Exploring food commodity price risk preferences among Tanzanian households

Linden McBride, Cornell University

lem247@cornell.edu

Selected paper prepared for presentation at the Agricultural and Applied Economics Association's 2014 AAEA Annual Meeting, Minneapolis, MN July 27-29, 2014.

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1. Introduction

Increasing food price volatility has led to renewed discussion of food price stabilization among policy makers and international agencies. An often-cited concern in such discussions is the widespread assumption that smallholders and the poor are hit harder by food price volatility than are other demographic groups (FAO 2012). While intuitively reasonable—i.e., one would expect volatile food prices to affect the real incomes of households that allocate a majority of expenditures to food in significant ways—little evidence is available to support the concern that this effect is necessarily negative. In fact, recent analyses from Ethiopia and Zambia suggest that the benefits of food price stabilization—the obverse of food price volatility—may actually accrue disproportionately to wealthier households (Bellemare, Barrett, and Just 2013 and Mason and Myers 2013). Given the growing interest in stabilization programs and the mixed messages emerging from policy, theory, and empirical analyses, greater comprehension of the effects of and demand for food price stabilization is critical.

To that end, this paper applies a model to estimate food price risk aversion over multiple commodities, newly developed by Bellemare, Barrett, and Just (2013) (hereafter, BBJ), to recent data from Tanzania to examine the extent to which poor households are food price risk averse. Significantly, the BBJ model accommodates estimation of multiple commodity price risk, allowing one to observe a more complete picture of how price volatility and covolatility of food commodities affect households.

This paper uses commodity price distributions and household income to estimate marketable surplus functions for a set of selected food commodities. The marketable surplus functions are estimated via fixed effects estimation and seemingly unrelated regression to mitigate the effects of unobservable household, time, and location specific heterogeneity as well as the likely correlation of error terms. The resulting estimates are used to generate a matrix of price risk aversion coefficients that captures the direct and indirect effects of price volatility and covolatility on household welfare. Finally, these estimates are used to calculate household level willingness to pay (WTP) for commodity price stabilization. Analysis of the relationship between WTP and household income as well as analysis of WTP across net buyers and sellers of the selected commodities offers insight into the potential distributional benefit incidence of the stabilization of these commodities.

The results suggest a negative relationship between household income and total WTP for the stabilization of all the selected commodities where the correlation between prices and income is assumed to be zero, and a statistically insignificant relationship between income and WTP where the zero correlation assumption is relaxed. Analysis of commodity specific WTP by income level and market status suggests that household level preferences over price stabilization are more nuanced than currently policy discourse acknowledges.

The paper progresses as follows: the theoretical framework around which the current policy debate and from which the BBJ model is drawn is briefly reviewed in Section 2; Section 3 discusses estimation methods and data; Section 4 presents results and implications; Section 5 concludes.

2. Theoretical Background

The growing number of recent papers addressing food price volatility—whether policy papers such as OECD (2011) and FAO (2012) or academic papers such as Dawe and Timmer (2012) and Anderson, Ivanic, and Martin (2013)—present food price volatility as harmful to producers and as particularly harmful to consumers. For example, in their unambiguously titled paper, "Why stable food prices are a good thing," Dawe and Timmer (2012) warn that food price volatility will push poor households into poverty traps. However, theories and empirical analyses of price risk and stabilization suggest that the effects of price volatility may not be so clear.

The theoretical and empirical consensus is that producer behavior and welfare under price risk are generally as Sandmo (1971) describes: an income risk averse firm will produce less under price risk than under certainty (Schmitz, Shalit, and Turnovsky 1981). However, consumer behavior and welfare under price risk are less clear. Waugh (1944) and Turnovsky, Shalit, and Schmitz (1980) show that under certain conditions, determined by the consumer's coefficient of relative income risk aversion (or the income elasticity of the marginal utility of income), income elasticity of demand, price elasticity of demand, and the budget share of the commodity in question, consumers will gain welfare under price risk and lose welfare under certainty. For example, Turnovksy et al (1980) find that a necessary condition for a consumer to prefer price stability over a single commodity is that the coefficient of relative income risk aversion be greater than twice the income elasticity of demand. Therefore, where income risk aversion is low and where expenditures on the commodity make up a small share of the total budget, price volatility may be preferred.

The different preferences exhibited by producers and consumers facing price volatility are reflective of their different standings relative to price realization. Producers must make investment decisions before prices are realized whereas consumers can make decisions after prices are realized, when prices are "stochastic but certain" (Helms 1985, Just Hueth, and Schmitz 1982). For households that both produce and consume a given commodity under price risk, preferences become reflective not only of income risk preferences and budget shares, but also of households' net relationship with the market (whether buyer, seller, or autarkic). For such households, both income and consumption are affected by price volatility.

Therefore, to accommodate the multivariate risk faced by agricultural households that are both producers and consumers, Finkelshtain and Chalfant (1991, 1997) combine Sandmo (1971) with the marketable surplus literature and find that net buyer, income risk averse households may actually increase production under price risk. Additionally, Finkelshtain and Chalfant (1997) find that the benefits of price stabilization are decreasing in the absolute value of the price elasticity of marketable surplus and that benefits from price stabilization are decreasing in income elasticity for households with negative marketable surplus (net buyers) while the opposite is true for net sellers.

Modifying Turnovksy et al (1980), Newbery and Stiglitz (1981), and Finkelshtain and Chalfant (1991) to accommodate the agricultural household model, Barrett (1996) shows that price risk can explain the inverse farm size productivity relationship often observed in developing country settings. Barrett (1996) demonstrates how small, net buyer, agricultural households will increase labor inputs, and therefore production, in the face of food price risk while the same price risk will induce large, net seller, agricultural households to underemploy labor and therefore decrease production. Finally, BBJ (2013) further extend the model to capture the price risk aversion of households over multiple commodities.

Therefore, given that outcomes depend greatly on the interaction of production, consumption, income and price elasticity, and income risk preferences, the effect of stabilization regimes on smallholders is not as clear as policy discourse implies. Significantly, BBJ (2013) estimate multivariate risk aversion using Ethiopian Rural Household Survey (ERHS) data from the 1990s and find that wealthier households and net sellers have higher demand for food commodity price stability than do smallholders and net buyers. This finding suggests a distributionally regressive benefit incidence of price stabilization. To observe whether such findings are unique to Ethiopia or hold more broadly, after a brief description of the theoretical model and the data, I turn to estimation of this model within the Tanzania data.

3. Estimation of price risk aversion over multiple commodities

Drawing on the theoretical framework of the agricultural household model and extending Turnovksy et al. (1980), Finkelshtain and Chalfant (1991, 1997), and Barrett (1996), BBJ 2013 have shown that one can estimate household willingness to pay for price stabilization over *m* commodities as

$$WTP = \frac{1}{2}\left[\sum_{j=1}^{m}\sum_{i=1}^{m}\sigma_{ij}A_{ij} + \ 2\sum_{i=1}^{m}\sigma_{yi}A_{yi}\right] \qquad \text{[EQ1]}$$

Where σ_{ij} is the covariation of the price of commodity *i* with the price of commodity *j*; σ_{yi} is the covariation of the price of commodity *i* with household income, *y*; A_{ij} is the matrix of price risk aversion coefficients, calculated as

$$A_{ij} = -\frac{M_i}{p_j}[\beta_j(\eta_j - R) + \epsilon_{ij}] \qquad \text{[EQ2]}$$

and A_{yi} is a vector of price and income risk aversion coefficients, calculated as

$$A_{yi} = \frac{M_i}{y}(\eta_i - R) \qquad \text{[EQ3]}$$

The Arrow Pratt coefficient of relative income risk aversion is represented by R, where $R = -yV_{yy}/V_y$ (and where V is household indirect utility in income, y, and subscripts indicate partial derivatives). The marketable surplus of commodity i, M_i, and the budget share of marketable surplus, β_i, can be calculated directly from the data as shown in equations 4 and 5,

$$M_i = Production_i - Consumption_i \qquad \text{[EQ4]}$$

$$\beta_i = \frac{M_i p_i}{y} \qquad \text{[EQ5]}$$

Prices, p_i, and income, y, are observed in the data and the income and price elasticity of marketable surplus parameters, η_j and ϵ_{ij} respectively, must be estimated from the data. Details on the mathematical derivation of this model are available in the BBJ 2013 appendix, available online.[1] Details on the empirical estimation of this model are available in Section 3.3, below.

3.2 Data

To examine demand for food price stabilization among Tanzanian households, I estimate price risk aversion coefficients and willingness to pay (WTP) using nationally representative, cross-country comparable, Living Standards Measurement Study-Integrated Survey on Agriculture (LSMS-ISA) panel data from Tanzania (TZA). While

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[1] See http://marcfbellemare.com/wordpress/research/

the LSMS-ISA panel data collection is ongoing, two rounds are currently available for TZA; these include TZA 2008-09 and TZA 2010-11. Each round includes extensive measurement of seasonal agricultural production quantity and value, agricultural sales and processing, household income,[2] and food consumption quantity and expenditures.

Descriptive statistics for the TZA data are provided in Tables 1 and 2 below. The TZA data include approximately 3,200 households observed across the two survey rounds, 2,300 of whom participate in agricultural production. The food commodities that have been selected for inclusion in the analysis are displayed in Table 1. These commodities were selected because they fit two criteria: a) they were consumed weekly by at least twenty percent of households within each survey round, and b) the same commodity is available and identifiable in the both the production and consumption survey models. Unfortunately, due to (b), a number of commodities that play an important role in the Tanzanian diet, such as meat, beans, and vegetables are not included in the analysis.[3]

The data that are amenable to identification across the production and consumption modules include several food commodities that play a large role in the Tanzanian diet such as maize flour (which is used to make the east African staple, *ugali*), milk (used for *chai*, a milk-based tea consumed throughout the day), and several other staples such as rice, maize, and cassava.

