An Empirical Analysis of Pre-Determined Food Demand in Russia

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Abstract

The Exact Affine Stone Index (EASI) model of Lewbel and Pendakur (2009) offers distinct advantages over its predecessor models, however it does not account for a widely observed phenomenon of pre-committed demand. This may lead to biased elasticity estimates when such pre-commitments are present. This study offers a methodological solution by deriving the generalized EASI (GEASI) model, which incorporates pre-committed quantities into the consumer demand structure. The empirical advantage of the GEASI model is illustrated through its application to the analysis of food demand structure in Russia based on novel provincial-level panel data on household food expenditures over 2007-2014. The results provide strong empirical evidence for the presence of pre-committed demand for key food commodities such as cereals, eggs, and fats/oils. Further comparative analysis highlights the significance of pre-commitment bias in the context of food demand in Russia and illustrates the effectiveness of the GEASI approach in addressing it. The findings extend the empirical literature on food demand in Russia by presenting estimated elasticities that account for potential pre-commitments as well as for unobserved provincial heterogeneity.

Keywords: EASI demand model, food demand in Russia, generalized EASI model, pre-committed demand.

JEL Code: D11, D12.

1. Introduction

Public policy on trade and food security and the analysis of policy impact on nutrition and health rely heavily on economic models of consumer behavior and demand structure estimation. However, many of the advanced models used in the literature are unable to account for a widely observed phenomenon of *pre-committed demand*. The pre-committed demand is a portion of consumer demand insensitive to variations in economic factors (Gorman 1976; Piggott 2003; Tonsor and Marsh 2007). Over the pre-committed portion of demand, commodities are deemed as non-discretionary with prices playing little role in explaining consumer behavior. Once these pre-commitment levels are achieved, however, consumers become considerably sensitive to price movements over the discretionary portion of the demand curve (Rowland, Mjelde, and Dharmasena 2017). This phenomenon is more frequently observed in the context of developing nations characterized by subsistence consumption, low incomes, widespread inequality, and food insecurity (Samuelson 1947-1948; Stone 1954; Pollak 1981). However, recent studies in agricultural economics literature have revealed presence of food demand pre-commitments not only in the context of developing nations (Hovhannisyan and Gould 2011), but also, in the context of developed nations such as the US and Japan (Tonsor and Marsh 2007). Pre-commitments have also been observed in non-food contexts such as energy consumption (Rowland, Mjelde, and Dharmasena 2017). Thus, in situations where pre-commitments exist, but are not explicitly accounted for in demand estimations, the policy decisions based on the results of such estimations may not produce the intended effect.

Recent advances in consumer demand theory coupled with increased availability of disaggregate consumption data provide better opportunities for more accurate delineation of consumer behavior. The Exact Affine Stone Index (EASI) model of Lewbel and Pendakur (2009) has recently gained prominence in economic literature as a state-of-the-art demand system due to a number of distinct advantages over the more traditional demand models such as the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980) and its variants. Specifically, the EASI specification relieves Gorman's (1981) rank restriction on Engel curves, and allows for arbitrary curvilinear effects with the shape of the Engel curve determined by the data. Further, the EASI model accounts for unobserved consumer heterogeneity; which is necessary because consumers vary not only in terms of their economic circumstances but also with respect to their tastes and preferences (Browning and Carro 2007). The importance of modelling flexible Engel curves and allowing for unobserved consumer heterogeneity cannot be overstated given the empirical evidence of highly nonlinear Engel curves and the findings indicating that typical observables (e.g., income, prices, and demographics) can only explain half of the variation in budget shares (Banks et al. 1997). However, despite its major advantages over the previous demand systems such as the AIDS family of models, the EASI model, in its current specification does not account for potential pre-committed consumption quantities and may produce demand estimates that do not accurately reflect the actual demand structure.[1]

The purpose of this paper is to extend the applicability of the EASI demand model to situations where the presence of pre-committed demand is a valid assumption. Its contribution to the literature is twofold. First, it introduces the generalized EASI (GEASI)

[1] The Generalized AIDS (Bollino 1987) and the Generalized Quadratic AIDS (Banks et al. 1997) models account for pre-commitments, however they are still subject to the same restrictive assumptions of representative consumer and constrained Engel curves.

model, which incorporates potential pre-committed quantities into the consumer demand structure. The main advantage of the GEASI is that the Marshallian, Hicksian, and expenditure elasticities derived from this specification provide an accurate reflection of consumer price and income responsiveness in the presence of pre-committed demand component. An additional enhancement provided by GEASI approach is that the estimated economic effects are not dependent on the unit of measurement when the shifters are incorporated through demographic translation (Alston, Chalfant and Piggott 2001).

Second, the paper presents new empirical evidence from the application of the GEASI specification to the estimation of food demand structure in Russia. The choice of Russia as an empirical setting is motivated by two major factors. First, the empirical evidence on food demand in Russia is relatively limited despite the important role that Russia has played historically in global food markets. Second, the economic sanctions imposed on Russia by the western countries and a subsequent import ban in 2014 by Russia on a number of food and agricultural products from the U.S., European Union, Canada, and Australia have elevated Russia to the center of global policy debates. While the importance of Russia's role in global agri-food trade is generally recognized by policy makers and researchers, many questions still remain regarding the structure of food demand in Russia and the related short-term and long-term trade implications. The empirical analysis is based on the most recent nationally representative, provincial-level panel data on household food consumption in Russia over 2007-2014 period. The unique contribution of this empirical application to the literature on food demand in Russia is that the resulting food demand elasticities account for potential pre-commitments as well as for unobserved provincial heterogeneity.

The results provide strong empirical evidence for the presence of pre-committed demand for key food commodity groups such as cereals, eggs, and fats/oils. Further comparative analysis illustrates a presence of significant bias in elasticity estimates when the existing pre-commitments are not accounted for in demand estimations. The refined demand estimation approach presented in this paper offers a methodological solution for eliminating such bias and producing most reliable elasticity estimates for informing public policy. The empirical findings on the structure of food demand in Russia provide valuable and timely insights for policy decisions in light of ongoing economic sanctions and the globally increased role of Russia.

