Welfare impact of a commercialization policy for Brazilian family farmers

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The Brazilian National School Lunch Program – PNAE was modified in 2009 by Law No. 11,947 of 2009 to waive family farmers from bidding in the process of food purchases and started to require that at least 30% of food purchases for public schools should be bought from family farmers. The objective of the present paper is to evaluate the impact of the PNAE on the welfare of family farmers. For this purpose, we define a profit maximization problem and estimate a system of supply equations, incorporating decisions for subsistence consumption and supply for two different markets: institutional markets (PNAE) and other markets. The estimation is performed using cross-sectional farm-level data from 2017. Outputs were aggregated into 9 groups: milk and dairy products, beef, fruits, vegetables, grains, food products from agroindustry, pork, sale of the workforce, and other outputs. The preliminary estimates show that the supply elasticities for the general markets are consistent with the expected. Own price elasticities for milk (0.02), fruits (0.14), and vegetables (0.71) are low because those products are usually the most representative among family farmers. Milk is, on average, the source of 51.6% of the income of farmers who produce it in the sample; fruit represents 50.3%; and vegetables constitute 48.4% of those who sell vegetables. Elasticities for Pork (8.42), grains (6.55), and others (3.87) are high because these outputs are usually produced in small quantities and mainly for subsistence consumption. The elasticities of supply in general markets to the PNAE prices show that, except for food products and pork, the sales to general markets increase when the price of the same good increases in PNAE. This result implies that the effect of PNAE on the reallocation of land and labor from subsistence to commercial production is stronger than a possible substitution effect. The main policy implication of these results is that the changes made on PNAE in 2009 had broader impacts. The policy design originated by the Resolution N° 4 of 2015 of the Education National Funding Deliberative Council is already a virtue of the Program, given that it represents a transfer of welfare in the institutional markets in favor of family farmers, without generating social costs. What we emphasize here, however, is that promoting the market insertion of family farmers by reducing transactional costs also implies relevant allocative effects. We estimate that for every 1$ of purchases from family farmers through PNAE, \$1.354 in on-farm income is generated for participants.

Keywords: School Lunch Program; Family farmers; on-farm income; crop choice, subsistence.

Introduction

The Brazilian family farmers[1](FFs) face constraints such as the lack of management skills and difficulty in building social capital, which represents constraints to accessing more specialized markets (Abramovay, 1998). Due to that, they are usually dependent on intermediates who buy the products at a price smaller than the one observed in the final market, appropriating a considerable margin of the returns from agricultural production.

In this context, the National School Lunch Program (PNAE) was modified in 2009 by Law n° 11.947 of June 16, 2009, to support commercialization for family farmers. That Law imposed that at least 30% of the products purchased by public schools for the preparation of lunch for students should be bought from family farmers (Brazil, 2009). This Program follows a price list compatible with the local markets and establishes a maximum quota of value that can be sold by the FFs through the Program (under a waiver of bidding), which was around $6,042 annually per farmer in 2017.

The participation of family farmers in policies such as PNAE, by guaranteeing a stable and readily accessible local market, reduces the difference between the received price and the market price. This impact on the price received by farmers can have different intensities according to the product. Family farmers tend to market milk and free-range chicken more effectively to cooperatives and local consumers but may face difficulties in marketing fruit or other vegetables to supermarkets or other wholesale centers due to the need for sufficient volume. Therefore, participation in policies such as PNAE would close a much larger gap in the latter products, when compared to the former, changing the relative prices of outputs.

There are many study cases regarding the social relevance of PNAE, but none of those evaluate the final impact on farmers' welfare. Considering the change in relative prices due to the potential participation of family farmers in those programs, changes in profitability of agricultural activity due to the revenue related to the quota commercialized through those policies and to an additional gain from allocative effects are expected.

In this paper, we evaluate the impact of PNAE on the welfare of Brazilian family farmers. First, we estimated a system of supply functions for agricultural goods incorporating participation in PNAE and analyzed the impact of participation on crop choice. The results were used to estimate the impact on on-farm and off-farm revenues, and the final impact on welfare for participants was estimated as the change in total revenues minus the change in subsistence consumption.

Institutional markets for Brazilian family farming: PNAE

As a strategy to support family farmers in overcoming the market insertion challenges, the National School Lunch Program – PNAE was modified in 2009 by Law No. 11,947 / 2009. The new version of the program waives family farmers from bidding in the process of food purchases and requires that at least 30% of the resources passed on by the National Education Development Fund for buying food for public schools should be used in purchasing agricultural products from family farmers (Brazil, 2009).

The conditions for the purchase are set out in Resolution N° 4/2015 of the Education National Funding Deliberative Council, which describes the operational procedures that must be observed for

[1] In the resolutions of Law no. 11,326 / 2006 and the updates given by Decree no. 9.064 / 2017, AF is the rural family entrepreneur who practices activities in the rural area, has an area of up to four fiscal modules, predominantly family labor and own family income and management of the enterprise (BRAZIL, 2015).

the sale of products from family farming to executing entities, prioritizing agrarian reform settlements, traditional indigenous communities and quilombola communities (MEC, 2015). Schools can further complement the demand for buying from farmers in the rural territory (classification of territory used by the program), State, and Country, in this order of priority (Brazil, 2009).

According to the resolution nº 26 of 2013, the acquisition price is determined as the average price observed in at least three markets at the city level, prioritizing the family farming producer fair, if any, plus the inputs required in the public call notice, such as freight costs, packaging, charges and any other necessary for the supply of the product (MEC, 2013). If a survey can't be carried out in the city, it must be supplemented at the county, state, or national level, in that order (MEC, 2013).

Welfare effects of a policy under a revenue-constrained quota

Institutional purchasing policies such as PNAE have as their primary objective the insertion of family farmers in the market. The markets traditionally accessed by FFs are the national and international integrated chains, or local and regional production and consumption circuits (Maluf, 2004). Integrated chains are generally focused on commodities such as grains, animals, milk, and fruits for the agroindustry, while regional circuits are focused on more diversified products produced on a smaller scale (Ueno et al., 2016).

Commercialization through integrated chains tends to be associated with less autonomy of producers in the process of negotiating prices. Commercialization through regional circuits usually entails challenges when producers aim to increase the production scale due to aspects related to the requirements of regional markets such as the standardization of products, regular flow, and the low volume offered.

Another relevant difficulty for Brazilian family farmers is their limited logistic capacity. Many producers are unable to transport products to the markets and therefore are likely to sell their products to middlemen, who pay prices that are considerably lower than the price paid in the regional markets.

