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Estimating Energy Demand Elasticities for OECD Countries
A Dynamic Panel Data Approach

Abstract:
This paper estimates price and GDP/income elasticities of several energy goods in OECD countries over 1978 to 1999 by applying the one-step GMM estimation method suggested by Arellano and Bond (1991) to a panel data set. The energy demand is specified by a simple partial adjustment model. We find that compared to conventional OLS and Within estimator, the one-step GMM estimator gives more intuitive results in terms of sign and magnitude. The results show that for electricity, natural gas and gas oil demand, price elasticities are in general larger (in absolute value) while GDP/income elasticities are lower in the residential sector than in the industrial sector. This paper yields lower values for price elasticities compared to the results from earlier studies. The long-run GDP/income elasticities found in this paper, however, are quite similar to those found in earlier studies, and are around unity in general.

Keywords: Energy demand elasticities, Panel data, ADL models, Partial adjustment model, One-step GMM estimator

JEL classification: C23, Q41

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1. Introduction

There exists discernible divergence among the estimates of energy demand elasticities from empirical studies due to the differences in modeling methodologies and/or data sets applied in these studies.[1] This makes it difficult to predict future demand for energy and analyze the effects of policy measures, for instance, when addressing the issue of stabilizing the greenhouse gas concentration. In this paper we employ a dynamic panel data estimation technique that has not been applied for this purpose before (as far as we know), hoping to increase the understanding of energy demand.

The application of panel data estimation techniques to the study of energy demand was pioneered by Balestra and Nerlove (1966) and followed by many other researchers in recent years.[2] Usually this estimation method employs a pooled cross-section time-series data set consisting of a group of countries over a period of time and assumes a uniform vector of slope coefficients across countries but different intercepts in order to account for country-specific factors (e.g. Baltagi and Griffin, 1983).

It has been highly recognized that using a panel data set, by taking into consideration variations both across time and individual countries, is more efficient in estimation than using either pure cross-section or pure time-series data only (Hsiao, 1985,1986; Klevmarken, 1989; Solon, 1989). Moreover, Baltagi (2001) states that panel data are also better able to study the dynamics of adjustment in some circumstances.

However, in a dynamic context, some problems will emerge. For example, the presence of lagged dependent variables on the right hand side of a regression equation could result in correlation between these variables and the gross error term, which renders the conventional ordinary least square (OLS) estimator biased and inconsistent. For instance, in a one-way error component model, Nickell (1981) found the Within estimator (OLS estimator by taking into account fixed effects for individual countries) to be biased when the number of observations per unit is finite and small and its consistency will depend upon time length being large. To solve the problem, Anderson and Hsiao (1981) suggested an instrument variable (IV) estimation method that leads to consistent but not necessarily efficient estimates of the parameters in the model. Arellano and Bond (1991) proposed a generalized method of moments (GMM) procedure that is considered to be more efficient than the Anderson and Hsiao (1982) estimator.

To my knowledge the Arellano and Bond (1991) estimation method has not been widely, if ever, applied for energy demand analysis. As such, this paper aims to make use of a simple partial adjustment model and apply the Arellano and Bond (1991) GMM estimation method to a panel data

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[1] For a recent survey on international energy elasticities, see Atkinson and Manning (1995).

[2] For an up-to-date discussion on panel data estimation techniques and applications, see Baltagi (2001).

set in order to estimate simultaneously short- and long-run price and GDP/income energy demand elasticities for a variety of energy goods in OECD countries over the period from 1978 to 1999. We will also compare the GMM results with the OLS and Within estimates in this paper.

The rest of this paper unfolds as follows. In Section 2 we discuss the construction and specification of a partial adjustment model of energy good demand in detail. Section 3 reviews the data and discusses estimation techniques employed in this study. OLS estimates and GMM estimates of the model are presented in Section 4 and compared. Section 5 concludes.

2. Model Specification

In order to estimate simultaneously short- and long-run elasticities of energy demand from one model, the introduction of dynamic factors becomes indispensable. However, there has been no unanimous voice in the literature with regard to the manner in which the dynamic factor should enter the model. A model that explicitly considers dynamic optimization over time is appealing in theory (e.g. Pindyck and Rotemberg, 1983), but is possibly less attractive for estimation purposes. While an *ad hoc* model has the virtue of simplicity of estimation (e.g. Prosser, 1985), it is harder to interpret convincingly. More often than not, it is researchers that make the final judgment on how to compromise between these two aspects.[3]

Given the data collected, we shall employ the autoregressive distributed lag (ADL) model in this study. Although the ADL model belongs generally to the family of *ad hoc* models, some of them have really sound behavioral theory as the foundation for the model construction. A general ADL (p, q) model has the form

(1) $$y_t = \mu + \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{j=0}^{q} \boldsymbol{\beta}'_{k,j} \mathbf{x}_{k,t-j} + u_t ,$$

where y_t is the current value of the dependent variable (energy use or energy demand in this study [4]), γ_i, $i = 1,2,..., p$, are coefficients of (autoregressive) lagged values of the dependent variable y. $\mathbf{x}_{k,t-j}$, $j = 0,1,..., q$, are *k*-element column vectors of current and distributed lagged values of independent variables and $\boldsymbol{\beta}_{k,j}$ is a column vector with *k* coefficients.[5] μ is a usual constant and u_t a white noise error term.

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[3] For a discussion on different dynamic models and the relationship among them, see Watkins (1991).

[4] Strictly speaking, energy use and energy demand are different concepts. The former is what we observe and is influenced by both demand and supply factors. In this study, we have implicitly assumed energy market to be in equilibrium at any observation year and therefore use either of the two concepts equivalently.

[5] In this paper, we only choose real energy price and per capita GDP/income as independent variables. Thus we have $k = 2$.

Restrictions on the lag length p and q, or more precisely, on the distribution of the coefficients γ_i and $\boldsymbol{\beta}_{k,j}$ will give different ADL models, and the way dynamic adaptation is modeled depends on the lag structure assumed. One particular case, which is employed in this study on energy demand analysis, is the ADL (1,0) model or so-called partial adjustment model. Although it is not derived from explicit dynamic optimization, this model rests on sound theoretical foundation for the model construction. Moreover, the virtue of simplicity of estimation remains.