The rest of the paper is organized as follows: Section 2 develops the GEASI demand model along with the respective elasticity formulas; Section 3 provides a brief description of the data and variables; Section 4 presents the empirical application of the GEASI to the analysis of food demand in Russia, together with a comparative analysis and the related policy implications; Section 5 presents a summary of main conclusions of the paper; and lastly, the Appendix provides the details concerning the derivation of the elasticity formulas.

2. The generalized EASI demand model

Consider the following cost function underlying the EASI demand system (Lewbel and Pendakur 2009):

$$\ln C\left(p,u,\varepsilon\right) = u + \sum_{j=1}^{J} m_j\left(u\right)\ln p_j + \sum_{j=1}^{J}\sum_{k=1}^{J}\alpha_{jk}\ln p_j \ln p_k + \sum_{j=1}^{J}\varepsilon_j \ln p_j \tag{1}$$

where C represents cost, u is utility, $m_j\left(u\right)$ is a general function of u, p_j expresses the j^{th} product's price, ε_j reflects unobserved preference heterogeneity, and α_{jk} are parameters.

Using the Shephard's Lemma $\left(i.e., \frac{\partial \ln C}{\partial \ln p_i} = w_i \right)$ and the cost function in (1), Lewbel and Pendakur (2009) derive a linear approximate EASI demand specification that satisfies the restrictions stemming from consumer theory:

(2) $$w_i\left(p,u,\varepsilon\right) = m_i\left(u\right) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k + \varepsilon_i$$

To incorporate *pre-committed demand* into the EASI system, we follow Bollino (1987) to generalize the EASI cost function in (1) via the inclusion of overhead costs as follows:[2]

(3) $$\ln\left(C - t'p\right) = u + \sum_{j=1}^{J} m_j\left(u\right) \ln p_j + \sum_{j=1}^{J}\sum_{k=1}^{J} \alpha_{jk} \ln p_j \ln p_k + \sum_{j=1}^{J} \varepsilon_j \ln p_j$$

where t_j is a parameter representing pre-committed quantity of the j^{th} product.

The GEASI model is derived through the application of the Sheppard's Lemma to this more general cost function in (3). More specifically, differentiating both sides of the cost function with respect to $\ln p_i$ generates the following functional relationship:

(4) $$\frac{\partial \ln\left(C - t'p\right)}{\partial \ln p_i} = m_i\left(u\right) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k + \varepsilon_i$$

Further simplification of the left hand side of the equation (4) yields:

(5)

$$\frac{\partial \ln\left(C - t'p\right)}{\partial \ln p_i} = \frac{\partial \ln\left(C - t'p\right)}{\partial p_i} \frac{\partial p_i}{\partial \ln p_i} = \left(\frac{1}{\left(C - t'p\right)} \frac{\partial\left(C - t'p\right)}{\partial p_i} \right) p_i = \left(\frac{\left(\partial C / \partial p_i\right) - t_i}{C - t'p} \right) p_i$$

Substituting (5) into (4) results in:

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[2] The approach used by Bollino (1987) to derive the generalized AIDS model from the indirect utility function cannot be applied here since $m_j\left(u\right)$ is in general an unknown function of utility.

$$\text{(6)} \qquad \left(\frac{(\partial C / \partial p_i) - t_i}{C - t' p} \right) p_i = m_i(u) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k + \varepsilon_i$$

Rearranging (6) yields the following expression for $\frac{\partial C}{\partial p_i}$:

$$\text{(7)} \qquad \left(\frac{\partial C}{\partial p_i} - t_i \right) p_i = (C - t' p) \left(m_i(u) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right)$$

$$\frac{\partial C}{\partial p_i} p_i - t_i p_i = (C - t' p) \left(m_i(u) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right)$$

$$\frac{\partial C}{\partial p_i} p_i = t_i p_i + (C - t' p) \left(m_i(u) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right)$$

$$\frac{\partial C}{\partial p_i} = t_i + \frac{1}{p_i} (C - t' p) \left(m_i(u) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right)$$

Next, both sides of (7) are multiplied by $\left(\frac{p_i}{C} \right)$ to generate Hicksian budget share equations since

$w_i = \left(\frac{\partial C}{\partial p_i} \right) \left(\frac{p_i}{C} \right) = \left(\frac{q_i p_i}{C} \right)$:

$$\begin{aligned} w_i &= \frac{p_i}{C} \left(t_i + \frac{1}{p_i} (C - t' p) \left(m_i(u) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right) \right) \\ \text{(8)} \qquad &= \frac{t_i p_i}{C} + \left(\frac{C - t' p}{C} \right) \left(m_i(u) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right) \\ &= \frac{t_i p_i}{C} + \left(1 - \frac{t' p}{C} \right) \left(m_i(u) + \sum_{i=1}^{J} \alpha_{ik} \ln p_k \right) \end{aligned}$$

Finally, the implicit GEASI Marshallian demand system is obtained by: (*i*) substituting consumer total expenditure *X* for *C* given a utility maximizing consumer, and (*ii*) replacing $m_i(u)$ with a particular function offered by Lewbel and Pendakur (2009) as shown below:

(9) $$w_i = \frac{t_i p_i}{X} + \left(1 - \frac{t'p}{X}\right)\left(\sum_{r=0}^{L} \beta_{ir}\left(\ln\left(X - t'p\right) - w'\ln p\right)^r + \sum_{i=1}^{J} \alpha_{ik} \ln p_k\right) + \varepsilon_i$$

where $m_i(u)$ is replaced by $\sum_{r=1}^{L} \beta_{ir} y^r$ with $y = \ln(X - t'p) - w'\ln p$ and r denotes the order of the polynomial function of real income that provides a flexible representation of Engel curves. Note that the system in (9) is subject to the theoretical restrictions of adding-up $\left(\sum_{i=1}^{J} \beta_{i0} = 1;\ \sum_{i=1}^{J} \beta_{ir} = 0, \forall r = 1,..., L; \sum_{i=1}^{J} \alpha_{ik} = 0, \forall k = 1,..., J\right)$ and symmetry $(\alpha_{ik} = \alpha_{ki}, \forall i, k = 1,..., J)$. Importantly, the EASI model is nested in the GEASI specification and can be obtained via the joint restriction of $t_i = 0, \forall i = 1,..., J$ on the GEASI model.