Due to the aspects described above, family farmers face higher transactional costs than other producers, thus being unable to commercialize at prices observed in the final markets. Those costs can even inhibit their entry into competitive markets, as discussed by (Pingali et al., 2005), which highlights the importance of policies reducing transactional costs to promote market insertion of small farmers.

A flowchart representing the main agents in the commercialization through institutional markets and general markets (other than PNAE) is shown in Figure 1.

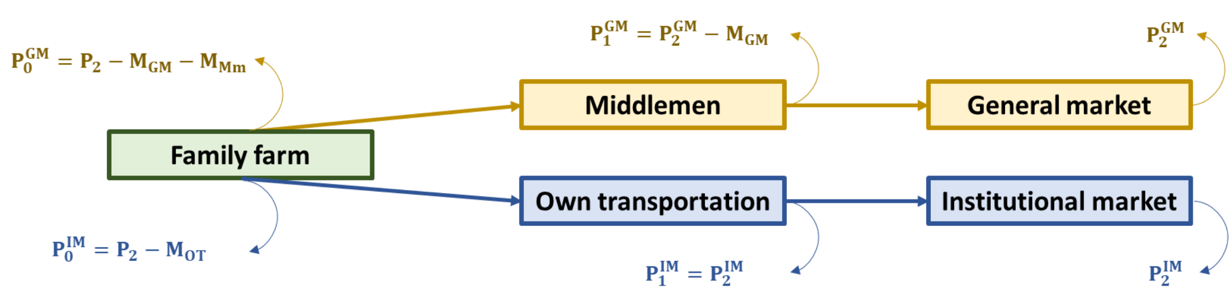

Figure 1. Agents and output prices in PNAE and general markets.

When selling to general markets, the middlemen charge a margin equal to M_{Mm}, which is equivalent to the transactional cost of the good from the farm to the final market. Besides that, the general markets also charge a markup M_{GM} that is the cost of transacting production from the middlemen to the final consumer. A family farmer usually receives, then, a price equal to the difference between the price paid by final consumers net of transactional costs, which is equal to $P_0^{GM} = P_2 - M_{GM} - M_{Mm}$.

Selling to PNAE, the producer is benefited from the fact that the institutional market does not include a markup over the products traded, because products bought through PNAE are delivered directly to the kitchen where food is prepared for public schools. Besides that, they commercialize at a price P_2^{IM}, which is supposed to be compatible with the price P_2^{GM} (MEC, 2013), and then the main determinant of the price net of transactional costs is the cost of own transportation (it includes packing).

When the farmers have direct access to the general markets, the price net of transactional costs received is expected to be very close to the price paid by PNAE because $M_{Mm} = 0$. This is not the common case for Brazilian family farmers, given that just a small share of those producers can sell all of their surplus in fairs or any other accessible final market.

If middlemen are exercising market power, or if the transportation costs differ between family farmers and other agents, the decrease in the difference between the price net of transactional costs received from the two markets can present varying intensities according to the product and can lead to distortions in relative prices. Family farmers tend to market milk and chicken more effectively to local cooperatives and consumers but may face difficulty in marketing fruits or other vegetables to supermarkets or other wholesale centers due to the need for sufficient volume and transportation. Thus, marketing in PNAE would lead to a much larger gain for the latter products, when compared to the first.

In addition, the stability of the marketing channel created by such policies makes producers less vulnerable to the loss of perishable products due to the predictability of demand. All these effects are supposed to affect the expected price for different products. As a result, relative prices between different products are changed, and the farmers' decision on which is the most profitable basket to produce is affected.

Methodology

An inherent characteristic of Brazilian family farming is that consumption and production decisions are linked between each other and also with exogenous markets. From a behavioral point of view, (Schneider, 2003) uses the concept of "pluriactivity" to refer to the situation in which those farmers and their families dedicate themselves to the exercise of a varied set of economic and productive activities, not necessarily linked to agriculture or land cultivation.

From a social perspective, Schneider & Niederle (2010) define the pluriactivity as a livelihood diversification strategy adopted by family farmers to obtain autonomy in the modern agricultural context. Those farmers usually produce under capital constraints Lonborg & Rasmussen (2014), on small land, and using family labor. Therefore, family labor allocation between on-farm and off-farm activities is a key point when analyzing the economic behavior of such producers, and it is driven by consumption needs.

For simplification purposes, we model the pluriactivity assuming that labor can be allocated in on-farm activities (subsistence or commercial production), and off-farm activities. The theoretical model proposed in this section takes into account two specificities of family farming. The first one is that prices of family labor and land are shadow prices determined according to the tradeoff between allocation for subsistence production, commercial production, or, in the case of labor, the labor market. According to Sadoulet & De Janvry (1995), this is the right approach when the consumption and production decisions are not separable, and prices of inputs and outputs become endogenous, being determined internally by the household as a shadow price.

We assume an optimization problem that includes subsistence consumption. For analytical purposes, it is solved in two steps. In the first step, farmers minimize the cost of subsistence consumption for a pre-allocation of land and labor across crops.

$$Min_{Ls,ls,Y_B}\ C_S = r_L(R)L_s + r_l(R)l_s + P_B Y_B \tag{1}$$

st

$$Fl.\theta_s \leq Y_s + Y_B$$

$$Y_s = f_S(L_s, l_s)$$

$$L_s \leq L - \sum_{i=1}^{m} L_i$$

$$Fl_s \leq Fl - \sum_{i=1}^{m} Fl_i$$

$$R + Prev \geq P_B Y_B$$

Where C_S is the cost of subsistence; R is the revenue from commercial surplus in the farm; $r_L(R)$ and $r_l(R)$ are the shadow prices of land and labor, respectively, that are given by the marginal revenue of those resources if they are allocated in commercial surplus; L_s is the land allocated to subsistence production, l_s is the labor allocated to subsistence production; P_B is the market price of subsistence goods, Y_s is the production of subsistence and Y_B is the quantity of subsistence goods bought from other markets; Fl is the number of family members and θ_s is the subsistence consumption per capita, and $Prev$ is the income from pensions and programs of income redistribution.

When deciding about subsistence consumption, the main tradeoff faced by farmers is that they can produce or buy subsistence goods. If they decide by using the available resources to produce such goods, they face the opportunity cost of allocating resources to other activities and obtaining remuneration, which could be used to buy Y_B.

