

Bunn, Derek W.; Fezzi, Carlo

Working Paper

Interaction of European Carbon Trading and Energy Prices

Nota di Lavoro, No. 63.2007

Provided in Cooperation with:

Fondazione Eni Enrico Mattei (FEEM)

Suggested Citation: Bunn, Derek W.; Fezzi, Carlo (2007) : Interaction of European Carbon Trading and Energy Prices, Nota di Lavoro, No. 63.2007, Fondazione Eni Enrico Mattei (FEEM), Milano

This Version is available at:

<https://hdl.handle.net/10419/74196>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Interaction of European Carbon Trading and Energy Prices

Derek W. Bunn and Carlo Fezzi

NOTA DI LAVORO 63.2007

JUNE 2007

CCMP – Climate Change Modelling and Policy

Derek W. Bunn, *Department of Decision Science, London Business School*
Carlo Fezzi, *CSERGE, School of Environmental Sciences, University of East Anglia*

This paper can be downloaded without charge at:

The Fondazione Eni Enrico Mattei Note di Lavoro Series Index:
<http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm>

Social Science Research Network Electronic Paper Collection:
<http://ssrn.com/abstract=993791>

The opinions expressed in this paper do not necessarily reflect the position of
Fondazione Eni Enrico Mattei
Corso Magenta, 63, 20123 Milano (I), web site: www.feem.it, e-mail: working.papers@feem.it

Interaction of European Carbon Trading and Energy Prices

Summary

This paper addresses the economic impact of the EU Emission Trading Scheme for carbon on wholesale electricity and gas prices. Specifically, we analyse the mutual relationships between electricity, gas and carbon prices in the daily spot markets in the United Kingdom. Using a structural co-integrated VAR model, we show how the prices of carbon and gas jointly influence the equilibrium price of electricity. Furthermore, we derive the dynamic pass-through of carbon into electricity price and the response of electricity and carbon prices to shocks in the gas price.

Keywords: Carbon Emission Trading, Energy Markets, Structural VECM

JEL Classification: Q48, L94, C32

We would like to thank Sirio Aramonte, Luca Fanelli, Stefano Sacchetto and an anonymous referee for their helpful comments. A preliminary version of this paper was presented at the EAERE-FEEM-VIU Summer School on "Computable General Equilibrium Modeling in Environmental and Resource Economics", held in Venice from June 25th to July 1st, 2006 and supported by the Marie Curie Series of Conferences "European Summer School in Resource and Environmental Economics".

Address for correspondence:

Derek W. Bunn
Department of Decision Science
London Business School
Sussex Place Regent's Park
NW1 4SA London
UK
E-mail: dbunn@london.edu.

1 Introduction

As part of its commitment to the Kyoto Protocol, in January 2005 the European Union implemented a scheme of tradable CO₂ emission permits, whereby restricted allowances were allocated to various industrial emitters of carbon dioxide, specifying the amount of CO₂ they can emit each year. At the end of each year, companies must produce permits to cover their tonnes of CO₂ emitted. Since companies are allowed to trade permits freely with one another within the EU, the scheme was intended to ensure not only that overall emissions would be reduced, but also that the cuts are made by those firms that can achieve the most efficient abatement costs (European Commission, 2003). With the success of this scheme having major implications, not only for the continuing commitment of the EU to greenhouse gas abatements, but also to other countries and regions which are considering the introduction of a similar scheme, its progress has been subject to intense scrutiny, even before substantial empirical evidence has accumulated (European Commission, 2005; Smale et al. 2006, Sijm et al. 2006, Bentz and Trück 2006).

Prior to the emergence of actual evidence from carbon trading in practice, extensive theoretical and simulation analyses have speculated upon its broad effects (eg, McKibbin et al. 1999, Criqui and Viguer 2000, Böhringer 2002, Böhringer and Lange 2005, Barreto and Kypreos 2004, Huntington and Weyant, 2004). Regarding the EU power sector in particular, Linares et al. (2006) comment upon the Spanish situation, and Hauch (2003) on the Nordic region. Despite the longer term policy insights that such studies provided, the first phase of the EU Emission Trading Scheme (ETS) was introduced as an experiment, with open questions upon the short term properties of the carbon prices. The initial behaviour of the prices has indeed raised several concerns. In the first few months of 2005, carbon allowances were traded at about €7/tonne, raising steadily to a peak over €29/tonne in July, before falling back to around €20/tonne a month later and fluctuating around that level during the rest of 2005. As daily trading essentially reflects a forward market on the annual commitment to settle emissions with permits, such volatility not only reflects basic uncertainty in the underlying annual price of abatement, but substantially adds to the risk management costs of participants. By April 2006, daily prices had again risen over €30/tonne, falling precipitously during three days at the end of the month to below €10/tonne when the first

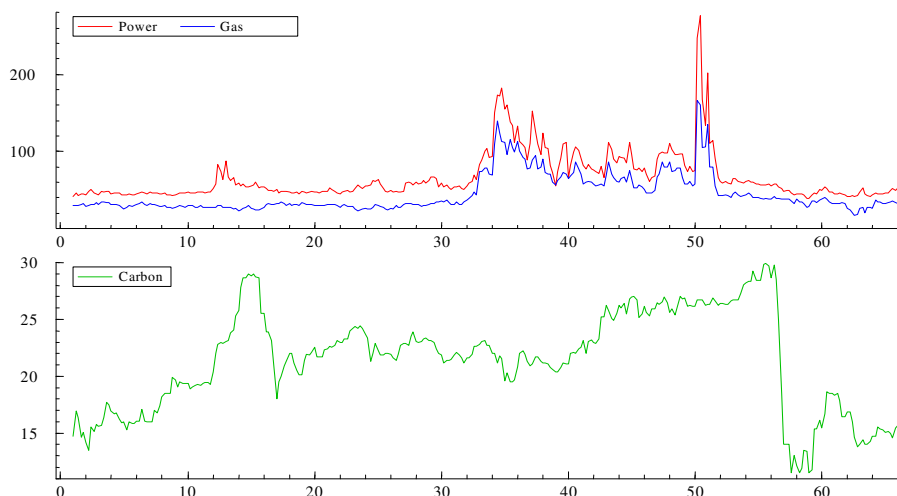
settlement news appeared and it became apparent that far less abatement had been needed in the first year than the market had been expecting. Shocks of that magnitude affect the asset values of power companies with, for example, British Energy losing 5% of its stock market value during those three days in April 2006. By January, 2007, spot carbon prices had fallen to €4/tonne, but forward prices for 2008 were trading around €16/tonne. The result of such uncertainty created investment aversion in the industry, to the extent that the major companies were identifying carbon price risk as the major factor in investment delays, despite institutional concerns about security of supply (Blyth, 2007).

