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## Article

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Article

# Distribution of Budget Shares for Food: An Application of Quantile Regression to Food Security <sup>1</sup>

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**Abstract:** This study examines, using quantile regression, the linkage between food security and efforts to enhance smallholder coffee producer incomes in Rwanda. Even though in Rwanda smallholder coffee producer incomes have increased, inhabitants these areas still experience stunting and wasting. This study examines whether the distribution of the income elasticity for food is the same for coffee and noncoffee growing provinces. We find that that the share of expenditures on food is statistically different in coffee growing and noncoffee growing provinces. Thus, the increase in expenditure on food is smaller for coffee growing provinces than noncoffee growing provinces.

**Keywords:** income elasticity; subsistence; marketing channels

**JEL:** O14, D12, C21

## 1. Introduction

In 2009, at the G8 <sup>2</sup> conference in L'Aquila, Italy, President Barack Obama pledged at least \$3.5 billion over three years to the global response against hunger. This pledge was formalized as the US government's Feed the Future initiative, with the United States Agency for International Development (USAID) as the lead implementing agency. Feed the Futures' goal is to "sustainably reduce global poverty and hunger." Over the past five years, Feed the Future has focused on staple food value chains, but there is an ongoing dialog over whether the focus should include smallholder cash crops as a critical intervention for reducing poverty. This study informs that dialog by hypothesizing that cash-crop development projects can increase income and thus food expenditure, and testing this hypothesis empirically using data from a Rwanda project improving the smallholder coffee value chain. Specifically, this paper uses quantile regression to quantify food income elasticities and their

<sup>1</sup> The views presented in this manuscript are those of the authors and do not necessarily represent the views of the United States Agency for International Development.

<sup>2</sup> The G8 was forum of eight countries—the original G7 or largest industrial economies including Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States with Russia as the eighth—now again the G7.

distribution across income quantiles. Quantile regression is the tool of choice because of specific interest in the response of the poor to the program.

The development activities under investigation sought to increase smallholder returns to coffee by improving by investment in coffee trees, local processing stations and facilities to enhance coffee quality, thereby improving the marketing channel and returns to smallholders. The specific USAID projects supporting these activities are the Partnerships for Enhancing Agriculture in Rwanda through Linkages (PEARL) from 2000 to 2005 and Sustaining Partnerships to Enhance Rural Enterprise and Agribusiness Development (SPREAD) from 2006–2010. While these programs pre-date the Feed the Future program, they match under the Feed the Future goals and results in a framework to increase the returns to smallholder agriculture, and assessment of their poverty impacts will provide evidence useful for informed decision making under Feed the Future.

Moss, Lyambabaje and Oehmke [1] quantify a 14 percentage point reduction in headcount poverty rate associated with PEARL/SPREAD. The Minister of Agriculture and Animal Resources (Dr. Gerardine Muskeshimana) responded by asking two of the authors: Why has stunting and wasting not declined in coffee producing areas? Moss, Oehmke and Lyambabaje [2] investigate this question by using Working's Model [3] with the hypothesis that coffee producers may have been spending additional income on non-food goods and services. To test this hypothesis they estimated whether the share and income elasticity of household expenditures on food differed between households that produce coffee and those that do not with the introduction of PEARL/SPREAD. They found that the income elasticity for households that produce coffee was the same as other households in Rwanda, *i.e.*, at the margin both coffee producing households and noncoffee producing households spend the same share of additional income on food. Their result was also robust to the inclusion of food produced by the household. However, Moss, Oehmke and Lyambabaje focus on coffee-producing regions, leaving several questions open—including the Minister's question about stunting and wasting. First, within the region, Moss Oehmke and Lyambabaje estimated an average income elasticity average over all income groups. The poorest of the population with the greatest likelihood of stunting and wasting may have a low income elasticity of food and spend additional income on non-food items, but that the effect is masked by the estimation of a single elasticity for all income groups. This study departs from Moss, Oehmke and Lyambabaje by using the quantile regression approach. Specifically, we estimate quantiles for income elasticity by applying quantile regression to Working's Model. Quantile regression allows for the measurement of the effects of cash crop income on food expenditure by income group (quantile). Specifically, two interpretations of the hypothesis that coffee income has no effect on stunting and wasting are that a) the poorest quantile(s) do not participate in cash coffee production and/or b) the poorest quantile(s) do not allocate additional cash to food consumption. Moss, Lyambabaje and Oehmke [2] reject households subjectively classified in every poverty category participated in the USAID supported coffee activities. This paper examines the second hypothesis—that the poorest households' expenditures on food differ from richer households as measure by the income elasticity.

