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The changing demand for energy in rich and poor countries over 25 years

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ABSTRACT

Country-specific income and own-price elasticities of demand for private consumption of energy are compared across time and affluence for 43 countries that participated in the 1980, 1996, and 2005 International Comparison Program based on estimates from a ten-good-demand system. Results indicate that income elasticities of demand for energy are significantly larger than unitary in 1980, are approximately unitary in 1996 but become inelastic for all 43 countries in 2005. Own-price elasticities decrease absolutely going from 1980 to 1996 to 2005 ranging from −0.8 to −1.0 in 1980, −0.7 to −0.8 in 1996, and −0.6 to −0.7 in 2005. Elasticity estimates are also calculated for the set of countries in 1996 and 2005 that do not participate in the ICP in 1980.

1. Introduction

The global demand for energy has increased greatly in recent years and is projected to grow even more. In 1996 global demand is 374.631 quadrillion Btu and in 2005 it is 461.958 quadrillion Btu and increasing (U.S. Energy Information Administration, 2010a,b). For the Organisation for Economic and Co-operation Development (OECD) countries, total energy demand increases by almost 10% from 1996 to 2005. For non-OECD countries the total energy demand increases by nearly 43% during the same time period. By 2030 the global demand for energy is projected to be 678.300 quadrillion Btu and non-OECD countries will account for approximately 59% of that demand (U.S. Energy Information Administration, 2010a,b).

Clearly, energy consumption is increasing. This increase may have far-reaching impacts, especially for developing countries. However, are the effects really that different for developing countries versus developed countries? Are there differences across countries? And how has demand for energy changed across time for these countries?

To answer these questions, the sensitivity of energy demand to changes in income and own-price are analyzed by fitting a demand system of 10 categories of goods including energy to 1996 and 2005 International Comparison Program (ICP) data for 43 countries that participated in the ICP in 1980, 1996, and 2005 and are compared with elasticities reported for 1980 by Seale et al. (1991). Specifically, the Florida model (Clements and Chen, 2010; Muhammad et al., 2011, Seale et al., 1991; Seale et al., 2003; Seale and Regmi, 2006, 2009; Theil et al., 1989; Theil, 1997) is fit to the two data sets, and parameter estimates are used to calculate income and three types of own-price elasticities of demand for energy across a wide spectrum of countries with differing per capita income levels. The elasticity estimates from Seale et al. (1991) are used in a comparison across the results for 1980, 1996, and 2005 ICP data. The expenditure elasticities are expected to be inversely related to per capita income levels and thus to decrease across time, from 1980 to 1996 to 2005, as per capita income levels generally increase for each country. The change in the quantity demanded of energy for richer consumers should be smaller than that of poorer consumers for the same percentage change in per capita income. Accordingly, as a country's per capita income increases over time, its demand for energy should become less sensitive to a percentage change in income, and the magnitude of the income elasticities is expected to decline over time. As described by Timmer (1981), the same results are expected for own-price elasticities.

2. Previous evidence

Evidence on the magnitude of income and own-price elasticities of demand for energy has differed somewhat. In the 1970s and early 1980s, the

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consensus is that the income elasticity of demand for energy is about unitary, and it own-price elasticity is about −0.4 with a representative range of −0.03 to −0.5 (Kouris, 1983a; Pindyck, 1979; and Taylor, 1977). Dahl (1993), based on the surveys of Taylor (1977), Kouris (1983b), and the Energy Modeling Forum (1981), summarizes their results to an average income elasticity of total (residential) energy of about 0.96 with a minimum of 0.73 and a maximum of 1.18. She summarizes the own-price elasticity of demand for energy to be about, on average, −0.4 with a minimum of −0.7 and a maximum of −0.17.

Other evidence suggests that the demand for energy is more sensitive to changes in income and prices than the above surveys report. Pindyck (1979) presents evidence that the own-price elasticity for total residential energy is about −1.1. Zilberfarb and Adams (1981) estimate that the income elasticity of demand for energy in developing countries is close to 1.35 while Beenstock and Wilcocks (1981) find the long-run elasticity of demand for aggregate energy over the period of 1950–78 to be closer to two than to one or about 1.8.

Fiebig et al. (1987) study energy demand in the context of a complete demand system and find that both income and own-price elasticities vary inversely with per capita income levels in a sample of low-, middle-, and high-income countries. Their findings suggests that, based on 1975 ICP data for 30 countries, the income elasticity of demand for energy ranges from 1.24 for the United States, the richest country in their sample, to 1.64 for India, the poorest country in the sample. They calculate three types of own-price elasticities and find all three to be of similar magnitudes. For example, the Slutsky or income compensated own-price elasticity ranges from −0.60 for the United States to −0.84 for India while the Cournot or uncompensated own-price elasticity ranges from −0.69 for the United States to −0.88 for India.

Seale et al. (1991) also estimate a cross-country-demand system that includes energy. They use data from Phases II (1970), III (1975), and IV (1980) of the ICP. In total, their pooled and extended sample includes 57 countries after omitting some countries identified as outliers based on information inaccuracy measures. The data include 31 countries that participate in only one of the three phases, 13 countries that participate in two phases, and 13 countries that participate in three phases. To account for persistent preferences in individual countries, they impose an AR(1) error term. They also find that the 27 new countries in the 1980 Phase IV data have larger covariance terms than those participating in the earlier phases, and they correct for heteroskedasticity for this group using maximum likelihood and the scoring method (Harvey, 1990, p. 134–35). The data are separated into 11 consumption goods: food; beverages and tobacco; clothing and footwear; gross rent; house furnishing; medical care; transport and communications; recreation; education; other; and energy. Energy is composed of gasoline, grease and oil used for transport and of fuel and power including electricity, gas, liquid fuels, and other fuels, water charges and ice. Their results from the extended pooled estimation are used as a starting point for comparing the income and own-price elasticities of demand for energy in 1996 and 2005, and the parameter estimates are reported in column (2) of Table 1.

Rothman et al. (1994) use data from 53 countries collected during Phase V (1985) of the ICP. In their analysis of total energy, they combine 129 goods at the basic headings into six categories: grains and starches; other foods; clothing and household; health and education; energy; and other goods. Three models are used to estimate the demand for energy: the translog; Deaton and Muellbauer's (1980) Almost Ideal Demand System (AIDS); and the generalized logit. Based on the properties of the results, they suggest that the generalized logit performs best. They find that both the generalized logit and the translog models estimate the average (across all countries) income elasticity of demand for total energy to be 1.05 while the AIDS estimates the average elasticity similarly at 1.02.

The ranges of the income elasticities from the three models over the 53 countries differ with those of the generalized logit and translog models being most similar. The range of the generalized logit is .91 for the richest country, United States, to 1.31 for the poorest, Ethiopia, and the income elasticities of demand for total energy follows an inverse relationship with per capita income levels among the 53 countries. The range of the translog model is tighter with a range of 0.98 for the United States and 1.09 for Ethiopia while the range of the AIDS is tightest going from 1.01 for the United States to 1.04 for Ethiopia. Again, the income elasticities of demand for total energy follow an inverse relationship with per capita income levels.

The average own-price elasticities of demand for total energy estimated by the three models are similar in magnitude; it is −0.78 for the generalized logit, −0.72 for the translog, and −0.69 for the AIDS. The ranges are less similar with the range of the generalize logit going from −0.60 to −1.04, that of the translog going from −0.58 to −0.81, and that of the AIDS going from −0.36 to −0.78. Unlike the income elasticities, the own-price elasticities of demand for total energy do not follow any clear relationship with income.

Brenton (1997) fits an 11-good linear expenditure system (LES) to the 1980 Phase IV ICP data of 60 countries: food; beverages and tobacco; clothing and footwear; energy; housing; furniture and appliances; medical care; transport and communications; recreation; education; and other goods. In Brenton's words, he finds the degree of fit “generally disappointing” whether the sample is estimated as one, two or three regimes of countries. For the one regime procedure, the calculated income elasticities are all above one and are larger as per capita income is smaller. When breaking the sample into two or three subsets, the fit is still low, and the elasticities of the low-income countries are generally higher than those of the high- and middle-income countries. The price elasticities of the one regime procedure are all similar in magnitude at approximately −0.96. For the two and three regime procedure, no pattern in terms of own-price elasticities and income levels emerges.

Brenton (1997) also fits the AIDS model to the 1980 ICP data for a six-good system: food; drink and tobacco; clothing and footwear; energy; housing and furniture; transport and communications; and all other goods and services. In interpreting the results, one should keep in mind that all parameters in the energy equation are statistically insignificant whether for one or two regimes. When fitting the complete set of countries, the income elasticity of demand for energy is essentially unitary or about 1.03 for all countries, low, middle, and high income, while the compensated own-price elasticities are approximately −0.93 for all countries. When re-estimating the AIDS to two sub-samples of the data, the income elasticities of the poor countries are lower than those of the rich countries, and they are inelastic. The income elasticities of the rich countries are elastic and greater than 1.0. Most are around 1.2 with a few at 1.3, 1.4, and one at 4.7.

3. Data

There are many phases of the ICP. Phase I is for the year 1970, Phase II for 1970 (and 1973) and supersedes Phase I, Phase III for 1975, Phase IV for 1980, Phase V for 1985, Phase VI for 1993, and Phase VII for 2005. The numbers of countries for which data are collected for each year are 10, 16, 34, 60, 64, 117, and 146, respectively (ICP, 2010a). Additionally, the 1996 ICP collects data on 115 countries.