Hence the objective of this paper is to analyse, econometrically, evidence from the first two years of the EU ETS, with the aim of determining its interrelationship with gas and power prices. Specifically, we propose a structural, cointegrated vector autoregressive (SVAR) model, estimated on daily market data, which encompasses both short-run and equilibrium relations between electricity, gas and carbon prices. From this, we can estimate the transmission of shocks between gas, carbon and power prices, and thereby address questions on the short term economic impact and potential efficiency of the scheme. The paper is organised as follows: section 2 presents the main features of the interaction between carbon, gas and electricity prices, section 3 introduces the statistical framework regarding the structural cointegrated VAR model, and section 4 describes its estimates on the EU ETS data. Section 5 concludes.

2 Carbon price formation and the electricity market

As for any other freely-traded product, the price of carbon allowances is determined by the balance between supply and demand. In the case of carbon permits, it is appropriate to distinguish between the short term daily market, where trading actually happens, and the ‘long term’ settlement (each multiyear Phase of the scheme), where the mandatory requirements of the scheme are balanced and audited. Initially the EU ETS was designed to operate through two Phases (Phase 1: 2005-2007; Phase 2: 2008-2012). Each member state of the EU agrees on a national allocation plan (NAP) for annual abatement for each Phase, based upon a restricted percentage of the “business as usual” projection of emissions from particular facilities. Thus there is an annual requirement

Figure 1: Daily day-ahead electricity and gas price in United Kingdom, carbon price (source: *Platts*)



for abatement (in tonnes CO₂), D_j , ($j = 1, 2$ for Phases), which will be uncertain because of the underlying “business as usual” baseline. Across the EU there exists essentially a supply function for abatement, $f(\cdot)$, reflecting the increasing marginal costs within a year of reducing a tonne of CO₂. Thus, in terms of the power sector responsiveness in the short run, for low levels of abatement $f(\cdot)$ will reflect the substitution of German lignite by hard coal, then the more expensive option of replacing hard coal by gas (mainly in Spain and the UK) will appear further up this abatement supply function. Thus, the supply function is convex, discontinuous, uncertain and variable throughout the year, reflecting the switching costs between primary fuels. Essentially, therefore, agents trade in the daily market, buying and selling carbon allowances, against their own expectations, $E_t[f(D_j)]$, which evolve through the year on the annual equilibrium price for carbon.

Furthermore, to the extent that annual allowances are granted to the scheme participants at the beginning of each Phase, and that a daily price for carbon emerges from the markets, these allowances reflect new liquid assets (some critics argue that polluters have been given windfall profits in the short term), and thus their consumption (eg. to produce power) involves the opportunity cost of carbon at the market price (see also Sijm et al. 2006). Of course, production in excess of allowances does require the direct purchase from the market of an allowance. So it is to be expected that the price of carbon will be an additional increment to the short-term fuel costs of power

generation, the aggregate effect of which will depend on the technology mix across the whole of the EU and the pricing behavior of firms.

Figure 1 shows the sample of data used in this study, weekdays from April 2005¹ to May 2006, with UK electricity and gas prices (upper plot), as well as EU carbon allowances (lower plot). Whilst gas and power prices are closely related, carbon seems quite distinct. Evidently, fundamental analysis would suggest that gas shocks should transmit to power, and power shocks could transmit to gas if the power market is a substantial part of the gas market, which is the case in the UK but not in EU as a whole. Moreover, both electricity and gas consumption are influenced by weather conditions. As for carbon price, the structural considerations illustrated above (i.e. the coal to gas switching) might suggest that in a closed system it would be substantially dependent upon gas prices, but this would be confounded in a particular case with national markets for gas and power, given the much wider EU market for carbon.

Despite, therefore, these structural considerations, because of the intricate and confounding nature of the interrelationships, we approached the model specification through the data-driven paradigm, as advocated in Sims (1980), Hendry and Mizon (1993). In other words, firstly data dynamics are modelled through a detailed statistical specification without imposing any 'a-priori' economic restriction and, only in a second step, the structural model is derived with a downward testing procedure as a restriction of the statistical model describing the data.

The three series did not reject unit root tests on levels, whilst differences appeared to be stationary². Therefore, in order to avoid the risk of spurious regression, we modeled the series as I(1) with a cointegration methodology (following Johansen, 1991). This technique seeks to ensure valid inference in non-stationary systems. So far, it has been used predominantly to estimate long-run macroeconomic relationships. Implementations in high-frequency context are less common: Baillie and Bollerslev (1989) and Diebold et al. (1994) have used it to evaluate

¹From April 2005, the England and Wales power market expanded to include Scotland.

²Modelling non-stationary variables as stationary invalidates in most cases the inferential procedure, cf. Granger and Newbold (1974), Hendry (1980), Phillips (1986) and Hendry and Juselius (2000). We tested for unit roots using the ADF unit root test (Said and Dickey 1984) and the KPSS stationarity test (Kwiatkowski, Phillips, Schmidt and Shin, 1992).

daily financial market outcomes, whilst in the electricity market context, Fezzi and Bunn (2006) estimated two cointegrating vectors for daily supply and demand interactions.

3 The model

We implement a structural cointegrated VAR model, following Pesaran and Shin (1998), Garratt et al. (1998). This methodology merges the structural VAR approach with the cointegration technique, having the attractive feature that the estimated equilibrium relationships give a clear economic interpretation whilst the short-run dynamics are flexibly estimated in a VAR specification. Structural VARs were introduced by Bernanke (1986), Sims (1986) and Blanchard and Quah (1989), in response to criticism regarding the “lack of economic interpretability” (Cooley and ReLoy, 1985) of the classical VAR approach proposed in Sims (1980). In a classical VAR all the variables are modelled as endogenous a priori, as a function of their on past values, i.e. as:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \dots + A_p y_{t-p} + u_t , \quad (1)$$

with y_t = vector of n endogenous variables, $A_1, \dots, A_p = n \times n$ regression matrices, p = number of lags chose to ensure no serial correlation in the residual component u_t with covariance matrix Σ_u . Equation (1) is a reduced form since the contemporaneous relations between the endogenous variables are not modelled and therefore it may difficult to give to the residual a direct economic interpretation, especially if the cross-correlation matrix Σ_u contains high values. Alternatively, the structural VAR has been developed to transform the reduced form VAR model into a system of structural equations, whose impulse response function and variance decomposition present, in principle, direct economic meanings. This can be achieved either by imposing restrictions on the residual cross-correlation matrix or on the long-run relations. A SVAR model can be written in the form:

$$B_0 y_t = B_1 y_{t-1} + B_2 y_{t-2} + \dots + B_p y_{t-p} + \varepsilon_t , \quad (2)$$

where $\varepsilon_t = B_0 u_t$, $B_q = B_0 * A_q$, $q = 1, \dots, p$ and the correlation matrix of the residuals is $\Omega = B_0 \Sigma_u B_0$ (in general equal to the identity matrix). Considering only short-run restrictions (for long-run restrictions see

