Hysteresis and Energy Demand: the Announcement Effects and the effects of the UK Climate Change Levy

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Abstract

This paper presents an empirical analysis of the announcement effects of the United Kingdom's Climate Change Levy, which was announced in March 1999 and introduced in April 2001. The existence and nature of the effects are estimated by dummy variables within time-series regressions on quarterly and annual data 1973-2003 for UK energy demand by using sectors. The demands are explained by output and relative energy prices for the sector and outside temperatures in a cointegrating framework. A significant permanent effect is found for Commercial and Other Final Users, implying path dependency or hysteresis in their energy demand. It is shown that the announcement of the CCL did not just bring forward an adjustment to new relative prices arising from the CCL but it permanently reduced energy demand to a much greater extent that would be expected from the estimated price responses on their own.

1 Introduction

This paper reports an empirical analysis of the announcement effects (AE) of the Climate Change Levy (CCL) introduced by the UK Government in 2001. Although the CCL was introduced on 1st April 2001, it was formally announced in the March 1999 Budget to allow for further consultation on the details of the tax and to give businesses a full two years to adjust.

In this study the AE of the CCL is measured through the estimation of the responses to the announcement and eventual imposition of the tax. In the sense of Agnolucci and Ekins (forthcoming) the AE, following an official proposal to impose an environmental tax, is defined as responses taken between the time of the announcement of the tax and its actual implementation, whilst the general effect is defined to include any further effect in the sectors affected by the tax after its announcement, including the effects due to the rise in the price. The AE is therefore estimated by analysing the stability of the relationship between energy demand and its determinants. Note that the AE might persist after the tax is imposed. Clearly the AE is included in the general effect. Finally the overall effect of a tax can be defined by all changes brought about by the tax both in the sectors affected by the tax and in the rest of the economy.

2 The Climate Change Levy

In the March 1998 Budget, the Chancellor set up an inter-departmental task force chaired by an industrialist, Lord Marshall. The Marshall Report was published in November 1998, recommending that economic instruments had a role to play in improving the efficiency of business use of energy and that in order to help business with future energy investment, a clear signal should be given of the long-term direction of climate change policy. In addition, any tax should be designed to protect the competitive position of UK industry.

In the March 1999 Budget the Chancellor responded to the Marshall Report by announcing the Government's intention to introduce the CCL on the business use of energy from April 2001. In order to ensure that the levy caused no overall increase in the tax burden on business, the revenues from the levy were to be mainly used to reduce National Insurance Contributions by 0.5 percentage point. The statement was accompanied by illustrative rates of 0.21 p/kWh on the use of coal and gas and 0.60 p/kWh on the use of electricity, and suggesting lower rates (50% of the full rates) for energy-intensive users provided that they agreed targets for improving efficiency (these became incorporated into Climate Change Agreements (CCAs)). Use of fuels by large-scale electricity generation, transportation and households were to be excluded from the levy.

In the consultation period after the 2001 Budget there was a sustained and vociferous lobbying campaign led by the Confederation of British Industry (CBI), particularly focussing on the competitive position of energy-intensive users. The arguments were widely reported in the business media and ensured that the impending taxation of energy use was well publicised.

The eventual rates of CCL as introduced in the 2001 Budget were less than the original proposals with the rates set as follows:

- 0.15p/kWh for gas;
- 1.17p/kg (equivalent to 0.15p/kWh) for coal;
- 0.96p/kg (equivalent to 0.07p/kWh) for liquefied petroleum gas (LPG); and
- 0.43p/kWh for electricity[1].

The CCL does not apply to fuels used by the domestic or transport sector, or fuels used for the production of other forms of energy (e.g. electricity generation) or for non-energy purposes. In addition, the levy does not apply to energy used by registered charities for non-business uses, and energy used by very small firms, i.e. those using a de minimis (domestic) amount of energy. Finally, it does not apply to oils, which are already subject to excise duty. There are also several further exemptions from the Levy, including:

- Electricity generated from new renewable energy (e.g. solar and wind power);
- Fuel used by good quality combined heat and power schemes and exports of electricity from such schemes ("Good Quality CHP"-certified via the CHP Quality Assurance Programme CHPQA);
- Fuels used as a feedstock; and
- Electricity used in electrolysis processes, for example, the chlor-alkali process, or primary aluminium smelting.