2.1 Elasticity Formulas for the GEASI Model

We derive the expenditure, Hicksian, and Marshallian elasticity formulas for the GEASI model using the expenditure share equations in (9). Specifically, the GEASI expenditure elasticity formula is provided below:[3]

(10) $$E = \left(diag(W)\right)^{-1}\left[\left[I_J + \left(\left(\frac{X - t'p}{X}\right) * B\right)(\ln p)'\right]^{-1}\left[\frac{t \circ p}{X} + \frac{t'p}{X} A + B\right]\right] + 1_J,$$

where E is the $(J \text{ x } 1)$ expenditure elasticity vector with e_i denoting its i^{th} element, W represents the (J x 1) vector of observed commodity budget shares, $\ln p$ is the $(J \text{ x } 1)$ vector of log prices, B is a (J x 1) vector with its i^{th} element represented by $\sum_{l=1}^{L}\left(\beta_{il} + \beta_{il}^{u} Urb_{rt}\right) l y^{l-1}$

$A = \left(\sum_{r=0}^{L} \beta_{ir}\left(\ln\left(X - t'p\right) - w'\ln p\right)^r + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right)$, 1_J is a $(J \text{ x } 1)$ vector of ones, and $\circ$ is the

[3] The details concerning the elasticity derivations are provided in the Appendix.

Hadamard-Schur product with $t \circ p = [t_1 p_1, ..., t_N p_N]$. Equation (10) accounts for the fact that expenditure shares (w_i) also appear on the right side of the GEASI system through real expenditure (y_{rt}) and its polynomials.

Hicksian elasticities for the GEASI model are:

$$(11) \qquad e_{ij}^H = \frac{1}{w_i}\left[\frac{t_i p_i}{X} - \frac{t_i p_i}{X} A + \left[1 - \frac{t' p}{X}\right]\alpha_{ii}\right] + w_j - \delta_{ij}, \ \forall i, j = 1, ..., J,$$

where δ_{ij} is the Kronecker delta equaling 1 if $i = j$, and 0 otherwise.

Using the Hicksian (e_{ij}^H) and expenditure elasticity estimates (e_i), the Marshallian price elasticities (e_{ij}^M) can be obtained from the Slutsky equation: $e_{ij}^M = e_{ij}^H \frac{\alpha_{ij}}{w_i} - w_j \text{e}_i$.

$$(12) \qquad e_{ij}^M = \left[\left[\frac{t_i p_i}{X} - \frac{t_i p_i}{X} A + \left[1 - \frac{t' p}{X}\right]\alpha_{ii}\right] + w_j - \delta_{ij}\right]\frac{\alpha_{ij}}{w_i^2} - w_j \text{e}_i.$$

3. Data and Construction of Variables

The empirical advantage of the GEASI model is illustrated through an empirical study of food demand structure in Russia. The analysis is based on the most recent household food expenditures panel data provided by the Federal State Statistics Service (FSSS) of Russian Federation. The data provide detailed information on consumption patterns for representative households from across the 79 provincial-level administrative divisions of Russia (such as oblasts, autonomous republics, etc.) over an eight-year period from 2007 to 2014. The data are collected by the FSSS through annual surveys of representative households as part of the Household Income and Food Expenditure Survey. The survey is conducted using a two-stage stratified systematic random sampling method, where a third of households are dropped each period and replaced with a fresh sample of equal size based on a rotating-sample design. The collected data are subsequently aggregated by the FSSS to the respective administrative division level.

The current study is focused on seven most widely consumed food commodity groups categorized as meats (*i.e.*, beef, poultry, pork, and other meats), vegetables, cereals, eggs, fats/oils, sugar, and dairy. Categorizing commodities this way results in a 4,434 total observations for the GEASI demand system. The descriptive statistics presented in Table 1 illustrate the relative importance of each commodity groups sampled. As it appears, meats hold the largest average budget share of 35.7% followed by cereals, dairy, vegetables, and sugar with respective budget shares of 18.0%, 17.5%, and 12.8%. Eggs and fats/oils, in contrast, account for relatively lower shares of the total expenditures on food commodities included in the analysis, representing 2.4% and 2.1% respectively. According to data, meats are the most expensive food group (15.2 Rubles/kg), followed by sugar (6.0 Rubles/kg), and fats/oils (4.8 Rubles/kg).

4. An Empirical Application of the GEASI Demand System to the Analysis of Food Demand in Russia

The choice of Russia as an empirical setting serves a dual purpose of a) illustrating the empirical value of the GEASI model and b) contributing timely and relevant empirical insights on food demand in Russia for informing policy decisions.

The existing empirical literature in this area is limited in its ability to inform current public policy in that the previous studies either do not reflect present reality (*e.g.*, Sheng 1997; Elsner 1999) or have a limited scope of analysis focusing on a small number of narrowly defined food commodities (*e.g.*, Shiptsova et al. 2004). The more recent study by Staudigel and Schrock (2015) is the first to examine consumer food preferences in Russia based on the Russian Longitudinal Monitoring Survey (RLMS) data covering 1995-2010. Despite offering the first comprehensive analysis of considerably disaggregate food categories, a major limitation of this study stems from the data quality as the survey is based on seven-day recall information. More specifically, the empirical findings rely on an assumption that the seven-day recall information accurately reflects consumption patterns throughout the year. This can be a strong assumption under a wide range of circumstances and, if not true, may lead to biased demand estimates (Altonji and Siow 1987). Additionally, the unobserved provincial heterogeneity, which may reflect the effects of cultural, religious and other idiosyncrasies on local food customs, remains unaccounted for in the previous literature. Finally, previous studies employ demand specifications such as the Linear Approximate AIDS or similar systems, which are characterized by restrictive Engel curves and produce elasticities that are dependent on the data scale (Alston, Chalfant, and Piggott 2001). The combination of the advanced modeling approach and the detailed panel data used in this paper allows us to address all of these shortcomings in a single application while also accounting for potential pre-commitments in the demand structure.