Blanchard and Quah, 1989) one has to impose $n * (n - 1)/2$ restrictions on the matrix B_0 (plus the normalisation restrictions achieved by setting the covariance matrix of the structural shocks to identity) in order to identify all the parameters of equation (2) from the reduced form model (1). These restrictions should, in general, be motivated by economic theory (see, among others, Amisano and Giannini, 1997). In this paper, we derive them from two auxiliary regressions, in the next section.

The SVAR technique has also been implemented in vector error-correction models with cointegrated variables. The Johansen (1991) procedure for testing the presence of cointegrating vectors starts with a reduced form VAR model (equation 1), and therefore without imposing any ‘a priori’ restrictions. The model can be re-written in the following error-correction form:

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \dots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t , \quad (3)$$

where $\Pi = A_1 + A_2 + \dots + A_p$ and $\Gamma_i = -(A_{i+1} + \dots + A_p)$. Model (3) can be augmented considering the simultaneous interactions between endogenous variables and therefore giving structural meaning to the residual component:

$$B_0 \Delta y_t = \Psi y_{t-1} + \Lambda_1 \Delta y_{t-1} + \dots + \Lambda_{p-1} \Delta y_{t-p+1} + \varepsilon_t , \quad (4)$$

where equation (3) can be obtained simply pre-multiplying the system by B_0^{-1} . Thus, to compute the responses to the economic shocks ε_t , one has to link the forecast errors u_t in the reduced form model (3) to the structural residuals ε_t through the identity: $\varepsilon_t = B_0 u_t$. In the next section we show how to identify the residual matrix, based on two auxiliary regressions.

Our modelling approach starts from a reduced form VAR considering electricity, gas and carbon prices as potentially endogenous ‘a priori’. Furthermore, we include, as exogenous variables, atmospheric temperature (which is the most important determinant of electricity and gas demand on daily basis) and three dummy variables in order to capture the huge drop in carbon price over three days, following news of the settlement, at the end

of April 2006. In this model the main purpose of the exogenous variables is to capture the co-movements of the endogenous ones and, therefore, highlight the interactions among the endogenous. As shown, for instance, by Engle et al. (1986), the energy demand (and, therefore, price) and temperature relationship is a highly non-linear ‘V’ shaped function, since energy is used for both heating and cooling purposes. Thus, following an explorative analysis, we identify a threshold at which the price-temperature gradient reverses and define two variables and a dummy from the original temperature, namely cold temperature, t_{cold} , hot temperature, t_{hot} and d_{temp} .

Defining $y'_t = [p_{electricity}, p_{gas}, p_{carbon}]$, $z'_t = [t_{hot,t}, t_{cold,t}, d_{temp}]$ ³ and $x'_t = [y'_t, z'_t]$, and $d_t =$ deterministic term containing centered seasonal dummies to capture the weekly seasonality and three dummy variables encompassing the carbon shock, the reduced form VECM system can be written as:

$$\Delta y_t = \omega \Delta z_t + \alpha \beta' y_{t-1} + \Gamma_1 \Delta y_{t-1} + \dots + \Gamma_{p-1} \Delta y_{t-p+1} + C d_t + u_t . \quad (5)$$

In this model temperature and deterministic factors affect the short run dynamics of the price series that revert towards the equilibrium vector(s) $\beta' y_{t-1}$ according to the adjustment coefficients α . Thus, it is possible to identify the structural interactions among the variables by imposing restrictions on the matrix B_0 (eq. 4), which we do in the next section through two auxiliary regressions.

4 The results

The above model is estimated using day-ahead electricity (UKPX) and gas prices (NBP) for United Kingdom and European carbon emission price (source: Platts). Atmospheric temperature is represented by the daily

³The model is actually estimated using the differentiated variables Δt_{cold} and Δt_{hot} , which are not simply the first differences of t_{cold} and t_{hot} . In fact, to linearise a "V" relation in the first differences, one has to consider that if during the intra-period variation the temperature crosses the threshold the relationship is reverted. To overcome this problem Δt_{hot} is defined as all the variation of the temperature that occurs above the threshold and as Δt_{cold} all the variation that occurs below. If, for instance, the threshold is $60^\circ F$ and temperature drops from $63^\circ F$ to $55^\circ F$, $\Delta t_{hot} = -3$ and $\Delta t_{cold} = -5$. Furthermore, on the first differences, the dummy disappears.

<i>Trace Test</i>				
<i>Ho</i>	<i>r</i>	<i>n-r</i>	<i>p-value</i>	<i>eigenv.</i>
0	2	54.090	[0.000]	0.1223
1	1	11.821	[0.474]	0.0253
2	0	3.5225	[0.499]	0.0108

<i>Cointegrating vector estimates</i>			
$1p_{electricity} - 0.628p_{gas} - 0.428p_{carbon} - 0.592$			
[...]	[-11.926]	[-3.985]	[-1.842]

Table 1: Cointegration tests and vector estimates with LR test

average temperature in London, available from the archive provided by the University of Dayton. We transform the endogenous variables (electricity, gas and carbon prices) into their natural logarithms to reduce variability, and thus obtaining directly the elasticity values from the parameter estimates. We estimate model (5) with one lag in the endogenous variables (selected by the Hannan-Quinn criterion), and test for the number of cointegrating vectors using the trace test introduced in Johansen (1991). We restrict the intercept to lie in the cointegration space since we do not find evidence of a trend in the dynamics of the variables.

The results, reported in table 1, strongly support⁴ the presence of one cointegrating vector. Observing the cointegrating coefficients, we are reassured that all the estimates have plausible signs. Furthermore, they are all significant according to the Likelihood Ratio (LR) test as showed in Johansen (1996). The coefficients can be interpreted as price elasticities, implying, for instance, that a gas price rise of 1%, would, in equilibrium, be associated with an electricity price rise of 0.63%. Furthermore, since all the coefficients are strongly significant, all the price variables are important to define the equilibrium vector, i.e. both carbon and gas prices are crucial to define the level to which electricity price is attracted over time.

