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TO WHAT EXTENT CAN NON-PRICE/INCOME INSTRUMENTS INFLUENCE THE DEMAND FOR ENERGY?

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ABSTRACT

The demand for energy is not simply a function of price and income, but can be shown also to be a function also of the underlying energy demand trend (UEDT). The UEDT captures behavioural responses to non-fiscal instruments, including technological change, but also encapsulating attitudinal responses/changes in demand that might result for instance from increased public awareness of how environmentally damaging energy use can be, hence reflecting underlying consumer preferences.

This study estimates a longitudinal econometric model for the aggregate demand functions of a sample of 17 OECD countries for the period 1960-2005. This approach to modelling will enable UEDT's to be observed for each of the countries, as well as the normal price and income elasticities. The model results will provide an indication of the extent to which price/income based instruments can be used to reduce the demand for energy, as well as indicating the extent to which consumers have responded to non-price/income instruments.

JEL Classification: C33, Q41.

Key Words: OECD Aggregate energy demand; Asymmetry; Exogenous non-economic factors.

To what extent can non-price/income instruments influence the demand for energy?

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1. Introduction

The aggregate demand for energy represents an important area of research in the current international climate due to increasing concerns over long-term environmental sustenance. At the time of writing, the world is in the clutches of an international recession dubbed the 'credit crises' which is dramatically affecting the incomes of nations. As such it is therefore useful to assess the extent to which demand changes as a result of changes in the conventional price and income responses.

However, the notion that demand is purely derived form rational economic response to price and income movements is one that has been regarded as a simplistic representation for a long time. It is well understood from inception level microeconomics that preferences and tastes have an explicit role in explaining consumption patterns. Further, it is well understood also that technological advances and reductions in service costs can lead to demand movements. Therefore the following will re-emphasise recent and ongoing empirical discussion surrounding the modelling of all of these aspects for a sample of 17 OECD countries.

This paper principally extends previous research by Adeyemi and Hunt (2007) – hereafter AH – in one particular direction to attempt to elucidate the empirical extent to which demand actually changes as a response to the various inducing factors. In particular the sample period is extended by a number of years from 1962-2003 in AH to 1960-2004. Further, two new countries are added to the sample, and the demand for energy is expanded from industrial energy consumption to include all uses and therefore represent aggregate energy consumption.

The paper proceeds by describing the methodology in Section 2, while Section 3 presents the data and empirical results, including an analysis of the derived contributions of the various demand drivers. Section 4 concludes the paper with a short review of the key findings and an outline of some of the potential directions in which this line of research could be extended.

2. Methodology

The method adopted builds upon the model used by AH but for some small changes. The specific method used in this example takes first differences which allows for a more direct consideration of the contribution of price, income and underlying energy demand trend (UEDT) effects upon demand. The use of a Koyck lag specification as used in AH subsequently loses its economic meaning and therefore it is not included in the remainder of the empirical analysis. The estimated models are as follows;

$$\Delta e_{it} = \beta \Delta y_{it} + \gamma_m \Delta p_{\max,it} + \gamma_c \Delta p_{cut,it} + \gamma_r \Delta p_{rec,it} + \theta_t \Delta D_t + \Delta \varepsilon_{it} \qquad (1)$$

$$\Delta e_{it} = \beta \Delta y_{it} + \gamma \Delta p_{it} + \theta_t \Delta D_t + \Delta \varepsilon_{it} \qquad (2)$$

$$\Delta e_{it} = \beta \Delta y_{it} + \gamma_m \Delta p_{\max,it} + \gamma_c \Delta p_{cut,it} + \gamma_r \Delta p_{rec,it} + \Delta \varepsilon_{it} \qquad (3)$$

Where; e_{it} is the natural log of aggregate energy demand in country *i* and year *t*; y_{it} is the natural log of Gross Domestic Product; p_{it} is the natural log of energy prices which is also decomposed into $p_{\max,it}$, $p_{cut,it}$ and $p_{rec,it}$, capturing asymmetric price responses via separate variables for the historical maximum, cumulative price cuts, and cumulative price rises; D_t represents a time dummy for year *t*. β, γ and θ are parameters to be estimated and $\Delta(.)$ is used to denote the first difference of a variable.