The approach to measuring income elasticity and food expenditures is based on Working's Law: The empirical relationship discovered by Holbrook Working in 1943 [3] that the share of the household expenditures on food declined with the logarithm of family income

$$w_f = a + b \ln(E) . \quad (1)$$

Kumar, Holla, and Guha [4] suggest that a non-linear variant of Working's Law could be used to develop a measure of poverty. Specifically, modifying Equation (1)

$$w_f = a + b \ln(E) + c (\ln(E))^2 \quad (2)$$

yields the possibility that the share of income spent on food first increases before declining. This is inconsistent with the findings of Workings. Under typical assumptions  $b < 0$ , Kumar, Holla, and Guha contend that very poor households have insufficient income to meet their nutritional needs. Hence, as

income increases, expenditures on food increase until some point of food sufficiency is reached. Under this conjecture,

$$w_f = a + [b + c \ln(E)] \ln(E) \quad (3)$$

so that  $b + c \ln(E) > 0$  up to some income level  $E^*$ . After this point,  $b + c \ln(E) < 0$ . From this construction  $b > 0$  and  $c < 0$ . The critical income level, where the household becomes food sufficient, is then defined by the point:  $\ln(E^*) = -b/2c > 0$ .

The use of Working's model to examine poverty is not new. Theil, Chung, and Seale [5] built on the basic Working's model to develop the Florida Demand Model to explain international differences in consumption patterns. In its most general form, the budget share for good  $i$  in country  $c$  ( $w_{ic}$ ) can be written as

$$w_{ic} = \alpha_i + \beta_i q_c + (\alpha_i + \beta_i q_c) \left[ \ln\left(\frac{p_{ic}}{\bar{p}_i}\right) - \sum_{j=1}^m (\alpha_j + \beta_j q_c) \ln\left(\frac{p_{jc}}{\bar{p}_j}\right) \right] + \phi(\alpha_i + \beta_i q_c^*) \left[ \ln\left(\frac{p_{ic}}{\bar{p}_i}\right) - \sum_{j=1}^m (\alpha_j + \beta_j q_c) \ln\left(\frac{p_{jc}}{\bar{p}_j}\right) \right] \quad (4)$$

where  $\alpha_i + \beta_i q_c$  is the traditional Working's model (*i.e.*,  $q_c = \ln(E_c)$  or the natural logarithm of the average household expenditure in country  $c$ ),  $p_{ic}$  is the price of good  $i$  in country  $c$ ,  $\bar{p}_i$  is the geometric average price of good  $i$  across countries,  $q_c^* = 1 + q_c$ , and  $\phi$  is the income flexibility of demand ([5], p. 33). Their results indicate that the basic Working's formulation was sufficient to explain most of the international variation in consumption patterns. The explanatory power of the simple Working's formulation is amplified by considering the effect of price changes on the income constraint (*i.e.*, the "quadratic terms" Equation (4)) and the marginal utility of income (*i.e.*, the cubic terms in Equation (4), which involve the income flexibility components). In addition, most of the variation in shares across countries was explained by the Engel Curve for food—Working's original contention.

Studies have raised questions about the overall shape of the Engel curves (e.g., since the Working's formulation is a special case of the Engle curve). For example, Banks, Blundell, and Lewbel [6] suggest that the Engel curves for several categories may be quadratic—as based on the Quadratic Almost Ideal Demand System (QAIDS). To analyze this empirical possibility, Banks, Blundell, and Lewbel construct nonparametric estimates of the Engle curves using the nonparametric estimator developed by Hardle and Jerison [7]. They find that the Engel Curves for clothing and alcohol are quadratic, but the Engel Curve for food is linear in logs.

Moss, Oehmke and Lyambabje [2] use the Working's model to examine whether policy interventions affect the household expenditures on food. Using the same Rwandan dataset used in this study, they examine whether a coffee marketing channel intervention changed the share of the household budget spent on food

$$w_F = \alpha_F + \beta_F \ln(E) + \gamma_F d + \delta_F d \ln(E) \quad (5)$$

where  $d$  is the household's participation in the commercial coffee market. In addition to this basic conjecture, they examined whether the market intervention affected the relationship between income and share of food including the value of home production.