Even though useful to understand the equilibrium price of electricity in the “long run”, this cointegrating

⁴Since exogenous and deterministic variables are included, and thus the original critical values are no longer valid, we compute the approximated p-values based on Doornik (1998).

	$\Delta p_{electricity}$	Δp_{gas}	Δp_{carbon}
EC_{t-1}	-0.249 (-5.235)	-0.094 (-2.047)	-0.004 (-0.292)
$\Delta p_{electricity,t-1}$	-0.119 (-2.240)	—	—
$\Delta p_{gas,t-1}$	0.192 (3.450)	—	0.036 (2.002)
$\Delta p_{carbon,t-1}$	—	—	—
$\Delta t_{cold,t}$	-0.013 (-4.364)	-0.007 (-2.185)	—
$D_{carb,t}$	—	—	-0.123 (-3.148)
$D_{carb,t-1}$	—	—	-0.305 (-7.904)
$D_{carb,t-2}$	—	—	-0.269 (-7.025)
TESTS			
$AR(3), \chi(27)$		37.42 [0.087]	
$ARCH(5), \chi(180)$		253.53 [0.000]	
$Normality$		3363.18 [0.000]	
CORRELATIONS			
$u_{electricity}$	1	—	—
u_{gas}	0.72	1	—
u_{carbon}	0.10	0.04	1

Table 2: Vector error-correction model estimates and tests, t-ratios in parenthesis

vector does not contain any information regarding the short term interactions of those prices (matrixes B_0 and Λ_i , $i = 1, \dots, p$, in model 4) nor how fast each of the variables moves towards the equilibrium (matrix α in model 5). In order to analyse these issues we estimate model (5) with the software *jmulti* (Lütkepohl and Krätzig, 2004) using 3SLS and eliminate the non-significant coefficients through a recursive procedure, i.e. sequentially excluding the regressors with the lowest t-ratio and ultimately minimising the HQ criterion (see Brüggemann and Lütkepohl, 2001).

Dependent: $p_{electricity}$			Dependent: p_{gas}		
Intstrum: <i>Int. flow, stored gas</i>			Intstrum: <i>excess capacity</i>		
variable	coefficient	t-ratio	variable	coefficient	t-ratio
k	0.23	1.87	k	0.30	0.14
$p_{gas,t}$	0.69	2.87	$p_{elec,t}$	0.30	1.52
$p_{elec,t-1}$	0.75	19.36	$p_{gas,t-1}$	0.89	19.85
$p_{gas,t-1}$	-0.48	-2.03	$p_{elec,t-1}$	-0.25	-1.52
$t_{hot,t}$	0.012	2.01	$temp$	-0.004	-3.45
$t_{cold,t}$	-0.002	-2.00	$temp_{t-1}$	0.002	1.63
$d_{temp,t}$	-0.94	-2.23			
$t_{hot,t-1}$	-0.005	-0.57			
$t_{cold,t-1}$	0.002	3.28			
$d_{temp,t-1}$	0.48	0.84			

Table 3: Auxiliary regressions estimates

The final estimates are reported in table 2⁵. According to the adjustment coefficient values (see Johansen, 1991) there is evidence of long-run weak exogeneity in the carbon price. Nevertheless, carbon price is influenced by lagged gas price, even though the significance level is not very high. Although there is no serial correlation, there is evidence of ARCH and non-normality in the residuals. However, this is not likely to be a major problem in our cointegration analysis since the Johansen ML estimator present small sample properties consistent with the asymptotic values even this drawbacks are present (see Gonzalo, 1994). Observing the correlation matrix we see how the cross-correlation between gas and electricity residuals is quite high and, on the other hand, how the cross correlation between carbon residuals and the others is fairly low. In order to identify matrix B_0 (model 4) and give structural meaning the residuals we need to impose 3 restrictions on the B_0 matrix itself.

⁵Normality test computed as in Doornik and Hansen (1994); AR LM test computed regressing the residuals on the explanatory variables and lagged residuals; Arch LM test computed regressing the squared residuals on the lagged squared residuals, as in Lütkepohl H., Krätzing M. (2004).

Because of the low magnitude of the cross correlation involving carbon residuals, two of the restrictions can be imposed on them without substantially changing the results. Most important is the restriction regarding the interaction of electricity and gas price, given the high-value of the cross-correlation, and it is clearly crucial to understand if this high cross-correlation is caused mainly by gas price influencing electricity price or vice versa. To investigate this we conduct two auxiliary $ADL(1,1)$ regressions using instrumental variables. The first equation measures the instantaneous effect of the gas price on the electricity price, using as instruments the gas available in the storage facilities (source: National Grid) and the quantity of gas flowing through the Zeebrugge-Bacton interconnector, the only gas interconnection between UK and Europe at the time. Using $w_t = [t_{hot,t}, t_{cold,t}, d_{temp,t}, p_{gas,t-1}, p_{electricity,t-1}, t_{hot,t-1}, t_{cold,t-1}, d_{temp,t-1}]$ we can write:

$$p_{electricity,t} = b_0 + b_1 p_{gas,t} + \theta' w_t + e_{et} .$$

The second equation⁶ measures the effect of electricity on gas prices, and uses as instruments the excess generation capacity available on the system (source: National Grid) and can be written as:

$$p_{gas,t} = \delta_0 + \delta_1 p_{electricity,t} + \vartheta' w_t + e_{gt} .$$

The estimates of both regressions with 2SLS are reported in table 3⁷. Since the parameter b_1 do not appear to be significantly different from zero, whereas δ_1 is strongly significant, we can conclude that the high-cross correlation between gas and electricity residuals is due to the influence of gas on electricity, and not the other way round. Therefore, we impose the restriction on the matrix B_0 and obtain the equations relating the structural residuals ε_t to the reduced form residuals u_t :

$$u_{elect,t} = \varepsilon_{elect,t} - b_{12}\varepsilon_{gas,t} - b_{13}\varepsilon_{carb,t} ,$$

$$u_{gas,t} = \varepsilon_{gas,t} - b_{23}\varepsilon_{carb,t} ,$$

$$u_{carb,t} = \varepsilon_{carb,t} ,$$

⁶In the gas price regression actual temperature is used, since the V relation holds for electricity only.