The lower rates for energy-intensive users that agree to enter a CCA were set at 20% of the full rates, instead of the initial proposals of 50%, representing a considerable success for the lobbying efforts of the CBI.

[1] A more detailed description of the tax can be found at www.defra.gov.uk/environment/ccl/intro.htm.

3 Methodological issues in the estimation of the model

When analysing the effect of a tax, two issues have to be addressed. Firstly, while in theory the focus is on the responses of economic agents, at the empirical level only the outcome arising from those responses is normally observable. Secondly, analysing the effect of a tax requires the construction of a baseline or a business-as-usual scenario.

In this study an econometric approach is adopted that enables both the construction of a baseline and of indicators of the effect of the tax. This approach involves regressing energy consumption on its determinants over time. The parameters of the regression and the analysis of the parameters' stability allow measuring the direct energy savings brought about by the announcement of the CCL and more generally by its introduction. In order to compute the overall effect of the tax, the estimated energy demand below is then included in a general model of the economy (MDM-E3) and various scenarios are constructed, with and without the CCL and its AE. Comparison of the CCL scenario with a counterfactual scenario without the tax provides an estimate of the CCL overall effects. However these scenarios are not available for this paper and so they are not discussed further.

Econometric analyses of energy demand are usually based on log-linear specification such as that used by Pesaran and Smith (1995) and Pesaran et al (1998)[2]:

$$\ln E_t = \alpha_1 + \alpha_2 \ln Y_t + \alpha_3 \ln P_t + \alpha_4 \ln E_{t-1} + \varepsilon \quad \text{(1a)}$$

or

$$\ln E_t = \alpha_1 + \alpha_2 \ln Y_t + \alpha_3 \ln P_t + \alpha_4 \ln E_{t-1} + \alpha_5 \ln Y_{t-1} + \alpha_6 \ln P_{t-1} + \varepsilon \quad \text{(1b).}$$

In the model above, the economy-wide energy consumption in tons of oil equivalent, E, is a function of the real Gross Domestic Product (GDP), Y, and of an aggregate index of energy prices relative to the GDP deflator, P. The subscript t indicates the period of observation and the term ε is the stochastic error. The difference between (1a) and (1b) is in the inclusion of lagged independent variables.

There is substantial empirical literature on such functions reviewed in Barker et al. (1995) with equations estimated for UK industrial and whole-economy energy demand by Hunt and Manning (1989), Barker (1995), Hunt and Judge (1996) and Hunt et al. (2003). These studies report results on both annual and quarterly data. The advantage of using annual data is that they are available at a much more detailed level and that they sidestep the problems of seasonality. However, the purpose of the research reported here is to identify the AE of the CCL. Using annual data, if 1 January 1999 is taken as the announcement date of CCL, only four annual observations are available for the analysis of the AE (1999-2002). The limited number of annual data points is likely to be a problem in the detection of the AE and therefore energy demand equations are estimated using quarterly data. This means that, if the beginning of the second quarter in 1999 is taken as the announcement date, seventeen observations are available to test for the AE (1999Q2-2003Q2) [3].

3.1 Seasonality

UK energy demand typically exhibits extreme seasonality due to the use of fuels for heating in winter. In this study, seasonality is treated by the use of seasonally adjusted data using current

[2] This study compares a theoretical treatment based on value shares from production functions with the traditional log-log model adopted here. They conclude with: "Although the theory suggests an equation determining the value share of energy, the data strongly prefer a traditional equation explaining the logarithm of energy demand, though this may reflect deficiencies in the measure of the share used." The neoclassical production function approach cannot accommodate hysteresis effects without violating the basic assumptions of the model.

[3] It is worth pointing out that according to the definition of AE in section 2, the estimation should be carried out on a sample ending on 2001Q1. However, the rigidity of the energy demand (see below) makes this definition less clear-cut. In addition, using not many observations after the breakdate is thought to bias the results of stability tests (see Hansen, 2001).

best-practice techniques (Hylleberg, 1992). This is partly because some data on the main sector of interest, Commerce and Other Final Users, are only available in seasonally adjusted form. Hunt and Judge (1996) and Hunt et al. (2003) estimate sets of equations for UK energy demand for the whole economy, and the residential, manufacturing and transportation sectors using the structural time-series model of Harvey (1989). Hunt et al. (2003) compare these estimates with those using a cointegrating approach, as adopted here, and conclude that the structural time-series model outperforms the cointegrating model. However they include fixed seasonal dummies in an equation with seasonally unadjusted variables, rather than using seasonally adjusted variables directly, so that their method and results are not entirely comparable with ours.