This paper extends Equation (5) using quantile regression to estimate Working's model to explain food security by considering the potential effect of income on the distribution of food budget shares using quantile regression

$$w_{Fi} = a_0 + a_1 \ln(E_i) + a_2 (\ln(E_i))^2 \quad (6)$$

Equation (6) allows for the possibility of a peak in food security following Kumar, Holla, and Guha [4]. The model estimated in this study is

$$w_{Fi} = a_0 + a_1 \ln(E_i) + a_2 (\ln(E_i))^2 + a_3 d_i + a_4 (d_i \ln(E_i)) + a_5 [d_i (\ln(E_i))^2] \quad (7)$$

where  $w_{Fi}$  is the share of food expenditures for household  $i$  (both with and without home production),  $E_i$  is the level of household expenditures (both with and without home production), and  $d_i$  is a dummy variable that is zero if the household is from a province that does not produce coffee and one if household is from a province that does.

Equation (7) is estimated using the ordinary least squares procedure in R and Quantreg [8] (an R package for estimating quantile regression). The advantage of using quantile regression is that it is more robust to extremes in the dependent variable than ordinary least squares (e.g., it is less sensitive to outliers). We are specifically interested in whether there is extreme behavior by low income households in the purchase of food which would contribute to stunting and wasting even when income rises.

We compute the income elasticity of demand at each of these quantiles where the income elasticity ( $\eta_F$ ) can be expressed as

$$\eta_F = \frac{w_F + a_1 + 2a_2 \ln(E)}{w_F}. \quad (8)$$

The hypothesis that increases in income among the poorest are not contributing to reductions in stunting and underweight because the poor spend relatively less on food is tested by comparing the income elasticity of food across income quantiles. A lower income elasticity among the lower income quantiles would corroborate the hypothesis; equal or higher elasticities would not. The authors recognize that stunting and underweight are complex phenomena that depend on food, health, sanitation and other factors, and that if the hypothesis is corroborated it does not mean that the poor are not spending their money on useful items (such as health care). Nonetheless, understanding food expenditures is an important first step in understanding occurrence stunting and underweight.

## 2. Experimental Section

The data used in this study are taken from the Enquête Intégrale sur les Conditions de Vie des ménages –3 (or EICV3) dataset [9] which is a survey of household conditions in Rwanda. Unlike Moss, Oehmke, and Lyambabaje, we use the full country sample that contains information for 14,308 households. Household expenditures are a small part of the information gathered. The data, in addition to household expenditures contain information about whether each individual in the household works on the farm and/or off. The amount of production inputs purchased and quantity of output sold and/or consumed by the household. For the purpose of this study, we focus on household expenditures on school, health, household durables, household non-durables, small tools, luxury goods, food, other goods and gifts. Information on major purchases such as household durables are asked in a single visit based on annual purchases. The expenditures on items such as tools are based on a four week window. The data on food purchases are gathered through ten household visits over the year. In each visit, the household is asked how much was expended for each food group since the last visit. In each visit the household is also asked about food consumed from home production. Household and other data are then used to determine market price of each home production category. Household expenditures are computed as the sum of each expenditure category. The sum of food expenditures and the sum of food expenditures plus the value of home consumption are then used to compute the food expenditure share, which is the dependent variable in Equation (7).

The standard deviations for the estimated parameters are computed by bootstrapping 50,000 times the results from each procedure. For consistency reasons, the sample is sorted by whether the household is from a noncoffee or coffee producing province. In the bootstrapping procedure, only errors for each respective province type are drawn to create the pseudo-sample. The 50,000 draws are retained to compute the variances for income elasticities and testing for the equivalence of income elasticities across specifications.

## 3. Results and Discussion

The estimated parameters and standard deviations are presented in Table 1. All the parameters are statistically significant at any conventional level of confidence. In addition, Wald tests for the

significance of the coffee dummies indicate that these parameters taken together are also statistically significant. Hence, we conclude that the Engel curves for households are structurally different between coffee growing areas of Rwanda and those areas that do not grow coffee. Of course, statistical significance may not imply economically important differences.