Due to psychological reasons, people do not change their consumption habits immediately following a price decrease or an income increase perhaps because the process of change may involve some immediate disutility. Technological and institutional reasons also account for the dynamic nature. It takes time for producers to adjust the energy utilizing equipments when the price of energy goods changes. Therefore, one may expect that short-run price or income elasticities are generally smaller (in absolute value) than the corresponding long-run elasticities.

For the reasons mentioned above, the energy demand in this study is modeled as partial adjustment behavior of either industrial producers who demand energy goods as production inputs or residential consumers who need energy goods for direct use.

The derivation of the ADL (1,0) model is as follows. Consider the following equation form [6]

(2) $$y_t^* = \alpha_0 + \alpha_1 P_t + \alpha_2 I_t + \varepsilon_t ,$$

where y_t^* is desired demand of either industrial sector or residential sector for one type of energy good at time t; P_t is the corresponding real price of this type of energy good at time t [7]; I_t is either a country's real gross domestic product (GDP) at time t which is relevant for the industrial sector, or real disposable income at time t which is relevant for the residential sector; ε_t is a usual error term and assumed to be identically and independently distributed with zero mean and constant variance, i.e., $\varepsilon_t \sim IID\ (0, \sigma^2)$; α_0, α_1 and α_2 are parameters in the model.

Note that y_t^* here is the *desired* demand, which is unobservable to researchers. What the researchers could observe is the *actual* demand, y_t. The relationship between the desired demand and the actual demand is characterized by the partial adjustment behavior of either industrial producers or residential consumers as follows,

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[6] We have tried to introduce a linear time trend in order to catch the effect of autonomous technology development in this equation. However, the time trend is not significant.

[7] Due to the characteristic of the data set with many missing values, no cross-price effects are considered in equation (2).

(3) $$y_t - y_{t-1} = \theta\left(y_t^* - y_{t-1}\right),$$

where y_{t-1} is previous (one time period lagged) actual demand; θ is a parameter with range as (0,1] and is referred to as the coefficient of adjustment.

Equation (3) states that the *actual* change occurring during one time period, $(y_t - y_{t-1})$, is just a share of the difference (or change) between the desired demand in the current period and the actual demand in the previous period, i.e., $(y_t^* - y_{t-1})$, the *desired* change. Clearly, the coefficient of adjustment, θ, reflects the speed of adjustment towards the desired level of demand, the larger the value of θ is, the faster the adjustment is. If the value of θ equals 1, the actual demand will immediately approach to the desired level during the current period.

Inserting the expression for y_t^* derived from equation (3) into equation (2) and rearranging yields

(4) $$y_t = \beta_0 + \gamma y_{t-1} + \beta_1 P_t + \beta_2 I_t + u_t,$$

where the new parameters are related to the old ones in the following way: $\beta_0 = \theta\alpha_0$, $\beta_1 = \theta\alpha_1$, $\beta_2 = \theta\alpha_2$ and $\gamma = 1-\theta$; The new error term is given by $u_t = \theta\varepsilon_t$.

From equation (4) the short-run and interim effects of a change in the real price can be easily obtained as

(5)

The current period: $\dfrac{\partial y_t}{\partial P_t} = \beta_1$;

One period after: $\dfrac{\partial y_{t+1}}{\partial P_t} = \gamma\beta_1$;

Two periods after: $\dfrac{\partial y_{t+2}}{\partial P_t} = \gamma^2\beta_1$;

…

Therefore, the long-run effect of a price change, which is just the sum of all the short-run and all the interim effects, can be written as [8]

(6) $$\beta_1 + \gamma\beta_1 + \gamma^2\beta_1 + \ldots = \beta_1 / (1-\gamma).$$

With β_1 replaced by β_2, equation (5) and (6) equally apply to the derivation of short- and long-run effects of a change in real GDP (or real disposable income).

Note that if the variables in equation (4) are in logarithms instead of level terms, as we shall do in this study, the short-run and long-run effects discussed above are simply short-run, intermediate and long-run elasticities with respect to the relevant variables.

In the present study we shall make use of a panel data set over countries. As a result, the regression equation (4) has two dimensions. The data and the estimation method will be illustrated in the following section.

3. Data and Estimation Method

The data for this study represents annual data of per capita consumption and real price of energy goods, real per capita GDP and/or real per capita disposable income for OECD countries over the period 1978 -1999.[9] The energy goods consist of electricity, natural gas, hard coal and gas oil (heating oil) used by the industrial and the residential sector, heavy fuel oil by the industrial sector, automotive diesel and motor gasoline by the whole economy in all the OECD countries.

All of the data are drawn from the OECD Statistical Compendium 2001 except for the prices, which are taken from the International Energy Agency (IEA)'s online databank. Due to lack of data, we take the prices of light fuel oil as those of gas oil in corresponding industrial sector and residential sector, and the prices of automotive diesel by the industrial sector as those of automotive diesel used by the whole economy. The prices of steam coal and heavy sulfur fuel oil by industrial sector are used as those of hard coal and heavy fuel oil respectively. The prices of motor gasoline are represented by those of premium leaded gasoline consumed by the residential sector.

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[8] Actually equation (4) can be written as $(1-\gamma L)y_t = \beta_0 + \beta_1 P_t + \beta_2 I_t + u_t$, where L is a Lag operator and its function is $L^i y_t = y_{t-i}$. Dividing by $(1-\gamma L)$ on both sides of the above equation yields $y_t = \beta_0 \sum_{i=0}^{\infty}\gamma^i + \beta_1\left(\sum_{i=0}^{\infty}\gamma^i L^i\right)P_t + \beta_2\left(\sum_{i=0}^{\infty}\gamma^i L^i\right)I_t + \left(\sum_{i=0}^{\infty}\gamma^i L^i\right)u_t$. Clearly we see that the partial adjustment (or ADL (1,0)) model has a special form of lag structure on the independent variables, i.e., geometrically declining lag.

[9] OECD countries in this study refer to the following 23 countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, Canada, Australia, Japan and New Zealand.

End-use prices for energy goods from IEA's databank, which are in US dollars per unit, are first converted back to domestic currency by using annual market exchange rates. Real prices are then computed by dividing these prices by the GDP deflator in each country. The latter is obtained as national GDP at current prices divided by real national GDP at 1995 constant prices. We also divide national disposable income at current prices by the GDP deflator for the respective individual country to get real national disposable income.