[2] Household level income aggregates for the TZA data were produced by the Rural Income Generating Activities project at FAO. Details on their aggregation and imputation methods can be found at http://www.fao.org/economic/riga/rural-income-generating-activities/en/

[3] For example, matching up meat production and processing from the production module with consumption of meat in the consumption module would require untenable assumptions about the amount of meat that can be harvested from a given number of slaughtered but unsold livestock holdings; without knowing the size or the value of the slaughtered but unsold animals, it would be easy to introduce error/bias into an attempt to make these data correspond across modules. Likewise, consumption of beans is recorded in the consumption module under the category, “Peas, beans, lentils, and other pulses.” Without knowing the relative ratio of beans to other pulses within this category, little analysis can be done with beans as a commodity. In addition, working with the pulses category as a whole poses serious challenges because the marketable surplus value is generated by subtracting the amount consumed in kg from the amount produced in kg. If a household were to produce beans but consume lentils, the marketable surplus for pulses would be upwardly biased due to the fact that beans weigh more than lentils. It would furthermore be difficult to assign an appropriate market price to the pulses category given that beans, peas, and lentils have different market prices. Finally, the vegetable category poses the same problem as that posed by the pulse category; we have “onions, tomatoes, carrots, and green peppers” as a single category in the consumption module. Little analysis can be done on the commodities within this category without making assumptions that would add bias of unpredictable direction to the analysis.

Table 1 displays the mean marketable surplus for each of the selected commodities across the full panel as well as each annual round. A positive mean marketable surplus for a given commodity in the full sample indicates that the average household in the data is a net seller of that commodity across the two survey rounds; this is the case for maize (cob), cassava, milk, bananas, and citrus fruits. A negative mean marketable surplus indicates that that the average household in the data is a net buyer of that commodity; this is the case for rice, maize flour, cassava flour, sweet and Irish potatoes, sugar, groundnuts, coconut, salt, and tea. Finally, the frequently observed median marketable surplus value of zero indicates that, across these commodities, many households are autarkic.

In observing the mean marketable surplus values by survey round, we can see that the full sample aggregation masks some of the year-to-year changes in marketable surplus. In particular we see that the marketable surplus of milk nearly quadruples from one round to the next while the marketable surplus of cassava switches from positive to negative, suggesting that the average household significantly increased milk production and switched from net sales to net purchases of cassava between the two rounds. We also see a notable decrease in the consumption of maize flour and sweet potato relative to production, and a decrease in the production of banana relative to consumption.

Commodity unit prices, household income, and the calculated budget shares of the selected commodities are displayed in Table 2. The commodity prices are drawn from the LSMS-ISA community level survey data. We see considerable variation in prices across regions and survey rounds, as reflected by the standard deviation of prices for each commodity. The average household income is 1,607,305 Tsh or approximately 964.28 USD by current exchange rates (1USD=0.0006Tsh). The median income is significantly lower at 776,930 or 466.16 USD, reflecting the positive skewness of the income distribution.

Table 2 also displays the budget shares of marketable surplus for the selected commodities. As shown in EQ5, budget shares are calculated as the product of marketable surplus and price, divided by household income. Because prices are identified at the community level and marketable surplus and income are identified at the household level, the minimum and maximum budget shares may be greater and less than one by calculation; i.e., the commodity price assigned to a given household at a given time in this analysis may not be the price that household actually faced when selling or purchasing the commodity. Therefore, the prices and budget shares present only an approximation of the true price and true budget share.[4]

The calculated budget shares indicate that purchases of staples such as rice and maize flour make up a significant part of the average household budget while sales of maize and milk make up a significant part of the average household income.

[4] Reported budget share values have been winsorized at 1% to mitigate the effect of outliers on the estimation of WTP.

Table 1. Descriptive statistics: Annual marketable surplus of selected food commodities

Marketable surplus (Kg)	Full sample mean (N=7107)				Round 2008/09 (N=3837)		Round 2010/11 (N=3270)	
	Mean	Std. Dev	Median	Nonzero obs.	Mean	Std. Dev	Mean	Std. Dev
Rice	-111.82	382.99	-78.21	4681	-101.32	464.39	-124.14	255.96
Maize, Cob	166.99	707.91	0.00	4079	173.43	823.95	159.43	540.92
Maize Flour	-179.09	396.38	-130.35	6143	-223.21	456.93	-127.32	302.61
Cassava	14.20	487.38	0.00	3070	32.87	637.65	-7.71	195.79
Cassava Flour	-27.37	112.81	0.00	1238	-33.49	125.01	-20.18	96.07
Sweet Potato	-41.90	193.76	0.00	1950	-59.43	236.72	-21.34	122.77
Irish Potato	-24.60	87.12	0.00	1959	-26.99	106.83	-21.80	55.62
Sugar	-39.43	35.80	-26.07	5257	-42.53	38.71	-35.79	31.68
Groundnut	-1.68	60.32	0.00	1974	-1.57	74.83	-1.80	36.58
Coconut	-49.50	213.62	0.00	2744	-50.99	262.45	-47.75	135.50
Milk*	130.69	1328.89	0.00	2116	50.72	547.86	224.53	1862.85
Salt	-13.33	7.95	-13.04	6801	-14.01	8.65	-12.54	6.96
Tea	-1.95	3.76	-1.04	4497	-2.45	4.35	-1.36	2.80
Banana	51.61	259.71	0.00	2683	60.20	303.64	41.54	195.54
Citrus	4.91	231.08	0.00	2061	3.73	256.14	6.29	197.69

*Liters of milk have been converted to kilograms of milk (using specific density of 1031kg/m3) so as to make the calculations that follow comparable across commodities.

Table 2. Descriptive statistics: Commodity prices, income, and budget shares, N=7107

	Mean	Std. Dev	Median	Min	Max
Prices					
Rice, Hulled (Tsh/Kg)	1176.533	183.767	1200.000	741.773	2116.763
Maize, Cob (Tsh/Kg)	532.610	83.555	571.429	166.081	809.227
Maize Flour (Tsh/Kg)	738.517	123.172	748.985	376.053	1237.845
Cassava (Tsh/Kg)	331.061	89.186	333.333	0.088	712.729
Cassava Flour (Tsh/Kg)	476.819	222.124	500.000	66.667	1061.812
Sweet Potato (Tsh/Kg)	347.591	113.791	357.143	1.336	678.117
Irish Potato (Tsh/Kg)	699.868	168.822	683.006	0.676	1732.367
Sugar (Tsh/Kg)	1549.888	325.719	1500.000	831.332	2400.000
Groundnut (Tsh/Kg)	1558.617	449.798	1500.000	587.322	2500.000
Coconut (Tsh/Kg)	846.218	314.368	715.661	0.579	1818.182
Milk (Tsh/Kg*)	731.844	547.655	581.959	0.450	4932.524
Salt (Tsh/Kg)	596.157	224.755	589.469	59.480	2522.139
Tea (Tsh/Kg)	8211.100	3763.993	8057.210	0.830	22049.620
Banana (Tsh/Kg)	701.402	264.669	769.231	0.972	1538.462
Citrus (Tsh/Kg)	572.103	155.314	534.989	100.000	1200.000
Income					
Annual income (Tsh)	1607305	2544661	776930	-1147883	51800000
Budget shares of marketable surpluses					
Budget share of Rice	-0.262	1.134	-0.041	-11.297	3.103
Budget share of Maize, Cob	0.094	0.923	0.000	-7.275	4.021
Budget share of Maize Flour	-0.378	1.493	-0.059	-12.647	4.263
Budget share of Cassava	-0.010	0.281	0.000	-1.938	1.585
Budget share of Cassava Flour	-0.036	0.185	0.000	-1.754	0.287
Budget share of Sweet Potato	-0.030	0.168	0.000	-1.560	0.565

Budget share of Irish Potato	-0.030	0.141	0.000	-1.481	0.099
Budget share of Sugar	-0.127	0.349	-0.037	-3.342	0.391
Budget share of Groundnut	-0.017	0.212	0.000	-1.739	1.106
Budget share of Coconut	-0.085	0.369	0.000	-3.798	0.759
Budget share of Milk	0.056	0.576	0.000	-1.288	5.940
Budget share of Salt	-0.022	0.057	-0.008	-0.540	0.107
Budget share of Tea	-0.031	0.117	-0.003	-1.194	0.025
Budget share of Banana	0.053	0.289	0.000	-0.810	2.322
Budget share of Citrus	0.004	0.137	0.000	-0.599	1.298

Note: Prices and income are in 2010/2011 Tsh. Note that prices are estimated at the community level while marketable surplus is estimated at household level; therefore, $M_i p_i$ may exceed the budget, y, by calculation. Reported budget share values have been winsorized at 1% to mitigate the effect of outliers on the estimation of WTP.

*Liters of milk have been converted to kg of milk (using a specific density of 1031kg/m3) so as to make the calculations that follow comparable across commodities.