The ICP also has prices which are determined through purchasing power parities (PPPs) (ICP, 2010b). A PPP “between two countries, A and B, is the ratio of the number of units of country A's currency needed to purchase in country A the same quantity of a specific good or service as one unit of country B's currency will purchase in country B” (ICP, 2008). PPPs are used because there are problems with exchange rate conversions. Exchange rates conversions can be unstable, and therefore may not accurately compare prices in different countries (ICP, 2010b). The US dollar is used as the currency for comparison. The PPP guarantees that each currency exchanged for one US dollar will buy the same amount of goods in every country (ICP, 2010b).

The ICP reports data on both private and government consumption. The data used for analysis in this paper are those of private consumption

Table 1
Maximum likelihood estimation of ten goods including energy, 1980, 1996 and 2005.

Good or parameter	1980 pooled[a] (57 countries)		1996 data (43 countries)		2005 data (43 countries)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Income flexibility, ϕ	−0.729	(0.024)[b]	−0.756	(0.030)	−0.708	((0.050)
Coefficient β_i						
Food, beverages, and tobacco	−0.135[c]	–[d]	−0.130	(0.008)	−0.101	(0.010)
Clothing and footwear	−0.004	(0.003)	−0.001	(0.003)	−0.002	(0.002)
Gross Rent	0.014	(0.003)	0.035	(0.005)	0.022	(0.004)
House Furnishing	0.014	(0.003)	−0.001	(0.003)	0.000	(0.002)
Medical Care	0.022	(0.003)	0.032	(0.004)	0.024	(0.004)
Transport and communications	0.022	(0.003)	0.002	(0.004)	0.011	(0.004)
Recreation	0.018	(0.002)	0.019	(0.003)	0.024	(0.003)
Education	0.005	(0.004)	0.009	(0.006)	−0.004	(0.003)
Other	0.031	(0.003)	0.039	(0.007)	0.035	(0.003)
Energy	0.012	(0.002)	−0.004	(0.011)	−0.010	(0.003)
Coefficient α_i						
Food, beverages, and tobacco	0.213[e]	–[f]	0.129	(0.014)	0.161	(0.019)
Clothing and footwear	0.077	(0.004)	0.063	(0.006)	0.050	(0.005)
Gross Rent	0.109	(0.005)	0.138	(0.009)	0.162	(0.008)
House Furnishing	0.087	(0.004)	0.062	(0.005)	0.056	(0.003)
Medical Care	0.089	(0.004)	0.116	(0.006)	0.108	(0.007)
Transport and Communications	0.097	(0.005)	0.073	(0.006)	0.127	(0.007)
Recreation	0.070	(0.003)	0.084	(0.005)	0.101	(0.006)
Education	0.066	(0.005)	0.076	(0.006)	0.025	(0.005)
Other	0.124	(0.005)	0.170	(0.007)	0.158	(0.005)
Energy	0.068	(0.004)	0.089	(0.011)	0.052	(0.005)
K1	1.520	(0.153)	N.A.	N.A.	N.A.	N.A.

N.A. = not applicable.
[a] This column is from Table 1, column (5) of Seale et al. (1991).
[b] Asymptotic standard errors are reported in parentheses.
[c] This figure is the sum of the beta parameters of food and of beverages and tobacco from Table 1, column (5) of Seale et al. (1991).
[d] The asymptotic standard errors of the betas of food and of beverages and tobacco are 0.006 and 0.003, respectively (Seale et al., 1991).
[e] This figure is the sum of the alpha parameters of food and of beverages and tobacco from Table 1, column (5) of Seale et al. (1991).
[f] The asymptotic standard errors of the alphas of food and of beverages and tobacco are 0.010 and 0.005, respectively (Seale et al., 1991).

in the years 1996 and 2005, and the data sets are obtained from the World Bank. Aggregation from basic headings to category headings is based on the Geary-Khamis (GK) method (Dikhonov, 1997; Geary, 1958; Khamis, 1972). These data sets include a total of 115 countries in 1996 and 145 countries in 2005 as Greece is not included in the 2005 sample obtained from the World Bank. One country, Herzegovina, in the 1996 ICP data does not have associated population data so it is excluded from the sample leaving 114 countries (Seale et al., 2003). Comoros in the 2005 ICP data is excluded from the sample due to missing data leaving a total of 144 countries.

Differences exist in terms of aggregation for the categories food and beverages and tobacco of Seale et al. (1991) and of this study for the 1996 and 2005 ICP data. Seale et al. (1991) aggregate the data into 11 categories of goods: food; beverages and tobacco; clothing and footwear; gross rent; house furnishings, furniture; medical care; transport and communications; recreation; education; other; and energy. For our purposes, the categories of food and beverages and tobacco in the 1996 and 2005 ICP data are combined into one category leaving 10 aggregate categories; food, beverages and tobacco; clothing and footwear; gross rent; house furnishings, furniture; medical care; transport and communications; recreation; education; other; and energy. For the 1970, 1975, 1980 and 1996 ICP data, the food category only includes food prepared and consumed at home. The 2005 category includes food consumed away from home in addition to food prepared and consumed at home.

There are slight differences in the way the category energy is formed as well, but in all cases it is private consumption of energy. In the 1970, 1975 and 1980 ICP data used by Seale et al. (1991), energy consists of gasoline, grease and oil used for transport and communications, and fuel and power including electricity, gas, liquid fuels, and other fuels, water charges and ice. The 1996 ICP data are available at a more aggregated level (26 goods) than the previous ICP data or the 2005 ICP data so that energy is defined to include operation of transportation equipment from transport and communication and fuel and power. For the 2005 ICP data, energy is defined to consist of electricity, gas, and other fuels from gross rent and power and fuel and lubricants for personal transport equipment from transport and communications.

4. The Florida model and estimation issues

As mentioned previously, the Florida model is used by Seale et al. (1991) to estimate the demand for energy. Specifically, the Florida model is

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

where w_{ic} $(=p_{ic}/E_c)$ is the budget share of a good i $(=1,\ldots,n)$ in country c $(=1,\ldots,N)$, p_{ic} is the price of good i in country c, q_c is the natural log of real per capita income in country c, $E_c\left(=\sum_{i=1}^{n}p_{ic}q_{ic}\right)$ is nominal per capital income in country c, $q_c^*=1+q_c$, $\bar{p}_i$ is the geometric mean price of good i over all countries, ϕ is the income flexibility (the reciprocal of the income elasticity of the marginal utility of income), and ε_{ic} is the error term. The following adding-up conditions apply: $\sum_{i=1}^{n}\alpha_i=1$ and $\sum_{i=1}^{n}\beta_i=0$.

It is important to understand the linear income term of the Florida model, $\alpha_i+\beta_i q_c$. In particular, the sign of its β_i parameter indicates whether a good is income elastic or inelastic. If it is positive and significantly different from zero, it indicates that good i has an income elasticity greater than one and is therefore income elastic. If its sign is negative and statistically different from zero, it indicates that the good has an income elasticity less than one and is income inelastic. If β_i is zero or near zero and statistically insignificant from zero, it indicates that the good is unitary elasticity. Accordingly, a β_i that is statistically zero does not indicate the model is fitting the data poorly, but that good i is statistically unitary elastic.

The Florida model may be estimated with maximum likelihood, for example, by the scoring method (Harvey, 1990, p. 134–35). When fitting the Florida model to 1970, 1975, and 1980 ICP data, Theil et al. (1989) find that the countries participating for the first time in the 1980 ICP have a larger covariance matrix than that of countries participating in the 1980 and earlier years. Essentially, the covariance matrices of the two groups of countries are of different sizes or group heteroskedasticity. To correct for group heteroskedasticity, they utilize a search routine that is maximum likelihood to find an appropriate weight for the second group's covariance matrix. Seale et al. (1991) also find group heteroskedasticity in their data and develop a scoring method to estimate the appropriate weight for correcting group heteroskedasticity. Seale and Regmi (2006) find covariance matrices of different sizes for three groups of countries in the 1996 ICP data and correct for this with maximum likelihood. Muhammad et al. (2011) also find group heteroskedasticity in the 2005 ICP data. The maximum likelihood method for correcting for group heteroskedasticity is presented in Appendix A.

Quality differences of the ICP data in the same year exist among countries. This is not surprising given the difference in affluence and general development among the countries in the ICP. Theil et al. (1989) suggest that undercounting of food consumption in poor African countries is part of the reason these countries are found to be outliers. Others have also identified outliers in the ICP data, and it is often the case that being an outlier is associated with first-time participation with the ICP (Fiebig et al., 1987; Seale and Regmi, 2006; Seale et al., 1991; Seale et al., 2003). This too is not surprising given the complexity and information requirements of participating in the ICP. For example, in the 2005 ICP, 22 countries (Maldives, Angola, Burkina Faso, Comoros, Cape Verde, Democratic Republic of Congo, Djibouti, Gabon, Guinea Bissau, Guinea, Liberia, Lesotho, Morocco, Mauritania, Namibia, Rwanda, Sao Tome and Principe, Sudan, Swaziland, Todo, Uganda, and Zimbabwe) fail to submit price data for all basic headings and results from missing categories are imputed using results from countries within each region to produce full results (ICP, 2008).