Although it is real GDP (or disposable income) and the real energy prices in domestic currency that influence energy demand, analysis of panel data requires internationally comparable statistics. Therefore, real national GDP and/or real national disposable income in individual countries are converted to a US dollar base by using 1995 market exchange rates for the respective countries. Finally, the per capita terms of consumption, real GDP and/or real disposable income are taken as the correspondent aggregate terms divided by the respective population for each individual country.

Due to missing values in the data set for some energy goods during some period of time, the finally obtained panel data set is unbalanced (See Appendix Table A1 and A2 for a brief view of the quality of the data sets employed in this study). This diverges from the conventional balanced panels where each country has the same number of observations across the time dimension.[10]

For the purpose of this study, all the variables, per capita consumption, real prices, real per capita GDP and/or real per capita disposable income are log-transformed.

As we have panel data, we rewrite equation (4) with two dimensions as follows,

$$y_{it} = \beta_0 + \gamma y_{it-1} + \beta_1 P_{it} + \beta_2 I_{it} + u_{it}, \tag{7}$$

where the new subscript i, $i = 1,2,...,N$, stands for the country and the previous subscript in equation (4), t, $t = 1,2,...,T$, is still the time.

With the belief that systematic variation occurs across the individual countries but not across time, the error term u_{it} is assumed to have a structure of a one-way error component in the following way

$$u_{it} = \mu_i + \eta_{it}, \tag{8}$$

where μ_i denotes the unobservable individual country specific effect and η_{it} denotes the remainder disturbance (genuine error term). Note that μ_i is time-invariant and accounts for any country-specific

[10] The econometric software used in this study is the package of Panel Data Models in PcGive (Doornik and Hendry, 2001), which is expressly designed to handle such unbalanced panels.

effect that is not included in the regression equation (7). It may be assumed to be either a fixed parameter or a random variable. The remainder disturbance varies with individual countries and time and can be thought of as the usual disturbance in the regression.

Here we assume $\mu_i \sim IID\,(0,\ \sigma_\mu^2)$ and $\eta_{it} \sim IID\,(0,\ \sigma_\eta^2)$, independent of each other and among themselves. Further assumptions are

$$E(I_{it}\mu_i) \neq 0\ ,\ i = 1,2,...,N\ ,\ t = 1,2,...,T\ ;$$

(9)

$$E(I_{it}\eta_{is}) = 0 \text{ and } E(P_{it}\eta_{is}) = 0\ ,\ i = 1,2,...,N\ ,\ t = 1,2,...,T\ .$$

The former one states that the unobserved country specific effect is correlated with the country's real per capita GDP or disposable income that are indicators of the economic level of the country. The latter one indicates that P_{it} and I_{it} are strictly exogenous.

Since y_{it} is a function of μ_i, it immediately follows that y_{it-1} is also a function of μ_i. Thus, y_{it-1}, which is a right hand side regressor in (7) is correlated with the error term. This renders the usual OLS estimators biased and inconsistent. Although the Within (fixed effects) estimator wipes out the μ_i by transformation, $(y_{it-1} - \bar{y}_{i.-1})$ (where $\bar{y}_{i.-1} = \sum_{t=2}^{T} y_{it-1} /(T-1)$)[11] will still be correlated with $(\eta_{it} - \bar{\eta}_{i.})$ (where $\bar{\eta}_{i.} = \sum_{t=1}^{T} \eta_{it} / T$), even if η_{it} are not serially correlated. This is because y_{it-1} is correlated with $\bar{\eta}_{i.}$ by construction. The latter average contains η_{it-1} which is obviously correlated with y_{it-1}.

Anderson and Hsiao (1981) once suggested first differencing equation (7) to remove the μ_i and then using $\Delta y_{it-2} = (y_{it-2} - y_{it-3})$ or simply y_{it-2} as an instrument for $\Delta y_{it-1} = (y_{it-1} - y_{it-2})$. These instruments will not be correlated with $\Delta\eta_{it} = (\eta_{it} - \eta_{it-1})$, as long as the η_{it} themselves are not serially correlated. This instrument variable (IV) estimation method leads to consistent but not necessarily efficient estimates of the parameters in the model (Baltagi, 2001).

Arellano and Bond (1991) proposed a generalized method of moments (GMM) procedure, which is considered to be more efficient than the Anderson and Hsiao (1982) estimator. This method, by utilizing the orthogonality conditions that exist between lagged values of y_{it} and the disturbances

[11] This is somewhat modified when facing unbalanced panel data, see Greene (2000).

η_{it}, can generate consistent estimates when the number of countries N and/or the time T goes to infinity. In the following we shall apply this GMM method to estimate equation (7).

Taking first difference of equation (7) yields

$$\Delta y_{it} = \gamma \Delta y_{it-1} + \beta_1 \Delta P_{it} + \beta_2 \Delta I_{it} + \Delta \eta_{it}, \quad i = 1,2,\ldots,N,\ t = 3,4,\ldots,T. \tag{10}$$

It is easily verified that Δy_{it-1} is correlated with $\Delta \eta_{it}$ through the correlations between y_{it-1} and η_{it-1}. However, there exist qualified instrument variables that are correlated with Δy_{it-1} but not with $\Delta \eta_{it}$, namely, y_{i1}, $y_{i2} \cdots y_{it-2}$ for Δy_{it-1}.

Define a matrix with $(T-2)$ rows as

$$\mathbf{Z}_i = \begin{pmatrix} [y_{i1}, \Delta P_{i3}, \Delta I_{i3}] & & & 0 \\ & [y_{i1}, y_{i2}, \Delta P_{i4}, \Delta I_{i4}] & & \\ & & \cdots & \\ 0 & & & [y_{i1}, \ldots, y_{iT-2}, \Delta P_{iT}, \Delta I_{iT}] \end{pmatrix}, \quad i = 1,2,\ldots,N. \tag{11}$$