Our results that find nonlinearity of the Working's curves (Table 1) are in sharp contrast with those of Kumar, Holla, and Guha [3] who hypothesize that the share of expenditures on food will first increase and then decline as the household reaches food security. This would imply a positive  $a_1$  and a negative  $a_2$ . The results presented in Table 1 are consistently opposite. In fact the results are consistent with a minimum point for the share of income spent on food. The question is whether this minimum is in the relevant range of incomes observed in the sample.

As a starting point, we derive the first and second derivatives of the Working relationship with respect to household expenditures

$$\begin{aligned} \frac{\partial w_F}{\partial E} &= \frac{a_1 + 2a_2 \ln(E)}{E} \\ \frac{\partial^2 w_F}{\partial E^2} &= \frac{-a_1 + 2a_2(1 - \ln(E))}{E^2} \end{aligned} \quad (9)$$

Note that since expenditures are strictly positive, the point concavity of the Working's specification is determined by

$$-a_1 + 2a_2(1 - \ln(E)). \quad (10)$$

Given the observed income range presented in Table 2 the Working's relationship is convex throughout. The key is whether the minimum point on the Working's relationship is within the observed expenditures range.

Table 3 presents the distribution of the minimum point for the Working's curves for each set of estimated parameters. In general, the computed critical values are higher than the 3rd Quantile of the household per capita incomes presented in Table 2. The possible exception involves the cash based expenditures for coffee producing provinces for  $\tau = 0.75$ . In general, the critical values for the cash plus home production results reach a minimum at  $\ln(E) = 12.95$ . Hence, these results are more consistent with the typical expectations of the Working's model (*i.e.*, that the share of food in the consumer budget declines as income increases).

**Table 1.** Estimated working's model coefficients using ordinary least squares and quantile regression.

Parameter	Cash Income Only				Cash Income and Home Production			
	OLS	Quantile Regression			OLS	Quantile Regression		
		$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$		$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$
$a_0$ – Constant	0.9488 (0.0472) <sup>a</sup>	0.3728 (0.0257)	0.8697 (0.0412)	1.4006 (0.0741)	2.1064 (0.0611)	1.6618 (0.0377)	2.2519 (0.0493)	2.7389 (0.0842)
$a_1$ – Log(Expenditure)	–0.1402 (0.0089)	–0.0541 (0.0048)	–0.1345 (0.0078)	–0.2163 (0.0139)	–0.3062 (0.0113)	–0.2483 (0.0070)	–0.3411 (0.0092)	–0.4114 (0.0156)
$a_2$ – Log(Expenditure) <sup>2</sup>	0.0055 (0.0004)	0.0021 (0.0002)	0.0055 (0.0004)	0.0089 (0.0006)	0.0114 (0.0005)	0.0094 (0.0003)	0.0132 (0.0004)	0.0159 (0.0007)
$a_3$ – Coffee Dummy	0.6274 (0.0620)	0.3421 (0.0358)	0.6150 (0.0532)	1.2268 (0.0898)	0.2566 (0.0790)	0.1936 (0.0520)	0.3403 (0.0638)	0.9153 (0.1047)
$a_4$ – Dummy $\times$ Log(Expenditure)	–0.1013 (0.0119)	–0.0540 (0.0069)	–0.1038 (0.0102)	–0.2221 (0.0171)	–0.0312 (0.0149)	–0.0298 (0.0098)	–0.0554 (0.0120)	–0.1587 (0.0197)
$a_5$ – Dummy $\times$ Log(Expenditure) <sup>2</sup>	0.0038 (0.0069)	0.0021 (0.0003)	0.0043 (0.0005)	0.0098 (0.0008)	0.0005 (0.0007)	0.0011 (0.0005)	0.0021 (0.0006)	0.0066 (0.0009)

<sup>a</sup> Numbers in parenthesis denote standard errors.