As suggested, this specification provides the benefit of more directly identifying the contribution of the UEDT to aggregate energy demand levels and hence the change in behaviour that is influenced by exogenous or behavioural factors. This is done by defining the change in the UEDT component of the model as $\Delta\mu_{it} = \sum_{t=1}^{T} \theta_t \Delta D_t$ i.e. treating it as a single variable, and then comparing this series to Δe_{it} which will be done in Section 3.

Huntington (2006) has argued that in order to choose between the three competing models standard F-tests for parameter restrictions should be used to identify the model with the best explanatory power[1], specifying two testable null hypotheses:

$$H_0 : \gamma_m = \gamma_r = \gamma_c \tag{4}$$

and

$$H_0 : \theta_t = 0 \tag{5}$$

[1] The F-test is given by: $F_{(k,DF_{UR})} = [(SSR_R - SSR_{UR})/k]/[SSR_{UR}/DF_{UR}]$
Where *SSR* = the sum of squared residuals, *DF* = degrees of freedom, *UR* = unrestricted model, *R* = restricted model, and *k* = $DF_R - DF_{UR}$

This is augmented by the following logic test for the asymmetric specifications;

$$|\gamma_m| \geq |\gamma_r| \geq |\gamma_c| \tag{6}$$

This logic test therefore implies that the absolute value of the demand response to increases in the maximum historical price of fuel is greater than that for responses to price rises which in turn is greater than response to price cuts. Equations (1), (2) and (3) are therefore estimated for OECD aggregate energy demand using ordinary least squares over the period 1960-2004 and testing the restrictions discussed in the previous section accordingly.

3. Data and Empirical Results

The panel data used in the analysis consists of 17 OECD countries (Austria, Belgium, Canada, Denmark, France, Greece, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the UK, and the USA) and covers the period from 1960 to 2004. The primary source of these data is the International Energy Agency (IEA) database *Energy Statistics of OECD Countries* available at www.iea.org. This includes each country's aggregate energy consumption in thousand tonnes of oil equivalent (ktoe).

The Data are summarised in Tables 1 and 2, showing that the implied responses of demand to price and income vary across countries (noting that these figures contain connected scatter plots and hence imply no functional relationships by themselves). The data generally shows that rising prices are met by lower demand, and rising incomes with higher demand, consistent with conventional economic wisdom.

Table 1: Replications of GH 2002 (Figure 3) for OECD 17.