4.1 Estimation methods

A series of GEASI and EASI specifications allowing for a range of Engle curves extending from linear to sextic are estimated via the GAUSSX programming module. The demand equations are estimated using the NLS estimation procedure with allowance being made for contemporaneous correlation across the stochastic terms of the system. Based on the Likelihood Ratio (*LR*) test outcome, the GEASI model is found empirically superior to the EASI model across all the specifications considered (Table 2). The results are robust to the inclusion of provincial fixed effects, which account for unobserved time-invariant characteristics of the Russian administrative divisions/provinces. As discussed above, this unobserved provincial heterogeneity can influence food consumption patterns through its effects on deeply rooted local food customs and traditions.

To identify the GEASI specification that offers the best fit of the data, the degree of polynomial function (*L*) is increased one at a time starting at *L*=1, and the *LR* test procedure is adopted to evaluate the incremental gain in the explanatory power of the more general models. It is worth noting that *L* should be less than the number of demand equations (*R*) for the demand system to converge. The results indicate that at *L*=6 the GEASI system provides the best fit of the data, and considerably enhances the explanatory power relative to one less degree of income polynomial (the respective *p*-value associated with the test statistic is 0.00). Based on the results of model diagnostics, the sextic GEASI model is deemed as the most preferred specification for the use in the analysis.

4.2 Empirical results

Table 3 presents the parameter estimates from the GEASI system with a sextic Engel curve structure. Pre-committed demand coefficients for cereals (t_3), eggs (t_4) and fats/oils (t_5) are estimated to be positive and statistically significant, which provides evidence for pre-committed consumption levels for cereals (21.0 kg), eggs (46.4 unit) and fats/oils (3.5 kg). To evaluate the relative importance of these pre-commitments in the food demand structure for Russian consumers, we also compute the shares of pre-commitment and discretionary amounts in total consumption.. As can be seen from Table 4, pre-commitments account for 17.6%, 18.4%, and 27.8% of cereal, eggs, and fats/oils demands, respectively.

Tables 5 and 6 report the GEASI Marshallian $\left(e_{ij}^{M}\right)$, expenditure $\left(e_{i}\right)$, and Hicksian elasticity $\left(e_{ij}^{H}\right)$ estimates based on the formulas derived in the Appendix and evaluated at sample mean values. The own-price elasticity estimates are found to be consistent with consumer theory and are statistically significant. Further, own price elasticities are less than unitary elastic for all commodities and fall in the range of -0.679 for fats/oils to -0.277 for vegetables, which conforms to prior expectations given the degree of commodity aggregation. Expenditure elasticities are estimated to be positive, significant, and inelastic for the majority of commodities with the exception of vegetables (1.350) and dairy products (1.101). Interestingly, cereals (0.705), eggs (0.763) and fats/oils (0.550) are found to have the lowest expenditure elasticities.

4.3 Comparative analysis and pre-commitment bias in elasticity estimates

To examine the effects of omitting pre-committed demand on estimated elasticities, we present a comparative analysis of the EASI and GEASI models. As can be seen from Table 7, ignoring pre-commitments when consumer behavior is of non-discretionary nature over a certain portion of the demand curve can lead to significant biases in estimated Marshallian and expenditure elasticities.[4] In particular, the bias in Marshallian own-price elasticities is positive across all commodities and is extremely large for cereals (108.6%), eggs (16-fold), and fats/oils (237.9%) - commodity groups for which pre-commitment is found to be a valid assumption. Expenditure elasticities, in contrast, are shown to be overestimated for cereals (-19.1%), eggs (-27.8%), fats/oils (-42.1%), and sugar (-6.9%), and underestimated for the remaining commodities. This implies that consumers tend to become increasingly price-responsive once pre-commitments are satisfied. The results of comparative analysis indicate that ignoring pre-committed demand when it is a legitimate assumption will result in estimated demand curves that do not accurately reflect the actual demand. This is the case because the unaccounted low elasticity over the non-

[4] The Hicksian elasticity estimates and the bias stemming from the omission of pre-commitments are not presented to preserve space but are available upon request.

discretionary portion of actual demand tends to be wrongly attributed by the EASI model to the entire estimated demand curve.

4.4 Policy implications of pre-commitment bias

As a final exercise, we use the Marshallian own-price elasticity estimates from the EASI and GEASI specifications and the OECD-projected food prices changes for Russia to illustrate the practical implications of the pre-commitment bias in price-induced consumption response. Domestic food prices have been on the rise following the embargo imposed by Russia in 2014 on the imports of meat, dairy, fruit, and vegetables from the European Union, United States, Canada, Australia, and Norway (FAO, 2015).[5] For example, pork and chicken prices saw an increase by 27%, while fruit price registered a 21% increase in 2014. Given that the import ban was extended by the government of Russian Federation until the end of 2017, food prices are expected to stay on a rising trajectory in the near future (EURACTIV, 2016). Specifically, according to the OECD projections, prices for meats, cereals, fats/oils, sugar and dairy products in Russia are projected to increase by 8.7%, 5.3%, 17.7%, 26.8% and 16.8%, respectively, by year 2020. Using these price forecasts and the estimated own-price elasticities, we find that ignoring pre-commitments considerably understates the predicted reductions in the consumption of these commodities. The estimated monetary equivalent of the bias ranges from $31 million for meats to $103 million for dairy products. We acknowledge that this is a mere simulation exercise and not a comprehensive policy analysis, nevertheless, it does illustrate the potential policy implications of pre-commitment bias and highlights the advantage of the methodological solution offered by the GEASI model.

[5] These products collectively account for about two-thirds of total food expenditures in Russia (FAO 2015).