3.3 Econometric model

To calculate the matrix of price risk aversion coefficients, the own and cross price elasticity, ϵ_{ij}, and income elasticity, η_i, of marketable surplus for each commodity must first be estimated. Following BBJ 2013, I estimate the marketable surplus function as a linear regression of marketable surplus on commodity price, p_{jlt} (in region *l* at time *t*) and household expenditures, y_{kt}, to estimate own and cross price elasticity, ϵ_{ijk}, as well as expenditure elasticity, η_{ik}, of marketable surplus for each commodity in each household,

$$sinh^{-1}M_{ikt} = \alpha_i + \eta_i sinh^{-1}y_{kt} + \sum_{i=j}^{m} \epsilon_{ij} sinh^{-1}p_{jlt} + \lambda_i d_k + \tau_i d_{lt} + \nu_{ikt} \quad \text{[EQ6]}$$

where *m* is the total number of commodities under analysis and d_k and d_{lt} are household and region-time dummies, respectively. Marketable surplus, M_{ikt}, is calculated as the difference between the production and the consumption of commodity *i*, in household *k,* at time period *t*. The inverse hyperbolic sine, where $sinh^{-1}x = \ln(x + \sqrt{1 + x^2})$, is used in place of a log transformation so as to preserve the households reporting zero valued marketable surplus.

Fixed effects estimation is used to mitigate the effect of unobserved heterogeneity in households, locations, and time on the elasticity of marketable surplus estimates. However, this estimation procedure will not resolve all sources of endogeneity. In addition to household level unobservables, the relationship between income and production is a potential source of endogeneity in the estimation of this model. The endogeneity of income arises from the possibility of reverse causality in the marketable surplus function in that an increase (decrease) in marketable surplus may increase (decrease) the household income. Therefore, the reported results cannot be interpreted as causal.

Finally, the set of marketable surplus functions is estimated via seemingly unrelated regressions (SUR) so as to account for the likely correlation of error terms across the set of functions. In such a setting, SUR will improve the efficiency of the estimates.

The elasticity estimates from EQ6 are used to generate the matrix of price risk aversion coefficients for each household,

$$\hat{A}_{ijk} = -\frac{M_{ik}}{p_{jlt}}[\beta_{jk}(\hat{\eta}_{jk} - R_k) + \hat{\epsilon}_{ijk}] \quad \text{[EQ7]}$$

where $R_k = -y_k V_{yy}/V_y$ is the Arrow Pratt coefficient of relative income risk aversion, and β_{jk} is the budget share of commodity *j* in household *k*. Following BBJ 2013, *R=1* is initially assumed for all households.

Finally, the estimated price risk aversion coefficients are used to calculate each household's WTP for price stability (or the "risk premium") over all commodities,

$$WTP_k = \frac{1}{2}\left[\sum_{j=1}^{m}\sum_{i=1}^{m}\sigma_{ijk}\hat{A}_{ijk} + 2\sum_{i=1}^{m}\sigma_{yik}\hat{A}_{yik}\right] \qquad \text{[EQ8]}$$

where σ_{ij} is the covariation of prices for commodities *i* and *j*, σ_{yi} is the covariation of the price of commodity *i* with household income, *y*, and $\hat{A}_{yik} = \frac{M_{ik}}{y_k}(\hat{\eta}_{ik} - R_k)$. In the case that income is not correlated with prices, the estimation of WTP can be simplified to,

$$WTP_k = \frac{1}{2}\left[\sum_{j=1}^{m}\sum_{i=1}^{m}\sigma_{ijk}\hat{A}_{ijk}\right] \qquad \text{[EQ9]}$$

Likewise, household WTP for stabilization of a single commodity while accounting for the covolatility of prices, WTP_{ki}, is estimated as,

$$WTP_{ki} = \frac{1}{2}\sigma_{iik}\hat{A}_{iik} + \sum_{j\neq i}^{m}\sigma_{ijk}\hat{A}_{ijk} + \sigma_{yik}\hat{A}_{yik} \qquad \text{[EQ10]}$$

Again making the assumption that income is not correlated with prices, EQ10 simplifies to,

$$WTP_{ki} = \frac{1}{2}\sigma_{iik}\hat{A}_{iik} + \sum_{j\neq i}^{m}\sigma_{ijk}\hat{A}_{ijk} \qquad \text{[EQ11]}$$

As estimated, negative WTP values represent the amount by which a household would need to be compensated to accept price stabilization while positive WTP values represent the amount a household would be willing to pay for price stabilization.

4. Results and discussion

The marketable surplus function estimates are presented in Table 3. The coefficients can be interpreted as own price, cross price, and income elasticities of marketable surplus. Coefficients on the round and region dummies have been suppressed.

The own price elasticity of marketable surplus estimates the percent change in a commodity's marketable surplus due to a change in the price of that commodity. As the price of a given commodity rises we expect households to produce/sell more of that commodity and purchase less of it, resulting in positive elasticity terms, the magnitude depending on the household's marketable surplus response to the price change. From Table 3, we can see that, where statistically significant, own price elasticity of marketable surplus is positive with the exceptions of sweet potatoes, Irish potatoes, and groundnuts. It is possible that the negative own price elasticity signs on these two commodities are due to the profit effect, wherein a price rise and its associated profits lead to greater consumption of particular goods and, therefore, counterintuitive signs on own price elasticity estimates (Singh 1986).

Table 3. Annual marketable surplus estimates

	(1) Rice	(2) Maize, Cob	(3) Maize Flour	(4) Cassava	(5) Cassava Flour	(6) Sweet Potato	(7) Irish Potato	(8) Sugar	(9) Groundnut	(10) Coconut	(11) Milk	(12) Salt	(13) Tea	(14) Banana	(15) Citrus
Rice	**1.331*****	-3.901***	2.505***	0.0742	-0.145	0.454	0.0957	0.204	0.246	0.122	-0.131	0.0914	0.0191	1.588***	0.657***
	(0.335)	(0.427)	(0.462)	(0.367)	(0.233)	(0.285)	(0.205)	(0.160)	(0.237)	(0.221)	(0.309)	(0.0860)	(0.0763)	(0.280)	(0.237)
Maize, Cob	-0.577*	**1.774*****	0.526	-0.239	-0.526**	0.981***	0.161	-0.0480	0.236	-0.0493	0.436	-0.225***	-0.0359	-0.215	-0.699***
	(0.325)	**(0.413)**	(0.447)	(0.355)	(0.225)	(0.276)	(0.199)	(0.155)	(0.230)	(0.215)	(0.299)	(0.0833)	(0.0740)	(0.272)	(0.230)
Maize Flour	0.587*	1.736***	**-0.328**	-0.0842	0.376*	0.109	0.480***	0.0675	-0.280	-0.225	0.233	0.213***	0.0102	0.0811	-0.00624
	(0.300)	(0.381)	**(0.413)**	(0.328)	(0.208)	(0.254)	(0.184)	(0.143)	(0.212)	(0.198)	(0.276)	(0.0769)	(0.0683)	(0.251)	(0.212)
Cassava	-0.255**	-0.188	0.175	**0.599*****	0.271***	-0.102	-0.0196	-0.0326	-0.118	-0.0251	-0.150	0.00251	-0.0416	0.00838	-0.216**
	(0.121)	(0.153)	(0.166)	**(0.132)**	(0.0836)	(0.102)	(0.0738)	(0.0573)	(0.0852)	(0.0796)	(0.111)	(0.0309)	(0.0274)	(0.101)	(0.0853)
Cassava Flour	-0.105	0.0746	0.0248	-0.0961	**0.0722**	0.373**	-0.0755	-0.0295	0.301**	0.0375	0.259	0.0390	0.109***	0.0269	0.330**
	(0.182)	(0.232)	(0.251)	(0.199)	**(0.126)**	(0.155)	(0.111)	(0.0866)	(0.129)	(0.120)	(0.168)	(0.0467)	(0.0414)	(0.152)	(0.129)
Sweet Potato	0.415***	0.0914	0.000244	0.198	0.0461	**-0.305*****	-0.0356	0.0342	0.124	0.151*	0.148	-0.0118	0.0568*	0.447***	0.116
	(0.136)	(0.173)	(0.188)	(0.149)	(0.0945)	**(0.116)**	(0.0834)	(0.0648)	(0.0963)	(0.0900)	(0.125)	(0.0349)	(0.0310)	(0.114)	(0.0964)
Irish Potato	-0.0489	0.167	-0.408***	-0.0248	0.0661	0.0729	**-0.234*****	-0.0898*	0.459***	-0.0831	0.107	0.000684	-0.00308	-0.0771	-0.0837
	(0.110)	(0.140)	(0.151)	(0.120)	(0.0762)	(0.0933)	**(0.0673)**	(0.0523)	(0.0777)	(0.0726)	(0.101)	(0.0282)	(0.0250)	(0.0919)	(0.0778)
Sugar	-1.094**	-0.216	1.719***	1.506***	0.424	-0.677*	0.442	**0.432****	-0.0497	-0.683**	0.152	-0.0925	-0.194*	-0.849**	0.915***
	(0.443)	(0.564)	(0.610)	(0.485)	(0.307)	(0.376)	(0.271)	**(0.211)**	(0.313)	(0.293)	(0.408)	(0.114)	(0.101)	(0.370)	(0.314)
Ground nut	0.0859	-0.764**	-1.692***	-0.111	-0.243	0.223	0.0711	-0.313**	**-1.002*****	0.397**	-0.281	-0.227***	-0.0703	-0.417*	-0.0664
	(0.286)	(0.364)	(0.394)	(0.313)	(0.199)	(0.243)	(0.175)	(0.136)	**(0.202)**	(0.189)	(0.264)	(0.0734)	(0.0652)	(0.239)	(0.203)
Coconut	-0.0942	-0.00163	-0.128	-0.671***	-0.0206	-0.353***	0.154**	0.0178	0.0446	**0.188****	0.0605	0.0297	0.0265	-0.109	-0.171*
	(0.124)	(0.157)	(0.170)	(0.135)	(0.0858)	(0.105)	(0.0758)	(0.0589)	(0.0875)	**(0.0817)**	(0.114)	(0.0317)	(0.0282)	(0.103)	(0.0876)
Milk	-0.0578	0.424***	0.184	-0.157*	-0.0529	0.101	0.0279	-0.0240	0.0310	0.0161	**-0.0618**	-0.0160	0.0235	0.115*	0.155***
	(0.0827)	(0.105)	(0.114)	(0.0904)	(0.0573)	(0.0702)	(0.0506)	(0.0393)	(0.0584)	(0.0546)	**(0.0761)**	(0.0212)	(0.0188)	(0.0691)	(0.0585)
Salt	0.279**	-0.462***	0.124	-0.142	0.178**	0.126	0.157**	0.0180	0.128	0.154*	0.257**	**0.112*****	0.0254	0.0332	-0.0400
	(0.122)	(0.156)	(0.169)	(0.134)	(0.0849)	(0.104)	(0.0750)	(0.0583)	(0.0866)	(0.0809)	(0.113)	**(0.0314)**	(0.0279)	(0.102)	(0.0867)
Tea	0.0666	0.0722	-0.191***	0.0415	-0.0409	-0.0150	0.0987***	-0.0606***	0.0174	-0.0222	0.00818	-0.00948	**0.0178***	-0.00881	0.135***
	(0.0448)	(0.0570)	(0.0617)	(0.0490)	(0.0311)	(0.0380)	(0.0274)	(0.0213)	(0.0317)	(0.0296)	(0.0413)	(0.0115)	**(0.0102)**	(0.0375)	(0.0317)
Banana	-0.0616	-0.125	-0.223**	0.210**	0.0201	0.157**	0.00345	0.0343	-0.00747	0.115**	-0.0137	0.0442**	-0.0159	**-0.0846**	0.0976*
	(0.0821)	(0.104)	(0.113)	(0.0898)	(0.0569)	(0.0697)	(0.0503)	(0.0391)	(0.0580)	(0.0542)	(0.0756)	(0.0211)	(0.0187)	**(0.0686)**	(0.0581)
Citrus	-0.0794	0.582***	-0.400*	-0.0150	-0.355***	0.379***	-0.287***	-0.107	-0.238**	0.0565	-0.0480	-0.0194	-0.0991***	0.0394	**1.017*****
	(0.152)	(0.193)	(0.209)	(0.166)	(0.105)	(0.129)	(0.0929)	(0.0722)	(0.107)	(0.100)	(0.140)	(0.0389)	(0.0345)	(0.127)	**(0.107)**
Inc	**-0.0148**	**0.107*****	**0.0145**	**0.0236***	**-0.00239**	**-0.0134**	**-0.0201*****	**-0.0147*****	**-0.00441**	**-0.0250*****	**-0.0133**	**-0.0113*****	**-0.00301**	**5.73e-05**	**0.0205****
	(0.0113)	**(0.0144)**	**(0.0155)**	**(0.0123)**	**(0.00783)**	**(0.00958)**	**(0.00691)**	**(0.00537)**	**(0.00798)**	**(0.00746)**	**(0.0104)**	**(0.00289)**	**(0.00257)**	**(0.00944)**	**(0.00799)**