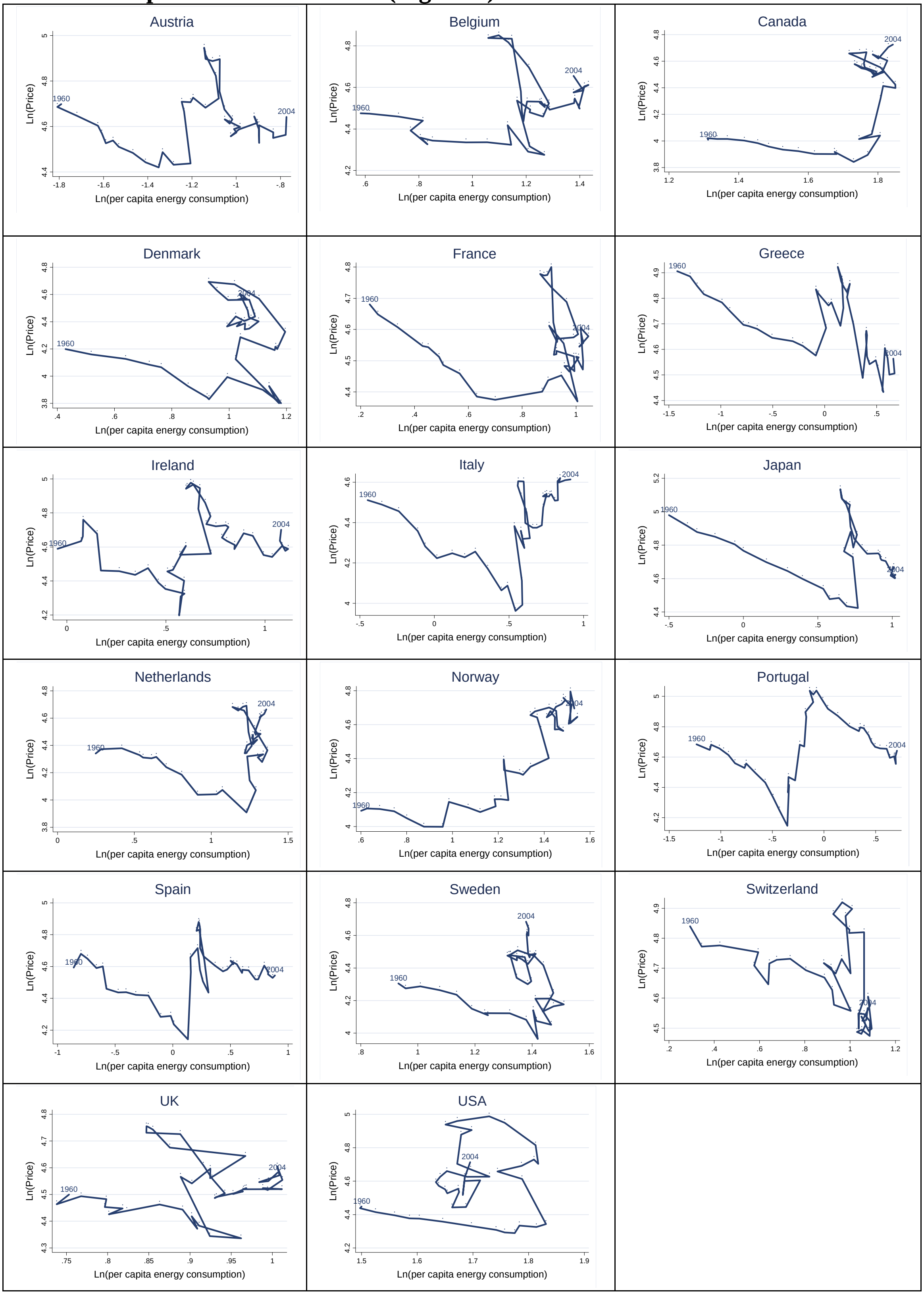
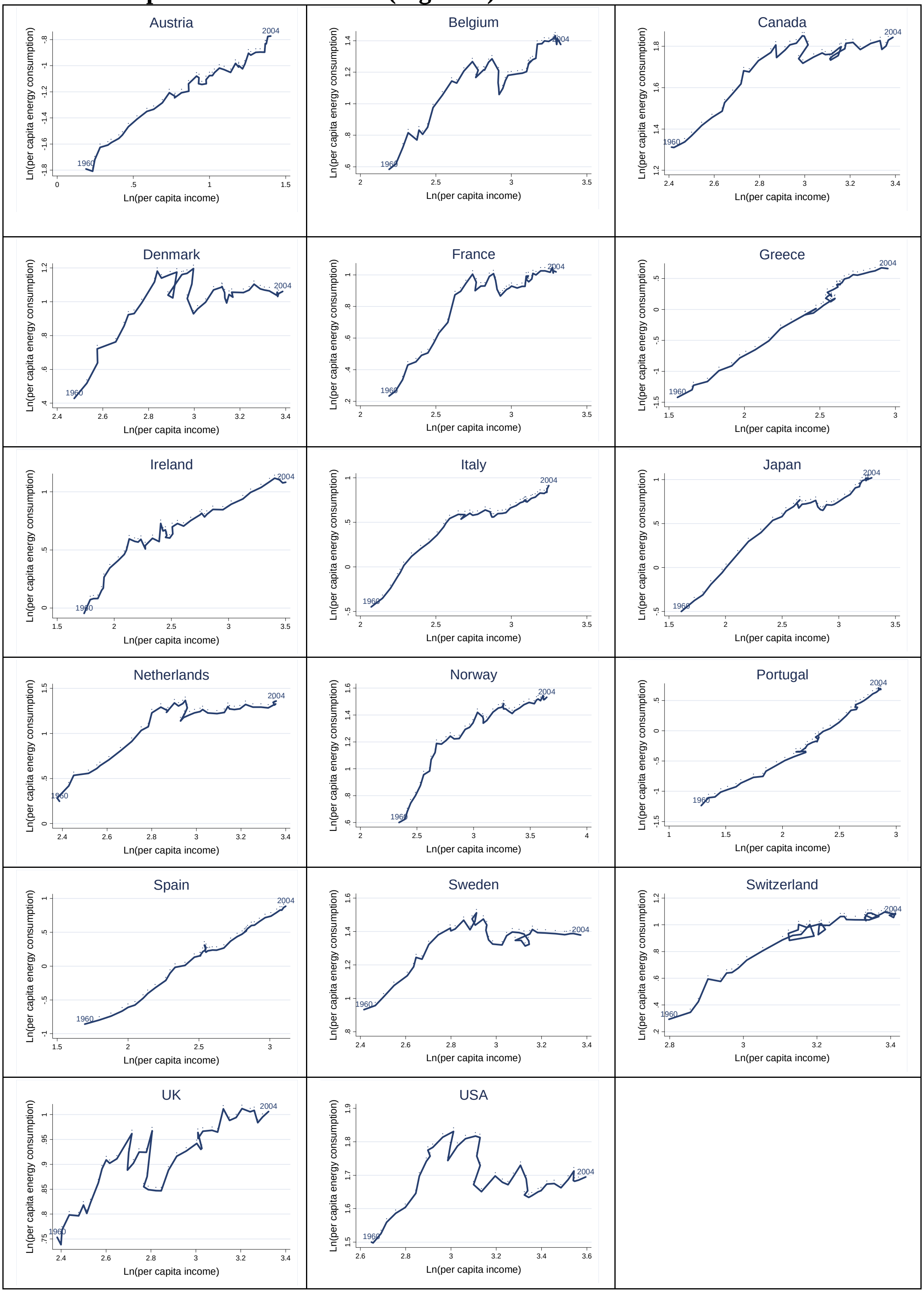


