to 9. Once again, in every case our core qualitative results remain, that is, WTP for price stabilization is everywhere positive and increasing as income levels increase.

Taking stock of how robust our findings are, we note that the most robust of our findings are that (i) the average welfare loss incurred due to price volatility—alternatively, WTP for price stabilization—is positive, which is consistent with conventional wisdom, but also that (ii) it is increasing as levels of household income increase in these data, which runs counter to conventional wisdom on the welfare impacts of commodity price volatility.

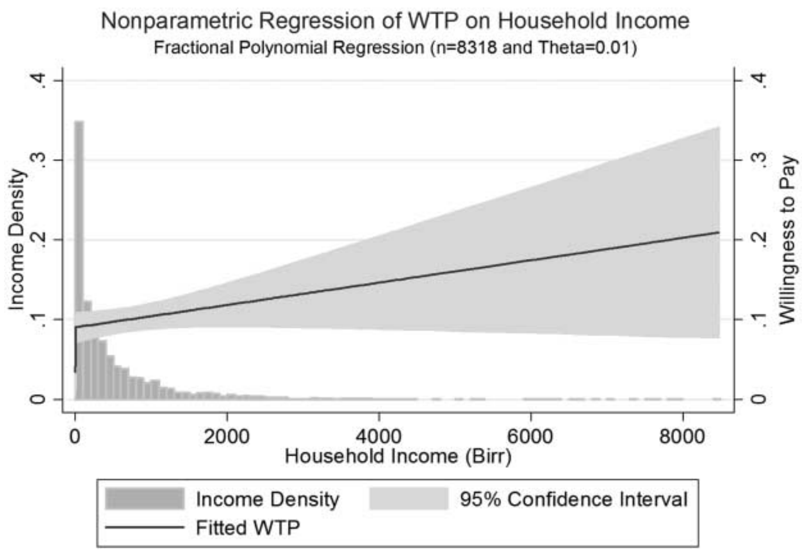

Figure 6. SUR Estimation of OLS Specifications with $\theta = 0.01$

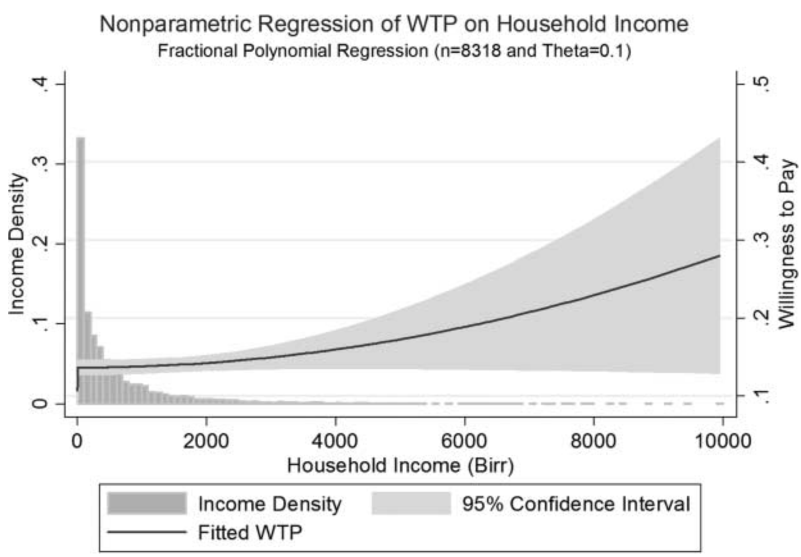

Figure 7. SUR Estimation of OLS Specifications with $\theta = 0.1$

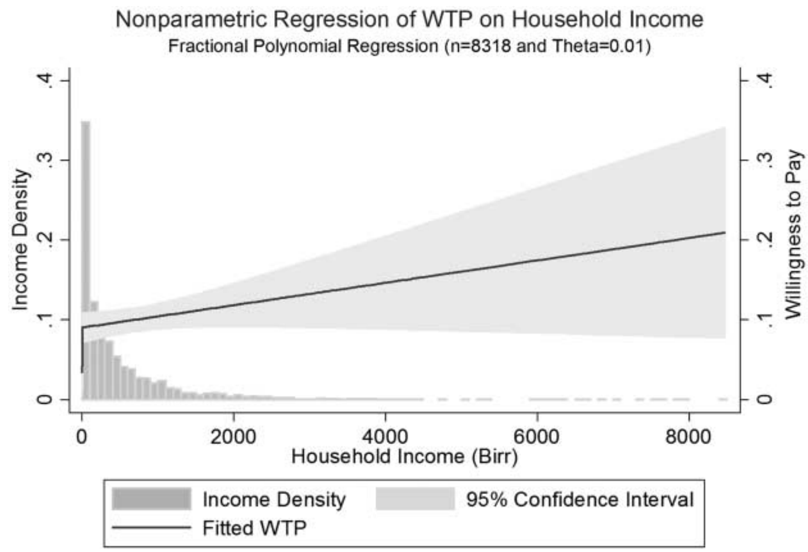

Figure 8. SUR Estimation of OLS Specifications with θ = 0.5

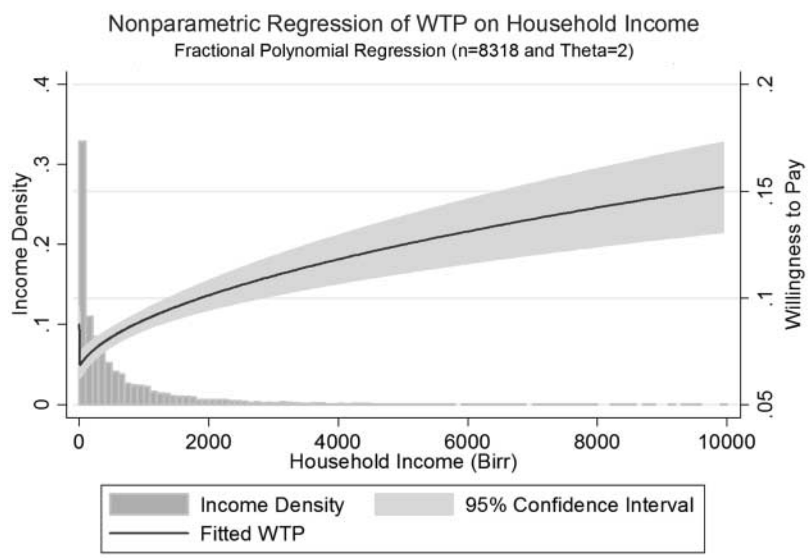

Figure 9. SUR Estimation of OLS Specifications with θ = 2

Conclusions

This article has considered the distributional effect of a pure stabilization policy for the prices of food staples in a typical developing country setting. This complements studies by Helms (1985) and Wright and Williams (1988), both of which provide numerical assessments of the welfare costs of price instability. Our contribution is mainly methodological; we developed a method with which to study the impacts of price volatility on the welfare of agricultural households in developing countries. Our empirical illustration suggests that price stabilization yields net welfare gains in rural Ethiopia, but in a distributionally regressive fashion. This contrasts with the conventional wisdom in current food policy debates, which commonly conflates increases in mean food prices—which clearly hurt poor net food buyers—with increased fluctuations around the (perhaps higher) mean (Barrett and

Bellemare 2011). Our approach allows us to isolate and estimate the welfare effects of food price volatility.

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.

In the empirical illustration portion of the article, we estimate the matrix of price risk aversion coefficients using panel data from rural Ethiopia. We find that the households in the data are, on average, significantly price risk averse over the prices of specific commodities, as well as over covolatility in the prices of the same commodities. We also reject the hypothesis of symmetry of the matrix of price risk aversion, consistent with rejecting symmetry of the Slutsky matrix.

More importantly, assuming a coefficient of relative (income) risk aversion equal to 1, we find that in these data, the average household's WTP to fully stabilize commodity prices at their means is about 18% of its income. 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, indicates that the benefits of price stabilization are increasing as levels of household income increase, suggesting a distributionally-regressive benefit incidence from price-stabilization policy. Given the renewed interest in this topic among national and international policy-makers, the complex and heterogeneous welfare effects of multivariate commodity price volatility appears to be a topic that merits further exploration.

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