**Table 2.** Quantiles of the natural logarithm of household expenditures by province type.

Province Type	Min	1st Quartile	Median	3rd Quartile	Max
All Households	5.298	9.374	9.983	10.665	21.129
Noncoffee Provinces	6.392	9.592	10.220	11.000	18.932
Coffee Provinces	5.298	9.211	9.771	10.358	21.129

**Table 3.** Distribution of natural logarithms of expenditures that minimize share of food expenditures.

Province	Mean	Std. Dev.	Min	1st Quartile	Median	3rd Quartile	Max
<i>Cash Expenditures</i>							
<i>Ordinary Least Squares</i>							
Noncoffee Provinces	12.710	0.177	12.028	12.600	12.715	12.835	13.770
Coffee Provinces	12.955	0.130	12.320	12.880	12.965	13.047	13.598
<i>Quantile Regression <math>\tau = 0.25</math></i>							
Noncoffee Provinces	13.024	0.285	12.118	12.831	13.012	13.207	14.821
Coffee Provinces	13.028	0.190	12.244	12.896	13.016	13.138	14.142
<i>Quantile Regression <math>\tau = 0.50</math></i>							
Noncoffee Provinces	12.279	0.128	11.743	12.192	12.278	12.365	12.875
Coffee Provinces	12.199	0.082	11.810	12.145	12.200	12.253	12.532
<i>Quantile Regression <math>\tau = 0.75</math></i>							
Noncoffee Provinces	12.128	0.133	11.650	12.038	12.129	12.223	12.694
Coffee Provinces	11.688	0.054	11.420	11.653	11.690	11.724	11.877
<i>Cash Expenditures Plus Home Production</i>							
<i>Ordinary Least Squares</i>							
Noncoffee Provinces	13.446	0.130	12.838	13.364	13.449	13.536	14.103
Coffee Provinces	14.179	0.158	13.400	14.088	14.192	14.292	14.882
<i>Quantile Regression <math>\tau = 0.25</math></i>							
Noncoffee Provinces	13.224	0.089	12.836	13.161	13.221	13.280	13.649
Coffee Provinces	13.280	0.105	12.714	13.211	13.274	13.342	13.842
<i>Quantile Regression <math>\tau = 0.50</math></i>							
Noncoffee Provinces	12.946	0.075	12.578	12.893	12.945	12.995	13.245
Coffee Provinces	12.945	0.073	12.535	12.897	12.945	12.989	13.283
<i>Quantile Regression <math>\tau = 0.75</math></i>							
Noncoffee Provinces	12.904	0.105	12.483	12.836	12.908	12.980	13.362
Coffee Provinces	12.637	0.068	12.266	12.593	12.641	12.680	12.880

In Figure 1a we present the estimated budget share for noncoffee provinces based on cash purchases while Figure 1b presents the comparable budget shares including home production. The cash expenditures on food levels out after approximately 60,000 Rwanda Franc (RWF) in Figure 1a. In addition, the quantile regression results increases slightly at around 250,000 RWF per capita. By comparison, the budget shares for food expenditures including home production presented in Figure 1b declines relatively smoothly throughout the entire range. The results for coffee growing provinces are similar. Figure 1c shows that share of cash income spent on food levels out at about 50,000 RWF. In addition, the minimum for expenditure share expenditure for food is reached at about 120,000 RWF. The expenditure shares on food then start to increase, rising from about 0.065 at 120,000 RWF to around 0.075 at 270,000 RWF. To compare the relative range of budget shares, the median budget share and relative inter-quartile range (e.g., the difference between 3rd quartile and the 2nd quartile divided by the median) for the graphs are presented in Table 4. These results indicate that the more complete definition of expenditures yield more consistent Working's relationships than the relationship using cash expenditures alone (e.g., the Working's curves have smaller relative inter-quartile ranges).