Table 2: Replications of GH 2002 (Figure 5) for OECD 17.



The data are thus used to estimate the econometric models and the results are presented in Table 3. The subsequent discussion in this section focuses first upon the model selection process, then discusses the implications of the demand models and then presents the country specific contribution calculations, presented in a series of graphs.

Table 3: OECD Aggregate Energy Demand

Estimated Parameters	**Equation (1)**	**Equation (2)**	**Equation (3)**
β (income)	0.536***	0.535***	0.884***
γ (price)		-0.113***	
γ_m (price-max)	*-0.100**		*-0.305****
γ_r (price-rec)	*-0.062**		*-0.126****
γ_c (price- cut)	*-0.186****		*-0.136****
Time Dummies Included	*Yes*	*Yes*	*No*
No. of observations	731	731	731
No. of estimated parameters	47	45	4
SSR	0.622	0.626	0.900
Diagnostics			
Autocorrelated errors	t=-0.14	t=0.43	t=1.06
Nested Restriction Tests			
No fixed time effects: $\theta_t = 0$	F=7.12***	F=7.35***	
Symmetric price response: $\gamma_{max} = \gamma_{rec} = \gamma_{cut}$	F=2.08		F=5.15***
Non-Nested J Tests		t=215.03***	t=40.68***

Notes: *** indicates significant at 1% level, ** indicates significant at the 5% level and * indicates significant at the 10% level.