The method for identifying outliers is by calculating information inaccuracy measures for all countries,

$$I_c = \sum_{i=1}^{11} w_{ic} \ln(w_{ic}/\hat{w}_{ic}) \tag{2}$$

where w_{ic} is the observed budget share of good i in country c, and $\hat{w}_{ic}$ is the predicted share from the model. I_c has a lower bound of 0 when $w_{ic} = \hat{w}_{ic}$, but no upper bound. For example, Seale and Regmi (2006) fit the Florida model to the 114 countries in the 1996 ICP, calculate I_c for all countries, omit all countries where $I_c > 0.135$, re-estimate the model with the remaining countries, and iterate until all countries included have information inaccuracy values less than 0.135. Using this procedure, they identify and omit 23 countries from the sample of 114 countries. However, Seale and Regmi (2009) show that the parameter estimates with or without the outliers are pairwise statistically the same and opt for reporting the full-sample results. Using the same procedure, Muhammad et al. (2011) identify and omit 19 countries in the 2005 ICP data out of the 144 countries leaving a sample of 125 countries. They find substantial differences between the parameter estimates obtained with or without the outliers being included.

5. Results for 43 countries

Seale et al. (1991) fit the Florida model to the pooled 1970, 1975 and 1980 ICP data for 57 countries of which 51 participate in 1980, and they estimate the αs, βs, φ, a heteroskedasticity term, K, and an AR(1) parameter, τ, with maximum likelihood using the program *Gauss*. Of the 51 countries in 1980, 43 (listed in column (1) of Table 2) participate in the 1996 and 2005 ICPs while eight countries (Columbia, Costa Rica, Dominican Republic, El Salvador, Greece, India, Panama, and Yugoslavia) do not.

For this paper, we first focus on these 43 countries. The Florida model is fit separately to the 1996 and 2005 data of the 43 countries, and the αs, βs, and φ are estimated with maximum likelihood using *Gauss for Windows*. The parameter results with associated asymptotic standard errors from Seale et al. (1991) are reported in columns (2) and (3) of Table 1. Those of the 1996 ICP are reported in columns (4) and (5) of Table 1 while those of the 2005 ICP are reported in columns (6) and (7).

While the focus of this paper is on energy demand, it is worth commenting on some of the parameters of the other nine goods. In all three years, the income parameter, β, of food, beverages and tobacco is negative and statistically different from zero indicating that this good is a necessity and income inelastic. The βs for this group in 1980 and 1996 are similar, but it is smaller absolutely in 2005. This is partially because the aggregations of 1980 and 1996 are similar for the group, food, beverages, and tobacco, and include only food prepared and consumed at home, while the 2005 category includes additionally food consumed away from home.

In all three years, the β of clothing and footwear is negative, is not statistically different from zero, and indicates that this category is statistically unitary elastic. The βs of gross rent and transportation and communication are all positive, but their magnitudes differ among the three phases. Differences across the years also occur for the β of education which is positive in 1980 and 1996 but is negative in sign in 2005. However, the parameter is statistically the same as zero in all three phases.

Concentrating on energy, its β parameter is positive and statistically significantly different from zero ($\alpha = .05$) in 1980 indicating that energy is a luxury good and income elastic in that year. In 1996, the parameter turns negative but is not statistically different from zero so that energy in that year is statistically unitary. In 2005, the parameter is again negative but is statistically different from zero and indicates that for this year energy is a necessity and income inelastic.

The αs are not directly comparable across the three periods. One can relate these, however, to the predicted budget shares for the United States as its real per capita income is normalized to equal one. Thus, the Florida model predicts that the budget share of the United States is about 0.07 in 1980, 0.09 in 1996 and 0.05 in 2005. The actual budget shares for the United States in these years are 0.09, 0.08 and 0.06, respectively.

5.1. Income elasticities

Income elasticities may be calculated from the parameters of the Florida model. The income elasticity is computed as

$$\eta_i = \theta_{ic}/\bar{w}_{ic} = 1 + \beta_i/\bar{w}_{ic}, \tag{3}$$

where w_{ic} is the budget share for good i in country c calculated at geometric mean prices, and θ_{ic} is the marginal share of good i in country c also evaluated at geometric mean prices (Seale and Regmi, 2006). An income elasticity measures the percent change in quantity demanded for a good when total income increases by 1%.

The income elasticities for the 43 countries in 1980, 1996, and 2005 data are displayed in columns (3), (6), and (9) of Table 2. Countries, listed in columns (1), (4), and (7) of Table 2, are ranked by affluence in descending order in each of the years. For each of the years, the United States is the richest country and Tanzania is the poorest. Note that the orders differ

Table 2
A cross-country tabulation of income elasticities of demand, 43 countries, 1980, 1996, and 2005.

	1980[a]			1996			2005	
Country	Per capita income	Income elasticities	Country	Per capita income	Income elasticities	Country	Per capita income	Income elasticities
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
United States	1.000	1.173	United States	1.000	0.952	United States	1.000	0.815
Canada	0.992	1.174	Luxembourg	0.972	0.952	Luxembourg	0.906	0.818
Germany	0.850	1.178	Denmark	0.808	0.952	Austria	0.750	0.824
Luxembourg	0.845	1.179	Hong Kong	0.799	0.952	United Kingdom	0.720	0.825
Belgium	0.829	1.179	Canada	0.754	0.952	Norway	0.692	0.827
Denmark	0.825	1.179	Japan	0.741	0.952	Netherlands	0.692	0.827
France	0.811	1.180	Germany	0.718	0.953	Canada	0.682	0.827
Netherlands	0.779	1.181	Austria	0.715	0.953	Germany	0.681	0.827
Austria	0.757	1.182	Italy	0.701	0.953	France	0.658	0.828
United Kingdom	0.717	1.184	Norway	0.695	0.953	Japan	0.644	0.829
Norway	0.701	1.185	Belgium	0.693	0.953	Belgium	0.643	0.829
Italy	0.697	1.185	United Kingdom	0.686	0.953	Hong Kong	0.623	0.830
Hong Kong	0.688	1.185	France	0.682	0.953	Denmark	0.607	0.830
Japan	0.616	1.189	Netherlands	0.646	0.953	Ireland	0.604	0.831
Finland	0.599	1.190	Finland	0.587	0.953	Italy	0.592	0.831
Spain	0.559	1.193	Israel	0.577	0.953	Spain	0.584	0.832
Israel	0.456	1.201	Ireland	0.522	0.953	Finland	0.562	0.833
Ireland	0.454	1.201	Spain	0.508	0.953	Portugal	0.466	0.838
Uruguay	0.414	1.205	Portugal	0.505	0.953	Israel	0.446	0.839
Venezuela	0.412	1.205	Korea	0.495	0.953	Korea	0.379	0.843
Portugal	0.396	1.206	Argentina	0.385	0.954	Hungary	0.353	0.845
Hungary	0.374	1.209	Hungary	0.346	0.954	Poland	0.314	0.847
Brazil	0.368	1.210	Uruguay	0.314	0.954	Argentina	0.224	0.855
Argentina	0.361	1.211	Tunisia	0.307	0.954	Chile	0.205	0.857
Poland	0.346	1.212	Poland	0.283	0.955	Uruguay	0.204	0.857
Chile	0.324	1.215	Chile	0.273	0.955	Brazil	0.157	0.862
Peru	0.231	1.232	Brazil	0.217	0.955	Venezuela	0.151	0.863
Ecuador	0.205	1.239	Venezuela	0.177	0.955	Peru	0.136	0.865
Korea	0.204	1.239	Morocco	0.176	0.956	Tunisia	0.132	0.865
Paraguay	0.197	1.241	Botswana	0.168	0.956	Ecuador	0.121	0.867
Tunisia	0.182	1.246	Peru	0.168	0.956	Paraguay	0.102	0.870
Philippines	0.168	1.251	Philippines	0.163	0.956	Botswana	0.086	0.873
Bolivia	0.144	1.261	Indonesia	0.126	0.956	Sri Lanka	0.085	0.873
Sri Lanka	0.131	1.268	Sri Lanka	0.108	0.956	Bolivia	0.077	0.874
Pakistan	0.118	1.275	Ecuador	0.103	0.957	Philippines	0.076	0.875
Morocco	0.114	1.278	Bolivia	0.101	0.957	Indonesia	0.075	0.875
Botswana	0.106	1.284	Paraguay	0.091	0.957	Pakistan	0.071	0.876
Indonesia	0.092	1.295	Pakistan	0.082	0.957	Morocco	0.069	0.876
Senegal	0.078	1.311	Senegal	0.069	0.957	Senegal	0.040	0.884
Nigeria	0.067	1.326	Madagascar	0.038	0.958	Nigeria	0.039	0.884
Madagascar	0.065	1.329	Zambia	0.035	0.959	Zambia	0.027	0.889
Zambia	0.042	1.384	Nigeria	0.029	0.959	Madagascar	0.027	0.889
Tanzania	0.033	1.424	Tanzania	0.020	0.959	Tanzania	0.023	0.891

[a] 1980 figures are from Table 2 of Seale et al. (1991).

among the years as the rankings in terms of affluence have changed over the 25 years.

The 1980 income elasticities of demand for energy from Seale et al. (1991) are reported in column (3) of Table 2. Starting with the United States and traveling towards the middle- and low-income countries, the income elasticities increase in magnitude, and all are above 1.0 and elastic. The range is from 1.17 for the United States to 1.42 for Tanzania.