3.2 Temperature Effects

All the studies of UK energy demand referred to above include temperature as a variable in the estimated equations and nearly always find highly significant effects. Studies on electricity demand in the UK (Peirson and Henley, 1994) and Spain (Pardo et al., 2002) both include temperature effects in the dynamic component of the equation and find them to be significant and important. Accordingly equation 1(b) has been extended to include seasonally adjusted temperature variables.

3.3 Sectoral and total energy demand

Equations analogous to (1a) and (1b) can be estimated both for the total energy consumption and at a more disaggregated level. As pointed out by Pesaran and Smith (1995), disaggregated analysis is helpful as residential, industrial and transportation demands for different types of energy differ systematically in ways likely to bias the aggregate estimates. Furthermore, as shown in Agnolucci and Ekins (forthcoming), the announcement effect has generally been detected in the consumption of single fuels and/or sectors of the economy.

In the case of the CCL, if analysis is conducted only for total energy, changes in the business, commercial and public sector (i.e. the sectors paying the tax) could be easily concealed by the constant consumption pattern in the transport and household sectors (i.e. the sectors not subject to the tax). Therefore, the likelihood of there being an announcement effect was tested for energy used in i) the Industrial Sector and ii) Commerce and Other Final Users Sector (commerce, public administration and others) and iii) the whole economy. However, in cases i) and iii) the hypothesis of there being an AE was rejected by the data and this analysis is not presented here.

The analysis of fuel-specific equations could be accommodated by using a model with an equation for each of the fuels used (e.g. a VAR model[4]). Since the fuels are often good substitute, the total energy demand in relation to the output of the fuel users is likely to be more stable than the individual components, although this is debatable. However, this approach is rather data intensive and time consuming, due to the numerous cross-equation relationships to be estimated, so it has not been followed.

3.4 Demand Rigidity

As pointed out by Baltagi and Griffin (1984), time-series estimation of energy demand has problems with the long lags related to the time needed by economic actors to adjust their demand to the long-term desired outcome (i.e. because of long-term contracts signed by firms, the building of power stations, etc.). This issue is of particular concern here, especially for the AE, as the time needed by the policy to affect the energy consumption blurs the temporal border of this effect. In the definition of AE above, it is implied that the response of the economic actors is more or less immediate. However, if this response is constrained by the rigidities in the energy system, the effects of the announcement of a policy might materialise rather slowly, accumulating over the period after the actual announcement date and persisting after the policy is implemented. In order to take the rigidity of the energy system into account

[4] A VAR model is a model where a set of variables is regressed on the differences of their lagged values $\mathbf{y}_t = \boldsymbol{\mu} + \boldsymbol{\Delta}_1 \mathbf{y}_{t-1} + \ldots + \boldsymbol{\Delta}_p \mathbf{y}_{t-p} + \mathbf{v}_t$.

the estimation period of the AE is extended to 2003Q2 and different dummy profiles, implying different degrees of rigidity, are also tested.

Pesaran and Smith (1995) also note that time-series estimation underestimates the total effect of the price change, as it works through the system, and therefore the time-series estimates of price elasticities are normally biased downwards. It is sometimes suggested that the price effect on energy demand can be better analysed using a panel dataset, although it is also the case that these biases may be present in dynamic panel data studies. However, as a panel dataset is not readily available, the use of time series was the only approach that could be employed in this study.

3.5 Hysteresis

There is considerable discussion of hysteresis in energy demand equations in the literature, focussed on asymmetrical responses to rising and falling prices. Such asymmetries mean that energy demand in any year depends on the previous time path of relative prices, i.e. the long-run solution is dependent on the precise short-run fluctuations in prices (Gately, 1993; Walker and Wirl, 1993; Hogan, 1993; Grubb, 1995; Ryan and Plourde, 1996, 2000 and 2002). The idea is that because energy is used via capital stock with a long lifetime, and since technical change is cumulative, the energy savings which are introduced when energy prices rise are generally not reversed when energy prices fall again, i.e. energy demand responds to rises in real prices, but not falls.