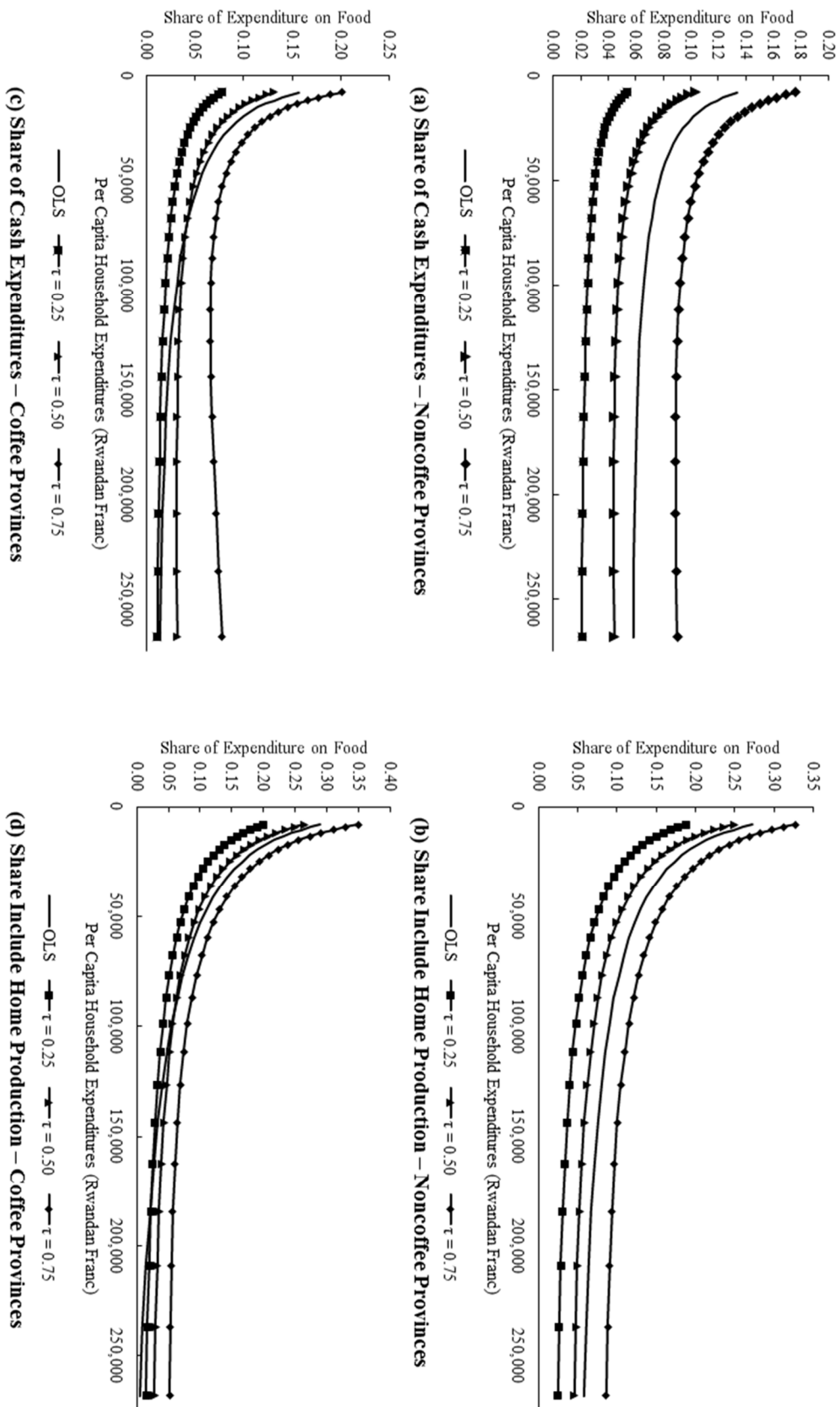


Figure 1. Share of expenditures on food as a function of total expenditures.

**Table 4.** Dispersion of share of food expenditures.

Household Expenditures	Cash Food Expenditures		Cash and Home Production	
	Median	Inter-Quartile Range	Median	Inter-Quartile Range
Noncoffee Provinces				
50,000	0.0558	1.3252	0.1032	0.7667
75,000	0.0502	1.3804	0.0827	0.8658
100,000	0.0474	1.4234	0.0707	0.9548
150,000	0.0449	1.4854	0.0576	1.1055
200,000	0.0442	1.5267	0.0509	1.2227
Coffee Provinces				
50,000	0.0499	0.9904	0.0945	0.5708
75,000	0.0406	1.1349	0.0706	0.6170
100,000	0.0359	1.2968	0.0567	0.6809
150,000	0.0321	1.6024	0.0415	0.8455
200,000	0.0313	1.8444	0.0337	1.0371

We now focus on the more complete definition of household expenditures on food (*i.e.*, including home production as part of food production and adding the value of home production to household expenditures) and examine the implied difference in the income elasticity of food to address the question raised by the Minister of Agriculture and Animal Resources in Rwanda. Following the intuition from Kumar, Holla, and Guha [4] and Theil, Chung, and Seale [5] less food secure households have high income elasticities of demand for food (*i.e.*, a larger portion of the marginal income is dedicated to the purchase of food). The results in Table 5 indicate that for the poorest households (*i.e.*, those households at the 1st quartile of income), the income elasticities are fairly similar.