Traveling through time to 1996, we see that the income elasticities of demand for energy are slightly below unity with a tight range between 0.95 and 0.96. These elasticities are smaller and differ markedly from the corresponding ones of 1980. The range is also notably smaller. The elasticity of the United States has decreased from 1.17 to 0.95 while that of Tanzania has diminished considerably from 1.42 to 0.96.

The pattern of smaller income elasticities of demand for energy for each country continues as we travel to 2005. Now the income elasticities are all below 1.0. For the United States, it is 0.82 while it is 0.89 for Tanzania. As can be seen by inspecting the income term, β, for energy, the elasticities are significantly different from 1.0.

5.2. Three measures of own-price elasticities

Three types of own-price elasticities may be obtained by making different assumptions concerning income (Theil et al., 1989, pp. 110–113). The Frisch own-price elasticity measures the change in quantity demanded when own-price changes and income is compensated in such a way as to keep the marginal utility of income constant. It is calculated from the Florida-model parameters as

$$F_{iic} = \varphi(\bar{w}_{ic} + \beta_i)/\bar{w}_{ic} = \varphi\eta_i. \tag{4}$$

The Slutsky own-price elasticity is obtained by compensating income such that real income is held constant. It is calculated from the Florida-model parameters as

$$S_{iic} = \frac{\varphi(\bar{w}_{ic} + \beta_i)(1-\bar{w}_{ic}-\beta_i)}{\bar{w}_{ic}} = F_{iic}(1-\bar{w}_{ic}-\beta_i). \tag{5}$$

The Slutsky price elasticity is most often used in the measurement of welfare from changes in price.

The Cournot or uncompensated own-price elasticity is obtained when nominal income is held constant. It is calculated from the Florida-model parameters as

$$C_{iic} = \frac{\varphi(\bar{w}_{ic}+\beta_i)(1-\bar{w}_{ic}-\beta_i)}{\bar{w}_{ic}} - (\bar{w}_{ic}+\beta_i) = S_{iic} - (\bar{w}_{ic}+\beta_i). \qquad (6)$$

The Cournot own-price elasticity includes both the substitution effect and the income effect from a change in own-price. It measures the market response of quantity demanded when own-price changes. Cournot elasticities are often used in econometric and simulation models.

The three types of own-price elasticities of energy demand for the 43 countries in 1980, 1996, and 2005 are displayed in Table 3 below. The countries in Table 3 are listed by affluence in descending order.

5.2.1. Frisch own-price elasticities

The Frisch own-price elasticities of demand for energy reported in columns (2), (6), and (10) of Table 3 are larger than the corresponding Slutsky ones reported in columns (3), (7), and (11) of Table 3, but they are smaller than the corresponding Cournot own-price elasticities reported in columns (4), (8), and (12). When traveling from rich to poor countries, the Frisch own-price elasticities increase absolutely in all three periods. While traveling in time from 1980 to 1996 and from 1996 to 2005, the Frisch own-price elasticities grow smaller absolutely and the ranges become smaller as well. In 1980, the Frisch own-price elasticity of energy demand is −0.86 for the United States and increases in size absolutely until it becomes just greater than unity for Tanzania. The own-price elasticity of energy demand in the United States in 1996 (−0.72) is smaller in size absolutely than the 1980 value. As one travels towards poorer countries, the elasticities increase only slightly to −0.73 for Tanzania. Traveling from 1996 to 2005, the own-price elasticity of energy demand decreases absolutely for the United States with a value of −0.64. The range between the richest and poorest countries is small, and their values increase absolutely until reaching Tanzania with a value of −0.70.

5.2.2. Slutsky own-price elasticities

In 1980, the Slutsky own-price elasticity for energy demand increases in absolute value from −0.79 in the United States to −1.00 or unitary for the poorest country, Tanzania. It is somewhat smaller for the United States (−0.66) in 1996 than in 1980 with no significant change in value going from the United States to Tanzania. As with the Frisch, the

Table 3
A cross-country tabulation of own-price elasticities of demand, 1980, 1996, and 2005.

	1980[a]				1996				2005		
Country	Frisch	Slutsky	Cournot	Country	Frisch	Slutsky	Cournot	Country	Frisch	Slutsky	Cournot
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
United States	−0.855	−0.787	−0.867	United States	−0.719	−0.658	−0.743	United States	−0.636	−0.609	−0.651
Canada	−0.855	−0.787	−0.867	Luxembourg	−0.719	−0.658	−0.743	Luxembourg	−0.638	−0.611	−0.654
Germany	−0.859	−0.792	−0.870	Denmark	−0.720	−0.658	−0.744	Austria	−0.643	−0.614	−0.659
Luxembourg	−0.859	−0.792	−0.870	Hong Kong	−0.720	−0.658	−0.744	United Kingdom	−0.644	−0.615	−0.660
Belgium	−0.859	−0.793	−0.870	Canada	−0.720	−0.658	−0.744	Norway	−0.645	−0.615	−0.661
Denmark	−0.859	−0.793	−0.870	Japan	−0.720	−0.658	−0.744	Netherlands	−0.645	−0.615	−0.661
France	−0.860	−0.794	−0.871	Germany	−0.720	−0.658	−0.744	Canada	−0.645	−0.616	−0.662
Netherlands	−0.861	−0.795	−0.871	Austria	−0.720	−0.658	−0.744	Germany	−0.645	−0.616	−0.662
Austria	−0.861	−0.796	−0.872	Italy	−0.720	−0.658	−0.744	France	−0.646	−0.616	−0.663
United Kingdom	−0.863	−0.798	−0.873	Norway	−0.720	−0.658	−0.744	Japan	−0.647	−0.617	−0.663
Norway	−0.863	−0.798	−0.874	Belgium	−0.720	−0.658	−0.744	Belgium	−0.647	−0.617	−0.663
Italy	−0.863	−0.798	−0.874	United Kingdom	−0.720	−0.658	−0.744	Hong Kong	−0.647	−0.617	−0.664
Hong Kong	−0.864	−0.799	−0.874	France	−0.720	−0.658	−0.744	Denmark	−0.648	−0.618	−0.665
Japan	−0.867	−0.803	−0.876	Netherlands	−0.720	−0.658	−0.744	Ireland	−0.648	−0.618	−0.665
Finland	−0.867	−0.804	−0.877	Finland	−0.720	−0.658	−0.745	Italy	−0.649	−0.618	−0.665
Spain	−0.869	−0.806	−0.879	Israel	−0.720	−0.658	−0.745	Spain	−0.649	−0.618	−0.666
Israel	−0.875	−0.813	−0.884	Ireland	−0.720	−0.657	−0.745	Finland	−0.650	−0.619	−0.667
Ireland	−0.875	−0.814	−0.884	Spain	−0.720	−0.657	−0.745	Portugal	−0.654	−0.621	−0.671
Uruguay	−0.878	−0.817	−0.886	Portugal	−0.720	−0.657	−0.745	Israel	−0.655	−0.622	−0.672
Venezuela	−0.878	−0.817	−0.886	Korea	−0.721	−0.657	−0.745	Korea	−0.658	−0.624	−0.676
Portugal	−0.878	−0.817	−0.886	Argentina	−0.721	−0.657	−0.746	Hungary	−0.659	−0.625	−0.677
Hungary	−0.879	−0.819	−0.888	Hungary	−0.721	−0.657	−0.746	Poland	−0.661	−0.626	−0.679
Brazil	−0.881	−0.821	−0.889	Uruguay	−0.721	−0.657	−0.746	Argentina	−0.667	−0.629	−0.686
Argentina	−0.882	−0.822	−0.890	Tunisia	−0.721	−0.656	−0.746	Chile	−0.669	−0.630	−0.688
Poland	−0.882	−0.823	−0.890	Poland	−0.721	−0.656	−0.747	Uruguay	−0.669	−0.630	−0.688
Chile	−0.884	−0.824	−0.891	Chile	−0.721	−0.656	−0.747	Brazil	−0.673	−0.632	−0.692
Peru	−0.886	−0.827	−0.893	Brazil	−0.722	−0.656	−0.747	Venezuela	−0.673	−0.633	−0.693
Ecuador	−0.898	−0.842	−0.904	Venezuela	−0.722	−0.656	−0.748	Peru	−0.675	−0.633	−0.695
Korea	−0.903	−0.848	−0.909	Morocco	−0.722	−0.656	−0.748	Tunisia	−0.675	−0.633	−0.695
Paraguay	−0.903	−0.848	−0.909	Botswana	−0.722	−0.655	−0.748	Ecuador	−0.677	−0.634	−0.697
Tunisia	−0.905	−0.850	−0.910	Peru	−0.722	−0.655	−0.748	Paraguay	−0.679	−0.635	−0.699
Philippines	−0.908	−0.845	−0.914	Philippines	−0.722	−0.655	−0.748	Botswana	−0.681	−0.636	−0.702
Bolivia	−0.911	−0.858	−0.917	Indonesia	−0.723	−0.655	−0.749	Sri Lanka	−0.681	−0.636	−0.702
Sri Lanka	−0.919	−0.867	−0.924	Sri Lanka	−0.723	−0.655	−0.749	Bolivia	−0.682	−0.637	−0.704
Pakistan	−0.924	−0.872	−0.928	Ecuador	−0.723	−0.655	−0.749	Philippines	−0.683	−0.637	−0.704
Morocco	−0.929	−0.879	−0.933	Bolivia	−0.723	−0.655	−0.749	Indonesia	−0.683	−0.637	−0.704
Botswana	−0.931	−0.881	−0.935	Paraguay	−0.723	−0.654	−0.749	Pakistan	−0.683	−0.637	−0.705
Indonesia	−0.935	−0.886	−0.939	Pakistan	−0.723	−0.654	−0.750	Morocco	−0.684	−0.637	−0.705
Senegal	−0.944	−0.895	−0.947	Senegal	−0.723	−0.654	−0.750	Senegal	−0.690	−0.639	−0.713
Nigeria	−0.955	−0.908	−0.957	Madagascar	−0.724	−0.653	−0.752	Nigeria	−0.690	−0.639	−0.713
Madagascar	−0.966	−0.920	−0.968	Zambia	−0.724	−0.653	−0.752	Zambia	−0.694	−0.640	−0.717
Zambia	−0.969	−0.923	−0.970	Nigeria	−0.725	−0.652	−0.752	Madagascar	−0.694	−0.640	−0.717
Tanzania	−1.008	−0.997	−1.008	Tanzania	−0.725	−0.651	−0.753	Tanzania	−0.695	−0.641	−0.719

[a] 1980 figures are from Table 2 of Seale et al. (1991).