5. Conclusions

The contribution of this study to the literature is both methodological and empirical. From the methodological perspective, it presents a solution to the problems associated with pre-commitment bias in demand estimations. Specifically, it introduces the GEASI demand model, which allows estimation of the Marshallian, Hicksian, and expenditure elasticities that have the promise of providing a more accurate reflection of consumer price and income responsiveness in the presence of pre-committed demand (while maintaining all of the advantages of the EASI specification over its predecessor models). From the empirical perspective, the significance of pre-commitment bias is illustrated in the context of consumer food preferences and consumption patterns in Russia using novel household food expenditure panel data obtained from the Federal Statistical Service of Russian Federation. The estimated elasticities uniquely extend the empirical literature on food demand in Russia in that potential pre-commitments as well as unobserved provincial heterogeneity have been taken into account. The empirical findings offer valuable and timely insights into the food demand structure in Russia and can be useful in informing public policy decisions in light of the increasing role of Russia globally.

The distinct advantages of the GEASI model create a potential for wide range of empirical applications such as examining consumer response to changing food structures brought by various economic and social reforms. This makes the approach useful for researchers and policy makers in a range of disciplines including agricultural economics, international development, health and nutrition, and trade.

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Table 1. Descriptive Statistics for Food Expenditures, Prices, and Budget Shares

Variable	Mean	STD	Min	Max
Per Capita Expenditure (Rubles/Capita)				
Meats	1023.8	357.6	381.4	2963.8
Vegetables	364.7	137.2	111.0	1334.4
Cereals	508.1	152.4	208.9	1132.0
Eggs	66.6	25.5	23.2	274.8
Fats/Oil	58.8	14.7	24.0	104.3
Sugar	226.1	76.9	74.6	623.4
Dairy	505.2	191.0	171.1	1745.4
Agricultural Commodity Price (Rubles/kg)				
Meats	15.2	5.1	4.8	58.1
Vegetables	4.2	5.2	0.8	66.3
Cereals	4.4	1.8	1.6	17.8
Eggs	0.3	0.2	0.1	1.8
Fats/Oil	4.8	1.3	1.5	9.2
Sugar	6.0	2.3	1.6	14.5
Dairy	2.3	1.6	0.5	17.7
Budget Share (%)				
Meats	35.7	3.1	26.9	49.0
Vegetables	12.8	1.9	7.5	19.6
Cereals	18.0	1.7	14.1	25.2
Eggs	2.4	0.4	1.1	4.8
Fats/Oil	2.1	0.4	1.1	3.7
Sugar	7.9	1.2	4.2	14.3
Dairy	17.5	1.6	11.3	23.4
Per Capita Income (1,000 Rubles)	21.5	4.6	10.9	33.2

Source: Household Food Expenditure Survey, Federal State Statistics Service of Russian Federation, 2007–2014.

Note: One US Dollar was exchanged for 25 Russian Rubles in 2007, and by 2014 the US Dollar appreciated to 37 Rubles.

Table 2. Summary of the Model Diagnostic Tests

	Hypothesis		Likelihood Ratio value	df.	p-value
Food commodities are not consumed in pre-committed quantities ($t_j = 0, \forall j = 1, ..., n$), that is, GEASI and EASI models are equivalent					
(i)	Linear Engel Curve	(i.e., *r*=1)	99.9	7	0.00
(ii)	Quadratic Engel Curve	(i.e., *r*=2)	112.6	7	0.00
(iii)	Cubic Engel Curve	(i.e., *r*=3)	108.4	7	0.00
(iv)	Quartic Engel Curve	(i.e., *r*=4)	112.0	7	0.00
(v)	Quintic Engel Curve	(i.e., *r*=5)	113.6	7	0.00
(vi)	Sextic Engel Curve	(i.e., *r*=6)	114.3	7	0.00

Note 1: The EASI and GEASI specifications are estimated on household food expenditure panel data obtained from the National Bureau of Statistics of China. The data cover 79 provinces/administrative districts over the span 2007-2014, and include seven widely consumed food commodity groups (*i.e*., meats, vegetables, cereal, eggs, fats/oils, sugar and dairy). A total of 4,434 observations have been utilized in the demand system estimation.

Note 2: The degree of polynomial functions estimated cannot exceed 6 (*i.e*., R<J), otherwise the resulting Engel curves will be arbitrarily complex (Lewbel and Pendakur 2009).