In the context of the UK energy demand and AE of the CCL, the hypothesis of the hysteris is tested through the use of a transitory and a permanent dummy variable. If both variables are equal zero, there will not be an AE. If only the former dummy is statistically significant, the AE will be only temporary, while if only the latter is different from zero, the AE is said to have permanently reduced the UK energy demand, irrespective of any additional effects through increases in energy prices. The argument is that the response to the CCL announcement by business leads to changes in the procedure and capital stock of energy use that permanently reduces the demand for energy, by for example new installation of more efficient fuel-burning equipment, more insulation of buildings and a more developed and efficient energy-saving industry.

4 Implementation of the single-equation test for AE

In this section the hypothesis of AE is tested. In particular, the AE takes the form of reduction, either temporary or permanent, in the energy demand, measured by the introduction of a dummy variable on the intercept of the regression. This corresponds to the economy being more energy efficient, given the income and the price level, as a result of the announcement of the CCL. This particular configuration of the AE was selected as it seemed likely that it would be difficult to identify any structural breaks associated with changes in the other parameters, this being due to the moderate size of the CCL and to the many other changes occurring at the same time in the energy sector (e.g. the conspicuous fall of energy prices after the introduction of NETA).

The AE is tested in an Error Correction Model (ECM)

$$\Delta e_t = a_0 + \varphi\left(e_{t-1} - \theta_1 y_{t-1} - \theta_2 p_{t-1} - \theta_3 te_{t-1}\right) + \sum_{j=0}^{s} \delta_j^{'} z_{t-j} + \beta_1 \Delta y_t + \beta_2 \Delta p_t + \beta_3 \Delta te_t + \sum_{j=1}^{s} \rho_j^{'} w_{t-j} + \varepsilon_t \quad (2)$$

[5],

[5] It can be easily shown that equation (2) is simply a reparameterisation of equation 1.

where E_t is the energy consumption per capita in tons of oil equivalent, P_t^e an aggregate index of energy prices, P_t an index of the general level of prices, Y_t the real output per capita, $e_t = \ln(E_t)$, $p_t = \ln(P_t^e / P_t)$, $y_t = \ln(Y_t)$, $\mathbf{z}_t$ is a vector of I(0) exogenous variables, and w = $(e_t, y_t, p_t)'$; Δ indicates first difference of the variables, e.g. $\Delta e_t = e_t - e_{t-1}$. The ECM model has the advantage of being able to distinguish between long-run (θ_1, θ_2 and θ_3) terms and short-run components (a_0, φ, β_1, β_2, ρ and δ).

In testing for AE, this study follows the approach suggested by Pesaran, Smith and Shin (PSS) (2001). PSS (2001) tests the existence of a relationship between the levels of variables, irrespective of whether the regressors are stationary, cointegrated of order 1 or mutually cointegrated (i.e. some are stationary, some are integrated of order 1). Studies using the Engle and Granger approach to test for cointegration are usually criticised because of the low power of the ADF test, on which this approach is based. It is worth mentioning that this criticism does not apply to this study as the PSS test, instead of the ADF, is used.

Given the ECM in (2) a test for the AE can be implemented following the steps below.

a) Use Least Squares (LS) with the pre-announcement observations to estimate (2) for different values of the lags and select an appropriate order by using the usual information selection criteria.
b) For the selected model test the existence of a long-run demand equation using the PSS test.
c) If a long-run energy demand equation exist, run the error correction equation, using pre- and post-announcement observations with announcement dummies. A test of no structural break corresponds to testing the null hypothesis that the coefficient of the dummies is zero.
d) If a long-run energy demand is not identified on the pre-announcement observations, run the error correction equation with φ = 0.

As already mentioned in section 3.3, the model above was estimated for both the total energy demand and at a more disaggregated level - i) Industrial Sector and ii) Commerce and Other Final Users Sector (i.e. the commercial, agricultural and public sectors), although only the results for ii) are presented as it was the only instance in which an AE was not rejected.