Solving equation (1), the resulting cost function is given as a function of their resource constraints, the number of family members, market prices, and income from pensions and programs of income redistribution. Shepard's Lemma provides expressions for land and family labor allocated to subsistence

$$L_S^* = f_L(Prev, P_B, R, L, L_i, Fl, Fl_i) \tag{2}$$

$$Fl_S^* = f_l(Prev, P_B, R, L, L_i, Fl, Fl_i) \tag{3}$$

In the second step, farmers maximize revenue subject to the resource constraints, that are given as the remaining labor $\left(Fl - Fl_S^*(.)\right)$ and land $\left(L - L_S^*(.)\right)$

$$Max_{y_i,L_i,Fl_i}\ R = \sum_{i=1}^{m}(P_i^0)\, Y_i(L_i, Fl_i, z) \tag{4}$$

st

$$\sum_{i=1}^{m} L_i \leq\ L - L_s^*(.)$$

$$\sum_{i=1}^{m} Fl_i \leq\ Fl - Fl_s^*(.)$$

$$\sum_{i=1}^{m} y_i Y_i(L_i, Fl_i, z) P_i^0 \leq\ \bar{R}^0$$

$$Y_i = f_i(L_i, Fl_i)$$

$$R^*(\boldsymbol{P^{T0}}, \boldsymbol{z}, L, L_s^{**}(\boldsymbol{P^{T0}}, \boldsymbol{z}), Fl, Fl_s^{**}(\boldsymbol{P^{T0}}, \boldsymbol{z}), \bar{R}^0) \tag{5}$$

The solution to this problem is the revenue function (5), where $\boldsymbol{P^{T0}}$ is the market constraint (a vector of output prices), $\boldsymbol{z}$ is a vector of nonallocable quasi-fixed inputs (technology, agricultural aptitude, and human capital); L and L_s are total land and land allocated to subsistence; and FL and FL_s are family labor allocated in production and subsistence. Participation in the policy PNAE leads to a change in the market constraint from $\boldsymbol{P^{T0}}$ to $\boldsymbol{P} = \boldsymbol{P^{T0}} \cup \boldsymbol{P^{T1}}$, but products sold to schools through PNAE are restricted by a revenue quota $\bar{R}^0$, which is the same for all of the participants in a given year. Because our estimation is performed using cross-sectional data, $\bar{R}^0$ is the same for the whole sample and then it is omitted.

Given that the same product can be sold to traditional markets and through the PNAE, the change in the market constraint can lead to changes in production. If there is no market power for intermediates and the transportation cost is the same independent of who transports the production, participation in PNAE would not be expected to impact production levels. However, transactional costs likely differ between family farmers and intermediates, and then participation in the program could decrease considerably the transactional costs for family farmers, an idea that is supported by many study cases (Damin, 2016; among others). In this case, PNAE would impact relative prices and production decisions.

In the present study, I analyze this hypothesis by estimating a revenue function for family farmers including the impact of participation in PNAE. Most of the farmers produce using primarily family labor (less than 1% of the farmers in our sample reported using hired labor) and also obtain an important share of their income from selling their workforce in other properties or urban activities. I consider that the sale of the labor force is also an allocation of their resources.

Differentiating equation (5) with respect to the prices observed in the general markets, from Hotelling's Lemma, it is obtained a system of supply equations

$$\frac{dR^*(.)}{dP_i} = Y_i^*(.) = f(\boldsymbol{P}, \boldsymbol{z}, L, L_s^{**}(\boldsymbol{P}, \boldsymbol{z}), Fl, Fl_s^{**}(\boldsymbol{P}, \boldsymbol{z})) \tag{6}$$

Where $Y_i^*(.)$ Is the output supply in general markets; and $\mathbf{P}$ includes prices on general markets and prices on PNAE for participants and only prices on general markets for farmers who do not participate in PNAE.

The impact of PNAE on the commercial supply of an output *i* is given as

$$Y_i(.|PNAE=1) - Y_i(.|PNAE=0) = Y_i^{PNAE}(.) + \sum_{j=1}^{J} \frac{dY_i^*(\boldsymbol{P},\boldsymbol{z},L,L_S^*(\boldsymbol{P},\boldsymbol{z}),Fl,Fl_S^*(\boldsymbol{P},\boldsymbol{z}))}{dP_{PNAE\,j}} . P_{PNAE\,j}$$

$$\Delta\%Y_i = \frac{1}{Y_i(.|PNAE=0)}\left\{Y_i^{PNAE}(.) + \sum_{j=1}^{J}\left[\frac{dY_i^*}{dP_{PNAE\,j}}|_{L_S,Fl_S} + \left(\frac{dY_i^*}{dL_S^*}\frac{dL_S^*(.)}{dP_{PNAE\,j}} + \frac{dY_i^*}{dFl_S^*}\frac{dFl_S^*(.)}{dP_{PNAE\,j}}\right)\right].P_{PNAE\,j}\right\} \quad (7)$$

Where Y_i^{PNAE} is the quantity of output *i* sold to PNAE; Y_i^* is the supply of good *i* in general markets; $P_{PNAE\,j}$ is the price of output *j* in PNAE. The first argument between square brackets in (7) is supposed to be negative because it gives the impact of a change in PNAE prices over the supply of *i* in general markets (other than PNAE) holding a fixed allocation of labor and land to subsistence. The second argument, between parentheses, is supposed to be weakly positive because it gives the impact of the change in PNAE prices due to the effect on the reallocation of labor and land from subsistence to commercial production. As the PNAE price increases, the shadow price of land and labor also increases and it makes subsistence production more expensive. Thus, the optimal allocation of land and labor to subsistence decreases, increasing the levels of remaining resources for commercial production.

Data and estimation

The estimation is performed using farm-level data with 40,687 observations for the year 2017, whose variables come from three datasets: the 2017 Brazilian Agricultural Census; the dataset of Declarations of Aptitude to the Brazilian National Program to Strengthen Family Farming (DAPs dataset), a confidential dataset made available by the Ministry of Agriculture, livestock, and supply; and data from the Brazilian Union Accounting System on prices and quantities of agricultural goods bought from family farmers to public schools through PNAE (PNAE dataset).

Outputs were aggregated into 9 groups: milk and dairy products, beef, fruits, vegetables, grains, food products from agroindustry, pork, sale of the workforce, and other outputs. Agricultural Census and PNAE data were used to calculate price indexes at the municipality level for the groups of outputs using a multilateral Divisia index.

Participation in the program potentially leads to an endogeneity due to selection bias. Farmers who have more access to information and have better conditions for dealing with bureaucratic aspects of the program are more likely to participate. To control for this problem I define a counterfactual sample for family farmers who sold agricultural goods to PNAE using a propensity score matching. We use the nearest neighbors algorithm, an approach that has been used to control for selection bias in the recent literature (González-Flores et al., 2014; De los Santos-Montero & Bravo-Ureta, 2017). After the matching procedure, it is obtained a sample with 12,208 observations from which 4,642 farmers participate in PNAE in such year, and 7,566 did not participate

Data on socioeconomic characteristics and local price index (Table 1) was used to match farmers at the regional level using propensity score estimated from a logistic model with the 2 nearest neighbors without replacement.