Cnst	5.85e-08	-1.07e-07	-6.14e-08	-4.13e-08	1.81e-08	-2.96e-08	4.06e-10	-1.55e-08	-7.39e-09	1.47e-08	-3.95e-09	1.37e-08	8.76e-09	1.64e-08	3.20e-08
	(0.0238)	(0.0303)	(0.0328)	(0.0261)	(0.0165)	(0.0202)	(0.0146)	(0.0113)	(0.0169)	(0.0157)	(0.0220)	(0.00611)	(0.00543)	(0.0199)	(0.0169)
Obs	7,107	7,107	7,107	7,107	7,107	7,107	7,107	7,107	7,107	7,107	7,107	7,107	7,107	7,107	7,107
R-sq	0.036	0.152	0.072	0.040	0.017	0.061	0.028	0.026	0.048	0.076	0.026	0.057	0.119	0.022	0.070

Standard errors in parentheses; *p<0.05, **p<0.01, ***p<0.001

The own and cross-price elasticity estimates can be understood, taking as example the first cell of Table 3, as follows: a one percent increase in the price of rice is associated with a 1.331 percent increase in the marketable surplus of rice, suggesting that households produce more rice (and/or consume less rice) when facing a rice price increase. Moving to the second column, we see that a one percent increase in the price of rice is associated with a 3.901 percent decrease in the marketable surplus of maize, suggesting that households switch from maize to rice production (or from rice to maize consumption) when facing a rice price increase.

Likewise, the income elasticity of marketable surplus values suggest a relationship between income and either the production or consumption of these goods, depending on the sign of the elasticity estimates. Notably, statistically significant negative signs on the income elasticities are observed for the two commodities that enter the analysis only as consumption goods—sugar and salt—indicating that as income rises, household consumption of these goods rises. Negative income elasticity of marketable surplus estimates are also observed for goods produced by a small number of households but consumed by a large number of households, such as Irish potatoes and coconuts. We see positive income elasticity estimates for heavily produced commodities such as maize and cassava, suggesting that an increase in income may increase the output of these commodities, via the household's ability to invest in productivity enhancing inputs.

The coefficients resulting from the estimates in Table 3 are used to calculate, as described above, the matrix of price risk aversion coefficients presented in Table 4. The magnitudes of the own and cross price risk aversion values that compose the matrix indicate the average welfare impact of price variation or co-variation: positive (negative) price risk aversion coefficients indicate that the variation or covariation in prices is welfare decreasing (increasing). From Table 4 we can see that the price variation of cassava and, to a lesser extent, coconut are welfare increasing for the average household in the sample. Meanwhile the variation of the other goods is, on average, welfare decreasing, with the variation in milk price producing the greatest welfare loss to the average household. The off-diagonals show the welfare effects of co-variation of the given commodity prices.

Table 4. Estimated matrix of price risk aversion for R=1, N=7107

	Rice	Maize, Cob	Maize Flour	Cassava	Cassava Flour	Sweet Potato	Irish Potato	Sugar	Groundnut	Coconut	Milk	Salt	Tea	Banana	Citrus
Rice	**0.2979**	0.5533	0.4403	0.0082	-0.0007	0.0294	0.0115	0.0222	0.0014	0.0414	-0.0107	0.0043	0.0011	-0.0766	0.0005
	0.0100	0.0273	0.0114	0.0036	0.0008	0.0023	0.0009	0.0009	0.0006	0.0028	0.0134	0.0002	0.0001	0.0049	0.0023
Maize, Cob	-0.1229	**0.0577**	0.1750	0.0086	-0.0302	0.0773	0.0057	-0.0088	0.0060	-0.0007	-0.0321	-0.0083	-0.0002	0.0434	0.0128
	0.0072	**0.0394**	0.0127	0.0176	0.0027	0.0060	0.0021	0.0010	0.0015	0.0021	0.0199	0.0004	0.0001	0.0040	0.0051
Maize Flour	0.1282	-0.4469	**0.3714**	0.0254	0.0234	0.0386	0.0268	0.0223	0.0045	-0.0049	-0.1084	0.0115	0.0009	-0.0233	-0.0007
	0.0070	0.0328	**0.0229**	0.0069	0.0029	0.0051	0.0028	0.0011	0.0017	0.0023	0.0326	0.0004	0.0001	0.0073	0.0016
Cassava	0.2586	0.3058	1.5042	**-5.6286**	0.9211	0.2946	0.0006	-0.0233	-0.0188	0.0025	0.0690	0.0013	-0.0005	-0.0015	0.9160
	0.4121	0.2119	1.0925	**5.1274**	0.3397	0.1228	0.0004	0.0082	0.0138	0.0019	0.0151	0.0003	0.0002	0.0026	0.4485
Cassava Flour	-0.0233	-0.0359	0.0192	0.0082	**0.0473**	0.0506	-0.0038	-0.0010	0.0017	0.0050	-0.0788	0.0026	0.0006	-0.0086	-0.0110
	0.0016	0.0030	0.0025	0.0030	**0.0032**	0.0034	0.0002	0.0002	0.0008	0.0010	0.0092	0.0001	0.0000	0.0010	0.0034
Sweet Potato	0.4382	-0.0068	0.0275	-0.0146	0.0273	**0.0067**	0.0009	0.0094	0.0040	0.0289	-0.0655	0.0011	0.0007	-0.0093	-0.0010
	0.1321	0.0322	0.0037	0.0090	0.0065	**0.0207**	0.0013	0.0007	0.0015	0.0027	0.0080	0.0002	0.0001	0.0409	0.0014
Irish Potato	0.0069	-0.1888	-0.2459	0.0019	0.0045	0.0170	**0.0012**	-0.0083	-0.0042	-0.0017	-0.0166	0.0007	0.0001	0.0061	-0.0051
	0.0100	0.0602	0.0802	0.0007	0.0008	0.0047	**0.0011**	0.0025	0.0342	0.0005	0.0046	0.0000	0.0000	0.0009	0.0053
Sugar	-0.0755	0.0166	0.2351	-0.0118	0.0097	-0.0159	0.0100	**0.0181**	0.0001	-0.0190	-0.0233	0.0004	0.0000	0.0261	-0.0021
	0.0034	0.0015	0.0061	0.0062	0.0005	0.0010	0.0005	**0.0003**	0.0001	0.0012	0.0059	0.0000	0.0000	0.0017	0.0020
Ground nut	0.0079	0.0936	-0.2248	0.0023	-0.0045	0.0100	0.0014	-0.0086	**0.0059**	0.0154	0.0176	-0.0020	-0.0001	0.0160	0.0007
	0.0006	0.0055	0.0064	0.0009	0.0004	0.0009	0.0001	0.0001	**0.0009**	0.0009	0.0030	0.0000	0.0000	0.0012	0.0002
Coconut	-0.0222	0.0022	-0.1300	0.1383	0.0014	-0.0166	0.0091	0.0089	0.0008	**-0.0551**	-0.0115	0.0032	0.0007	0.0976	0.0160
	0.0164	0.0014	0.0439	0.1830	0.0004	0.0015	0.0004	0.0007	0.0003	**0.1186**	0.0027	0.0004	0.0001	0.0475	0.0359
Milk	-0.0271	-0.0377	0.2625	0.0205	-0.0037	0.0183	0.0050	-0.0127	-0.0005	0.0016	**1.1662**	-0.0036	0.0002	0.0007	0.0007
	0.0079	0.0848	0.0874	0.0178	0.0010	0.0062	0.0021	0.0020	0.0006	0.0012	**0.2919**	0.0005	0.0002	0.0042	0.0042
Salt	0.0675	0.1374	0.0477	0.0049	0.0111	0.0120	0.0081	0.0027	0.0006	0.0175	-0.0628	**0.0035**	0.0002	-0.0050	0.0005
	0.0025	0.0069	0.0014	0.0016	0.0006	0.0007	0.0004	0.0001	0.0002	0.0011	0.0089	**0.0000**	0.0000	0.0004	0.0002
Tea	0.0252	-0.0259	-0.0886	0.0031	-0.0002	-0.0014	0.0194	-0.0037	0.0002	-0.0030	-0.0098	-0.0003	**0.0001**	0.0041	0.0056
	0.0047	0.0221	0.0677	0.0020	0.0000	0.0032	0.0156	0.0012	0.0004	0.0008	0.0100	0.0001	**0.0000**	0.0025	0.0023
Banana	-0.0605	0.1636	-0.2137	0.0200	-0.0028	0.0210	0.0000	0.0024	0.0014	0.0447	0.0186	0.0010	-0.0003	**0.1075**	0.0119
	0.0131	0.0497	0.0456	0.0106	0.0009	0.0105	0.0012	0.0011	0.0009	0.0124	0.0071	0.0004	0.0000	**0.0083**	0.0046
Citrus	-0.0136	-0.1763	-0.1437	0.0066	-0.0222	0.0374	-0.0123	-0.0079	-0.0002	0.0087	0.0110	-0.0005	-0.0004	-0.0031	**0.0424**
	0.0018	0.0106	0.0041	0.0032	0.0015	0.0024	0.0006	0.0002	0.0004	0.0008	0.0015	0.0000	0.0000	0.0005	**0.0052**