Regarding the frequency of the observations, the model above is estimated using quarterly data, as mentioned in 3.1. Available evidence indicates that if seasonally adjusted data are used in econometric modelling, estimated static and, in particular, dynamic relationships are distorted by the seasonal adjustment. Hylleberg (1992) points out that as the degree of distortion varies, the best advice for the researcher is to consider both the seasonally adjusted and the seasonally unadjusted series. However, some of the time series used in this study are not published in a non-deseasonalised format. In addition, preliminary analysis using non-deseasonalised data showed that serial correlation was a very serious issue.

Estimation of the overall effect of the CCL required the estimation of the annual MDM-E3 based energy demand equations, disaggregated to a broader level. The purpose of the quarterly equations was to determine whether or not there was a 'structural break' between 1998 and 1999 and hence confirm or reject the existence of a CCL announcement effect. The choice and profile of the CCL dummy adopted in the respecification and estimation of the annual equations in MDM-E3 was informed by the estimation results of the quarterly equations.

In determining the ‘best fitting’ model specification, a general-to-specific method was used. Literature, along with a priori knowledge, led us to begin with a specification including the dependent variable - energy demand/consumption - and regressing this against temperature, prices, output, investment (technological indicator), and a linear trend. However, it soon became clear that linear trend, income and the technological indicator were strongly correlated. Therefore, to avoid multicollinearity the last variable was discarded.

Uncertainty arose on how to treat the temperature, as ADF tests on the deseasonalised variable were not conclusive. However, ADF tests on the non-seasonally adjusted observations clearly rejected the null hypothesis of unit roots with or without the presence of a deterministic trend. One can wonder whether the eventual non-stationarity of the seasonally adjusted temperature time series has been built-in by the seasonal adjustment itself. Either way, it was decided to estimate the error correction model above twice, once treating the temperature as a stationary variable, and secondly treating it as a non-stationary variable. The former case implies using the level of the temperatures in the dynamic part of the model while the latter corresponds to using the levels in the long-term of the model and the first differences in the dynamic one[6]. In both cases, the general-to-specific procedure mentioned above pointed out that only price and temperature should be included in the dynamic part of the model.

Table 1. Comparison between a model treating the temperature as a non-stationary variable (Model 1) and another treating it as a stationary variable.

Estimated regression				
	Model 1 DE=A0+A1*DTE+A2*DP+A3*(E(-1)-A4*Y(-1)-A5*TE(-1)-A6*P(-1))		**Model 2** DLE=A0+A1*TE+A2*DP+A3*(E(-1)-A4*Y(-1)-A6*P(-1))	
Parameter	Estimate	t-value	Estimate	t-value
A0	1.5659	-7.0708	-1.6215	-8.8566
A1	-0.021763	-7.5079	-0.02158	-7.5487
A2	-0.49277	-5.6035	-0.48602	-5.6321
A3	-0.68737	-7.5425	-0.71397	-10.3323
A4	0.14006	4.2574	0.14358	4.7011
A5	-0.029275	-5.2606		
A6	-0.18079	-7.3789	-0.18071	-7.6934
Diagnostics				
R-Bar-Squared	.69985		0.70231	
S.E. of Regression	.032539		0.032405	
AIC	203.2799		204.1713	
SBC	194.0584		196.2671	
Serial Correlation	8.9875[.061] 2.1988[.075]		8.1283[.087] 1.9920[.102]	

As shown in Table 1, the estimation of the two models yields very similar results, although Model 2 deals more effectively with the serial correlation. For this reason it was decided to use Model 2 for the rest of the study, and therefore treat temperature as stationary. In terms of the PSS test, both models reject the null hypothesis of no cointegration, although the value of the PSS statistics in the case of Model 2 is twice as big as in the other case.

Model 2 is then estimated over the whole sample period (1973Q1-2003Q2) with the dummy variables, which are presented in Table 2 according to their statistical strength (i.e. largest negative t-ratio). The table shows only the annual average of the permanent dummy, whose quarterly values were computed according to the profile shown by the annual average. The dummies in the table were inserted into the brackets of equation 2, while their first differenced value, i.e. the transitory dummy, was inserted outside the brackets, in the dynamic part of the model. It is worth pointing out that the transitory dummy variable reverses to zero in mid 2002. Obviously, in correspondence of a zero transitory dummy the permanent one assumes a constant value.