Table 1. Covariables used in the matching procedure.

Variable	Description	Source
Family size	N° of family members living in the establishment	DAPs dataset
Age	Age of the primary operator	DAPs dataset
Female	Gender of the primary operator (=1 if female)	DAPs dataset
Married	Marital status of the primary operator (=1 if Married)	DAPs dataset
Single (marital status)	Marital status of the primary operator (=1 if single)	DAPs dataset
Illiterate	Education of the primary operator (=1 if illiterate)	DAPs dataset
Higher education	Education of the primary operator (=1 if higher than high school)	DAPs dataset
Land size	Land size in hectares	DAPs dataset
Income from retirement	the income per capita from retirement and other social benefits	DAPs dataset
Agricultural aptitude	Index relating soil quality and relief, varying between 0(worst)-1(better)	Sparovek et al. (2015)
Energy access	The average distance of properties three-phase energy source	GPP (2020)
Access to highways	The average distance of properties to paved highways	GPP (2020)
The relative price of milk and dairy	Divisia index / labor price (municipality level)	IBGE (2019), RAIS (2021)
The relative price of beef	Divisia index / labor price (municipality level)	IBGE (2019), RAIS (2021)
The relative price of fruits	Divisia index / labor price (municipality level)	IBGE (2019), RAIS (2021)
The relative price of vegetables	Divisia index / labor price (municipality level)	IBGE (2019), RAIS (2021)
The relative price of grains	Divisia index / labor price (municipality level)	IBGE (2019), RAIS (2021)
The relative price of food products	Divisia index / labor price (municipality level)	IBGE (2019), RAIS (2021)
The relative price of pork meat	Divisia index / labor price (municipality level)	IBGE (2019), RAIS (2021)
The relative price of other agricultural outputs	Divisia index / labor price (municipality level)	IBGE (2019), RAIS (2021)

The matched sample has 12,208 observations at the farm level and was used to estimate a system of supply equations. The quadratic normalized revenue function expressed in (5) is parametrized as

$$\tilde{R} = \propto_0 + \sum_{m=1}^{M} \propto_m \tilde{P}_m + \sum_{j=1}^{6} \gamma_j z_j + 0.5 * \sum_{m=1}^{M} \sum_{n=1}^{M} \propto_{mn} \tilde{P}_m \tilde{P}_n + \sum_{m=1}^{M} \sum_{j=1}^{6} \gamma_{mj} \tilde{P}_m z_j + \sum_{m=1}^{M} \beta_m \tilde{P}_m L + 0.5\beta_0 L^2 + \sum_{j=1}^{6} \gamma_{Lj} L z_j \quad (8)$$

Where $\tilde{R}$ is the revenue normalized with respect to the labor price; $\tilde{P}_m$ are relative prices of outputs with respect to the labor price; z_j are quasi fixed factors; L is the land size; and $\propto_m, \propto_{mn}, \gamma_j, \gamma_{mj}, \beta_m$, β_0, and θ_m are parameters to be estimated; and $\tilde{P}_m$ includes prices in traditional markets and PNAE prices for participants (M=15), and only prices in traditional markets for nonparticipants (M=8).

Applying Hotelling's Lemma for the prices on general markets, it is obtained a system of 8 supply equations, represented as

$$Y_m = \propto_m + 0.5 * \sum_{n=1}^{M} \propto_{mn} \tilde{P}_n + \sum_{j=1}^{6} \gamma_{mj} z_j + \beta_{Lm} L + \beta_{lm} l \quad (9)$$

Where Q_m is the quantity of output *m* sold to other markets rather than PNAE. We jointly estimate 8 supply equations for the general markets for the outputs: milk and dairy, beef, fruits, vegetables, grains, transformed food products, pork meat, and others. The sale of the labor force, which is one of the outputs, is omitted because labor price is used as the denominator for normalization. The explanatory variables of equation (9) are described in Table 2.

Table 2. Variables included in the supply functions.

Variable	Description	Variable in model	Mean	Sd	Source
Family size	N° of family members living in the establishment	z variable	3.40	1.61	DAPs dataset
Land size	Land size in hectares	L variable	18.57	29.92	DAPs dataset
Illiterate	Education of the primary operator (=1 if illiterate)	z variable	0.032	0.18	DAPs dataset
Higher education	Education of the primary operator (=1 if higher than high school)	z variable	0.029	0.17	DAPs dataset
Agricultural aptitude	Index relating soil quality and relief, varying between 0(worst) and 100(better)	z variable	27.266	12.25	Sparovek et al. (2015)
Energy access	The average distance of properties three-phase energy source	z variable	4.586	11.35	GPP (2020)
Participation in cooperatives	Participation in cooperative (=1 if yes)	z variable	0.077	0.27	DAPs dataset
Income from retirement	the income per capita from retirement and other social benefits	z variable	698.54	2,300	DAPs dataset
Price of milk and dairy	Divisia index / labor price (municipality level)	P variable	2.33	1.04	IBGE (2019)
Price of beef	Divisia index / labor price (municipality level)	P variable	1.97	0.83	IBGE (2019)
Price of fruits	Divisia index / labor price (municipality level)	P variable	1.82	0.90	IBGE (2019)
Price of vegetables	Divisia index / labor price (municipality level)	P variable	2.06	0.98	IBGE (2019)
Price of grains	Divisia index / labor price (municipality level)	P variable	2.00	0.77	IBGE (2019)
Price of food products	Divisia index / labor price (municipality level)	P variable	2.74	1.25	IBGE (2019)
Price of pork meat	Divisia index / labor price (municipality level)	P variable	2.55	1.00	IBGE (2019)
Price of other agricultural outputs	Divisia index / labor price (municipality level)	P variable	1.76	0.60	IBGE (2019)
PNAE price of milk and dairy	Divisia index / labor price (municipality level)	P variable	1.77	0.57	SCU (2020)
PNAE price of beef	Divisia index / labor price (municipality level)	P variable	2.71	0.88	SCU (2020)
PNAE price of fruits	Divisia index / labor price (municipality level)	P variable	3.77	4.00	SCU (2020)
PNAE price of vegetables	Divisia index / labor price (municipality level)	P variable	2.14	0.79	SCU (2020)
PNAE price of grains	Divisia index / labor price (municipality level)	P variable	3.15	7.22	SCU (2020)
PNAE price of food products	Divisia index / labor price (municipality level)	P variable	2.07	0.98	SCU (2020)
PNAE price of pork meat	Divisia index / labor price (municipality level)	P variable	2.18	1.32	SCU (2020)

The estimation is performed using unconstrained nonlinear least squares. Symmetry, homogeneity of degree 1 in prices, and convexity in the prices on general markets are imposed. Convexity is imposed through Cholesky factorization, and the initial values for the optimization problem are chosen following (Talpaz et al., 1989). The optimization problem is solved in R, using the Broydn-Fletcher-Goldfarb-Shanno (BFGS) algorithm, a quasi-Newton's method to solve unconstrained nonlinear optimization. Standard errors for the parameters are being bootstrapped, following (Arnade & Kelch, 2007).