Table 4
Maximum likelihood estimation of ten goods including energy, 1980, 1996 and 2005.

Good or parameter	1996 Data (114 countries)		1996 data (71 countries)		2005 data (125 countries)		2005 data (101 Countries)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Income flexibility, ϕ	−0.797	(0.021)[a]	−0.791	0.023	−0.708	(0.027)	−0.687	(0.035)
Coefficient β_i								
Food, beverages, and tobacco	−0.134	(0.006)	−0.126	(0.009)	−0.105	(0.004)	−0.095	(0.005)
Clothing and footwear	−0.006	(0.002)	−0.006	(0.003)	−0.002	(0.002)	−0.003	(0.002)
Gross rent and fuel	0.026	(0.004)	0.026	(0.006)	0.016	(0.003)	0.005	(0.004)
House furnishing	0.013	(0.002)	0.013	(0.003)	0.003	(0.001)	0.006	(0.002)
Medical care	0.024	(0.003)	0.024	(0.003)	0.020	(0.002)	0.013	(0.003)
Transport and communications	0.013	(0.003)	0.013	(0.003)	0.017	(0.002)	0.024	(0.003)
Recreation	0.020	(0.002)	0.020	(0.003)	0.026	(0.002)	0.034	(0.002)
Education	0.005	(0.002)	0.006	(0.003)	−0.003	(0.002)	−0.005	(0.002)
Other	0.033	(0.003)	0.023	(0.005)	0.030	(0.002)	0.021	(0.003)
Energy	0.006	(0.003)	0.010	(0.003)	−0.001	(0.002)	0.000	(0.002)
Coefficient α_i								
Food, beverages, and tobacco	0.154	(0.012)	0.154	(0.017)	0.170	(0.009)	0.187	(0.010)
Clothing and footwear	0.059	(0.004)	0.059	(0.007)	0.052	(0.004)	0.047	(0.004)
Gross rent and fuel	0.134	(0.008)	0.134	(0.011)	0.154	(0.006)	0.144	(0.007)
House furnishing	0.078	(0.004)	0.078	(0.006)	0.060	(0.003)	0.061	(0.003)
Medical care	0.106	(0.004)	0.106	(0.006)	0.095	(0.005)	0.078	(0.006)
Transport and communications	0.084	(0.004)	0.084	(0.006)	0.138	(0.005)	0.151	(0.006)
Recreation	0.074	(0.004)	0.074	(0.005)	0.103	(0.003)	0.120	(0.005)
Education	0.075	(0.004)	0.078	(0.006)	0.026	(0.004)	0.021	(0.004)
Other	0.146	(0.006)	0.119	(0.009)	0.141	(0.005)	0.124	(0.006)
Energy	0.090	(0.006)	0.088	(0.006)	0.063	(0.004)	0.068	(0.005)
K1	1.093	(0.107)	N.A.	N.A.	1.140	(0.120)	N.A.	N.A.
K2	1.110	(0.065)	N.A.	N.A.	1.500	(0.078)	N.A.	N.A.

N.A. = not applicable.
[a] Asymptotic standard errors are reported in parentheses.

elasticities decrease (absolutely) going from 1996 to 2005. In 2005, it is −0.61 for the United States while it increases absolutely, but not by much, when traveling to Tanzania where it reaches the value of −0.64.

5.2.3. Cournot own-price elasticities

The Cournot elasticities increase (in absolute terms) when traveling from affluent countries to poor countries for all three periods. In 1980, it starts at −0.87 for the United States and increases absolutely while traveling towards Tanzania where the elasticity is −1.01. The 1996 Cournot own-price elasticities for the countries are smaller than the corresponding ones in 1980. The range is also smaller going from −0.74 in United States to −0.75 in Tanzania. When traveling from 1996 to 2005, the Cournot own-price elasticity again decreases absolutely for all countries, but the range is somewhat larger than that of 1996. It is −0.65 in the United States and is −0.72 in Tanzania.

6. Analysis of remaining countries

In addition to the 43 countries above, there are 71 and 101 countries in the 1996 and 2005 data. The names of these countries are reported in columns (1) and (8) of Table 5. It is noteworthy that the vast majority of countries in both years are middle- and low-income countries.

If these 71 and 101 countries are poolable with the 43 in the same year, one could obtain more precise parameter estimates. However, if the data are not poolable, then pooling the country data could lead to misleading results and elasticity estimates. In order to decide whether the data are poolable, the Florida model is fit to the 71 and 101 country data separately. Parameter estimates with associated asymptotic standard errors in 1996 are reported in columns (4) and (5) of Table 4 and in columns (8) and (9) of Table 4 for 2005.

Next the data are pooled, and the Florida model is fit to the expanded data sets for 1996 and 2005. All 114 countries are used for analysis for 1996. For 2005, we follow Muhammad et al. (2011) and omit 19 countries that are identified as outliers leaving a sample of 125.[1] These parameter estimates are obtained by maximum likelihood utilizing the heteroskedastic extension in Appendix A. Parameter estimates with associated asymptotic standard errors in 1996 are reported in columns (2) and (3) of Table 4 and in columns (6) and (7) of Table 4 for 2005.

Concentrating on the β parameter of energy in 1996, it is clear that the coefficients in 1996 are statistically different between that of the 43 countries and the 71 countries. The estimate for the 43 countries is negative but statistically the same as zero while it is positive and statistically different from zero for the 71 countries. The estimate of the 43 countries indicates that energy is approximately unitary elastic while that of the 71 indicates that energy demand is elastic. The parameter estimate obtained from the full 144 countries is smaller than that of the 71, but it is still statistically different from zero indicating elastic demand.

Next concentrating on 2005, it is again clear that the β parameters for the 43 countries differs from that of the 101 countries. The β parameter of energy demand for the 43 countries is negative and statistically different from zero indicating that energy demand for these countries is inelastic. For the 101 countries, it is equal to zero and statistically the same as zero indicating unitary elasticity. The β parameter of energy of the 125 countries is barely negative (−0.001) and is statistically the same as zero.

Based on the above, it seems imprudent to pool the data of the 43 countries with the data of the remaining countries in either 1996 or 2005. As such, income and own-price elasticities are calculated in 1996 and 2005 for the remaining countries based on the 71 country and 101 country results, respectively. These elasticity estimates are

[1] The Florida model is also fit to the 2005 data of 144 countries, and the α (0.069) and β (−0.000) parameter estimates of energy as well as the elasticity estimates calculated from these parameters are essentially identical to those obtained using the data of 125 countries.

Table 5
A cross-country tabulation of income and price elasticities of demand, 1996 and 2005.