[6] It is worth reminding that the PSS test is applicable in both cases as it deals with both I(1) and I(0) variables.

Table 2. Comparison of different permanent dummy variables, PD.

Variable	1998	1999	2000	2001	2002	Estimate	t-value
PD1	0	0.125	0.5	0.88	1	-0.12897	-6.7718
PD2	0	0.2	0.6	0.92	1	-0.12584	-6.6618
PD3	0	0.149	0.42	0.8	1	-0.13333	-6.7188
PD4	0	0.1	0.35	0.7	1	-0.13712	-6.5942
PD5	0	0.1	0.32	0.66	1	-0.1374	-6.4742
PD6	0	1	1	1	1	-0.08212	-3.7966

As shown above the data failed to reject the hypothesis of no AE. In particular, when both a transitory and a permanent dummy variable were added to equation (2) only the latter was significantly different from zero. The different profiles in Table 2 show that the hypothesis of permanent AE is compatible with all dummy profiles, although a gradual AE (i.e. profiles LRD1-5) is much more statistically robust than a zero-one profile (i.e. full effect from the beginning of the announcement in 1999). While the hypothesis of no permanent AE is clearly rejected by the sample, the component of the model where a permanent AE has occurred, i.e. the dynamic or long-term part, cannot be identified as the two are observably equivalent. In this study it was chosen to put the permanent dummy inside the bracket, although the other choice, permanent effect in the dynamic part, is as good as ours.

Table 3 compares the estimate of the parameters in pre-announcement and in the whole sample. It is worth pointing out that coefficients of the regression with the dummy estimated over the whole sample are very similar to those in the regression estimated over the pre-announcement sample. Estimation of the regression over the whole sample without a dummy – not presented here - shows much less stable coefficients and generally worse diagnostic statistics, therefore reinforcing the case for there being an AE.

Table 3. Comparison between the regression with a dummy estimated over the whole sample and the regression without a dummy estimated in the pre-announcement sample.

Estimated regression				
	LE=A0+A1*DTE+A2*DP+A3*(E(-1)-A4*Y(-1)-A6*P(-1)-A7*PD1)) Sample 1973Q2-2003Q2		LE=A0+A1*TE+A2*DP+A3*(E(-1)-A4*Y(-1)-A6*P(-1)) Sample 1973Q2-1998Q4	
Parameter	Estimate	t-value	Estimate	t-value
A0	-1.6066	-9.06	-1.6215	-8.8566
A1	-0.02157	-7.995	-0.02158	-7.5487
A2	-0.45908	-5.6402	-0.48602	-5.6321
A3	-0.70748	-10.5566	-0.71397	-10.3323
A4	0.14752	4.9451	0.14358	4.7011
A5				
A6	-0.18048	-7.7655	-0.18071	-7.6934
A7	-0.12912	-6.6174		
Diagnostics				
R-Bar-Squared	0.67575		0.70231	
S.E. of Regression	0.032430		0.032405	
AIC	239.7821		204.1713	
SBC	229.9968		196.2671	
Serial Correlation	7.7747[.100] 1.8883[.118]		8.1283[.087] 1.9920[.102]	

5 Conclusion

As pointed out in Agnolucci and Ekins (forthcoming) the likelihood of observing an Announcement Effect is influenced by the credibility of the announcement, by the information set of the economic agents and by the capital expenditure needed to respond to the policy.

In this paper it has been shown that the announcement and following implementation of the CCL has caused a permanent reduction of energy demand in the Commercial and Other Final Users Sector due to the Announcement Effect. Analyses not presented here show that the null hypothesis of AE was rejected in the case of the Whole Economy and Industrial Sector. The lack of an AE in these sectors does not imply an absence of an environmental effect of the CCL. Due to the negative relation between the level of energy demand and energy price, the imposition of the tax (i.e. increase in the price) has contributed to reduce energy consumption.

However, the presence of an AE says that some firms changed their behaviour before the levy was introduced in April 2001. In environmental terms, this is a positive result as it shows that a credible Government policy of pre-announcing new taxes can lead to early action by firms. This study has shown that this change is found to be permanent and not transitory.