⁷Heteroskedasticity robust standard errors following White (1980).

with matrix B_0 equal to:

$$\begin{bmatrix} 1 & * & * \\ 0 & 1 & * \\ 0 & 0 & 1 \end{bmatrix} .$$

Given these restrictions, we use the a Maximum Likelihood procedure (Amisano and Giannini, 1997) to estimate matrix B_0 in model (4) and we use it to derive the dynamic response of the system to a shock on one of the structural residuals. This approach is useful to determine the dynamic impact, for instance, of a carbon price shock (e.g. at the end of April 2006) on electricity and gas price. As showed, for instance, in Lütkepohl and Krätzig (2004), this can be achieved by simply re-arranging equation (5) as a function of the residuals, and directly obtaining the dynamic impact of a shock at any lag. We use bootstrapped confidence intervals, as in Hall (1992), with 500 bootstrap replications. The estimated dynamic impact on the three prices of a sudden increase in carbon prices is reported in figure 2.

As shown, a carbon price shock produces a significant increase in the electricity price. Furthermore, even though the instantaneous reaction of electricity prices is significant, carbon price is fully passed-through only after some days. Gas price also increases but, at least in the first days, the increment is not significant. In the long run the price of gas is higher than before the shock, in line with the electricity price. A shock on gas prices as a similar effect: in line with the theory, it increases the overall prices of the three commodities. Nevertheless, the temporal dynamics and the magnitudes are different. In fact a gas price increase has its highest impact over the first few days and then its effect fades.

5 Conclusions

Using a structural, cointegrated VAR model, we show how carbon price is important in formulating the equilibrium price of electricity and gas in the UK, and that it is essentially exogenous. We also identify the

Figure 2: Impulse response functions for electricity, gas and carbon; shock on carbon price. Dotted line = 95% bootstrapped confidence intervals.

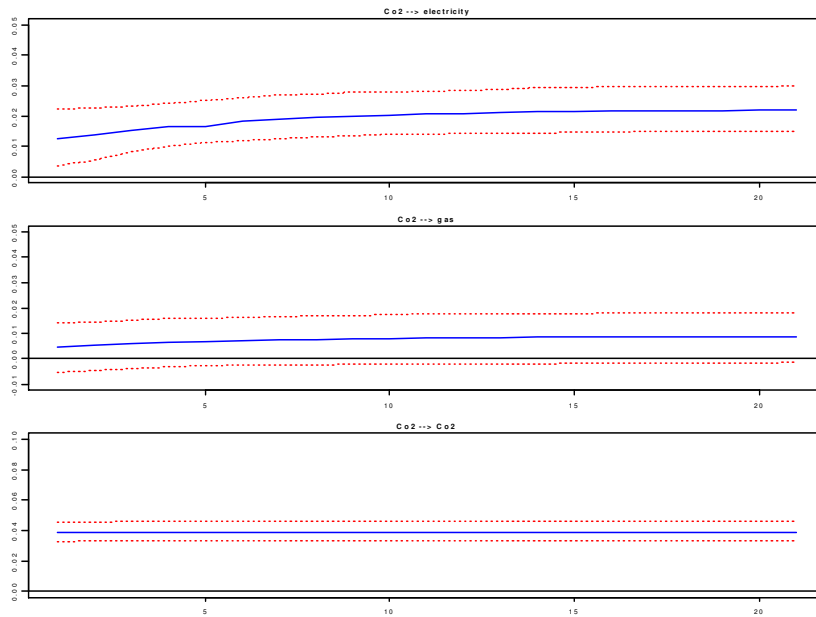
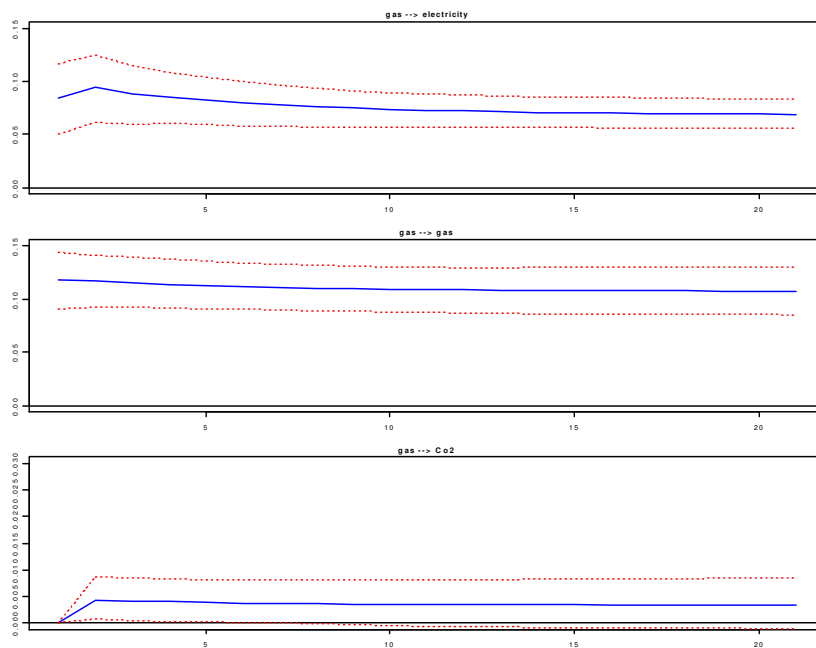


Figure 3: Impulse response functions for electricity, gas and carbon; shock on gas price. Dotted line = 95% bootstrapped confidence intervals



short-term dynamics and show that carbon prices react significantly and quickly to a shock on gas price, but, in turn, the dynamic pass-through of carbon to electricity price is only after some days. In particular, we estimated that eventually a 1% shock in carbon translates on average into a .42% shock in UK electricity, with [0.21; 0.64] as a 95% confidence interval. Essentially we see that gas drives carbon, whilst both carbon and gas drive electricity prices. Evidently one of the indirect effects of carbon trading has been to strengthen the link between gas and power, and to the extent that global gas prices are acquiring the geopolitical risk characteristics of oil, that may not be a welcome outcome.