Results and discussion

In Table 3 we present the means for the index of the price received by family farmers is classified as "Pronaf B", the poorest category of family farmers, constituted by those family farmers whose gross annual income is lower than \$6,042; by "Pronaf V", the one that performs economically better, constituted by farmers whose gross annual income is higher than \$6,042 and lower than \$108,761; and prices paid by PNAE.

Table 3. Index of prices received by family farmers in general markets (PRONAF B and V), and from PNAE.

	Price index (national average)		
	PRONAF B	**PNAE**	**PRONAF V**
Milk and dairy products	119.9	101.1	129.3
Beef	1.1	1.5	1.1
Fruits	97.6	208.4	105.5
Vegetables	109.2	122.0	121.8
Grains	110.4	186.2	113.8
Food products	145.9	117.1	148.0
Pork meat	1.4	1.1	1.5

Prices paid by PNAE are expected to be higher than prices received by farmers if they are selling to middlemen or if PNAE requires additional packs that are not required by other markets. Table 3 confirms those expectations, except for milk and dairy products, food products, and pork meat, for which the general markets pay a higher price than PNAE, especially for farmers classified as PRONAF V. It is possibly explained by the fact that PNAE purchases should be delivered to the kitchens where the food of public schools are prepared, thus requiring a simple packing. Another possibility is that when those products are sold locally in the general markets, strategies for product differentiation can be explored by the farmers, and it is not possible in PNAE. The supply elasticities are presented in Table 4.

The elasticities of supply for the general markets presented in Table 4 are consistent with the expected. Own price elasticities for milk, fruits, and vegetable are very low because those products are usually the most representative among family farmers. Milk is, on average, the source of 51.6% of the income of farmers who produce it in the sample; fruit represents 50.3%; and vegetables constitute 48.4% of those who sell vegetables. Pork, grains, and others present high elasticities, and it can be explained by the fact that those outputs are usually produced in small quantities and mainly for subsistence consumption. Then, increases in market prices lead to an increase in production that can also happen as a consequence of reallocation from subsistence to commercial production.

The elasticities of supply in general markets with respect to the PNAE prices show that, except for food products and pork, the sales to general markets increase when the price of the good increases in PNAE. Differentiating the supply of output i in the general markets with respect to its own price in PNAE:

$$\frac{dY_i^*(\boldsymbol{P},\boldsymbol{z},L,L_S^*(\boldsymbol{P},\boldsymbol{z}),Fl,Fl_S^*(\boldsymbol{P},\boldsymbol{z}))}{dP_{PNAE_i}} = \left[\frac{dY_i^*}{dP_{PNAE_i}}\Big|_{L_S,Fl_S} + \left(\frac{dY_i^*}{dL_S^*}\frac{dL_S^*(.)}{dP_{PNAE_i}} + \frac{dY_i^*}{dFl_S^*}\frac{dFl_S^*(.)}{dP_{PNAE_i}}\right)\right] \qquad (10)$$

Expression (10) shows that the effect of prices on PNAE on supply for general markets has two components. The first one is a substitution effect for a given fixed labor and land allocation to subsistence and is expected to be negative. The second one (between parentheses) is the effect due to the reallocation of land and labor from subsistence to commercial production and is expected to be positive. Thus, the positive effect observed for most of the outputs means that the effect of PNAE on the reallocation of land and labor from subsistence to commercial production is stronger than the substitution effect.

Table 4. Elasticities (or impact of a change from 0 to 1 for dummy variables) of supply to general markets

	Milk	Beef	Fruit	Vegetables	Grains	Food products	Pork	Others
Price of milk and dairy	0.02	-0.25	-0.06	-0.04	-0.28	-0.22	-0.72	-0.11
Price of beef	-0.07	1.03	0.23	0.19	0.62	0.87	3.01	0.37
Price of fruits	-0.04	0.49	0.14	-0.01	0.91	0.56	0.48	0.65
Price of vegetables	-0.01	0.21	-0.01	0.71	-0.35	-0.28	1.71	-0.35
Price of grains	-0.04	0.28	0.21	-0.17	6.55	-0.22	-1.45	2.51
Price of food products	-0.06	0.75	0.26	-0.23	-0.36	1.40	1.51	0.00
Price of pork meat	-0.04	0.60	0.04	0.31	-0.64	0.33	8.42	-2.39
Price of other agricultural outputs	-0.01	0.13	0.12	-0.13	2.18	0.00	-4.52	3.87
PNAE price of milk and dairy	0.50	-1.35	0.32	1.09	-2.57	-0.17	-0.77	-2.21
PNAE price of beef	-0.40	1.82	0.23	-0.34	1.80	0.71	2.82	2.58
PNAE price of fruits	0.38	-0.36	0.02	-0.05	0.10	0.02	0.05	-0.38
PNAE price of vegetables	0.28	0.04	-0.21	0.33	0.14	0.07	-0.49	0.34
PNAE price of grains	0.16	-0.62	0.02	-0.01	0.06	0.03	0.23	-0.04
PNAE price of food products	0.03	-0.43	0.14	-0.12	-0.46	-0.08	-0.22	-0.26
PNAE price of pork meat	0.12	-0.96	-0.45	-0.69	-0.66	-0.45	-1.84	-1.14
Family size	0.03	-0.20	-0.06	-0.33	-0.82	-0.47	-0.74	0.48
Land size	-0.33	0.50	-0.02	-0.07	-0.36	0.11	-0.32	0.11
Illiterate	-0.48	-1.65	-0.89	-1.45	-1.91	-0.67	-2.43	-0.22
Higher education	0.03	0.46	0.36	0.16	0.46	0.24	0.53	0.17
Income from retirement	-1.15	2.58	0.17	2.80	0.60	2.25	5.66	0.40
Participation in cooperatives	0.33	0.46	0.42	0.28	1.05	0.29	0.25	0.24

Despite that, the substitution effect among products is strong as can be seen for beef, vegetables, and other products. It is expected, then, that participation in PNAE changes crop choice considerably. The estimated effect for the participants, estimated according to equation (7), is presented in Table 5.