Note: All values significant at the 99% confidence level.

Table 5 displays the mean coefficients of price risk aversion for net sellers and net buyers. From this disaggregation it is clear that the magnitudes of the gains and losses among net buyers are generally smaller than those of net sellers. This general observation hold in the case of all commodities but rice, maize, and cassava flour, where the net buyers display a small but statistically significant greater welfare loss than do net sellers (and, in the case of maize, price variation is welfare increasing for net sellers).

Table 5. Mean coefficient of price risk aversion for R=1 by status relative to market

	Net sellers			Net buyers		
	Mean	Std. Err	Obs.	Mean	Std. Err	Obs.
Rice	0.0037	0.0542	614	0.5200	0.0144	4067
Maize, Cob	-1.0694	0.0521	2916	2.8971	0.1680	1218
Maize Flour	0.4218	0.0384	1338	0.4320	0.0320	4805
Cassava	-51.5767	34.3215	1033	6.3190	3.9640	2101
Cassava Flour	0.0290	0.0050	225	0.2643	0.0167	1246
Sweet Potato	0.6752	0.2020	376	-0.1254	0.0763	1642
Irish Potato	0.2291	0.0550	62	-0.0031	0.0037	1933
Sugar	--	--	--	0.0245	0.0004	5257
Groundnut	0.1338	0.0090	593	-0.0252	0.0010	1472
Coconut	-3.7277	3.6904	228	0.1814	0.0166	2527
Milk	13.9605	3.4325	597	-0.0299	0.0417	1539
Salt	--	--	--	0.0037	0.0000	6801
Tea	0.0019	0.0019	12	0.0002	0.0001	4485
Banana	0.4982	0.0362	1534	0.0000	0.0075	1235
Citrus	-0.2166	0.0482	524	0.2683	0.0160	1546

Note: All values significant at the 99% confidence level.

In particular, Table 5 suggests large losses for milk sellers and large gains for cassava sellers due to price variation in each of these commodities. Because harvesting of cassava can be delayed until advantageous or necessary—cassava can be harvested anywhere from six months to three years after planting (IITA 2104)—price volatility is welfare increasing for net sellers of this commodity. In contrast, milk prices are extremely volatile over the course of a year due to the seasonality of traditional milk production and milk is not easily processed or stored; therefore, price volatility in milk is welfare decreasing for net sellers. Note that the net buyers of these two commodities have explicitly opposing, though significantly smaller in magnitude, preferences from those of net sellers.

The average household willingness to pay for stabilization of each commodity as well as the entire basket of commodities is presented in Table 6. One can calculate WTP by considering either the rows or columns of the A_{ij} matrix; only row-based estimates are reported. The first column of Table 6 presents WTP calculated by assuming zero correlation between prices and household income (EQ9 and EQ11); the second column weakens this assumption, due significant correlation between commodity price and income (shown in Appendix B), and estimates WTP following EQ8 and EQ10.

Total WTP for stabilization of all commodities is approximately 16 percent of the sample median income when calculated using either approach. WTP for commodity specific price stabilization largely corresponds across the two columns with sign changes observed only in the case of coconut and salt, suggesting that income-price covariation makes households more price risk preferring over these two commodities. Across both columns, the total WTP is dominated by milk price risk aversion, which grows greater when income-price covariation is account for. We see in Table 7, where WTP is disaggregated by household status relative to the market, that milk sellers drive this result.

Table 6. Estimated WTP for price stabilization as a share of median household income, R=1

	Row-based		Accounting for ρ_{yp_i} (Row-based)	
	Mean	Std. Err	Mean	Std. Err
Rice	-2.11%	0.0124	-2.11%	0.0124
Maize, Cob	-0.54%	0.0165	-0.34%	0.0167
Maize Flour	-3.46%	0.0239	-3.46%	0.0239
Cassava	5.75%	0.0414	5.92%	0.0413
Cassava Flour	0.64%	0.0043	0.38%	0.0044
Sweet Potato	0.36%	0.0021	0.27%	0.0027
Irish Potato	1.25%	0.0157	1.07%	0.0157
Sugar	0.22%	0.0040	0.22%	0.0040
Groundnut	0.50%	0.0139	0.13%	0.0139
Coconut	0.83%	0.0219	-0.95%	0.0226
Milk	10.19%	0.0517	12.57%	0.0533
Salt	0.03%	0.0001	-0.02%	0.0005
Tea	0.28%	0.0013	0.10%	0.0017
Banana	1.64%	0.0060	1.72%	0.0063
Citrus	0.75%	0.0053	0.46%	0.0054
Total	16.66%	0.0683	16.27%	0.0701

Note: All values significant at the 99% confidence level. The commodity specific WTPs do not sum to the total WTP due to the fact that the A_{ij} matrix is not symmetric; that is, $A_{ij} \neq A_{ji}$.

Disaggregation of mean WTP by households' role in the market offers insight on the composition of total WTP. Table 7 presents the WTP estimates for net sellers and net buyers of each commodity; like column two of Table 6, these estimates account for the correlation between income and prices. Net buyers are price risk preferring over such commodities as rice, maize flour, sweet potato, milk, and salt—commodities over which net producers are, especially in the case of milk[5], strongly price risk averse. Likewise, the small groups of Irish potato and coconut sellers have strongly differing preferences from

[5] Note that the WTP shares are calculated as a share of the sample median household income for ease of comparison; therefore, they may exceed 100 percent of that income where WTP is high, as the sample median income is low (see Table 2).

the large groups of Irish potato and coconut buyers: the sellers would demand significant compensation in exchange for stabilization of these prices while the buyers prefer stabilization of these commodity prices.