1996, 71 countries						2005, 101 COUNTRIES					
			Own-price elasticities						Own-price elasticities		
Country	Per capita income	Income elasticities	Frisch	Slutsky	Cournot	Country	Per capita income	Income elasticities	Frisch	Slutsky	Cournot
1	2	4	5	6	7	1	2	4	5	6	7
Iceland	0.801	1.112	−0.880	−0.796	−0.891	Switzerland	0.726	1.000	−0.687	−0.641	−0.708
Barbados	0.796	1.112	−0.880	−0.796	−0.891	Iceland	0.689	1.000	−0.687	−0.641	−0.708
Switzerland	0.794	1.112	−0.880	−0.796	−0.891	Cyprus	0.640	1.000	−0.687	−0.641	−0.708
Bermuda	0.782	1.113	−0.880	−0.796	−0.892	Australia	0.636	1.000	−0.687	−0.641	−0.708
Australia	0.732	1.114	−0.881	−0.797	−0.892	Sweden	0.618	1.000	−0.687	−0.641	−0.708
Sweden	0.638	1.115	−0.882	−0.800	−0.893	Taiwan	0.567	1.000	−0.687	−0.641	−0.708
Bahamas	0.593	1.116	−0.883	−0.801	−0.894	New Zealand	0.551	1.000	−0.687	−0.641	−0.708
New Zealand	0.585	1.116	−0.883	−0.801	−0.894	Kuwait	0.507	1.000	−0.687	−0.641	−0.708
Mauritius	0.558	1.117	−0.884	−0.802	−0.894	Malta	0.501	1.000	−0.687	−0.641	−0.708
Singapore	0.536	1.118	−0.884	−0.803	−0.895	Singapore	0.480	1.000	−0.687	−0.641	−0.708
Greece	0.485	1.119	−0.885	−0.805	−0.896	Qatar	0.474	1.000	−0.687	−0.641	−0.708
Czech Republic	0.451	1.120	−0.886	−0.806	−0.896	Slovenia	0.439	1.000	−0.687	−0.641	−0.708
Slovenia	0.437	1.121	−0.886	−0.807	−0.897	Czech Republic	0.420	1.000	−0.687	−0.641	−0.708
Qatar	0.426	1.121	−0.887	−0.807	−0.897	Bahrain	0.380	1.000	−0.687	−0.641	−0.708
Oman	0.403	1.122	−0.887	−0.808	−0.897	Slovak Republic	0.351	1.000	−0.687	−0.641	−0.708
Slovakia	0.319	1.125	−0.890	−0.813	−0.900	Brunei	0.347	1.000	−0.687	−0.641	−0.708
St. Kitts & Nevis	0.311	1.126	−0.890	−0.814	−0.900	Estonia	0.332	1.000	−0.687	−0.641	−0.708
Gabon	0.301	1.126	−0.891	−0.814	−0.900	Lithuania	0.319	1.000	−0.687	−0.641	−0.708
Estonia	0.299	1.126	−0.891	−0.814	−0.900	Macao	0.318	1.000	−0.687	−0.641	−0.708
Trinidad & Tobago	0.291	1.127	−0.891	−0.815	−0.901	Croatia	0.316	1.000	−0.687	−0.641	−0.708
Antigua & Barbuda	0.273	1.128	−0.892	−0.816	−0.901	Lebanon	0.284	1.000	−0.687	−0.641	−0.708
Bahrain	0.269	1.128	−0.892	−0.816	−0.901	Mexico	0.274	1.000	−0.687	−0.641	−0.708
Mexico	0.263	1.128	−0.893	−0.817	−0.902	Latvia	0.270	1.000	−0.687	−0.641	−0.708
Iran	0.258	1.129	−0.893	−0.817	−0.902	Iran	0.251	1.000	−0.687	−0.641	−0.708
Romania	0.248	1.129	−0.893	−0.818	−0.902	Oman	0.235	1.000	−0.687	−0.641	−0.708
Lithuania	0.243	1.130	−0.894	−0.819	−0.903	Bulgaria	0.228	1.000	−0.687	−0.641	−0.708
Turkey	0.236	1.130	−0.894	−0.819	−0.903	Russia	0.220	1.000	−0.687	−0.641	−0.708
Grenada	0.233	1.130	−0.894	−0.820	−0.903	Kazakhstan	0.212	1.000	−0.687	−0.641	−0.708
Fiji	0.232	1.131	−0.894	−0.820	−0.903	Mauritius	0.204	1.000	−0.687	−0.641	−0.708
Russia	0.225	1.131	−0.895	−0.820	−0.903	Saudi Arabia	0.201	1.000	−0.687	−0.641	−0.708
Bulgaria	0.218	1.132	−0.895	−0.821	−0.904	Romania	0.200	1.000	−0.687	−0.641	−0.708
St. Lucia	0.216	1.132	−0.895	−0.821	−0.904	Belarus	0.196	1.000	−0.687	−0.641	−0.708
Latvia	0.214	1.132	−0.895	−0.821	−0.904	Serbia	0.196	1.000	−0.687	−0.641	−0.708
Dominica	0.203	1.133	−0.896	−0.822	−0.905	Bosnia-Herzegovina	0.193	1.000	−0.687	−0.641	−0.708
Kazakhstan	0.203	1.133	−0.896	−0.822	−0.905	Turkey	0.182	1.000	−0.687	−0.641	−0.708
Belarus	0.203	1.133	−0.896	−0.822	−0.905	Macedonia	0.180	1.000	−0.687	−0.641	−0.708
Lebanon	0.201	1.133	−0.896	−0.823	−0.905	South Africa	0.168	1.000	−0.687	−0.641	−0.708
Swaziland	0.197	1.133	−0.897	−0.823	−0.905	Montenegro	0.160	1.000	−0.687	−0.641	−0.708
St. Vincent & Grenadines	0.187	1.134	−0.897	−0.824	−0.906	Ukraine	0.154	1.000	−0.687	−0.641	−0.708
Egypt	0.186	1.134	−0.897	−0.824	−0.906	Malaysia	0.151	1.000	−0.687	−0.641	−0.708
Belize	0.185	1.134	−0.897	−0.824	−0.906	Armenia	0.141	1.000	−0.687	−0.641	−0.708
Macedonia	0.185	1.134	−0.897	−0.824	−0.906	Albania	0.130	1.000	−0.687	−0.641	−0.708
Thailand	0.170	1.136	−0.899	−0.826	−0.907	Colombia	0.127	1.000	−0.687	−0.641	−0.708
Ukraine	0.153	1.138	−0.900	−0.829	−0.908	Thailand	0.125	1.000	−0.687	−0.641	−0.708
Georgia	0.139	1.140	−0.902	−0.831	−0.909	Georgia	0.123	1.000	−0.687	−0.641	−0.708
Syria	0.138	1.140	−0.902	−0.831	−0.909	Jordan	0.121	1.000	−0.687	−0.641	−0.708
Guinea	0.130	1.141	−0.903	−0.832	−0.910	Egypt	0.114	1.000	−0.687	−0.641	−0.708
Zimbabwe	0.127	1.142	−0.903	−0.833	−0.911	Moldova	0.112	1.000	−0.687	−0.641	−0.708
Jamaica	0.126	1.142	−0.903	−0.833	−0.911	Swaziland	0.110	1.000	−0.687	−0.641	−0.708
Albania	0.123	1.142	−0.904	−0.834	−0.911	Fiji	0.106	1.000	−0.687	−0.641	−0.708
Jordan	0.114	1.144	−0.905	−0.835	−0.912	Equatorial Guinea	0.099	1.000	−0.687	−0.641	−0.708
Armenia	0.107	1.145	−0.906	−0.837	−0.913	Syria	0.092	1.000	−0.687	−0.641	−0.708
Moldova	0.096	1.147	−0.908	−0.839	−0.915	Azerbaijan	0.090	1.000	−0.687	−0.641	−0.708
Cameroon	0.096	1.147	−0.908	−0.839	−0.915	Gabon	0.089	1.000	−0.687	−0.641	−0.708
Kyrgyzstan	0.096	1.148	−0.908	−0.840	−0.915	Namibia	0.082	1.000	−0.687	−0.641	−0.708
Uzbekistan	0.095	1.148	−0.908	−0.840	−0.915	Cape Verde	0.076	1.000	−0.687	−0.641	−0.708
Cote d'Ivoire	0.090	1.149	−0.909	−0.841	−0.916	Kyrgyz Republic	0.075	1.000	−0.687	−0.641	−0.708
Azerbaijan	0.088	1.150	−0.909	−0.842	−0.916	Maldives	0.068	1.000	−0.687	−0.641	−0.708
Bangladesh	0.072	1.154	−0.913	−0.847	−0.919	Tajikistan	0.061	1.000	−0.687	−0.641	−0.708
Vietnam	0.071	1.154	−0.913	−0.847	−0.919	Lesotho	0.061	1.000	−0.687	−0.641	−0.708
Congo	0.065	1.156	−0.915	−0.850	−0.921	Sudan	0.058	1.000	−0.687	−0.641	−0.708
Turkmenistan	0.060	1.158	−0.916	−0.852	−0.922	China	0.054	1.000	−0.687	−0.641	−0.708
Nepal	0.058	1.159	−0.917	−0.853	−0.923	Bhutan	0.052	1.000	−0.687	−0.641	−0.708
Sierra Leone	0.058	1.159	−0.917	−0.853	−0.923	Iraq	0.050	1.000	−0.687	−0.641	−0.708
Kenya	0.053	1.161	−0.919	−0.855	−0.924	Mongolia	0.048	1.000	−0.687	−0.641	−0.708
Benin	0.049	1.164	−0.921	−0.858	−0.926	Vietnam	0.048	1.000	−0.687	−0.641	−0.708
Mongolia	0.039	1.170	−0.925	−0.864	−0.930	Yemen, Rep.	0.048	1.000	−0.687	−0.641	−0.708
Mali	0.039	1.170	−0.926	−0.864	−0.930	India	0.047	1.000	−0.687	−0.641	−0.708
Malawi	0.038	1.171	−0.926	−0.865	−0.931	São Tomé and Principe	0.045	1.000	−0.687	−0.641	−0.708
Yemen	0.035	1.174	−0.928	−0.868	−0.933	Cameroon	0.045	1.000	−0.687	−0.641	−0.708

(continued on next page)

Table 5 (*continued*)