Table 3. Parameter Estimates from the GEASI Expenditure Share Equations

Parameter	Meats	Vegetables	Cereals	Eggs	Fats/Oil	Sugar	Dairy
Pre-committed demand (t_i)	0.012	0.003	20.997 [a]	46.363 [a]	3.528 [a]	2.981	0.007
	(4.905)	*(1.290)*	*(7.423)*	*(9.941)*	*(0.742)*	*(3.069)*	*(8.852)*
Intercept (β_{i0})	0.368 [a]	0.150 [a]	0.153 [a]	0.023 [a]	0.015 [a]	0.066 [a]	0.227 [a]
	(0.008)	*(0.006)*	*(0.005)*	*(0.001)*	*(0.001)*	*(0.003)*	*(0.005)*
Real income (β_{i1})	0.138 [b]	-0.012	-0.096 [a]	-0.001	-0.019 [b]	-0.037	0.028
	(0.062)	*(0.032)*	*(0.033)*	*(0.007)*	*(0.007)*	*(0.021)*	*(0.040)*
Real income (β_{i2})	0.048	-0.051 [c]	0.016	-0.003	-0.001	-0.030 [a]	0.021 [a]
	(0.040)	*(0.026)*	*(0.021)*	*(0.004)*	*(0.004)*	*(0.014)*	*(0.002)*
Real income (β_{i3})	-0.043	0.045 [c]	-0.015	-0.001	-0.001	-0.001	0.016 [a]
	(0.035)	*(0.024)*	*(0.018)*	*(0.004)*	*(0.004)*	*(0.012)*	*(0.002)*
Real income (β_{i4})	-0.035 [c]	0.041 [a]	-0.019	0.004 [b]	-0.001	0.011	-0.001
	(0.019)	*(0.012)*	*(0.010)*	*(0.002)*	*(0.002)*	*(0.007)*	*(0.004)*
Real income (β_{i5})	0.005	-0.005	0.002	0.000	0.001	0.000	-0.002 [c]
	(0.006)	*(0.004)*	*(0.003)*	*(0.001)*	*(0.001)*	*(0.002)*	*(0.001)*
Real income (β_{i6})	0.004 [b]	-0.005 [a]	0.002 [b]	-0.001 [c]	0.000	-0.001	0.000
	(0.002)	*(0.002)*	*(0.001)*	*(0.000)*	*(0.000)*	*(0.001)*	*(0.000)*
Price (α_{1i}) meats	0.202 [a]	-0.061 [a]	-0.067 [a]	-0.008 [a]	-0.007 [a]	-0.009	-0.051 [b]
	(0.034)	*(0.009)*	*(0.010)*	*(0.002)*	*(0.002)*	*(0.006)*	*(0.022)*
Price (α_{2i}) veg.		0.103 [a]	-0.015 [b]	0.002	-0.003	-0.021 [a]	-0.006
		(0.011)	*(0.007)*	*(0.002)*	*(0.002)*	*(0.004)*	*(0.012)*
Price (α_{3i}) cereals			0.086 [a]	0.006 [a]	0.009 [a]	-0.004	-0.015
			(0.023)	*(0.002)*	*(0.002)*	*(0.005)*	*(0.010)*
Price (α_{4i}) eggs				0.009 [a]	-0.002 [b]	-0.008 [a]	0.001
				(0.004)	*(0.001)*	*(0.001)*	*(0.002)*
Price (α_{5i})fats/oils					0.007 [a]	-0.005 [a]	0.002
					(0.003)	*(0.001)*	*(0.002)*
Price (α_{6i}) sugar						0.056 [a]	-0.009
						(0.013)	*(0.007)*
Price (α_{7i}) dairy							0.077 [a]
							(0.004)

Note: The standard errors are in parenthesis. [a, b, c] identify parameter estimates that are statistically different from 0 at the 0.01, 0.05, and 0.10 significance levels, respectively.

Table 4. Pre-committed and Discretionary Demand as a Percentage of Annual Average Consumption

Commodity	Annual Average (kg)	Pre-commitment (kg)	Pre-commitment Percentage (%)	Discretionary Percentage (%)
Cereals	119.2	21.0	17.6	82.4
Eggs	251.9	46.4	18.4	81.6
Fats/Oil	12.6	3.5	27.8	72.2

Note: The "Annual Average" column displays the average quantity demanded for the respective commodities over the data period, *i.e.*, 2007-2014. The "Pre-commitment Percentage" is the pre-commitment level as a percentage of annual average quantity demanded. The "Discretionary Percentage" is the portion of annual average quantity demanded that responds to changes in economic factors.

Table 5. Marshallian Price and Expenditure Elasticity Estimates from the GEASI system

Commodity	Meats	Vegetables	Cereals	Eggs	Fats/Oil	Sugar	Dairy	Expenditure
Meats	**-0.458** [a]	-0.160 [a]	-0.143 [a]	-0.016	-0.013	-0.017	-0.133 [a]	0.990 [a]
	(0.040)	*(0.022)*	*(0.023)*	*(0.021)*	*(0.032)*	*(0.013)*	*(0.031)*	*(0.039)*
Vegetables	-0.576 [a]	**-0.277** [a]	-0.142 [a]	0.011	-0.021	-0.179 [a]	-0.103	1.350 [a]
	(0.084)	*(0.092)*	*(0.057)*	*(0.068)*	*(0.075)*	*(0.030)*	*(0.129)*	*(0.077)*
Cereals	-0.246 [a]	-0.041	**-0.462** [a]	0.044	0.058 [c]	0.010	-0.027	0.705 [a]
	(0.056)	*(0.045)*	*(0.053)*	*(0.046)*	*(0.030)*	*(0.016)*	*(0.077)*	*(0.055)*
Eggs	-0.232 [a]	0.107 [b]	0.319 [a]	**-0.631** [a]	-0.068	-0.303 [a]	0.086	0.763 [a]
	(0.065)	*(0.057)*	*(0.054)*	*(0.069)*	*(0.057)*	*(0.020)*	*(0.091)*	*(0.054)*
Fats/Oil	-0.166 [a]	-0.061	0.496 [a]	-0.072	**-0.679** [a]	-0.194 [a]	0.159 [a]	0.550 [a]
	(0.054)	*(0.054)*	*(0.045)*	*(0.047*	*(0.072)*	*(0.033)*	*(0.054)*	*(0.053)*
Sugar	-0.073 [a]	-0.241 [a]	0.004	-0.090	-0.055	**-0.317** [a]	-0.085	0.903 [a]
	(0.011)	*(0.082)*	*(0.066)*	*(0.074)*	*(0.092)*	*(0.017)*	*(0.195)*	*(0.063)*
Dairy	-0.311 [a]	-0.043	-0.067	0.008	0.014	-0.048	**-0.600** [a]	1.101 [a]
	(0.162)	*(0.213)*	*(0.215)*	*(0.216)*	*(0.137)*	*(0.133)*	*(0.019)*	*(0.005)*

Note 1: The standard errors are in parenthesis. [a, b, c] identify parameter estimates that are statistically different from 0 at the 0.01, 0.05, and 0.10 significance levels, respectively.

Note 2: The first column represents commodities with price change.