Then the instrument matrix, $\mathbf{Z} = \left[\mathbf{Z}_1^{'}, \ldots, \mathbf{Z}_N^{'}\right]^{'}$, is formed by stacking the above matrix over all individual countries i. By using the moment conditions given by $E\left(\mathbf{Z}_i^{'} \Delta \boldsymbol{\eta}_i\right) = 0$, where $\Delta \boldsymbol{\eta}_i^{'} = \left(\eta_{i3} - \eta_{i2}, \ldots, \eta_{iT} - \eta_{iT-1}\right)$, and premultiplying the equation (10) in vector form by $\mathbf{Z}^{'}$, one gets

$$\mathbf{Z}^{'} \Delta \mathbf{y} = \mathbf{Z}^{'} \left(\Delta \mathbf{y}_{-1}\right) \gamma + \mathbf{Z}^{'} \left(\Delta \mathbf{X}\right) \boldsymbol{\beta} + \mathbf{Z}^{'} \Delta \boldsymbol{\eta}, \tag{12}$$

where $\Delta \mathbf{y}$, $\Delta \mathbf{y}_{-1}$, and $\Delta \boldsymbol{\eta}$ are $N(T-2) \times 1$ matrices constructed respectively from matrices $\Delta \mathbf{y}_i^{'} = \left(y_{i3} - y_{i2}, \ldots, y_{iT} - y_{iT-1}\right)$, $\Delta \mathbf{y}_{i,-1}^{'} = \left(y_{i2} - y_{i1}, \ldots, y_{iT-1} - y_{iT-2}\right)$ and $\Delta \boldsymbol{\eta}_i^{'}$ in the same fashion as $\mathbf{Z}$. $\Delta \mathbf{X} = (\Delta \mathbf{P}, \Delta \mathbf{I})$ is a stacked $N(T-2) \times 2$ matrix and $\boldsymbol{\beta}^{'} = \left(\beta_1, \beta_2\right)$.

Now performing generalized least square (GLS) estimation method on (12) yields the so-called one-step GMM consistent estimator as

(13) $$\begin{pmatrix}\hat{\gamma}\\ \hat{\boldsymbol{\beta}}\end{pmatrix} = \left([\Delta\mathbf{y}_{-1}, \Delta\mathbf{X}]^{'}\mathbf{Z}\left(\mathbf{Z}^{'}(\mathbf{I}_N \otimes \mathbf{G})\mathbf{Z}\right)^{-1}\mathbf{Z}^{'}[\Delta\mathbf{y}_{-1}, \Delta\mathbf{X}]\right)^{-1}$$

$$\times\left([\Delta\mathbf{y}_{-1}, \Delta\mathbf{X}]^{'}\mathbf{Z}\left(\mathbf{Z}^{'}(\mathbf{I}_N \otimes \mathbf{G})\mathbf{Z}\right)^{-1}\mathbf{Z}^{'}\Delta\mathbf{y}\right),$$

where $$\mathbf{G} = \begin{pmatrix} 2 & -1 & 0 & \ldots & \ldots & 0 & 0 & 0 \\ -1 & 2 & -1 & \ldots & \ldots & 0 & 0 & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & 0 & \ldots & \ldots & -1 & 2 & -1 \\ 0 & 0 & 0 & \ldots & \ldots & 0 & -1 & 2 \end{pmatrix}$$ is a $(T-2)\times(T-2)$ matrix.[12]

According to equation (9), P_{it} and I_{it} are strictly exogenous regressors in equation (7). It is, however, not unusual to consider I_{it} as predetermined instead of strictly exogenous variable, which implies that the current GDP/income is affected by the previous use of energy. Then part of equation (9) has to be changed as

(14) $$E(I_{it}\eta_{is}) \neq 0 \text{ for } s < t \text{ and zero otherwise.}$$

That is, I_{it} is correlated with the previous disturbance η_{is}, $s < t$, but not the current and the future disturbances.

With this assumption, it is easy to verify that in the first difference equation (10), ΔI_{it} now is correlated with $\Delta\eta_{it}$ through the correlations between I_{it} and η_{it-1}. Still, we can find qualified instrument variables that are correlated with ΔI_{it}, but not with $\Delta\eta_{it}$, i.e., I_{i1}, I_{i2}, I_{it-1} for ΔI_{it}.

As a result, the matrix $\mathbf{Z}_i$ in (11) will be modified to

[12] Discussion on one-step GMM estimator in detail can be found in Baltagi (2001) and Doornik and Hendry (2001).

$$
(15) \quad \mathbf{W}_i = \begin{pmatrix} [y_{i1}, \Delta P_{i3}, I_{i1}, I_{i2}] & & & 0 \\ & [y_{i1}, y_{i2}, \Delta P_{i4}, I_{i1}, I_{i2}, I_{i3}] & & \\ & & \cdots & \\ 0 & & & [y_{i1}, \ldots, y_{iT-2}, \Delta P_{iT}, I_{i1}, \ldots, I_{iT-1}] \end{pmatrix},
$$

$$
i = 1,2,\ldots,N .
$$

One-step GMM estimators are again given by equation (13) with $\mathbf{Z}_i$ in (11) replaced by $\mathbf{W}_i$ in (15). To sum up, we finally apply the one-step GMM estimator presented in (13) and give the estimates in the following section.

4. Estimation Results

In order to compare, we apply conventional ordinary least square (OLS) estimation method to the pooled data and report the results in Appendix Table A3 and A4. The standard error of long-run elasticity is calculated by the dynamic analysis procedure in PcGive (Doornik and Hendry, 2001).

The OLS estimates show a typical pattern of sizable bias caused by using the lagged endogenous dynamic model with pooled data. The estimates of γ, the coefficient for the lagged dependent variable, tend to be biased towards unity and the short-run elasticities towards zero (Pesaran and Smith, 1995). Even worse, most of the results are either with unexpected sign (i.e., positive price elasticities and negative GDP/income elasticities) or insignificant.

Table 1: One-step GMM Estimates of Elasticities of Energy Goods in OECD. *Residential* Sector (With Strictly Exogenous Income)[a]

Products	SR price ela.	LR price ela.	SR income ela.	LR income ela.	γ	# of Obs.
Electricity	-0.030 (0.018)	-0.157 (0.095)	0.058 (0.047)	0.303 (0.265)	0.810 (0.031)	446
Natural Gas	-0.102 (0.161)	-0.364 (0.493)	0.137 (0.278)	0.490 (1.089)	0.720 (0.087)	351
Hard Coal	0.000 (0.227)	0.001 (0.443)	-1.148 (0.692)	-2.243 (1.511)	0.488 (0.166)	221
Gas Oil	-0.143 (0.056)	-0.318 (0.110)	0.030 (0.169)	0.066 (0.373)	0.443 (0.048)	364
Motor Gas.[b]	-0.191 (0.017)	-0.600 (0.082)	0.196 (0.059)	0.614 (0.189)	0.681 (0.051)	428

Notes: a. Standard errors in parentheses;
b. Motor gasoline for the whole economy.