6 REFERENCES

- [1] Amisano G., Giannini C. (1997) *Topics in Structural VAR Econometrics*, Second Edition, Springer-Verlag, Heidelberg.
- [2] Baillie R.T., Bollerslev T. (1989) *Common stochastic trends in a system of exchange rates*, Journal of Finance, vol. 44, n. 1, pp. 167-181
- [3] Barreto L., Kypreos S. (2004) *Emission trading and technology deployment in an energy-system "bottom-up" model with technology learning*, European Journal of Operational Research, vol. 158, pp. 243-261
- [4] Bentz E., Trück S. (2005) *Modelling CO2 emission allowance prices*, Bonn Graduate School of Economics, Working paper 24-8-2005
- [5] Bernanke B.S. (1986) *Alternative explanations of the money-income correlation*, Carnegie-Rochester Conference Series on Public Policy, Autumn 1986, pp. 49-100
- [6] Blanchard O.J., Quah D. (1986) *The dynamic effects of aggregate demand and supply disturbances*, American Economic Review, vol. 79, n. 4, pp. 655-673
- [7] Böhringer C. (2002) *Industry-level emission trading between power producers in the EU*, Applied Economics, vol. 34, n. 4, pp. 523-533

- [8] Böhringer C., Lange A. (2005), *On the design of optimal grandfathering schemes for emission allowances*, European Economic Review, vol. 49, pp. 2041-2055.
- [9] Brüggemann R., Lütkepohl H. (2001). *Lag selection in subset VAR models with an application to a U.S. monetary system*, in R. Friedmann, L. Knüppel and H. Lütkepohl (eds), *Econometric Studies: A Festschrift in Honour of Joachim Frohn*, LIT Verlag, Münster, pp. 107–128.
- [10] Brüggemann R., Lütkepohl H. (2004) *Structural vector autoregressive modelling and impulse responses*, in H. Lütkepohl and M. Krätzig (eds), *Applied Time Series Econometrics*, Cambridge University Press
- [11] Blyth W., Yang M., Bradley R., (2007) *Climate Policy and Investment*, Risk IEA, Paris
- [12] Cooley T., LeRoy S. (1985) *Atheoretical macroeconometrics: a critique*, Journal of Monetary Economics, vol. 16, 1985, pp. 283-306
- [13] Criqui P., Viguier L.L. (2000) *Kyoto and technology at world level: cost of CO2 reduction under flexibility mechanism and technical progress*, International Journal of Global Energy Issues, vol. 14, pp. 155-168
- [14] Diebold F.X., Gardeazabal J., Yilmaz K. (1994) *On cointegration and exchange rate dynamics*, The Journal of Finance, vol. 49, n. 2, pp. 727-735
- [15] Doornik J. A. (1998) *Approximations to the asymptotic distribution of cointegration tests*, Journal of Economic Surveys, vol. 12, pp. 573—593
- [16] Doornik J.A., Hansen H. (1994) *An omnibus test for univariate and multivariate normality*, Working Paper, Nuffield College, Oxford
- [17] Engle R. F., Granger C. W. J., Rice J. Weiss A. (1986) *Semiparametric estimates of the relation between weather and electricity sales*, Journal of the American Statistical Association, vol. 81, 1986, pp. 310-320
- [18] European Commission (2003) Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gases emission allowance trading within the Community and amending Council Directive 96/61/EC. OJ L275

- [19] European Commission (2005) Review of the EU Emissions trading scheme, Survey Highlights, November 2005, European Commission Directorate General for Environment
- [20] Fezzi C., Bunn D.W. (2006) *Structural analysis of high-frequency electricity demand and supply interactions*, London Business School, Working paper
- [21] Gonzalo J. (1994) *Five alternative methods of estimating long-run equilibrium relationships*, Journal of Econometrics, vol. 60, No. 1, 1994, pp. 203-233
- [22] Granger C.W.J., Newbold p. (1974) *Spurious regression in econometrics*, Journal of Econometrics, vol. 2, 1974, pp. 111-120
- [23] Garatt A., Lee K., Pesaran M.H., Shin Y. (1998) *A structural cointegrating VAR approach to macroeconomic modelling*, Cambridge Working Papers in Economics n. 9823
- [24] Hall P. (1992) *The bootstrap and Edgeworth expansion*, Springer, New York
- [25] Hauch J. (2003) *Electricity trade and CO₂ emission reduction in the Nordic countries*, Energy Economics, vol. 25, pp. 509-526
- [26] Hendry D.F. (1980) *Econometrics: Alchemy or Science?*, Economica, vol. 47, 1980, pp. 387-406. Reprinted in Hendry D.F.: (1993) *Econometrics: Alchemy or Science?*, Oxford, Blackwell Publishers
- [27] Hendry D.F., Mizon G.E. (1993) *Evaluating dynamic models by encompassing the VAR*, in P.C.B. Phillips ed.: *Models, methods, and applications of econometrics*, Blackwell, Oxford, 1993, pp. 272-300
- [28] Hendry D.F., Juselius K. (2000) *Explaining cointegration analysis: Part I*, The Energy Journal, vol. 21, 2000, pp. 1-42
- [29] Huntington H.G., Weyant J.P (2004) *Modeling energy markets and climate change policy*, In Cleveland, C.J. et al. *Encyclopedia of Energy*, pp. 41-53, Academic Press / Elsevier Science
- [30] Kwiatkowski D., Phillips P.C.B, Schmidt P., Shin Y. (1992) *Testing the null hypothesis of stationarity against the alternative of a unit root*, Journal of Econometrics, vol. 54, 1992, pp. 159-178

- [31] Johansen S. (1991) *Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models*, *Econometrica*, vol. 59, No. 6, 1991, pp. 1551-1580
- [32] Johansen S., Juselius K. (1994) *Identification of the long-run and short-run structure. An application to the ISLM model*, *Journal of Econometrics*, vol. 63, 1994, pp. 7-36
- [33] Johansen S. (1996) *Likelihood-based inference in cointegrated vector autoregressive models*, Oxford University Press, Oxford
- [34] Linares P., Santos F.J., Ventosa M., Lapedra L. (2006) *Impacts of the European emission trading directive and permit assignment methods on the Spanish electricity sector*, *The Energy Journal*, vol. 27, No 1, pp. 79 – 98
- [35] Lütkepohl H, Krätzig M. (2004) *Applied time series econometrics*, Cambridge University Press
- [36] McKibbin W., Ross M, Shackleton R., Wilcoxon P.J. (1999) *Emission trading, capital flows and the Kyoto Protocol*, *The Energy Journal*, Special Issue: The costs of the Kyoto Protocol, pp. 287-334
- [37] Pesaran M.H., Smith R.P. (1998) *Structural analysis of cointegrating VARs*, *Journal of Economic Surveys*, vol. 12, n. 5, 1998, pp. 471-504
- [38] Pesaran M.H., Shin Y. (1998) *Generalised impulse response analysis in multivariate models*, *Economics Letters*, vol. 58, pp. 17-29
- [39] Phillips P.C.B. (1986) *Understanding spurious regression in econometrics*, *Journal of Econometrics*, vol. 33, pp. 331-340
- [40] Said S.E., Dickey D.A. (1984) *Testing for unit roots in autoregressive moving average models of unknown order*, *Biometrika*, vol. 71, 1984, pp. 599-608
- [41] Sijm J., Neuhoff K., Chen Y. (2006) *CO₂ cost pass-through and windfall profits in the power sector*, *Climate Policy*, vol. 6, pp. 47-70
- [42] Sims C. (1980) *Macroeconomics and reality*, *Econometrica*, vol. 48, n. 1, pp. 1-48