Table 6. Hicksian Elasticity Estimates from the GEASI system

Commodity	Meats	Vegetables	Cereals	Eggs	Fats/Oil	Sugar	Dairy
Meats	-0.105 [a]	-0.034	0.035	0.007	0.008	0.062 [a]	0.040
	(0.040)	*(0.022)*	*(0.023)*	*(0.021)*	*(0.032)*	*(0.013)*	*(0.031)*
Vegetables	-0.094	-0.105	0.101 [b]	0.042	0.008	-0.072 [a]	0.133
	(0.084)	*(0.092)*	*(0.057)*	*(0.068)*	*(0.075)*	*(0.030)*	*(0.129)*
Cereals	0.005	0.049	-0.336 [a]	0.060	0.073 [a]	0.066 [a]	0.096
	(0.056)	*(0.045)*	*(0.053)*	*(0.046)*	*(0.030)*	*(0.016)*	*(0.077)*
Eggs	0.041	0.205 [a]	0.456 [a]	-0.614 [a]	-0.052	-0.243 [a]	0.219 [a]
	(0.065)	*(0.057)*	*(0.054)*	*(0.069)*	*(0.057)*	*(0.020)*	*(0.091)*
Fats/Oil	0.030	0.010	0.595 [a]	-0.059	-0.667 [a]	-0.150 [a]	0.255 [a]
	(0.054)	*(0.054)*	*(0.045)*	*(0.047)*	*(0.072)*	*(0.033)*	*(0.054)*
Sugar	0.250 [a]	-0.125	0.166 [a]	-0.069	-0.036	-0.245 [a]	0.073
	(0.011)	*(0.082)*	*(0.066)*	*(0.074)*	*(0.092)*	*(0.017)*	*(0.195)*
Dairy	0.082	0.097 [a]	0.131 [a]	0.034 [b]	0.038 [a]	0.040	-0.408 [a]
	(0.062)	*(0.033)*	*(0.015)*	*(0.016)*	*(0.007)*	*(0.033)*	*(0.019)*

Note 1: The standard errors are in parenthesis. [a, b, c] identify parameter estimates that are statistically different from 0 at the 0.01, 0.05, and 0.10 significance levels, respectively.

Note 2: The first column represents commodities with price change.

Table 7. Percentage Difference between Marshallian and Expenditures Elasticities from the EASI and GEASI Models (%)

Commodity	**Uncompensated Elasticity**							**Expenditure**
	Meats	Vegetables	Cereal	Eggs	Fats/Oil	Sugar	Dairy	
Meats	**10.8**	17.6	-32.5	-41.4	-47.6	-18.5	25.3	5.4
Vegetables	13.4	**17.3**	-42.0	-169.5	-43.5	2.0	50.2	4.1
Cereal	-37.9	-65.5	**108.6**	184.3	90.8	-113.6	-76.2	-19.1
Eggs	-49.3	-309.4	280.8	**1,683.6**	-59.9	-25.1	-501.4	-27.8
Fats/Oil	-60.5	-65.9	105.0	-60.9	**237.9**	-30.6	129.5	-42.1
Sugar	-29.5	0.2	-102.2	-23.3	-27.1	**94.2**	-10.6	-6.9
Dairy	20.9	128.4	-55.3	-392.9	124.2	-3.6	**3.7**	4.5

Note: The first column represents commodities with price change.

Appendix. ***Derivation of the Expenditure, Hicksian, and Marshallian Elasticity Formulas for the GEASI Model***

<u>Expenditure Elasticities</u>

To develop the expenditure elasticities for the GEASI model, we first derive the <u>general formula</u> for the expenditure elasticity using the definition of expenditure shares $w_i = \frac{p_i q_i}{X}$, which is rearranged to $q_i = \frac{w_i X}{p_i}$

$$\frac{\partial q_i}{\partial \ln X} = \frac{1}{p_i}\left[\frac{\partial X}{\partial \ln X} w_i + X\,\frac{\partial w_i}{\partial \ln X}\right] = \frac{1}{p_i}\left[X w_i + X\,\frac{\partial w_i}{\partial \ln X}\right] \tag{13}$$

$$\frac{\partial q_i}{\partial \ln X} = \frac{\partial e^{\ln q_i}}{\partial \ln X} = q_i\,\frac{\partial \ln q_i}{\partial \ln X} \tag{14}$$

$$\begin{aligned}\frac{\partial \ln q_i}{\partial \ln X} &= \frac{1}{q_i}\frac{\partial q_i}{\partial \ln X} = \frac{1}{q_i}\left[\frac{1}{p_i}\left[X w_i + X\,\frac{\partial w_i}{\partial \ln X}\right]\right] = \frac{1}{p_i q_i}\left[X w_i + X\,\frac{\partial w_i}{\partial \ln X}\right] = \frac{w_i}{p_i q_i} X + \frac{X}{p_i q_i}\frac{\partial w_i}{\partial \ln X}\\ &= \frac{1}{X} X + \frac{1}{w_i}\frac{\partial w_i}{\partial \ln X} = \frac{1}{w_i}\frac{\partial w_i}{\partial \ln X} + 1\end{aligned} \tag{15}$$

where use is made of the fact that $\frac{w_i}{p_i q_i} = \frac{p_i q_i}{X}\frac{1}{p_i q_i} = \frac{1}{X}$ and $\frac{X}{p_i q_i} = \frac{1}{w_i}$.

The GEASI expenditure elasticities are then obtained by substituting $\frac{\partial w_i}{\partial \ln X}$ derived from the GEASI model into (15). To this end, we utilize the respective GEASI expenditure share equations provided below (see equation (9)):

$$w_i = \frac{t_i p_i}{X} + \left[1 - \frac{t'p}{X}\right]\left(\sum_{r=0}^{L} \beta_{ir}\left(\ln\left(X - t'p\right) - w'\ln p\right)^r + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right) + \varepsilon_i$$

Let $A_1 = \frac{t_i p_i}{X}$, $A_2 = \left[1 - \frac{t'p}{X}\right]$, $A_3 = \left(\sum_{r=0}^{L} \beta_{ir}\left(\ln\left(X - t'p\right) - w'\ln p\right)^r + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right)$. The derivative of the expenditure shares with respect to log expenditure $\left(i.e., \frac{\partial w_i}{\partial \ln X}\right)$ is as follows:

$$\frac{\partial w_i}{\partial \ln X} = \frac{\partial A_1}{\partial \ln X} + \frac{\partial A_2}{\partial \ln X} A_3 + \frac{\partial A_3}{\partial \ln X} A_2 \tag{16}$$