Table 7. Estimated WTP for price stabilization by market status as share of median household income, R=1

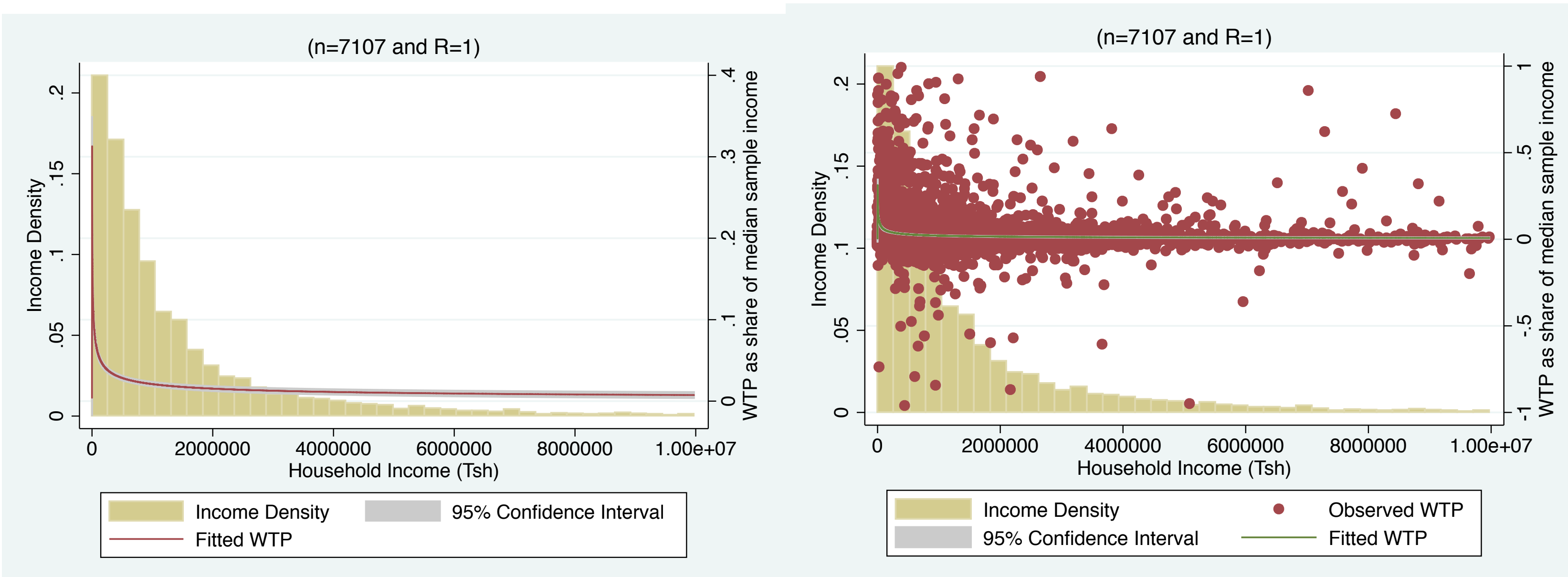
	Net sellers			Net buyers		
	Mean	Std. Err	Obs.	Mean	Std. Err	Obs.
Rice	-12.87%	0.1293	614	-1.74%	0.0095	4067
Maize, Cob	-4.40%	0.0328	2916	8.52%	0.0575	1218
Maize Flour	8.37%	0.0380	1338	-7.45%	0.0336	4805
Cassava	3.68%	0.0232	1033	18.21%	0.1392	2101
Cassava Flour	0.73%	0.0037	225	2.03%	0.0250	1246
Sweet Potato	6.91%	0.0337	376	-0.40%	0.0085	1642
Irish Potato	-72.07%	0.7254	62	6.24%	0.0527	1933
Sugar	--	--	--	0.30%	0.0054	5257
Groundnut	-9.65%	0.1548	593	4.51%	0.0251	1472
Coconut	-68.24%	0.6697	228	3.49%	0.0197	2527
Milk	150.77%	0.6315	597	-0.45%	0.0119	1539
Salt	--	--	--	-0.03%	0.0005	6801
Tea	5.19%	0.0571	12	0.14%	0.0027	4485
Banana	7.09%	0.0206	1534	1.06%	0.0255	1235
Citrus	-0.85%	0.0514	524	2.39%	0.0176	1546

Note: All values significant at the 99% confidence level.

So as to explore the benefit incidence of price stabilization, nonparametric fractional polynomial regressions of WTP for stabilization over the complete basket of goods on household income are displayed in Figures 1 and 2. Figure 1 presents the estimate of WTP that assumes zero correlation between prices and income (corresponding with column one of Table 6); Figure 2 presents the estimate of WTP that accounts for the correlation between prices and income (corresponding with column two of Table 6).

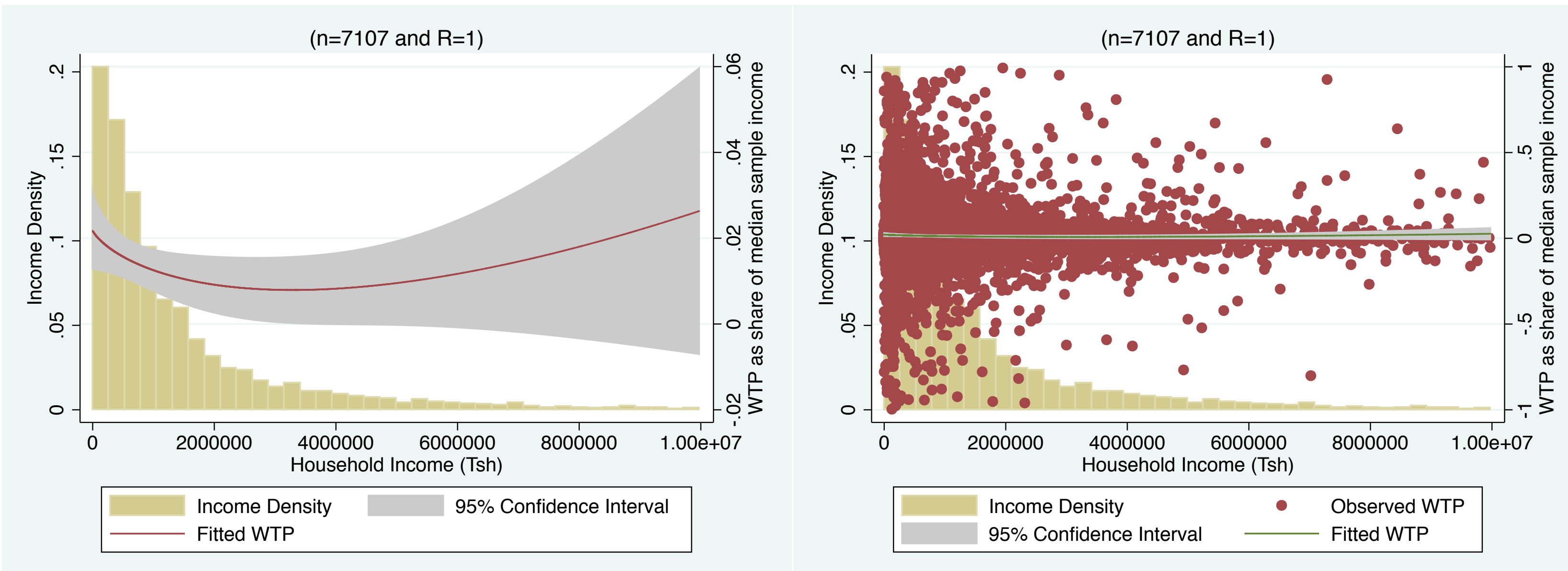
In the left panel of Figure 1, WTP for price stabilization as a share of median household income falls sharply among lower income households and flattens out beyond mean income households to remain constant among higher income households. The confidence intervals in the left panel of Figure 1 appear unreasonably tight. As a check on these results, a scatter plot of the actual data is presented in the right panel of Figure 1. In the second panel we can confirm that the bulk of the data lie above a WTP of zero at low income levels and then cluster around a WTP of zero as income grows large. The relationship between WTP and income suggested by these two panels is supported by a correlation coefficient of -0.0854 between income and WTP, significant at the 99% confidence level.

Figure 1. Nonparametric fractional polynomial regression of total WTP as share of median household income on household income, assuming zero correlation between price and income



The left panel of Figure 2 suggests that WTP falls slightly among low income households and then rises slightly among wealthier households well after surpassing mean income; however, the confidence intervals are large, making the relationship difficult to ascertain. The right panel of Figure 2 again overlays observed WTP. It is clear that the magnitude of WTP is greater at low income levels both in terms of price risk preference and price risk aversion; however, there is little discernable correlation between income and WTP. The visual lack of correlation is confirmed by a lack of statistically significant correlation between WTP and income. The differences between Figures 1 and 2 suggest that the observed correlation between WTP and income (Figure 1) dissipates when the correlation between price and income is accounted for (Figure 2).

Figure 2. Nonparametric fractional polynomial regression of total WTP as share of median household income on household income, accounting for correlation between price and income



Figures 1 and 2 suggest a very different relationship between WTP and income than that identified in BBJ 2013. There is reason to believe that at least some of the difference in the distributional benefit incidence of WTP observed here versus that observed in BBJ 2013 has to do with the different approaches to the calculation of the budget shares of marketable surplus applied in each analysis. See Appendix A for details.

So as to better understand the drivers of price risk preferences across income levels, WTP as a share of household income is plotted against household budget shares for a set of selected commodities in a manner first proposed in Barrett (1999). This analysis is presented in Figures 3 and 4. Figure 3 presents plots for the lowest income quintile (mean income 104,839 Tsh) while Figure 4 presents plots for the highest income quintile (mean income 5,220,533 Tsh). To interpret the panels of Figures 3 and 4, recall that households with negative budget shares are net buyers of a given commodity while those with positive budget shares are net sellers. Households with positive WTP shares are price stabilization preferring for that commodity while those with negative WTP shares are price volatility preferring. Note that the WTP estimates used for this analysis are those produced by accounting for the correlation between income and prices.

In comparison of the cassava panel of the low income households (Figure 3) with the cassava panel of the high income households (Figure 4), we see that poor households are nearly indifferent to cassava price volatility due to their dual role as buyers and sellers of this commodity. Wealthy households, on the other hand, are predominantly sellers of cassava and their preferences trend towards preference for price volatility. Moving to the next panel we see that poor and wealthy households have nearly opposite preferences over rice: poor households are predominantly net buyers with a high WTP for stabilization of rice prices; wealthy households are predominantly net sellers with a trend towards preference for price volatility.