- [43] Sims C. (1986) *Are forecasting models usable for policy analysis?*, Federal Reserve Bank Minneapolis, Quarterly Review (winter 1986), pp. 2 - 16
- [44] Smale R., Hartley M., Hepburn C., Ward J., Grubb M. (2006) *The impacts of CO2 emissions trading on firm profits and market prices*, Climate Policy, vol. 6, pp. 29-49
- [45] White H. (1980) *A heteroskedasticity-consistent covariance matrix estimator and direct test for heteroskedasticity*, Econometrica, vol. 48, 1980, pp. 817-838

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:

<http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm>

<http://www.ssrn.com/link/feem.html>

<http://www.repec.org>

<http://agecon.lib.umn.edu>

<http://www.bepress.com/feem/>

NOTE DI LAVORO PUBLISHED IN 2007

NRM	1.2007	<i>Rinaldo Brau, Alessandro Lanza, and Francesco Pigliaru: <u>How Fast are Small Tourism Countries Growing? The 1980-2003 Evidence</u></i>
PRCG	2.2007	<i>C.V. Fiorio, M. Florio, S. Salini and P. Ferrari: <u>Consumers' Attitudes on Services of General Interest in the EU: Accessibility, Price and Quality 2000-2004</u></i>
PRCG	3.2007	<i>Cesare Dosi and Michele Moretto: <u>Concession Bidding Rules and Investment Time Flexibility</u></i>
IEM	4.2007	<i>Chiara Longo, Matteo Manera, Anil Markandya and Elisa Scarpa: <u>Evaluating the Empirical Performance of Alternative Econometric Models for Oil Price Forecasting</u></i>
PRCG	5.2007	<i>Bernardo Bortolotti, William Megginson and Scott B. Smart: <u>The Rise of Accelerated Seasoned Equity Underwritings</u></i>
CCMP	6.2007	<i>Valentina Bosetti and Massimo Tavoni: <u>Uncertain R&D, Backstop Technology and GHGs Stabilization</u></i>
CCMP	7.2007	<i>Robert Küster, Ingo Ellersdorfer, Ulrich Fahl (lxxx): <u>A CGE-Analysis of Energy Policies Considering Labor Market Imperfections and Technology Specifications</u></i>
CCMP	8.2007	<i>Mònica Serrano (lxxx): <u>The Production and Consumption Accounting Principles as a Guideline for Designing Environmental Tax Policy</u></i>
CCMP	9.2007	<i>Erwin L. Corong (lxxx): <u>Economic and Poverty Impacts of a Voluntary Carbon Reduction for a Small Liberalized Developing Economy: The Case of the Philippines</u></i>
CCMP	10.2007	<i>Valentina Bosetti, Emanuele Massetti, and Massimo Tavoni: <u>The WITCH Model. Structure, Baseline, Solutions</u></i>
SIEV	11.2007	<i>Margherita Turvani, Aline Chiabai, Anna Alberini and Stefania Tonin: <u>Public Policies for Contaminated Site Cleanup: The Opinions of the Italian Public</u></i>
CCMP	12.2007	<i>M. Berrittella, A. Certa, M. Enea and P. Zito: <u>An Analytic Hierarchy Process for The Evaluation of Transport Policies to Reduce Climate Change Impacts</u></i>
NRM	13.2007	<i>Francesco Bosello, Barbara Buchner, Jacopo Crimi, Carlo Giupponi and Andrea Povellato: <u>The Kyoto Protocol and the Effect of Existing and Planned Measures in the Agricultural and Forestry Sector in the EU25</u></i>
NRM	14.2007	<i>Francesco Bosello, Carlo Giupponi and Andrea Povellato: <u>A Review of Recent Studies on Cost Effectiveness of GHG Mitigation Measures in the European Agro-Forestry Sector</u></i>
CCMP	15.2007	<i>Massimo Tavoni, Brent Sohngen, and Valentina Bosetti: <u>Forestry and the Carbon Market Response to Stabilize Climate</u></i>
ETA	16.2007	<i>Erik Ansink and Arjan Ruijs: <u>Climate Change and the Stability of Water Allocation Agreements</u></i>
ETA	17.2007	<i>François Gusdorf and Stéphane Hallegatte: <u>Compact or Spread-Out Cities: Urban Planning, Taxation, and the Vulnerability to Transportation Shocks</u></i>
NRM	18.2007	<i>Giovanni Bella: <u>A Bug's Life: Competition Among Species Towards the Environment</u></i>
IEM	19.2007	<i>Valeria Termini and Laura Cavallo: <u>"Spot, Bilateral and Futures Trading in Electricity Markets. Implications for Stability"</u></i>
ETA	20.2007	<i>Stéphane Hallegatte and Michael Ghil: <u>Endogenous Business Cycles and the Economic Response to Exogenous Shocks</u></i>
CTN	21.2007	<i>Thierry Bréchet, François Gerard and Henry Tulkens: <u>Climate Coalitions: A Theoretical and Computational Appraisal</u></i>
CCMP	22.2007	<i>Claudia Kettner, Angela Köppl, Stefan P. Schleicher and Gregor Thenius: <u>Stringency and Distribution in the EU Emissions Trading Scheme –The 2005 Evidence</u></i>
NRM	23.2007	<i>Hongyu Ding, Arjan Ruijs and Ekko C. van Ierland: <u>Designing a Decision Support System for Marine Reserves Management: An Economic Analysis for the Dutch North Sea</u></i>
CCMP	24.2007	<i>Massimiliano Mazzanti, Anna Montini and Roberto Zoboli: <u>Economic Dynamics, Emission Trends and the EKC Hypothesis New Evidence Using NAMEA and Provincial Panel Data for Italy</u></i>
ETA	25.2007	<i>Joan Canton: <u>Re dealing the Cards: How the Presence of an Eco-Industry Modifies the Political Economy of Environmental Policies</u></i>
ETA	26.2007	<i>Joan Canton: <u>Environmental Taxation and International Eco-Industries</u></i>
CCMP	27.2007	<i>Oscar Cacho and Leslie Lipper (lxxxii): <u>Abatement and Transaction Costs of Carbon-Sink Projects Involving Smallholders</u></i>
CCMP	28.2007	<i>A. Caparrós, E. Cerdá, P. Ovando and P. Campos (lxxxii): <u>Carbon Sequestration with Reforestations and Biodiversity-Scenic Values</u></i>
CCMP	29.2007	<i>Georg E. Kindermann, Michael Obersteiner, Ewald Rametsteiner and Ian McCallum (lxxxii): <u>Predicting the Deforestation-Trend Under Different Carbon-Prices</u></i>