Finally, while the lack of an AE for the total energy demand is likely to be due to the relatively small share of energy taxed by the CCL, in the case of the Industrial Sector one can wonder if the successful lobbying of the Confederation of British Industry against the levy prevented industrial firms from responding to the tax. It is worth noting that no major lobbying occurred in the case of the Commercial and Other Final Users Sector.

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Annex Sources of the Data

<u>Main sources of quarterly data used in the study</u>

Most of the data used in the quarterly model were collected from the following four publications: Monthly Digest of Statistics (ONS), UK Economic Accounts (ONS), Quarterly Energy Trends (DTI), and Quarterly Energy Prices (DTI). Data were collected for the following time series: energy consumption, energy prices, temperature, output per capita and gross investment. These were formed as both unadjusted and seasonally-adjusted time series for the most detailed sectors of the economy consistently available for quarterly data (much more detail is available for annual data) for Industry (mainly manufacturing) and Commerce and other final users. The Industrial Sector comprises the manufacturing sectors excluding fuel manufacture (SIC 1992 codes 17-22,24-37), together with construction (SIC 45), water supply (SIC 41) and mining and quarrying (SIC 13-14). Commerce and Other Final Users comprises Public Administration (SIC 75, 80, 85), Commerce (SIC 50-52, 55, 64-67, 70-74), Agriculture (SIC 01, 02, 05) and Miscellaneous (90-93, 99), but excludes domestic use. This grouping does not coincide exactly either with the users facing the CCL or with data available for gross output. However the differences are small and are not considered sufficient to distort any results.

<u>Energy consumption data</u>

Energy consumption data were collected from *Quarterly Energy Trends* from 1973Q1 to 2003Q2. The time-series were translated from various units to thousand tonnes of oil equivalent and were compared to the annual time-series in DUKES 2003 to ensure consistency across time.

Population data

Mid-year annual population estimates were collected from the *Annual Abstract of Statistics*, then linearly interpolated to obtain quarterly estimates.

Energy price data

The DTI *Quarterly Energy Prices* contains detailed data on energy prices by fuel and for various fuel users. It also publishes the quarterly UK GDP deflator in 1995 prices. From this source, time-series of relative energy price indices for each sector were calculated with and without the CCL. The DTI does not publish quarterly estimates of energy prices for Commerce and Other Final Users. We calculated prices excluding the CCL for this sector by first assuming individual fuel prices are 50% more than those for the Industrial Sector (a broadly representative figure chosen by inspection from annual data) and calculated an average energy price weighted by consumption of the different fuels. We added the CCL at the full rate from 2001Q2 onwards to obtain prices including the CCL.

The main problem with these data was the lack of price information for Commerce and Other Final Users. As this sector comprises a diverse array of activities it is likely there is a great variety of prices paid, hence our estimate is only a rough approximation. In addition, the method of averaging prices according to fuel consumption poses problems: a lot of the variation in prices is explained through swings in the relative consumption of gas/electricity.

Output data

Data on output from the Industrial Sector were collected from the *Monthly Digest of Statistics*. Output data for Commerce and Other Final Users and the whole economy were collected from UK Economic Accounts. From these two sources we gathered chain-linked output indices (reference year 2000) for the exact sectors specified in the classification above. The indices were then multiplied by their weights in whole-economy output in 2000, summed and scaled to current-price output for the UK in 2000. Output data were available for most series over 1948 - 2003Q2, and for all series over 1978 - 2003Q1. For industrial and whole economy sectors, both unadjusted and seasonally adjusted data were available. However, the ONS does not publish unadjusted data for the service sectors so that an unadjusted time series for Commerce and Other Final Users could not be formed.

Temperatures

Quarterly Energy Trends contains data on the average temperatures for the UK over 1989 - 2003 in degrees Celsius, both on a statistical and a calendar monthly basis. The monthly data were aggregated to obtain quarterly temperatures.

Seasonal adjustment

Where possible we used published seasonally adjusted versions of the variables listed above. Where these were not available, we used the X11 procedure in E-Views to adjust the data. We adjusted the following variables: energy consumption, temperature, and energy prices for the Commercial and Other Final Users Sector and the whole economy. We received already-adjusted versions of the following variables: output and industrial energy prices.

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