Table 2: One-step GMM Estimates of Elasticities of Energy Goods in OECD. *Industrial* Sector (With Strictly Exogenous GDP)[a]

Products	SR price ela.	LR price ela.	SR GDP ela.	LR GDP ela.	γ	# of Obs.
Electricity	-0.013 (0.022)	-0.044 (0.073)	0.300 (0.089)	1.035 (0.262)	0.710 (0.059)	432
Natural Gas	-0.067 (0.023)	-0.243 (0.086)	0.376 (0.254)	1.363 (0.918)	0.724 (0.046)	330
Hard Coal	0.162 (0.111)	0.589 (0.447)	1.155 (0.341)	4.203 (1.274)	0.725 (0.043)	287
Gas Oil	0.043 (0.070)	0.127 (0.205)	0.529 (0.276)	1.557 (0.591)	0.660 (0.088)	372
Auto. diesel [b]	-0.094 (0.018)	-0.268 (0.068)	0.425 (0.168)	1.207 (0.408)	0.648 (0.050)	412
Heavy Fuel	-0.167 (0.041)	-0.516 (0.161)	-0.084 (0.440)	-0.260 (1.363)	0.675 (0.060)	370

Notes: a. Standard errors in parentheses;
b. Automotive diesel for the whole economy.

In Appendix Table A5 and A6 we also give the pooled fixed effect estimates by applying the Within estimator. Allowing for country-specific fixed effects reduces the above problem somewhat, but the estimates are still unsatisfying. For example, the elasticities for motor gasoline have expected sign. However, an estimate of γ of 0.86 indicates that only 14 per cent of the adaptation occurs in the first year. Such a low value for the lagged endogenous variable implies a rather slow adjustment (adjustment would be only 75 per cent complete almost 10 years after a change in gasoline price [13]).

Finally the one-step GMM procedure is applied to the ADL (1,0) or partial adjustment model (7) by using panel data for the OECD countries over 1978 - 1999.[14] The estimation results are presented in Table 1 and 2.[15] Note that here we have assumed that GDP/income is strictly exogenous relative to equation (7). We also list the one-step GMM estimation results in Appendix Table A7 and A8 with the less restrictive assumption that GDP/income is predetermined (i.e., the current GDP/income is correlated with the previous error terms but not with the current error term, which implies that the current GDP/income is affected by the previous use of energy). However, no significant differences between the estimates appear under the two different assumptions. Thus the strict exogeneity assumption seems warranted.

[13] The interpretation should be done with care. Since all variables in equation (7) are in logarithms, a change of one variable is actually the percentage change of the level for that variable.

[14] We also tried ADL (1,1) and ADL (0,3) models. It appeared that the introduction of lagged independent variables did not add much.

[15] Among the selected OECD countries (see footnote 8), Turkey is less developed compared with the others. However, inclusion and exclusion of Turkey seem not to have significant impact on the estimates.

Since the assumption of no serial correlation in η_{it} is essential for the consistency of estimators in our model, we pay attention to the tests for the absence of first-order and second-order serial correlation in the first-differenced residuals. If the disturbances η_{it} are not serially correlated, there should be evidence of significant negative first-order serial correlation in the differenced residuals (i.e. $\Delta\eta_{it}$), and no evidence of second-order serial correlation in the differenced residuals. We use the conventional AR(1) and AR(2) tests and find that among eleven energy goods, nine show significant negative first-order serial correlation but no second-order serial correlation in the differenced residuals.

The estimation results show that for electricity, natural gas and gas oil demand, price elasticities are in general larger (in absolute value) while GDP/income elasticities lower in the residential than in the industrial sector. One possible explanation could be as follows. Because the OECD countries in the study are relatively mature societies, the consumption of energy goods in the residential sector may increase only to a moderate extent when income increases. On the other hand, the production of more variety of goods needs correspondingly more energy as input in the industrial sector. By intuition, the residential sector is generally more sensitive to the price change than the industrial sector.

To a large extent the estimated price elasticities in Table 1 and 2, compared to other studies (see Section 5), are low.[16] The price elasticities have expected negative sign in eight out of eleven cases. The exceptions are hard coal for the residential and industrial sectors and gas oil (light heating oil) for industry. These elasticities are however not significantly different from zero. In five cases, the price elasticities are significantly below zero at the 5 per cent significance level.

GDP/Income elasticities have expected positive sign in nine cases, of which four (electricity, hard coal in industrial sector, automotive diesel and motor gasoline) are significant at the 5 per cent significance level; one (gas oil in industrial sector) is significant at the 10 per cent significance level.

The estimates for hard coal have unexpected positive price elasticities in both the residential and industrial sector. It appears that the ADL (1,0) model fits the data worst for hard coal demand. Given a rather poor quality of data for hard coal since data are missing to a large extent, this is not a surprise. The estimate of hard coal also has negative income elasticity in the residential sector, which may be understandable as the use of coal often negatively affects the environment and is typically an inferior good. The same argument goes for demand for heavy fuel oil with negative GDP elasticity.

[16] Some researcher also found low price elasticity for natural gas in a recent study (see Krichene, 2002).

In the industrial sector, demand for gas oil has positive price elasticity. However, it is not significant from zero.

In the Appendix Table A9 and A10 we also report the results by grouping OECD western and northern European countries together.[17] The purpose is to reduce the heterogeneity caused by grouping all the OECD countries with the assumption that western and northern European countries are more homogeneous in economic structure than the other OECD countries.

The estimates of electricity, gas oil, motor gasoline and automotive diesel with relatively larger number of observation are better than the others in Table A9 and A10 in terms of sign and significance. This is not surprising since the consistency and efficiency properties of one-step GMM estimators hold only asymptotically, namely, in large samples. Furthermore, by taking into consideration of standard errors, these estimates are not different from their counterparts in Table 1 and 2, which seems to give an evidence that the unobservable individual country specific effect μ_i (see equation 8) has caught most part of the heterogeneity across the OECD countries.