**Table 5.** Estimated income elasticities for both purchased and home produced food.

Province	1st Quartile	Median	3rd Quartile
<i>Ordinary Least Squares</i>			
Pooled	0.5703 (0.0045) <sup>a</sup>	0.5096 (0.0059)	0.4199 (0.0099)
Noncoffee	0.5952 (0.0070)	0.5580 (0.0083)	0.5190 (0.0126)
Coffee	0.5532 (0.0056)	0.4812 (0.0077)	0.3716 (0.0131)
<i>Quartile Regression <math>\tau = 0.25</math></i>			
Pooled	0.5293 (0.0043)	0.4608 (0.0060)	0.3635 (0.0108)
Noncoffee	0.5259 (0.0066)	0.4613 (0.0087)	0.3711 (0.0152)
Coffee	0.5316 (0.0056)	0.4655 (0.0078)	0.3753 (0.0131)
<i>Quartile Regression <math>\tau = 0.50</math></i>			
Pooled	0.5292 (0.0040)	0.4706 (0.0054)	0.4011 (0.0092)
Noncoffee	0.5394 (0.0064)	0.4926 (0.0082)	0.4517 (0.0133)
Coffee	0.5211 (0.0048)	0.4587 (0.0068)	0.3801 (0.0113)
<i>Quartile Regression <math>\tau = 0.75</math></i>			
Pooled	0.5474 (0.0048)	0.5049 (0.0064)	0.4703 (0.0101)
Noncoffee	0.5923 (0.0081)	0.5699 (0.0096)	0.5722 (0.0138)
Coffee	0.5111 (0.0055)	0.4537 (0.0078)	0.3899 (0.0129)

<sup>a</sup> Numbers in parenthesis denote standard errors.

Like the statistical results for the regression coefficients presented in Table 1, the income elasticities for food are statistically significant at any conventional level of confidence. These results implicitly compare the estimated elasticity with zero (*i.e.*,  $z = 0.5703/0.0045 = 126.733$ ). A more important question is whether the elasticities are the same. For example, a “paired *t*” test for the equivalence between the elasticity for the 1st quartile and the 3rd quartile would be  $t = (0.5703 - 0.4199)/\sqrt{1/2 (0.0045^2 + 0.099^2)} = 19.56$ . Hence, the income elasticity for the 1st quartile is statistically different from the income elasticity for the 3rd quartile at any conventional level of confidence. Tables 6 and 7 present the results for a slightly more general form of this test. Specifically, Table 6 presents the *F* statistics for an analysis of variance (ANOVA) test for the hypothesis that the income elasticity of the 1st quartile equals to the income elasticity for the 3rd quartile and the hypothesis that the income elasticity is the same for the 1st quartile, the median and the 3rd quartile. These tests are computed using the data from the bootstrapping procedure used to generate the standard errors for the estimators in Table 1 and income elasticities in Table 5. The results in Table 6 indicate that all the income elasticities are different across quantiles. Table 7 presents a slightly different hypothesis—that the income elasticities are the same for each income quartile across types of provinces. One hypothesis is that the income elasticity for noncoffee provinces equals the income elasticity for coffee provinces for households in the first income quartile.

**Table 6.** *F* Test for equal income elasticities across Income quantiles.

	1st Quartile = 3rd Quartile	All Quantiles Equal
<i>Ordinary Least Squares</i>		
Pooled	9,534,928	5,585,004
Noncoffee	1,406,788	789,955
Coffee	8,189,922	4,806,700
<i>Quantile Regression <math>\tau = 0.25</math></i>		
Pooled	10,140,171	6,045,034
Noncoffee	4,331,513	2,567,090
Coffee	5,953,579	3,461,046
<i>Quantile Regression <math>\tau = 0.50</math></i>		
Pooled	8,100,107	4,710,787
Noncoffee	1,749,114	1,002,783
Coffee	6607890	3817624
<i>Quantile Regression <math>\tau = 0.75</math></i>		
Pooled	2,368,743	1,343,854
Noncoffee	81,205	66,564
Coffee	3,704,222	2,126,690