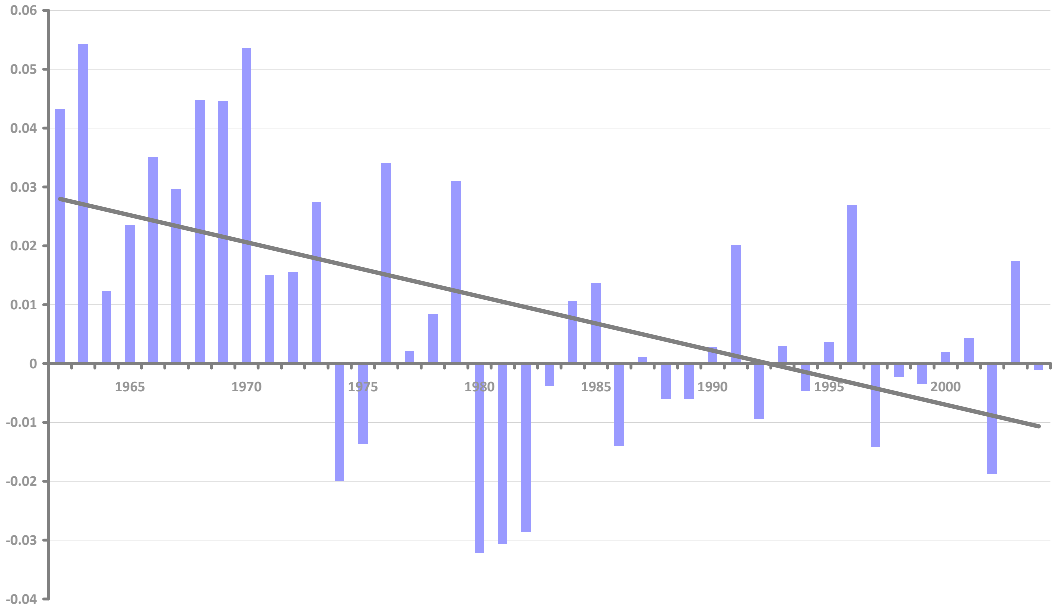
Applying the Huntington (2006) tests in (4) and (5), it can be seen that equations (1) and (2) are preferred to equation (3) since the null hypothesis of no fixed time effects is clearly rejected. However the results for the price symmetry tests are less clear cut, suggesting that for equation (3) that symmetry is an invalid restriction and for equation (1) that it is a valid restriction. Non-nested J-tests, applied in the same manner as AH, suggest that there is extra statistical information/performance available by adding the missing components from the other models; that is, there is something to be gained by adding the fixed time effects to an asymmetric model or decomposing the price variable in a symmetric model with fixed time effects.

The relative sizes of the coefficients on price-max and price-cut in equation (1) are not as expected therefore, on pragmatic grounds Equations (2) is chosen as the preferred model. Although it should be stressed that this is not a clear cut conclusion given the cumulative evidence in the results, and further research is needed to try and disentangle this complicated relationship.

The income variable is very significant suggesting a long run aggregate income elasticity of about 0.5 for both equations (1) and (2), which include the time dummies, but about 0.9 for equation (3) without the time dummies. However, the price effects are not well determined for all models; in equation (1) the price-max and price-rec are only significant at the 10% level, and based on test (4) cannot be regarded as statistically different from each other, thus supporting that asymmetric price responses may not be valid in this setting. For equations (2) and (3) the price elasticities are reasonably well defined albeit that for equation (3), as in (1), the relative magnitude of the decomposed components are not as would be expected. Hence they fail the logic test in equation (6) and provide further grounds for the rejection of this specification.