Table 5. Impact of participation on PNAE in the total quantity produced, for participants, by region.

	Milk	Beef	Fruit	Vegetables	Grains	Food products	Pork	Others
North	93%	-71%	-6%	11%	-74%	120%	-16%	-91%
Northeast	183%	-80%	-11%	15%	-65%	179%	0%	-86%
Southeast	51%	-74%	11%	23%	-73%	93%	59%	-86%
South	38%	-63%	16%	24%	-19%	75%	-4%	-93%
Midwest	35%	-42%	16%	25%	-34%	97%	9%	-100%

Table 5 shows that participation in PNAE leads to a general decrease in beef production, grains, and others, and increases the production of milk and dairy, vegetables, and food products. This calculation shows that the impacts of the program due to allocative effects are much more relevant than only the quantities bought and the value of the revenue quota. The participation of the quantity sold to PNAE in the total quantity produced for participants is shown in Table **6**.

Table 6. Percentage of the total production of participants that is sold to PNAE.

	Milk	Beef	Fruit	Vegetables	Grains	Food products	Pork	Others
N	8%	1%	9%	16%	14%	75%	30%	0%
NE	8%	16%	24%	29%	10%	87%	46%	0%
SE	1%	1%	7%	12%	13%	46%	43%	0%
S	6%	4%	13%	12%	1%	44%	4%	0%
MW	2%	0%	11%	13%	2%	48%	11%	0%

Comparing the tables above, it is observed that, except for the food products, most of the impact of PNAE in the total commercial surplus observed in Table 5 happens due to the effects given by equation (10). Those effects are mainly related to the difference among prices presented in Table 3, and then they vary across the territory according to the prices observed in general markets and in PNAE. In Figure 2 it is spatialized the impact of the program in the Brazilian municipalities considering participants and nonparticipants, according to equation (7).

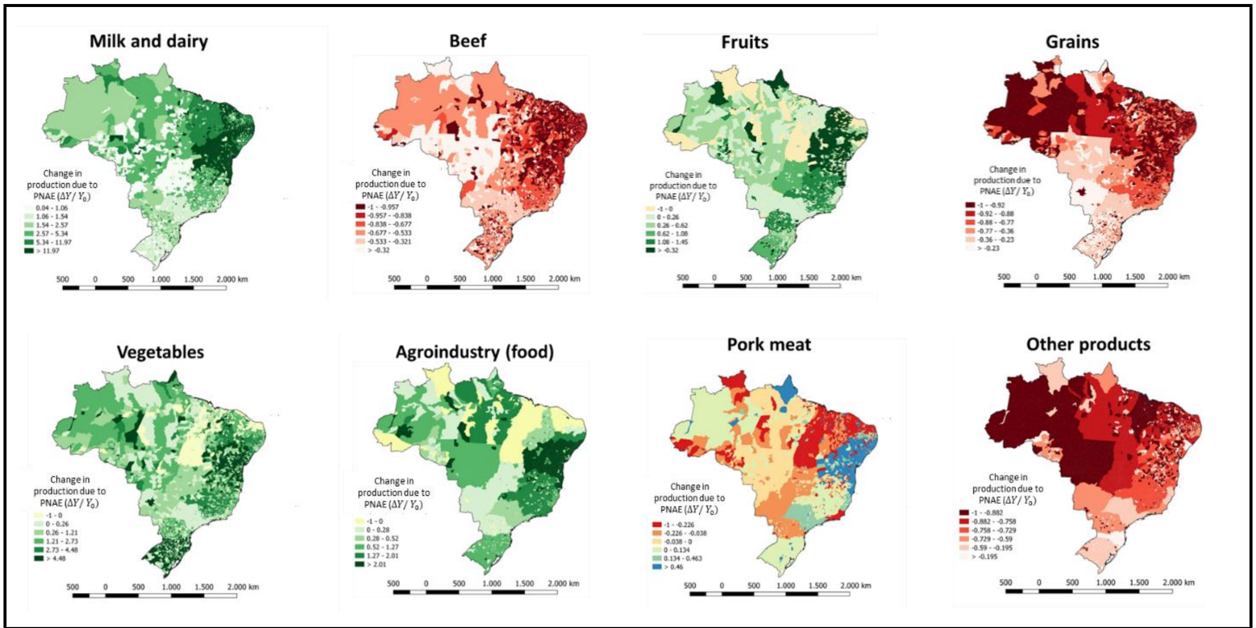

Figure 2. Estimated impact of PNAE on quantity produced for family farmers including participants and nonparticipants.

Obs: the impact is computed for each output only for farmers who produce it. For municipalities in which there were no observations, it is adopted the mean of the estimated impact in other municipalities located in the same state.

Figure 2 shows that the impacts vary across the territory and are usually higher (in percentage terms) in the Brazilian Northeast and extreme South. Except for pork meat, it is observed the signal of impact for almost all of the municipalities: an increase in milk and dairy, fruits, vegetables, and agroindustry; a decrease in beef, grains, and other products.

Those changes in quantities are also reflected as changes in agricultural revenues. An analysis of the variation in the income of producers shows that, due to participation in the Program, the average income from agricultural production grows, on average, 33.4%, an amount equivalent to $2,522 per producer per year (Figure 3).