Both poor and wealthy households are net sellers of milk with a preference for price stability, though the magnitude of this preference is much more pronounced among the poor and the statistical confidence of this preference is much more pronounced among the wealthy. While both poor and wealthy households devote a share of their budgets to coconut purchase, the poor buyers are price risk averse while the wealthy buyers are price risk preferring and the wealthy sellers are price risk averse. The poor and wealthy are nearly in agreement over stabilization of Irish potato prices except that the magnitude of the WTP for price stabilization and the quantity of purchase among the poor vastly outpaces that of the wealthy. In addition, there is evidence of Irish potato sellers with a preference for price volatility among the wealthy. Finally, both the poor and the wealthy prefer stabilization of maize prices but the magnitude of the WTP of the poor, who are primarily buyers of maize, vastly outweighs that of the wealthy, who are primarily sellers of maize.

Consistent with the suggested correlations in Figures 1 and 2, we can see that the poor appear more price stabilization preferring than the wealthy across these commodities while keeping in mind that the confidence intervals encompass zero in nearly every figure. Note also that these case studies have focused on the extreme quintiles of the income distribution, leaving out income quintiles 2, 3, and 4 where other groups of interest, such as smallholders, may be found. Nevertheless, comparison of the distribution of WTP and budget shares across these income quintiles offers insight about the limitations of observing price risk preferences in the aggregate as well as the limitations of policy analysis that fails to account for the different roles poor and wealthy households may take in different commodity markets. Any price stabilization policy effort should carefully identify the beneficiaries it is attempting to target. For example, Figures 3 and 4 suggest that a maize price stabilization policy might assist both the poorest and wealthiest households (and the poor more so than the wealthy), while a coconut price stabilization policy might assist the poorest households at the expense of the wealthiest.

Figure 3. WTP and budget share, lowest income quintile households

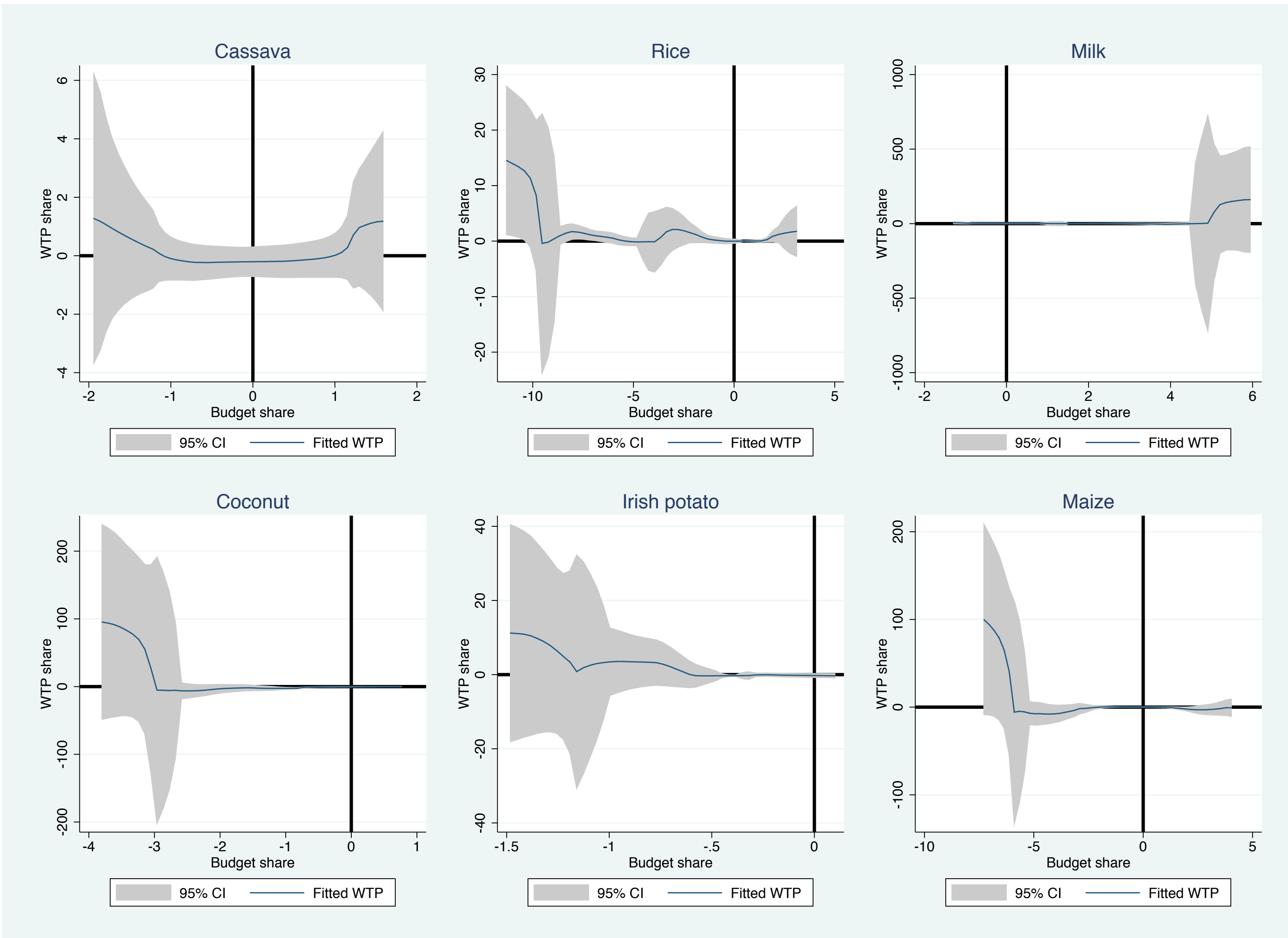
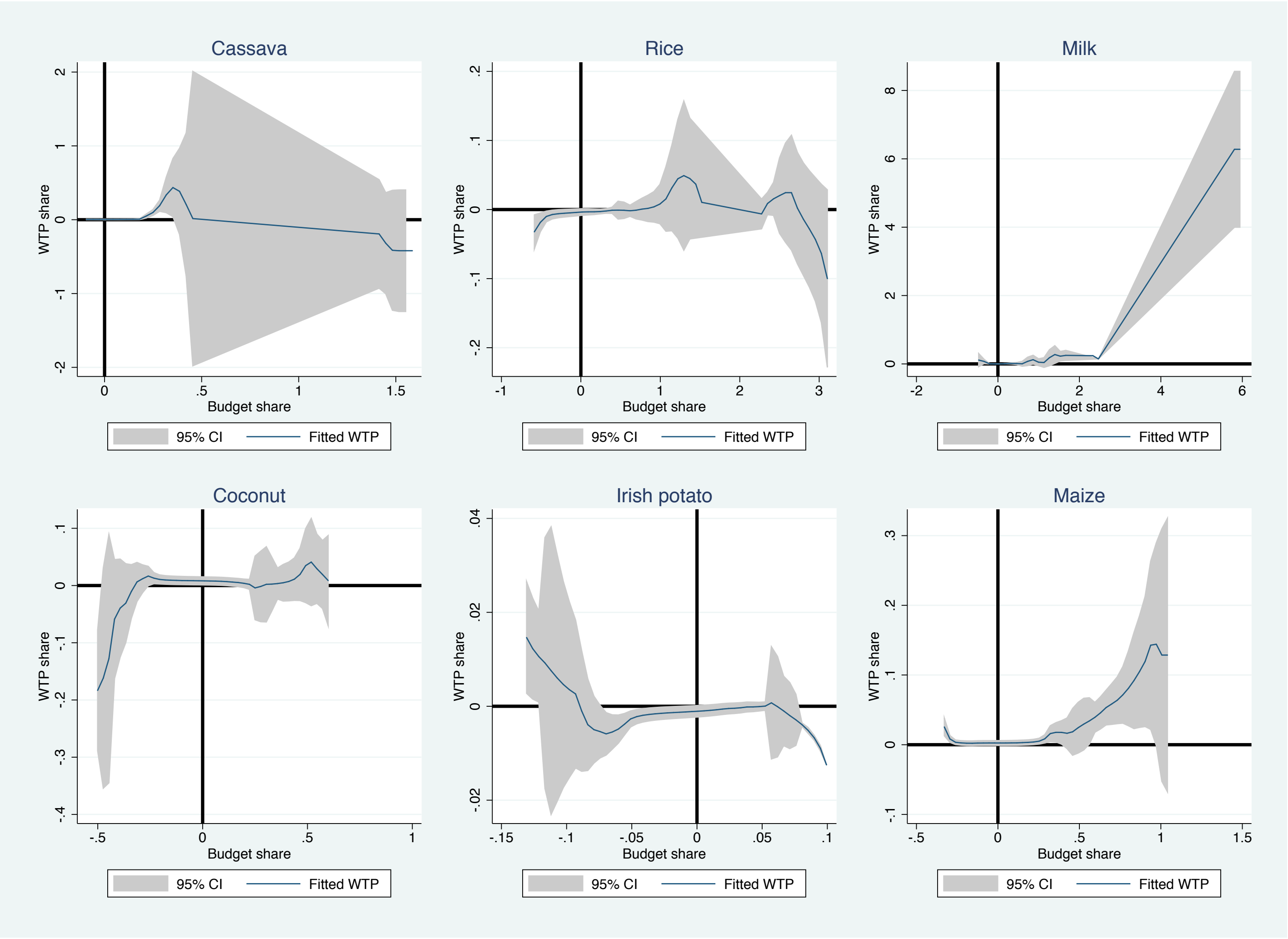


Figure 4. WTP and budget share, highest income quintile households



Section 5. Conclusion

This paper has estimated willingness to pay for price stabilization and explored the distributional benefit incidence of stabilization among Tanzanian households by market status and income level. Analyses of the preferences over stabilization of all commodities show either a greater WTP for stabilization among poor than wealthy households or no explicit relationship between WTP and income, depending on assumptions made in the course of estimating WTP.