(17) $$\frac{\partial(A_1)}{\partial \ln X} = \frac{\partial(t_i p_i / X)}{\partial \ln X} = t_i p_i \frac{\partial(1/X)}{\partial \ln X} = t_i p_i \left(-X^{-2} X\right) = -\frac{t_i p_i}{X}$$

(18) $$\frac{\partial(A_2)}{\partial \ln X} = \frac{\partial\left(1 - \frac{t' p}{X}\right)}{\partial \ln X} = \frac{t' p}{X}$$

(19) $$\frac{\partial(A_3)}{\partial \ln X} = \left[\sum_{r=0}^{L} r\beta_{ir}\left(\ln(X - t' p) - w' \ln p\right)^{r-1} + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right]\left[\frac{X}{X - t' p} - \left(\frac{\partial w}{\partial \ln X}\right)' \ln p\right]$$

where $\left(\frac{\partial w}{\partial \ln X}\right)' = \left(\frac{\partial w_1}{\partial \ln X}, ..., \frac{\partial w_i}{\partial \ln X}, ..., \frac{\partial w_N}{\partial \ln X}\right)'$.

Substituting (17)--(19) into (16) results in:

(20) $$\begin{aligned} \frac{\partial w_i}{\partial \ln X} &= -\frac{t_i p_i}{X} + \frac{t' p}{X} A_3 \\ &+ \left[\sum_{r=0}^{L} r\beta_{ir}\left(\ln(X - t' p) - w' \ln p\right)^{r-1} + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right]\left[\frac{X}{X - t' p} - \left(\frac{\partial w}{\partial \ln X}\right)' \ln p\right] A_2 \\ &= -\frac{t_i p_i}{X} + \frac{t' p}{X} A_3 + A_4\left[\frac{X}{X - t' p} - \left(\frac{\partial w}{\partial \ln X}\right)' \ln p\right] A_2, \end{aligned}$$

where $A_4 = \left[\sum_{r=0}^{L} r\beta_{ir}\left(\ln(X - t' p) - w' \ln p\right)^{r-1} + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right]$.

Note that the equation in (20) represents a (*J x J*) system of implicit equations with $\frac{\partial w_i}{\partial \ln X}$, $\forall i = 1, ..., J$ appearing on both sides of each of these equations. Using matrix algebra, we solve the system in (20) for $\frac{\partial w_i}{\partial \ln X}$ as follows:

(21) $$\frac{\partial w}{\partial \ln X} = \left[I_J + \left(\left(\frac{X - t' p}{X}\right) * B\right)(\ln p)'\right]^{-1}\left[\frac{t \circ p}{X} + \frac{t' p}{X} A_3 + B\right]$$

where B is a (*J* x 1) vector with its i^{th} element equaling $\left(\sum_{r=1}^{L} r\beta_{il} y^{r-1}\right)$, and A_3 is as previously defined, *i.e.*, $A_3 = \left(\sum_{r=0}^{L} \beta_{ir}\left(\ln\left(X - t'p\right) - w'\ln p\right)^r + \sum_{k=1}^{J} \alpha_{ik} \ln p_k\right)$.

Finally, we obtain the GEASI expenditure elasticity formula by substituting (21) into (15):

$$E = \left(diag\left(W\right)\right)^{-1}\left[\left[I_J + \left(\left(\frac{X - t'p}{X}\right) * B\right)\left(\ln p\right)'\right]^{-1}\left[\frac{t \circ p}{X} + \frac{t'p}{X} A_3 + B\right]\right] + 1_J, \tag{22}$$

where *E* is the (*J* x 1) expenditure elasticity vector with e_i denoting its i^{th} element, *W* is represents the (*J* x 1) vector of observed commodity budget shares, $\ln p$ is the (*J* x 1) vector of log prices, and 1_J is a (*J* x 1) vector of ones.

<u>Hicksian and Marshallian Elasticities</u>

We derive the GEASI Hicksian elasticities by deriving $\frac{\partial w_i}{\partial \ln p_j}$ for our more general model and substituting back into the Hicksian elasticity formula provided in general terms:

$$e_{ij}^H = \frac{1}{w_i}\left[\frac{\partial w_i}{\partial \ln p_j}\right] + w_j - \delta_{ij}, \;\; \forall i, j = 1, ..., J, \tag{23}$$

Using the GEASI expenditure share equations in (9), we obtain:

$$\frac{\partial w_i}{\partial \ln p_j} = -\frac{t_j p_j}{X} A_3 + \left[1 - \frac{t'p}{X}\right]\alpha_{ij}, \quad \forall i \neq j \tag{24}$$

$$\frac{\partial w_i}{\partial \ln p_i} = \frac{t_i p_i}{X} - \frac{t_i p_i}{X} A_3 + \left[1 - \frac{t'p}{X}\right]\alpha_{ii}, \tag{25}$$

Equations (24) and (25) are substituted into (23) to yield the GEASI Hicksian Elasticity formulas:

$$e_{ij}^H = \frac{1}{w_i}\left[\frac{t_i p_i}{X} - \frac{t_i p_i}{X} A_3 + \left[1 - \frac{t'p}{X}\right]\alpha_{ii}\right] + w_j - \delta_{ij}, \;\; \forall i, j = 1, ..., J, \tag{26}$$

Marshallian price elasticities $\left(e_{ij}^{M}\right)$ are obtained from the Slutsky equation: $e_{ij}^{M} = e_{ij}^{H} \frac{\alpha_{ij}}{w_i} - w_j \, \mathrm{e}_i$.

(27) $$e_{ij}^{M} = \left[\left[\frac{t_i p_i}{X} - \frac{t_i p_i}{X} A_3 + \left[1 - \frac{t' p}{X}\right]\alpha_{ii}\right] + w_j - \delta_{ij}\right]\frac{\alpha_{ij}}{w_i^2} - w_j \, \mathrm{e}_i \, .$$