5. Comparison with Results from Other Studies

Many studies on the estimation of energy demand elasticities use cross-section data, which is considered to be able to adequately obtain long-run effects. For instance, Field and Grebenstein (1980) estimated the aggregate energy price elasticity of between -0.54 and -1.65 by using pooled cross-section data for US manufacturing in 1971. By using cross-section data of aggregate energy for thirty nations, Fiebig *et al*. (1987) found price elasticity of between -0.66 and -0.88, and the income elasticity of between 1.24 and 1.64. Pindyck (1979) studied the structure of demand for energy on a cross-sectional basis for a group of OECD countries. In the residential sector, he estimated long-run price elasticities for liquid fuels of between -1.0 and -1.25, and for natural gas of -1.7. In the industrial sector, price elasticity for oil ranged between -0.22 and -1.17, and for natural gas, between -0.41 and -2.34. In the transport sector, the long-run gasoline price elasticity was found to be -1.31.

Dynamic time-series analyses possibly account for the majority of the estimation of energy demand elasticities. In a dynamic *ad hoc* model by using aggregate time-series data for the OECD countries over 1961 to 1981, Kouris (1983) found for primary energy demand a short- and long-run price elasticity of -0.15 and -0.43, and a short-run income elasticity of 1.08. In another dynamic *ad hoc* model by using aggregate time-series data for the OECD countries on aggregate final energy demand over 1960 to 1982, Prosser (1985) yielded a short- and long-run price elasticity of -0.22 and -0.40, and an income elasticity of 1.02, respectively.

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[17] They are Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Norway, Sweden, Switzerland and United Kingdom.

In recent years time-series analysis has become more popular especially with the development of some advanced time-series techniques, such as cointegration analysis. For instance, Bentzen and Engsted (1993) estimated the price and income elasticities for aggregate energy consumption in Denmark to be -0.14 and 0.67 in the short-run, and -0.47 and 1.21 in the long-run. By using aggregate time series data for the UK, Hunt and Manning (1989) found the short-run price and income elasticities for aggregate final energy consumption (on a heat supplied basis) to be -0.08 and 0.80, respectively. Their long-run price and income elasticities were -0.30 and 0.38, respectively.

There are quite a few studies using panel data in the estimation of energy demand elasticities. Balestra and Nerlove (1966) studied the demand for natural gas in the US. Their long-run estimates were -0.63 for the price elasticity and 0.62 for the income elasticity. Kouris (1976) pooled cross-section time- series data for eight nations and found the price and income elasticities for aggregate primary energy consumption to be -0.77 and 0.84, respectively. Using a panel data for seven nations on aggregate energy consumption, Nordhaus (1977) estimated the short-run elasticities of between -0.03 and -0.68 for price and between 0.29 and 1.11 for income, while the long-run elasticities were between -1.94 and 1.45 for price and between 0.26 and 1.42 for income. Hesse and Tarkka (1986) studied the energy demand in the European manufacturing industry before and after the 1973 oil price shock. Using two panel datasets of electricity for nine countries over 1960 to 1972 (before price shock) and over 1973 to 1980 (after price shock), they found price elasticities of between 0.31 and -0.35 before the price shock, and between 0.14 and -0.49 after the price shock, respectively.

Studies on the estimation of energy demand elasticities vary in many aspects. Therefore, it is hard to reach consensus on the magnitude of the various energy demand elasticities in the literature. However, the findings of this paper in general agree more with the empirical research that tends to yield low values for price elasticities. The (significant) long-run GDP/income elasticities found in this paper are quite similar to those of earlier empirical research, and are generally around unity (Atkinson and Manning, 1995).

Differences between the findings of this paper and those of other research could be due to the specification of the models. Recall that in the partial adjustment model, which we applied in this study, the long-run elasticity is implicitly restricted by the model itself through equation (6) (also see footnote 7). Differences could also arise from other various sources, including the use of cross-section or time-series data, the quality of the data set used, assumptions on the error terms and the estimation methodology.

6. Conclusion

This paper has estimated price and GDP/income elasticities of energy demand for electricity, natural gas, hard coal, gas oil in residential and industrial sectors, and heavy fuel oil in industrial sector, automotive diesel and motor gasoline in the whole economy. The one-step GMM estimation method suggested by Arellano and Bond (1991) has been applied to an unbalanced panel data set consisting of OECD countries over 1978 to 1999. The energy demand is specified by a simple partial adjustment model. Compared with the OLS and the Within estimator, the one-step GMM estimator gives more intuitive results in terms of sign and magnitude.

The estimated results show that for electricity, natural gas and gas oil demand, price elasticities are in general larger (in absolute value) while GDP/income elasticities are in general lower in the residential than in the industrial sector. Compared with the results from other studies, the findings of this paper yield low values for price elasticities. However, more recent time-series analyses also seem to support this. The (significant) long-run GDP/income elasticities found in this paper are quite similar to those of earlier empirical studies, and are generally around unity.

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Table A1: Available Data on Income, Consumption and Price for Energy Goods in the Residential Sector in OECD countries

Country	Income	Electricity		Natural Gas		Hard Coal		Gas/Diesel		Motor Gas.	
		Cnsp.[1]	Price	Cnsp.	Price	Cnsp.	Price	Cnsp.	Price	Cnsp.	Price
Austria	*[2]	*	*	*	79-99	*	*	*	*	*	78-92
Belgium	*	*	78-98	*	78-98	*	*	*	*	*	*
Denmark	*	*	*	83-99	84-99	*	79-99	*	*	*	78-95
Finland	*	*	*	*	*	*	*	*	*	*	78-93
France	*	*	78-98	*	*	*	*	85-99	*	*	*
Germany	*	*	*	*	*	*	78-94	*	*	*	78-96
Greece	*	*	*	*NA*[3]	*NA*	*	*NA*	*	*	*	*
Ireland	*	*	*	86-99	*	*	78-94	*	*	*	*
Italy	*	*	*	*	*	*	78-83	*	*	*	*
Luxembourg	*	*	*	*	*	78-91	*	*	79-99	*	79-98
Netherlands	*	*	*	*	*	*	78-87	*	*	*	78-96
Norway	*	*	*	*NA*	*NA*	*	79-85	*	*	*	*
Portugal	*	*	*	98-99	*NA*	78-91	*NA*	80-94	*NA*	*	78-98
Spain	*	*	*	*	*	*	*NA*	*	*	*	*
Sweden	*	*	78-97	85-99	*NA*	78-87	78-89	*	*	*	*
Switzerland	78-98	*	*	*	*	*	78-92	*	*	*	*
Turkey	*	*	*	88-99	88-99	*	80-99	*NA*	*	*	*
UK	*	*	*	*	*	*	*	*	*	*	*
USA	*	*	*	*	*	*	*NA*	*	*	*	*
Canada	*	*	78-94	*	*	*	*NA*	*	*	*	*
Australia	78-98	*	78-97	*	78-97	*	*NA*	*	78-83	*	*
Japan	78-98	*	*	*	*	*	*NA*	*NA*	*	*	*
NewZealand	78-98	*	*	*	*	*	81-84	*	78-87	*	78-95

Notes: 1, Abbreviation for consumption;
2, A star (*) indicates full data from year 1978 to year 1999;
3, *NA* indicates that no data are available.