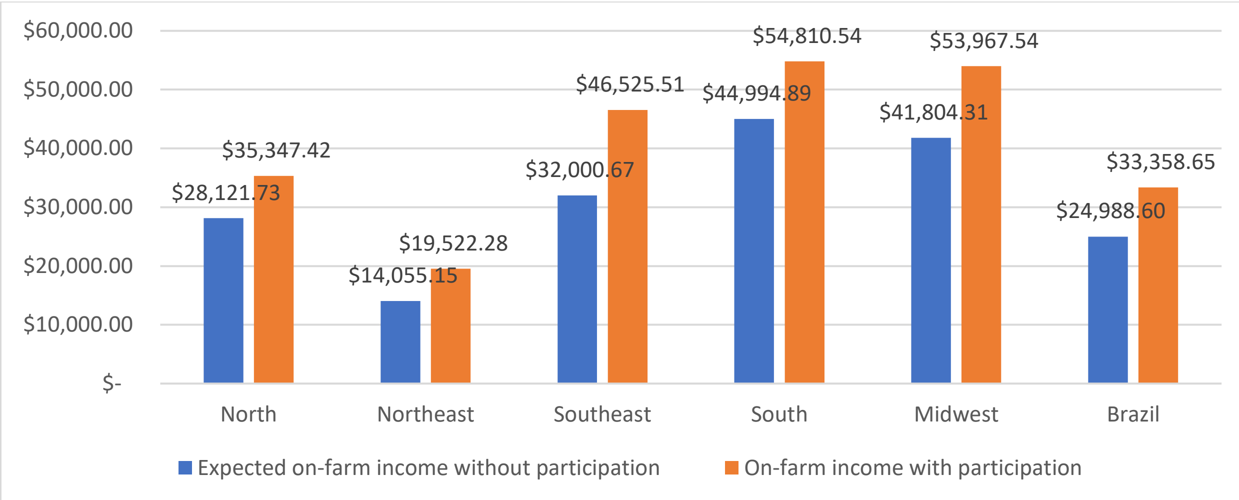

Figure 3. Agricultural income of participating producers with participation in the PNAE (observed) and without participation in the PNAE (estimated).

The value of subsistence consumption is reported as 0 for the sample of the present study. Data from the 2017 Agricultural Census shows that 17% of the production value of the Brazilian family farm is not sold (IBGE, 2019), which is likely to be used for subsistence consumption or as intermediate consumption for agroindustrial production. Off-farm income, a relevant allocation of family labor that could be affected by participation, is observed for only 5.51% of the participants in the sample, and it is statistically the same for the matched sample used in our estimation, showing no evidence of impact from participation in off-farm income.

The measure of the welfare impact of PNAE for participants proposed in this study is calculated as the difference between the change in revenue and the change in costs, which include subsistence consumption. The impact on revenues is equal to the impact on on-farm revenues (Figure 2) plus the impact on off-farm revenues (0). Change in subsistence consumption is not expected, given that it is reported as 0 for participants and non-participants. Therefore, participation in PNAE shows to increase annual on-farm income by $2,522 per farm (Figure 2). This value is 35.4% higher than the average annual PNAE ticket in 2017 (R$1,863 per farm), evidencing that the allocative effects of the Program contribute to the increase in the agricultural revenue of participants.

The numbers estimated in the present study show an important aspect of participation in PNAE. Facilitating the participation of family farmers represents a transference of welfare in institutional markets in favor of this public. The government does not incur costs to do it, and as a consequence generates an additional impact on the supply of family farmers to other markets. The appropriate welfare impact of such policy should be estimated as the change in profit net of subsistence consumption, but the available data only allows us to estimate the change in revenue.

Conclusions

The results discussed above highlight the role of allocative effects from a policy to support commercialization for small farmers. This effect has not been discussed in the recent literature in a model with economic behavior as we proposed, and is especially relevant for small farmers given the tradeoff between subsistence consumption and commercial production.

The main policy implication of these results is that the changes made on PNAE in 2009 had broader impacts. The policy design originated by the Resolution N° 4/2015 of the Education National Funding Deliberative Council is already a virtue of the Program, given that it represents a transfer of welfare in the institutional markets in favor of family farmers, without generating a deadweight loss. What we emphasize here, however, is that promoting the market insertion of family farmers by reducing transactional costs also implies relevant allocative effects. We estimate that for every 1$ of purchases from family farmers through PNAE, $1.354 in on-farm income is generated for participants.

Finally, these estimates potentially neglect changes in subsistence consumption, because it is reported as 0 for all the observations, though it is not consistent with the reality of the Brazilian family farming. Besides that, we do not account for effects on the consumer side, nor the general equilibrium ones, which means that the impacts estimated here do not correspond to the total welfare impacts of the policy.

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Appendix

Table A1. Logistic regression for the PSM (40,867 observations).

PNAE	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Age	0.009214	0.001197	7.70	0.00	0.006869	0.011559
N° of family members	0.053992	0.009622	5.61	0.00	0.035133	0.072851
Land size	-0.003155	0.000568	-5.56	0.00	-0.004268	-0.002043
Income from retirement	-0.000030	0.000006	-4.64	0.00	-0.000043	-0.000017
Agricultural aptitude	0.006044	0.001451	4.17	0.00	0.003201	0.008888
Distance to energy access	0.000004	0.000002	2.06	0.04	0.000000	0.000008
Distance to highways	-0.000002	0.000001	-1.45	0.15	-0.000004	0.000001
Women	-0.369378	0.035270	-10.47	0.00	-0.438506	-0.300250
Married	-0.024647	0.036081	-0.68	0.50	-0.095364	0.046070
Single	0.021734	0.132964	0.16	0.87	-0.238871	0.282340
Participation in cooperative	0.128196	0.064493	1.99	0.05	0.001791	0.254600
Nonassociated	0.012392	0.037544	0.33	0.74	-0.061191	0.085976
Illiterate	-1.202061	0.130396	-9.22	0.00	-1.457633	-0.946489
Higher education	0.490679	0.089929	5.46	0.00	0.314422	0.666936
Price of milk and dairy	0.020603	0.023793	0.87	0.39	-0.026031	0.067237
Price of beef	0.195320	0.047978	4.07	0.00	0.101286	0.289355
Price of fruits	0.075292	0.023955	3.14	0.00	0.028341	0.122243
Price of vegetables	-0.093392	0.024968	-3.74	0.00	-0.142328	-0.044456
Price of grains	0.056395	0.039478	1.43	0.15	-0.020980	0.133770
Price of food products	0.022648	0.016433	1.38	0.17	-0.009560	0.054855
Price of pork meat	-0.227718	0.035249	-6.46	0.00	-0.296804	-0.158631
Price of other agricultural outputs	-0.133477	0.054479	-2.45	0.01	-0.240253	-0.026701
PNAE price of milk and dairy	-0.064421	0.111433	-0.58	0.56	-0.282825	0.153984
PNAE price of beef	-0.390232	0.036651	-10.65	0.00	-0.462067	-0.318397
PNAE price of fruits	-0.023090	0.007984	-2.89	0.00	-0.038739	-0.007441
PNAE price of vegetables	-0.130516	0.037733	-3.46	0.00	-0.204472	-0.056560
PNAE price of grains	0.023871	0.003053	7.82	0.00	0.017887	0.029855
PNAE price of food products	0.105707	0.019915	5.31	0.00	0.066674	0.144739
PNAE price of pork meat	0.233165	0.020077	11.61	0.00	0.193814	0.272516
_cons	-1.479955	0.110544	-13.39	0.00	-1.696617	-1.263293

Table A2. Balancing tests for the matching procedure.