Disaggregation of these results by a household's role in a particular commodity market—whether net seller or net buyer—reveal that consumers and producers are commonly at odds in their preferences for price stability; they also reveal a surprising producer preference for price volatility for commodities produced by a small number of households but consumed by a large number of households, such as Irish potatoes and coconut. In addition, we see that seller preferences for milk price stabilization dominate total WTP estimates. Finally, in case studies of the relationship between WTP and budget shares by income level, we conclude that benefits of price volatility will accrue differentially to producers and consumers of different commodities within different income levels and that great care should therefore be taken in the discussion and planning of stabilization policies.

This results of this analysis are confronted by a number of limitations. Of particular concern, the prices, and therefore the budget shares and elasticity estimates, present an approximation due to the fact that the prices are reported at the community level and may therefore differ from the prices actually faced by buyers and sellers of these commodities. In addition, the effects of the endogeneity of income cannot be entirely mitigated; therefore, this paper is concerned with correlation only. Finally, although the LSMS-ISA data are rich in detail and number of observations, the TZA data at present cover only two waves of an eventually longer panel study. Both the price and income variation used in the present analysis are limited by the fact that a maximum of only two observations per household are available. As future waves of the TZA data become available, this analysis will be updated.

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Appendix A

Bellemare, Barrett, and Just have made their data and Stata-executable data analysis commands available for replication (see http://marcfbellemare.com/wordpress/research/). Examination of their Stata commands reveals that the budget share for each commodity, i, in each household, k, is estimated in BBJ 2013 as,

$$\beta_{ik} = \frac{M_{ik}P_{itl}}{\bar{y}} \qquad \text{[A.EQ1]}$$

where $\bar{y}$ is the mean household income across all households and all time periods.

I have learned through correspondence with the authors that this measure was taken due to the large number of zero-valued income households in the EHRS. The budget shares for such households would be undefined in the case that the budget share was calculated over actual household income as,

$$\beta_{ik} = \frac{M_{ik}P_{itl}}{y_k} \qquad \text{[A.EQ2]}$$

as has been done in the present analysis. However, calculation of the budget share by fixing the denominator of the budget expression at $\bar{y}$ produces β_{ik} values that distort the relationship of income to budget shares. To show this, I provide two brief simulations in Tables A1 and A2.

Consider Table A1. If the y column represents the vector of household incomes and the MP_{tl} column represents the product of household marketable surplus and current local price over a single commodity, then the true budget share for each household for that commodity is that calculated in column three. However, if the budget share is calculated with $\bar{y}$ in the denominator, estimated $\widehat{\beta_k}$ falls below true β_k for those households with income below the mean and falls above true β_k for those households with income above the mean. The final column of Table A1 suggests that the estimation errors caused by approximation of y with $\bar{y}$, $\widehat{\beta_k} - \beta_k$, are symmetric about the mean. We see in Table A2 that this need not be the case.

Table A1. Constant budget share with uniformly distributed income

MP_{tl}	y	True $\beta = \frac{MP_{tl}}{y}$	Estimated $\hat{\beta} = \frac{MP_{tl}}{\bar{y}}$	Estimate relative to true value	
				Estimate	Difference
0.5	1	0.5	0.091	under	0.409
1	2	0.5	0.182	under	0.318
1.5	3	0.5	0.273	under	0.227
2	4	0.5	0.364	under	0.136
2.5	5	0.5	0.455	under	0.045
3	6	0.5	0.545	over	-0.045
3.5	7	0.5	0.636	over	-0.136

4	8	0.5	0.727	over	-0.227
4.5	9	0.5	0.818	over	-0.318
5	10	0.5	0.909	over	-0.409
	$\bar{y}$ =5.5				

A second simulation, shown in Table A2, better approximates the distribution of income and budget share as seen in both the EHRS and the LSMS-ISA data: the budget share decreases across a right skewed income distribution. In this simulation, the estimation errors are no longer symmetric about the mean.

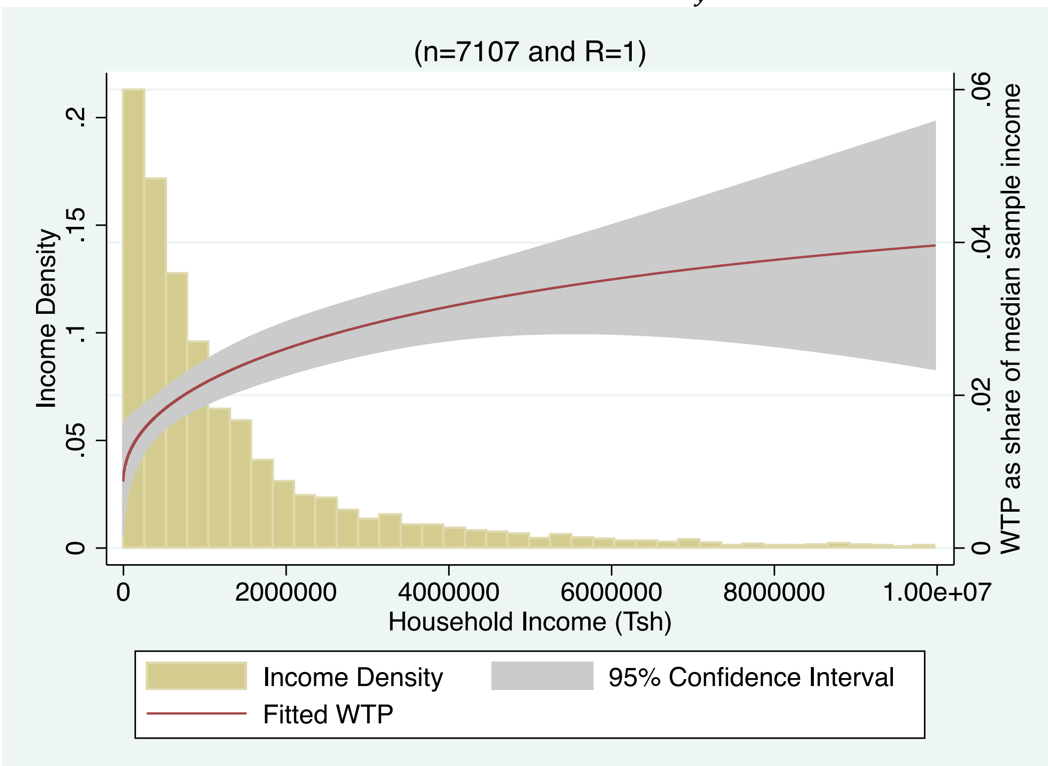
Table A2. Decreasing budget share with right skewed income distribution

MP_{tl}	y	True $\beta = \frac{MP_{tl}}{y}$	Estimated $\hat{\beta} = \frac{MP_{tl}}{\bar{y}}$	Estimate relative to true value	
				Estimate	Difference
0.7	1	0.7	0.127	under	0.573
1.3	2	0.65	0.236	under	0.414
1.2	2	0.6	0.218	under	0.382
1.1	2	0.55	0.200	under	0.350
1.5	3	0.5	0.273	under	0.227
1.35	3	0.45	0.245	under	0.205
1.6	4	0.4	0.291	under	0.109
1.75	5	0.35	0.318	under	0.032
2.7	9	0.3	0.491	over	-0.191
3	12	0.25	0.545	over	-0.295
	$\bar{y}$ =4.3				

In both Tables A1 and A2 it is clear that estimation of the budget share over mean income underestimates the budget share of marketable surplus for relatively poor households and overestimates it for relatively wealthy households.

In addition, it is possible to recover a relationship between income and WTP similar to that found in BBJ 2013 by estimating the budget shares as indicated in A.EQ1. The resulting regression of WTP on income is presented in Figure A1, which exaggerates and inverts the relationship between WTP and income that was observed in Figure 1. Figure A1 tells a clear story about a distributionally regressive benefit incidence of price stabilization while Figure 1 offered a relatively opaque story about a distributionally progressive benefit incidence of price stabilization.

Figure A1. Nonparametric fractional polynomial regression of WTP as share of median sample income on household income, where $\beta_{ik} = \frac{M_{ik}P_{itl}}{\bar{y}}$



These simulations and results suggest that calculation of the budget shares as $\beta_{ik} = \frac{M_{ik}P_{itl}}{\bar{y}}$ as opposed to as $\beta_{ik} = \frac{M_{ik}P_{itl}}{y_k}$ may have altered the relationship of poor and wealthy households to WTP in BBJ 2013 by artificially inflating the budget share of marketable surplus for wealthy households and artificially deflating it for poor households.

Appendix B

Table B1. Pairwise correlation between commodity price and household income

Price (Commodity)	Correlation with income
Rice	-0.0185
Maize, Cob	0.1373*
Maize Flour	0.0151
Cassava	0.1994*
Cassava Flour	0.3465*
Sweet Potato	0.2928*
Irish Potato	0.0882*
Sugar	0.0059
Groundnut	0.0745*
Coconut	0.1327*
Milk	0.2035*
Salt	0.1295*
Tea	0.2620*
Banana	0.0812*
Citrus	-0.0535*

*Indicates correlation statistically significant at a 99% confidence level
Note: Bonferroni correction made to account for family wise error rate