Table A2: Available Data on GDP, Consumption and Price for Energy Goods in the Industrial Sector in OECD countries

Country	GDP	Electricity		Natural Gas		Hard Coal		Gas/Diesel		Transportation Gas/Diesel		Heavy Fuel Oil	
		Cnsp.[1]	Price	Cnsp.	Price	Cnsp.	Price	Cnsp.	Price	Cnsp.	Price	Cnsp.	Price
Austria	*[2]	*	*	*	*	*	*	*NA*[3]	80-98	*	*	*	78-98
Belgium	*	*	78-98	*	78-97	*	78-90	*	*	*	*	*	*
Denmark	*	*	*	84-99	78-80	*	78-95	*	*	*	*	*	78-88
Finland	*	*	*	*	*	*	*	*	*	*	*	*	78-92
France	*	*	*	*	*	*	*	*	*	*	*	*	*
Germany	*	*	*	*	*	*	78-94	*	*	*	*	*	78-90
Greece	*	*	*	82-99	97-99	*	78-80	*	*	*	*	*	78-94
Ireland	*	*	*	79-99	*	*	*NA*	*	*	*	*	*	*
Italy	*	*	*	*	78-98	*	*	*	*	*	*	*	*
Luxembourg	*	*	78-89	*	79-82	*	*NA*	*	81-99	*	79-99	*	81-94
Netherlands	*	*	*	*	*	*	78-91	*	78-91	*	*	*	78-96
Norway	*	*	78-91	*NA*	*NA*	*	78-94	*	*	*	*	*	78-94
Portugal	*	*	*	97-99	*NA*	*	97-99	*	*NA*	*	*	*	*
Spain	*	*	*	*	*	*	*NA*	*	*	*	*	*	*
Sweden	*	*	78-97	85-99	*NA*	*	78-91	*	*	*	*	*	78-84
Switzerland	*	*	*	*	*	*	*	*	*	*	94-99	*	78-90
Turkey	*	*	*	82-99	88-99	*	79-99	*	*NA*	*	*	*	*
UK	*	*	*	*	*	*	*	*	*	*	*	*	*
USA	*	*	*	*	*	*	*	*	*	*	92-99	*	*
Canada	*	*	78-94	*	*	*	78-89	*	*	*	*	*	*
Australia	*	*	78-97	*	78-97	*	82-89	*	78-83	*	*NA*	*	78-83
Japan	*	*	*	*	*	*	*	*	*	*	*	*	*
NewZealand	*	*	*	*	*	*	78-84	*	*	*	*	*	*

Notes: 1, Abbreviation for consumption;
2, A star (*) indicates full data from year 1978 to year 1999;
3, *NA* indicates that no data are available.

Table A3: Pooled OLS Estimates of Elasticities of Energy Goods in OECD. *Residential* Sector [a]

Products	SR price ela.	LR price ela.	SR income ela.	LR income ela.	γ	# of Obs.
Electricity	0.004 (0.008)	1.174 (3.358)	-0.023 (0.003)	-7.012 (6.404)	0.997 (0.003)	469
Natural Gas	0.006 (0.076)	0.152 (1.960)	-0.213 (0.093)	-5.349 (3.090)	0.960 (0.024)	370
Hard Coal	0.025 (0.049)	1.403 (2.503)	-0.112 (0.057)	-6.267 (2.883)	0.982 (0.007)	237
Gas Oil	-0.045 (0.020)	2.992 (1.161)	-0.037 (0.034)	2.513 (1.960)	1.015 (0.007)	384
Motor Gas.[b]	-0.038 (0.009)	-0.986 (0.166)	0.035 (0.011)	0.898 (0.219)	0.961 (0.010)	451

Notes: a. Standard errors in parentheses;
b. Motor gasoline for the whole economy.

Table A4: Pooled OLS Estimates of Elasticities of Energy Goods in OECD. *Industrial* Sector [a]

Products	SR price ela.	LR price ela.	SR GDP ela.	LR GDP ela.	γ	# of Obs.
Electricity	-0.003 (0.003)	-1.826 (2.145)	-0.010 (0.003)	-5.930 (5.804)	0.998 (0.062)	455
Natural Gas	-0.035 (0.038)	-1.251 (0.851)	-0.111 (0.025)	-3.955 (1.895)	0.972 (0.017)	349
Hard Coal	0.058 (0.041)	0.948 (0.768)	-0.033 (0.018)	-0.544 (0.376)	0.939 (0.015)	307
Gas Oil	-0.034 (0.016)	-0.459 (0.258)	0.041 (0.026)	0.549 (0.326)	0.925 (0.014)	392
Auto. diesel [b]	-0.014 (17.181)	4.410 (0.051)	0.009 (0.009)	-2.753 (12.103)	1.003 (0.012)	434
Heavy Fuel	-0.049 (0.014)	1.407 (0.744)	-0.028 (0.013)	0.810 (0.376)	1.035 (0.014)	393

Notes: a. Standard errors in parentheses;
b. Automotive diesel for the whole economy.

Table A5: Pooled Fixed Effect Estimates of Elasticities of Energy Goods in OECD.*Residential* Sector[a]

Products	SR price ela.	LR price ela.	SR income ela.	LR income ela.	γ	# of Obs.
Electricity	-0.043 (0.013)	-3.692 (11.195)	-0.046 (0.048)	-3.980 (15.238)	0.988 (0.033)	469
Natural Gas	-0.196 (0.097)	-0.774 (0.297)	0.258 (0.149)	1.018 (0.572)	0.747 (0.059)	370
Hard Coal	-0.063 (0.133)	-0.400 (0.939)	-0.861 (0.351)	-5.490 (1.213)	0.843 (0.055)	237
Gas Oil	-0.036 (0.023)	-0.654 (0.455)	-0.008 (0.047)	-0.144 (0.857)	0.945 (0.017)	384
Motor Gas.[b]	-0.137 (0.016)	-0.986 (0.166)	0.051 (0.036)	0.366 (0.216)	0.861 (0.024)	451

Notes: a. Standard errors in parentheses;
b. Motor gasoline for the whole economy.