Variable	Unmatched Matched	Mean Treated	Mean Control	p-value	V(T)/V(C)	Variable	Unmatched Matched	Mean Treated	Mean Control	p-value	V(T)/V(C)
Age	U	45.464	43.994	0	0.83*	**Price vegetables**	U	2.037	2.2095	0	0.76*
	M	45.464	45.541	0.794	0.84*		M	2.037	2.0574	0.341	0.84*
Family size	U	3.4156	3.2963	0	0.99	**Price grains**	U	1.9795	2.1195	0	0.90*
	M	3.4156	3.4036	0.72	0.92*		M	1.9795	1.9979	0.276	0.92*
Area	U	18.94	102.74	0.354	0.00*	**Price of agroindustry (food)**	U	2.7064	2.7823	0	1.16*
	M	18.94	19.076	0.827	1.08*		M	2.7064	2.7296	0.38	1.11*
Retirement and benefits	U	785.51	920.41	0.004	0.70*	**Price of pork**	U	2.5203	2.8209	0	0.87*
	M	785.51	797.06	0.827	1.04		M	2.5203	2.5276	0.741	0.90*
Agricultural aptitude	U	27.475	25.336	0	1.22*	**Price of others**	U	1.7411	1.8908	0	0.87*
	M	27.475	27.45	0.919	1.05		M	1.7411	1.7567	0.244	0.93*
Access to energy	U	5671.9	3870.5	0	4.46*	**Price milk and dairy (PNAE)**	U	1.7487	1.8894	0	0.75*
	M	5671.9	5503.2	0.627	1.12*		M	1.7487	1.7595	0.406	0.81*
Access to highways	U	19781	18034	0	1.67*	**Price beef (PNAE)**	U	2.6752	2.9842	0	0.95
	M	19781	19581	0.63	1.03		M	2.6752	2.6821	0.717	0.93*
Women	U	0.301	0.40646	0	.	**Price fruits (PNAE)**	U	4.0402	4.1876	0.097	0.94*
	M	0.301	0.29537	0.551	.		M	4.0402	4.1058	0.561	1.06*
Married	U	0.71662	0.7056	0.118	.	**Price vegetables (PNAE)**	U	2.1737	2.3082	0	1.35*
	M	0.71662	0.72635	0.292	.		M	2.1737	2.1901	0.442	0.93*
Single	U	0.01486	0.01545	0.756	.	**Price grains (PNAE)**	U	5.1142	3.0925	0	87.88*
	M	0.01486	0.01327	0.512	.		M	5.1142	5.1857	0.886	1
Participation in cooperative	U	0.08087	0.04889	0	.	**Price of agroindustry (food) (PNAE)**	U	2.0625	2.1583	0	1.21*
	M	0.08087	0.08378	0.609	.		M	2.0625	2.0597	0.899	1.16*
Nonassociated	U	0.24899	0.24877	0.973	.	**Price of pork (PNAE)**	U	2.1887	2.301	0	0.86*
	M	0.24899	0.24927	0.975	.		M	2.1887	2.2082	0.509	0.91*
Price of milk and dairy	U	2.3073	2.4913	0	0.74*	**Illiterate**	U	0.0144	0.0449	0	.
	M	2.3073	2.3256	0.415	0.84*		M	0.0144	0.0200	0.039	.
Price beef	U	1.9485	2.1253	0	0.80*	**Higher education**	U	0.0363	0.0200	0	.
	M	1.9485	1.9645	0.389	0.82*		M	0.0363	0.0332	0.415	.
Price fruits	U	1.8136	1.9201	0	0.91*						
	M	1.8136	1.8151	0.938	0.96						

Table A3. Parameters estimated for the supplies to general markets

	Milk	Beef	Fruit	Vegetables	Grains	Agroindustry	Pork	Others
Price of milk and dairy	1.124	-5.191	-2.998	-0.919	-2.628	-2.939	-2.174	-0.972
Price of beef	-5.191	24.536	13.281	4.881	6.599	13.906	10.638	3.594
Price of fruits	-2.998	13.281	10.218	-0.422	10.858	10.112	1.923	7.542
Price of vegetables	-0.919	4.881	-0.422	18.095	-3.947	-3.862	5.994	-3.707
Price of grains	-2.628	6.599	10.858	-3.947	73.479	-3.303	-5.128	26.541
Price of food products	-2.939	13.906	10.112	-3.862	-3.303	14.660	4.124	-0.033
Price of pork meat	-2.174	10.638	1.923	5.994	-5.128	4.124	23.104	-18.594
Price of other agricultural outputs	-0.972	3.594	7.542	-3.707	26.541	-0.033	-18.594	44.567
PNAE price of milk and dairy	29.721	-38.488	20.590	42.075	-38.308	-4.243	-4.378	-26.852
PNAE price of beef	-16.555	34.233	10.030	-8.889	16.791	11.893	9.993	18.784
PNAE price of fruits	12.135	-6.071	0.661	-1.044	0.844	0.271	0.163	-2.283
PNAE price of vegetables	14.445	0.878	-11.078	10.542	1.822	1.541	-2.376	3.565
PNAE price of grains	5.787	-11.916	0.891	-0.153	0.608	0.485	0.851	-0.356
PNAE price of food products	1.409	-11.365	7.342	-4.071	-6.199	-1.619	-1.127	-3.081
PNAE price of pork meat	6.502	-24.743	-27.534	-22.547	-7.434	-11.460	-8.044	-11.069
N° of family members	1.330	-3.127	-1.903	-4.936	-5.968	-4.395	-1.748	3.033
Land size	-2.371	2.380	-0.197	-0.609	-1.405	0.371	-0.420	0.568
Income from retirement	-0.027	0.037	0.004	0.047	0.008	0.026	0.026	0.014
Illiterate	-23.379	-46.053	-35.677	-28.406	-27.957	-4.530	-11.559	-5.275
Higher education	6.885	63.777	70.536	20.392	44.239	11.950	19.389	4.506
Agricultural aptitude	2.218	2.571	-0.244	-0.171	3.657	0.348	0.804	1.027
Distance to energy access	-2.923	3.529	-0.950	0.170	-2.118	0.848	-1.218	-0.045
Participation in cooperative	82.017	49.478	122.664	38.719	233.785	15.001	42.805	16.079
Intercept	69.597	-246.207	-57.597	16.072	-196.565	-71.048	-70.564	-130.993

OBS: I have not bootstrapped my standard errors (it is taking too long to run then I will work on optimizing my code to speed it up).