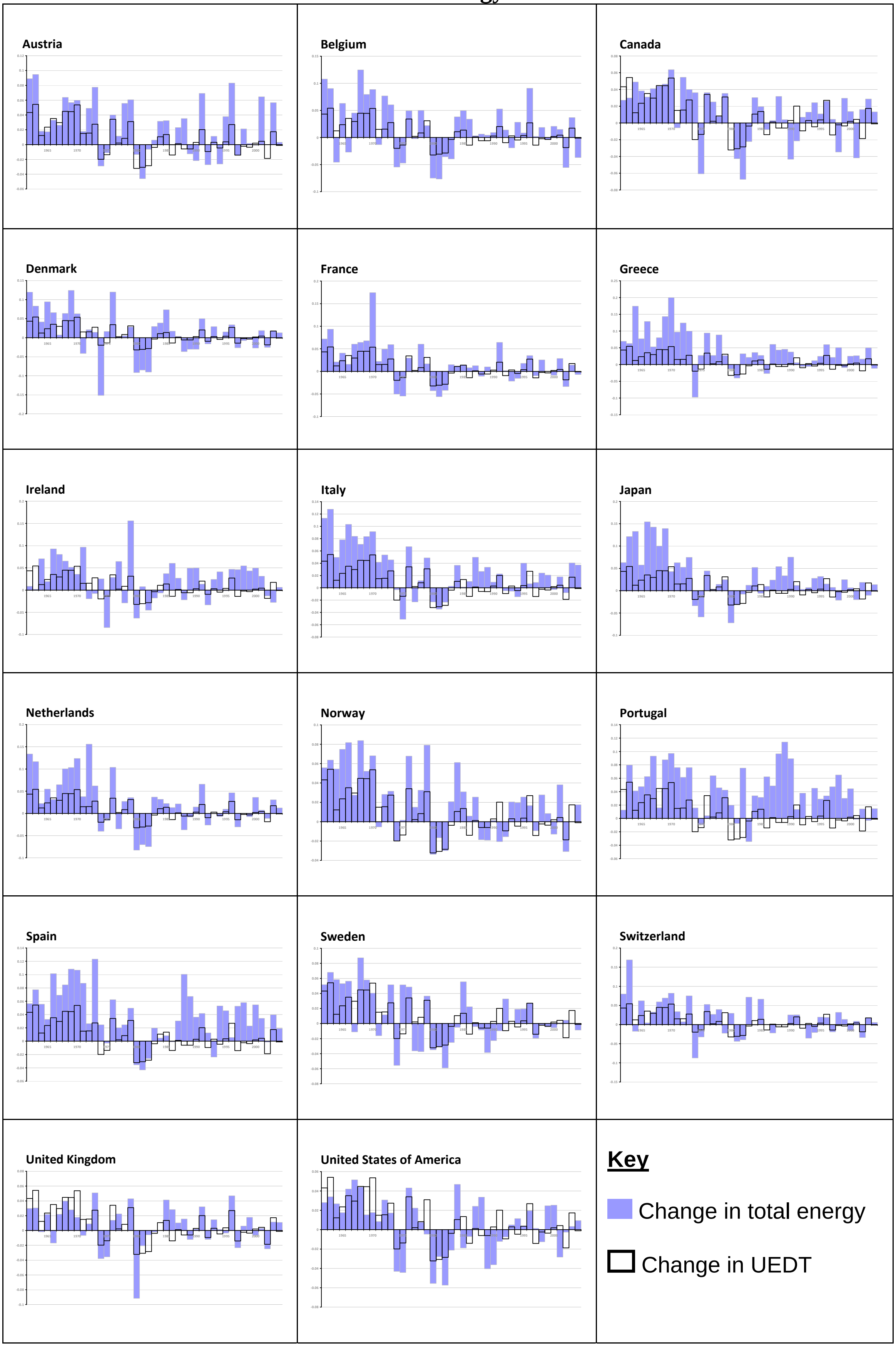
It is interesting to plot the implied UEDT given by $\Delta\mu_{it} = \sum_{t=1}^{T} \theta_t \Delta D_t$ which captures technical efficiency improvements as well as demand response to other exogenous non-economic factors (see Figure 1). This shows that the UEDT does not exhibit a *consistent* downward pattern (as would be implied by a simple time variable) but rather a trend with considerable variation from year to year with both upward and downward movement which is consistent with the UEDT approach adopted by Hunt *et al* (2003a and 2003b) in a time series context.

Figure 1: UEDT from model (2), with trendline.



The contributions of the UEDT have been calculated for each country based upon equation (1) and the results are given in Table 4, for ease of exposition these plots show only the $\Delta\mu_t$ relative to the total Δe_{it} and do not elucidate the impacts of the other variables.

Table 4: Contribution of UEDT to total energy demand for OECD 17 – Model 1.



4. Summary and Conclusion

This paper has demonstrated that there is a clear role for exogenous non-economic factors in explaining changes in energy demand consumption i.e. the elements of the UEDT, which encapsulate underlying consumer preferences, make tangible contributions to consumption behaviour. The contribution of these factors over time is not a trivial issue, rather, at a number of points in the sample period it can clearly be seen that the contribution is greater than the cumulative sum of the more traditional demand model components of price and income.

Future work should look more deeply into the estimated trends to determine how much of it might relate to such technological advances and how much is simply derived from fluctuations in the consumers underlying demand preferences induced by other factors within their decision making domain. For instance norms, expectations, habits, increased political and media awareness, advertising campaigns etc.

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Note:

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