**Table 7.** *F* Test for the equality of income elasticities across province types.

	1st Quartile	Median	3rd Quartile
OLS			
Noncoffee = Coffee	1,098,538	2,280,356	3,310,276
All the Same	667,114	1,374,194	1,983,870
$\tau = 0.25$			
Noncoffee = Coffee	20,908	5986	1589
All the Same	12,770	5559	10,029
$\tau = 0.50$			
Noncoffee = Coffee	256,722	503,388	847,400
All the Same	155,719	308,445	524,329
$\tau = 0.75$			
Noncoffee = Coffee	3,418,522	4,375,772	4,611,258
All the Same	2,072,686	2,603,527	2,703,810

Given that the income elasticities are statistically different, the next question is whether these differences are economically significant. Consider the results for  $\tau = 0.75$ . Following the development of the Working's model, these observations are the most food insecure households (*i.e.*, those households who spend the highest share of their income on food). Further focusing on the 1st Quartile of expenditures (e.g., the poorest of these households), the income elasticity is 0.5474 in the pooled results, 0.5923 for noncoffee provinces, and 0.5111 in coffee provinces. Intuitively, the households in the noncoffee growing provinces appear to be the most food insecure. We assume that a household with an annual expenditure per capita of 11,750 RWF (a somewhat round number approximately equal to the 1st Quartile). This household would spend 3374 RWF on food under the pooled estimates, 2338 RWF on food under the estimates for noncoffee growing provinces and 3714 RWF on food under the estimates for the coffee growing provinces. Hence, households in the coffee growing provinces spend more money on food and thus appear more food secure. However, if household income was to increase by five percent (e.g., 587.50 RWF) the pooled expenditure on food would increase by 322 RWF, the expenditures on food for noncoffee producing provinces would increase by 348 RWF, and the expenditures on food for coffee growing provinces would increase by 300 RWF. Essentially, the Working's curve for coffee growing provinces is steeper for coffee growing provinces than for noncoffee growing provinces (which is reasonable comparing Figure 1b with Figure 1d). So what does this mean? At one level, the results are consistent with Dr. Gerardine Muskeshimana's contention. The results suggest that the most food insecure households in coffee growing regions buy less food with an increase in income than other food insecure households in Rwanda. However, this result hides the finding that these households already spend more for food (e.g., 3714 RWF for food insecure households in coffee regions compared with 2338 RWF in other areas).

#### 4. Conclusions

Feed the Future is the major U.S. initiative to reduce poverty and end hunger worldwide. One of the major pathways for this initiative spearheaded by the United States Agency for International Development involves improving the returns to smallholder agriculture in 19 Feed the Future countries. In one of these countries (Rwanda), several programs have attempted to increase the returns to smallholders by improving the market channel for coffee. These efforts have been successful, increasing household income and reducing the incidence of poverty in provinces which produce coffee as a major cash crop. However, several have question whether these gains have actually reduced food security in these regions. Specifically, stunting and wasting remains a significant concern in these regions. In order to provide some insights into this question, this study compares the impact of additional income on food consumption between noncoffee producing and coffee producing provinces in Rwanda by applying quantile regression to a Working's formulation of food demand.

The empirical results imply that the quantity of food purchased for each additional Franc is different for noncoffee and coffee producing provinces. While this result appears to support the contention that programs did not have the desired effect on food security, the direction of the effect shows the reverse is actually true. Households in coffee producing provinces actually spend more on food than households in other provinces when home production is included in the analysis. However, the results indicate that households in coffee producing provinces spend a smaller share of each additional Franc on food than do households in other provinces.

Additional work is required to flush out the effect of improving returns to smallholders on food security. Specifically, our linkage between food security and returns to smallholders is weak. Basically, we test the implications for the general conjecture that food security is improved when more food is purchased by the household. One possibility would be to gather data on stunting and wasting by district (each province in Rwanda contains several districts). The model estimated in this study could then be used to test the hypothesis that increased household expenditures on food reduces the probability of stunting.

Econometrically the significance of the results reported in this study are primarily the result of a fairly large sample (*i.e.*, 14,308 households). While standard bootstrapping results are typically fairly robust, one alternative would be to test the level of significance for the sample estimates and elasticities using a “wild bootstrapping” procedure [10].

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