1996, 71 countries						2005, 101 COUNTRIES					
			Own-price elasticities						Own-price elasticities		
Country	Per capita income	Income elasticities	Frisch	Slutsky	Cournot	Country	Per capita income	Income elasticities	Frisch	Slutsky	Cournot
1	2	4	5	6	7	1	2	4	5	6	7
Tajikistan	0.034	1.175	−0.929	−0.869	−0.934	Cambodia	0.042	1.000	−0.687	−0.641	−0.708
						Djibouti	0.039	1.000	−0.687	−0.641	−0.708
						Kenya	0.038	1.000	−0.687	−0.641	−0.708
						Lao PDR	0.035	1.000	−0.687	−0.641	−0.708
						Côte d'Ivoire	0.035	1.000	−0.687	−0.641	−0.708
						Bangladesh	0.035	1.000	−0.687	−0.641	−0.708
						Mauritania	0.034	1.000	−0.687	−0.641	−0.708
						Benin	0.034	1.000	−0.687	−0.641	−0.708
						Ghana	0.032	1.000	−0.687	−0.641	−0.708
						Nepal	0.031	1.000	−0.687	−0.641	−0.708
						Togo	0.029	1.000	−0.687	−0.641	−0.708
						Congo, Rep.	0.028	1.000	−0.687	−0.641	−0.708
						Uganda	0.027	1.000	−0.687	−0.641	−0.708
						Burkina Faso	0.025	1.000	−0.687	−0.641	−0.708
						Guinea	0.024	1.000	−0.687	−0.641	−0.708
						Sierra Leone	0.024	1.000	−0.687	−0.641	−0.708
						Mali	0.022	1.000	−0.687	−0.640	−0.708
						Central African Rep.	0.022	1.000	−0.687	−0.640	−0.708
						Gambia	0.022	1.000	−0.687	−0.640	−0.708
						Chad	0.021	1.000	−0.687	−0.640	−0.708
						Angola	0.021	1.000	−0.687	−0.640	−0.708
						Rwanda	0.019	1.000	−0.687	−0.640	−0.708
						Malawi	0.018	1.000	−0.687	−0.640	−0.708
						Mozambique	0.017	1.000	−0.687	−0.640	−0.708
						Guinea-Bissau	0.014	1.000	−0.687	−0.640	−0.708
						Niger	0.014	1.000	−0.687	−0.640	−0.708
						Ethiopia	0.014	1.000	−0.687	−0.640	−0.708
						Zimbabwe	0.012	1.000	−0.687	−0.640	−0.708
						Liberia	0.010	1.000	−0.687	−0.640	−0.708
						Burundi	0.009	1.000	−0.687	−0.640	−0.708
						Congo, Dem. Rep.	0.005	1.000	−0.687	−0.640	−0.708

reported in Table 5, and countries are reported for each year based on per capita income in descending order.

In 1996, Iceland is the richest of the 71 countries with an income per capita level of about 80% that of the United States. Tajikistan is the poorest with just over 3% per capita income level of the United States. The income elasticity of demand for 1996 is elastic and greater than unity for all countries starting at 1.11 for Iceland and increasing in magnitude to 1.18 for Tajikistan. In 2005, Switzerland is the richest of the 101 countries, and Democratic Republic of Congo is the poorest. In all cases in 2005, the income elasticity of energy demand is unitary and is less than that of 1996.

In 1996, the three types of own-price elasticities of demand for energy are similar in magnitude and have an inverse relationship with per capita income. The range starts at −0.80 for the Slutsky in Iceland and increases absolutely to −0.93 for the Frisch and Cournot in Tajikistan. The own-price elasticities of energy demand are quite a bit smaller absolutely in 2005 compared to 1996. The range is reasonably tight starting at −0.64 for the Slutsky in Switzerland and increases to −0.71 for the Cournot in the Democratic Republic of Congo. If one considers the variation within each column of own-price elasticities in 2005, there is none.

7. Conclusions

Income and own-price elasticities of demand for energy are indicators of the sensitivity of energy demand to changes in income and own-price. This paper estimates the magnitudes of these elasticities in 1996 and 2005 and makes comparisons with estimates from 1980 for the same set of 43 countries participating in the 1980, 1996, and 2005 ICPs. Based on this evidence, the questions, do income and own-price elasticities vary systematically with per capita income levels in a given year and do income and own-price elasticities for a country, whether rich or poor, vary over time?, are answered. Income elasticities of energy demands are found to vary inversely with per capita income in 2005 but not as much as they vary in 1980. In 1996, the variation is negligible. Income elasticities for the same countries do vary significantly over time. In 1980, the income elasticities are elastic, in 1996 they are unitary elastic, and in 2005 they are inelastic.

Own-price elasticities of energy demand for this set of countries are also found generally to vary inversely with per capita income levels. For each country, the own-price elasticities over the 25-year period diminish in size absolutely. The magnitudes of these elasticities are all above–0.50 (absolutely) even for the year 2005 ranging from −1.01 in 1980 for the poorest country to −0.61 in 2005 for the richest one.

The demand system is also fit to other countries in 1996 and 2005 that participate in ICP in these years but not in 1980. These data sets consist of mostly middle- and low-income countries. The income elasticities in both years are larger than in the same years for the data of the 43 countries. They are elastic for 1996 and unitary elastic for 2005. The same patterns hold for own-price elasticities for these countries as for the 43 countries.

Several implications may be drawn from the evidence of this study on income elasticities. As income growth is usually larger for poorer countries than rich ones, it is expected that the demand for energy in the future will grow faster for the poorer countries than for the richer ones on a per capita basis. Further, if income elasticities continue to decrease in magnitude in future years, the demand for energy use for private consumption should grow at a slower rate in both rich and poor countries on a per capita basis.

The evidence on own-price elasticities is that they are larger absolutely than earlier conventional evidence of −0.40 or even −0.5, and energy demand in poorer countries is more sensitive to changes in price than in more affluent countries. This suggests that energy demand is significantly dampened by high relative energy prices. This also has implications for energy tax policy. If the purpose of energy tax policy is to lower the amount of energy consumed, the policy should be effective even in rich countries although it should be even more effective in poorer countries.

Additionally, there are several exogenous factors, such as increasing volatility in the Middle East and Africa, which could affect supply and, therefore, price (U.S. Energy Information Administration, 2011). This may lead to countries developing alternative types of energy that are produced at lower costs. Nuclear energy is an alternative to fossil fuel and accounts for nearly 20% of the electricity production in the United States (United States Environmental Protection Agency, 2012). However, unforeseen events such as the earthquake and resulting tsunami which affected Japan's Fukushima Daiichi has had a major impact on nuclear power growth and its viability (U.S. Energy Information Administration, 2011) leading to uncertainty about the use of nuclear energy.

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Appendix A. Maximum likelihood estimation and heteroskedastic extension

Let

$$y_{ic} = f_{ic}(\theta_i) + \varepsilon_{ic} \qquad \text{A.1}$$

where ε_{ic}~N(0,Σ^*), i (=1, …, n) represents good i, n being the total number of goods, c (=1, …, N) represents country c, and N is the total number of countries. Because of adding-up restrictions, $\Sigma^*$is an $n \times n$ singular covariance matrix. Accordingly, we drop one equation for estimation purposes (Barten, 1969). Define Σ to be the $(n-1)\times(n-1)$ resulting covariance matrix of the $n-1$ equations. Rewrite A.1 in vector and matrix notation where y_c and ε_c are $n-1$ vectors, and y_{ic} and ε_{ic} are the ith elements, respectively, such that

$$y_c = f_c(\theta) + \varepsilon_c, \qquad \text{A.2}$$

and θ is a parameter vector to be estimated. Define $f_c(\theta)$to be

$$f_c(\theta) = \alpha + q_c\beta + X_c(\alpha + q_c\beta) - (\alpha + q_c\beta)x_c^T(\alpha + q_c\beta) + \varphi X_c(\alpha + q_c^*\beta) - \varphi(\alpha + q_c^*\beta)x_c^T(\alpha + q_c^*\beta) \qquad \text{A.3}$$

where $\alpha = [\alpha_i]$ and $\beta = [\beta_i]$ are $n-1$ vectors of parameters, X_c is a diagonal matrix of order $n-1$ with x_{ic} as the ith diagonal element, x_c is a column vector ($x_c^T$is its transpose) with x_{ic} as its ith element ($i = 1, \ldots, n-1$), and $x_{ic} = \ln\left({}^{p_{ic}}/_{\bar{P}_i}\right) - \left({}^{p_{nc}}/_{\bar{P}_i}\right)$ where $\bar{P}_i = \sum_c p_{ic}/N$ is the geometric mean price of good i over all N countries.

The log-likelihood function of Eq. (A.3) is

$$L = \text{constant} + \frac{1}{2}N\ln\left|\Sigma^{-1}\right| - \frac{1}{2}\sum_{c=1}^{N}[w_c - f_c(\theta)]^T\Sigma^{-1}[w_c - f_c(\theta)], \qquad \text{A.4}$$

and it must be maximized with respect to both unknown $\Sigma^{-1}$and θ. First we maximize L with respect to Σ^{-1} with the resulting solution,

$$\mathrm{R}(\theta) = \frac{1}{N}\sum_{c=1}^{N}[w_c - f_c(\theta)][w_c - f_c(\theta)]^T. \qquad \text{A.5}$$

Substituting R for Σ into Eq. (A.4) yields the concentrated log-likelihood function,

$$L^* = \text{constant} + \frac{1}{2}N\ln\left|R^{-1}\right|, \qquad \text{A.6}$$

First-order and the expectations of second-order derivatives with respect to $\theta(=\alpha, \beta, \varphi)$ are presented in Theil et al. (1989, pp. 44–47). The ML estimates of θ can be obtain through the method of scoring (Harvey, 1990, p. 134–35), and the asymptotic standard errors are computed from the square root of the diagonal of $-M^{-1}$ where M is the expectation of the matrix of the second derivatives $d^2L/d\theta d\theta^T$.