Table A6: Pooled Fixed Effect Estimates of Elasticities of Energy Goods in OECD. *Industrial* Sector [a]

Products	SR price ela.	LR price ela.	SR GDP ela.	LR GDP ela.	γ	# of Obs.
Electricity	-0.007 (0.020)	-0.045 (0.124)	0.144 (0.029)	0.946 (0.187)	0.848 (0.029)	455
Natural Gas	-0.121 (0.035)	-0.507 (0.166)	0.057 (0.118)	0.238 (0.468)	0.761 (0.080)	349
Hard Coal	0.237 (0.100)	1.410 (0.696)	0.265 (0.264)	1.582 (1.646)	0.832 (0.029)	307
Gas Oil	-0.015 (0.041)	-0.089 (0.256)	-0.026 (0.100)	-0.155 (0.600)	0.833 (0.036)	392
Auto. diesel [b]	-0.085 (0.021)	-0.429 (0.150)	0.338 (0.096)	1.712 (0.165)	0.802 (0.043)	434
Heavy Fuel	-0.088 (0.027)	-4.889 (8.349)	-0.241 (0.121)	-13.331 (22.289)	0.982 (0.028)	393

Notes: a. Standard errors in parentheses;
b. Automotive diesel for the whole economy.

Table A7: One-step GMM Estimates of Elasticities of Energy Goods in OECD. *Residential* Sector (With Predetermined Income) [a]

Products	SR price ela.	LR price ela.	SR income ela.	LR income ela.	γ	# of Obs.
Electricity	-0.029 (0.018)	-0.132 (0.080)	0.088 (0.048)	0.398 (0.229)	0.780 (0.025)	446
Natural Gas	-0.114 (0.146)	-0.369 (0.427)	0.101 (0.220)	0.327 (0.732)	0.691 (0.061)	351
Hard Coal	0.049 (0.178)	0.102 (0.353)	-1.043 (0.679)	-2.178 (1.366)	0.521 (0.143)	221
Gas Oil	-0.122 (0.044)	-0.272 (0.089)	-0.029 (0.159)	-0.064 (0.353)	0.551 (0.046)	364
Motor Gas.[b]	-0.173 (0.019)	-0.584 (0.083)	0.171 (0.056)	0.577 (0.202)	0.704 (0.045)	428

Notes: a. Standard errors in parentheses;
b. Motor gasoline for the whole economy.

Table A8: One-step GMM Estimates of Elasticities of Energy Goods in OECD. *Industrial* Sector (With Predetermined GDP) [a]

Products	SR price ela.	LR price ela.	SR GDP ela.	LR GDP ela.	γ	# of Obs.
Electricity	-0.012 (0.018)	-0.037 (0.055)	0.325 (0.079)	0.987 (0.203)	0.670 (0.050)	432
Natural Gas	-0.074 (0.021)	-0.266 (0.077)	0.330 (0.236)	1.179 (0.859)	0.720 (0.043)	330
Hard Coal	0.170 (0.110)	0.607 (0.426)	1.307 (0.265)	4.670 (0.912)	0.720 (0.039)	287
Gas Oil	0.025 (0.067)	0.074 (0.202)	0.389 (0.214)	1.163 (0.443)	0.665 (0.091)	372
Auto. diesel [b]	-0.095 (0.020)	-0.270 (0.069)	0.447 (0.133)	1.266 (0.304)	0.647 (0.043)	412
Heavy Fuel	-0.161 (0.039)	-0.492 (0.142)	-0.025 (0.441)	-0.077 (1.351)	0.673 (0.047)	370

Notes: a. Standard errors in parentheses;
b. Automotive diesel for the whole economy.

Table A9: One-step GMM Estimates of Elasticities of Energy Goods in the *Residential* Sector of the OECD European Countries (With Strictly Exogenous Income) [a]

Products	SR price ela.	LR price ela.	SR income ela.	LR income ela.	γ	# of Obs.
Electricity	-0.025 (0.029)	-0.140 (0.160)	0.052 (0.059)	0.291 (0.356)	0.823 (0.028)	255
Natural Gas	0.021 (0.248)	0.075 (0.903)	0.258 (0.377)	0.934 (1.399)	0.724 (0.010)	205
Hard Coal	0.153 (0.181)	0.271 (0.303)	-1.629 (0.440)	-2.890 (1.405)	0.436 (0.159)	195
Gas Oil	-0.109 (0.058)	-0.264 (0.124)	0.041 (0.151)	0.100 (0.361)	0.587 (0.043)	252
Motor Gas.[b]	-0.170 (0.025)	-0.635 (0.088)	0.188 (0.063)	0.700 (0.293)	0.732 (0.044)	235

Notes: a. Standard errors in parentheses;
b. Motor gasoline for the whole economy.

Table A10: One-step GMM Estimates of Elasticities of Energy Goods in the *Industrial* Sector of the OECD European Countries (With Strictly Exogenous GDP)[a]

Products	SR price ela.	LR price ela.	SR GDP ela.	LR GDP ela.	γ	# of Obs.
Electricity	-0.035 (0.026)	-0.115 (0.080)	0.205 (0.097)	0.671 (0.240)	0.695 (0.079)	239
Natural Gas	-0.092 (0.026)	-0.331 (0.076)	0.024 (0.239)	0.086 (0.862)	0.722 (0.043)	180
Hard Coal	0.174 (0.140)	0.716 (0.627)	1.243 (0.454)	5.124 (1.585)	0.757 (0.038)	182
Gas Oil	0.112 (0.087)	0.317 (0.274)	0.361 (0.265)	1.017 (0.571)	0.645 (0.101)	230
Auto. diesel [b]	-0.114 (0.025)	-0.288 (0.069)	0.513 (0.188)	1.290 (0.324)	0.602 (0.080)	245
Heavy Fuel	-0.162 (0.049)	-0.365 (0.114)	0.610 (0.585)	1.374 (1.273)	0.556 (0.069)	193

Notes: a. Standard errors in parentheses;
b. Automotive diesel for the whole economy.

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