The heteroskedastic extension

Let there be G groups of countries and assume heteroskedasticity across the covariance matrices of the individual groups such that the covariance matrix of g (=1, …,G) is $K_g\Sigma$, and K_g is a scalar. In this case, the log-likelihood function is

$$L = \text{constant} - \frac{n-1}{2}\sum_g N_g \ln K_g + \frac{N}{2}\ln\left|\Sigma^{-1}\right| - \sum_g \frac{1}{2K_g}\sum_{c\in N_g}[w_c - f_c(\theta)]^T\Sigma^{-1}[w_c - f_c(\theta)] \qquad \text{A.7}$$

where $N = \sum_g N_g$, and the concentrated log-likelihood function is

$$L^* = \text{constant} - \frac{n-1}{2}\sum_g N_g \ln K_g + \frac{N}{2}\ln\left|R(\theta, K)^{-1}\right| \qquad \text{A.8}$$

where $R(\theta, K) = \frac{1}{N}\sum_g \frac{1}{K_g}\sum_{c\in N_g}[w_c - f_c(\theta)][w_c - f_c(\theta)]^T$, and K is defined as a vector of all K_g.

First-order derivatives of L^* with respect to $\theta(=\alpha, \beta, \varphi)$ are

$$\frac{dL^*}{d\theta^T} = \sum_g \frac{1}{K_g}\sum_{c\in N_g}\left[\frac{df_c(\theta)}{d\theta^T}\right]^T R^{-1}[w_c - f_c(\theta)] \qquad \text{A.9}$$

with $df_c(\theta)/d\theta^T$defined in Theil et al. (1989, pp.46–47). The first-order derivative of L* with respect to K_g is

$$\frac{dL^*}{dK_g} = -\frac{(n-1)N_g}{2K_g} - \frac{1}{2K_g^2}\sum_{c\in N_g}[w_c - f_c(\theta)]^T R^{-1}[w_c - f_c(\theta)], \qquad \text{A.10}$$

The second-order derivatives of L^* with respect to θ and K_g have zero expectations. Define M to be the matrix of the expectations of the second-order derivatives of L^* with respect to all $\theta(=\alpha, \beta, \varphi)$ and K_g. Thus,

$$M = \begin{bmatrix} \frac{d^2L^*}{d\theta d\theta^T} & 0 \\ 0 & \frac{d^2L^*}{dKdK^T} \end{bmatrix} \qquad \text{A.11}$$

where

$$\frac{d^2L^*}{d\theta d\theta^T} = \sum_g \frac{1}{K_g} \sum_{c \in N_g} \left[\frac{df_c(\theta)}{d\theta^T}\right]^T R^{-1} \left[\frac{df_c(\theta)}{d\theta^T}\right] \tag{A.12}$$

and $d^2L^*/dKdK^T$ is a $G \times G$ diagonal matrix with the gth diagonal element equal to

$$\frac{d^2L^*}{dK_g^2} = \frac{(n-1)N_g}{2K_g^2} - \frac{1}{K_g^3} \sum_{c \in N_g} [w_c - f_c(\theta)]^T R^{-1} [w_c - f_c(\theta)] \tag{A.13}$$

and all off-diagonal elements equal zero (i.e., $d^2L^*/dK_g dK_h = 0$ for $g \neq h$). The method of scoring (Harvey, 1990, p. 134–35) is used to estimate all $\theta(=\alpha, \beta, \varphi)$ and all elements of K. Asymptotic standard errors are calculated from the square root of the diagonals of $-M^{-1}$.

References

Barten, A.P., 1969. Maximum likelihood estimation of a complete system of demand equations. Eur. Econ. Rev. 1, 7–73.
Beenstock, M., Wilcocks, P., 1981. Energy consumption and economic activity in industrialized countries. Energy Econ. 3, 225–232.
Brenton, P., 1997. Estimates of the demand for energy using cross-country consumption data. Appl. Econ. 29, 851–859.
Clements, K.W., Chen, D., 2010. Affluence and food: a simple way to infer incomes. Am. J. Agric. Econ. 92 (4), 909–926.
Dahl, C.A., 1993. A survey of energy demand elasticities in support of the development of the NEMS. Prepared for United States Department of Energy, unpublished.
Deaton, A.S., Muellbauer, J., 1980. An almost ideal demand system. Am. Econ. Rev. 70, 312–326.
Dikhonov, Y., 1997. Sensitivity of PPP-based Income Estimates to Choice of Aggregation Procedure. Development Data Group, International Economics Department, World Bank, Washington, D.C.
Energy Modeling Forum, I.V., 1981. Aggregate elasticity of energy demand. Energy J. 2 (2), 37–76.
Fiebig, D.G., Seale Jr., J.L., Theil, H., 1987. The demand for energy: evidence from a cross-country demand system. Energy Econ. 9, 149–153.
Geary, R.C., 1958. A note on the comparison of exchange rates and purchasing power between countries. J. R. Stat. Soc. A 121, 97–99.
Harvey, A., 1990. The Econometric Analysis of Time Series, second ed. The MIT Press, Cambridge, MA.
International Comparison Program, Global Office, 2008. Global Purchasing Power, Parities, and Real Expenditures: 2005 International Comparison Program. The World Bank, Washington, D.C. http://siteresources.worldbank.org/ICPINT/Resources/icp-final.pdf Glob.
International Comparison Program, Global Office, 2010a. Overview. The World Bank Group. http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/ICPEXT/0,,contentMDK:22377119~menuPK:62002075~pagePK:60002244~piPK:62002388~theSitePK:270065,00.html or http://go.worldbank.org/PQ5ZPPYSY0.
International Comparison Program, Global Office, 2010b. What are PPPs? The World Bank Group. http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/ICPEXT/0,,contentMDK:22390971~pagePK:60002244~piPK:62002388~theSitePK:270065,00.html or http://go.worldbank.org/K520C6USR0.
Khamis, S.H., 1972. A new system of index numbers for national and international purposed. J. R. Stat. Soc. A 135, 96–121.
Kouris, G., 1983a. Energy consumption and economic activity in industrialized economies-a note. Energy Econ. 5, 207–212.
Kouris, G., 1983b. Energy demand elasticities in industrialized countries: a survey. Energy J. 4 (3), 73–94.
Muhammad, A., Seale Jr., J.L., Meade, B., Regmi, A., 2011. International evidence on food consumption patterns: an update using 2005 International Comparison Program Data. Technical Bulletin 1929. Economic Research Service, United States Department of Agriculture, Washington, D.C.
Pindyck, R.S., 1979. The Structure of World Energy Demand. The MIT Press, Cambridge, MA.
Rothman, D.S., Hong, J.H., Mount, T.D., 1994. Estimating consumer energy demand using international data: theoretical and policy implications. Energy J. 15, 67–88.
Seale Jr., J.L., Regmi, A., 2006. Modelling international consumption patterns. Rev. Income Wealth 52 (4), 603–624.
Seale Jr., J.L., Regmi, A., 2009. International consumption patterns: evidence from the 1996 International Comparison Programme. In: Ghatak, S., Levine, P. (Eds.), Development Macroeconomics: Essays in Memory of Anita Ghatak. Routledge, Taylor and Francis Group, London and New York, pp. 252–299.
Seale Jr., J.L., Walker, W.E., Kim, I.-M., 1991. The demand for energy: cross-country evidence using the Florida model. Energy Econ. 13, 33–40.
Seale Jr., J.L., Regmi, A., Bernstein, J., et al., 2003. International evidence on food consumption patterns. Technical Bulletin 1904. Economic Research Service, United States Department of Agriculture, Washington, D.C.
Taylor, L.D., 1977. The demand for energy: a survey of price and income elasticities. In: Nordhaus, W.D. (Ed.), International Studies of the Demand for Energy. North-Holland, Amsterdam, pp. 3–43.
Theil, H., 1997. In: Jorge, A., Salazar-Carillo, J. (Eds.), The Florida Model for Demand Analysis with Cross-country Data. Praeger Publishers, Westport, CT, pp. 227–236.
Theil, H., Chung, C.-F., Seale Jr., J.L., 1989. International Evidence on Consumption Patterns. JAI Press, Inc., Greenwich, CT.
Timmer, C.P., 1981. Is there curvature in the Slutsky matrix? Rev. Econ. Stat. 63, 395–402.
United States Energy Information Administration, 2010. Total primary energy consumption, in: International Energy Statistics. United States Department of Energy, Washington, D.C.. http://www.eia.doe.gov/oiaf/ieo/pdf/world.pdf.
United States Energy Information Administration, Office of Integrated Analysis and Forecasting, 2010. Chapter one: world energy demand and economic outlook. International Energy Outlook 2010. United States Department of Energy, Washington, D.C.. http://www.eia.doe.gov/oiaf/ieo/pdf/world.pdf.
United States Energy Information Administration, Office of Integrated Analysis and Forecasting, 2011. International Energy Outlook 2011. United States Department of Energy, Washington, D.C.. http://www.eia.gov/forecasts/ieo/pdf/0484%282011%29.pdf.
United States Environmental Protection Agency, 2012. Nuclear Energy. United States Environmental Protection Agency, Washington, D.C.. http://www.epa.gov/cleanenergy/energy-and-you/affect/nuclear.html.
Zilberfarb, B.-Z., Adams, F.G., 1981. The energy–GDP relationship in developing countries: Empirical evidence and stability tests. Energy Econ. 3, 244–248.