CCMP	30.2007	<i>Raul Ponce-Hernandez</i> (lxxxii): <u>A Modelling Framework for Addressing the Synergies between Global Conventions through Land Use Changes: Carbon Sequestration, Biodiversity Conservation, Prevention of Land Degradation and Food Security in Agricultural and Forested Lands in Developing Countries</u>
ETA	31.2007	<i>Michele Moretto and Gianpaolo Rossini</i> : <u>Are Workers' Enterprises Entry Policies Conventional</u>
KTHC	32.2007	<i>Giacomo Degli Antoni</i> : <u>Do Social Relations Affect Economic Welfare? A Microeconomic Empirical Analysis</u>
CCMP	33.2007	<i>Reyer Gerlagh and Onno Kuik</i> : <u>Carbon Leakage with International Technology Spillovers</u>
CCMP	34.2007	<i>Richard S.J. Tol</i> : <u>The Impact of a Carbon Tax on International Tourism</u>
CCMP	35.2007	<i>Reyer Gerlagh, Snorre Kverndokk and Knut Einar Rosendahl</i> : <u>Optimal Timing of Environmental Policy: Interaction Between Environmental Taxes and Innovation Externalities</u>
SIEV	36.2007	<i>Anna Alberini and Alberto Longo</i> : <u>Valuing the Cultural Monuments of Armenia: Bayesian Updating of Prior Beliefs in Contingent Valuation</u>
CCMP	37.2007	<i>Roeland Bracke, Tom Verbeke and Veerle Dejonckheere</i> : <u>What Distinguishes EMAS Participants? An Exploration of Company Characteristics</u>
CCMP	38.2007	<i>E. Tzouvelekas, D. Vouvaki and A. Xepapadeas</i> : <u>Total Factor Productivity Growth and the Environment: A Case for Green Growth Accounting</u>
CCMP	39.2007	<i>Klaus Keller, Louise I. Miltich, Alexander Robinson and Richard S.J. Tol</i> : <u>How Overconfident are Current Projections of Anthropogenic Carbon Dioxide Emissions?</u>
CCMP	40.2007	<i>Massimiliano Mazzanti and Roberto Zoboli</i> : <u>Environmental Efficiency, Emission Trends and Labour Productivity: Trade-Off or Joint Dynamics? Empirical Evidence Using NAMEA Panel Data</u>
PRCG	41.2007	<i>Veronica Ronchi</i> : <u>Populism and Neopopulism in Latin America: Clientelism, Trade Union Organisation and Electoral Support in Mexico and Argentina in the '90s</u>
PRCG	42.2007	<i>Veronica Ronchi</i> : <u>The Neoliberal Myth in Latin America: The Cases of Mexico and Argentina in the '90s</u>
CCMP	43.2007	<i>David Anthoff, Cameron Hepburn and Richard S.J. Tol</i> : <u>Equity Weighting and the Marginal Damage Costs of Climate Change</u>
ETA	44.2007	<i>Bouwe R. Dijkstra and Dirk T.G. Rübhelke</i> : <u>Group Rewards and Individual Sanctions in Environmental Policy</u>
KTHC	45.2007	<i>Benno Torgler</i> : <u>Trust in International Organizations: An Empirical Investigation Focusing on the United Nations</u>
CCMP	46.2007	<i>Enrica De Cian, Elisa Lanzi and Roberto Roson</i> : <u>The Impact of Temperature Change on Energy Demand: A Dynamic Panel Analysis</u>
CCMP	47.2007	<i>Edwin van der Werf</i> : <u>Production Functions for Climate Policy Modeling: An Empirical Analysis</u>
KTHC	48.2007	<i>Francesco Lancia and Giovanni Prarolo</i> : <u>A Politico-Economic Model of Aging, Technology Adoption and Growth</u>
NRM	49.2007	<i>Giulia Minoia</i> : <u>Gender Issue and Water Management in the Mediterranean Basin, Middle East and North Africa</u>
KTHC	50.2007	<i>Susanna Mancinelli and Massimiliano Mazzanti</i> : <u>SME Performance, Innovation and Networking Evidence on Complementarities for a Local Economic System</u>
CCMP	51.2007	<i>Kelly C. de Bruin, Rob B. Dellink and Richard S.J. Tol</i> : <u>AD-DICE: An Implementation of Adaptation in the DICE Mode</u>
NRM	52.2007	<i>Frank van Kouwen, Carel Dieperink, Paul P. Schot and Martin J. Wassen</i> : <u>Interactive Problem Structuring with ICZM Stakeholders</u>
CCMP	53.2007	<i>Valeria Costantini and Francesco Crespi</i> : <u>Environmental Regulation and the Export Dynamics of Energy Technologies</u>
CCMP	54.2007	<i>Barbara Buchner, Michela Catenacci and Alessandra Sgobbi</i> : <u>Governance and Environmental Policy Integration in Europe: What Can We learn from the EU Emission Trading Scheme?</u>
CCMP	55.2007	<i>David Anthoff and Richard S.J. Tol</i> : <u>On International Equity Weights and National Decision Making on Climate Change</u>
CCMP	56.2007	<i>Edwin van der Werf and Sonja Peterson</i> : <u>Modeling Linkages Between Climate Policy and Land Use: An Overview</u>
CCMP	57.2007	<i>Fabien Prieur</i> : <u>The Environmental Kuznets Curve in a World of Irreversibility</u>
KTHC	58.2007	<i>Roberto Antonietti and Giulio Cainelli</i> : <u>Production Outsourcing, Organizational Governance and Firm's Technological Performance: Evidence from Italy</u>
SIEV	59.2007	<i>Marco Percolo</i> : <u>Urban Transport Policies and the Environment: Evidence from Italy</u>
ETA	60.2007	<i>Henk Folmer and Pierre von Mouche</i> : <u>Linking of Repeated Games. When Does It Lead to More Cooperation and Pareto Improvements?</u>
CCMP	61.2007	<i>Arthur Riedacker</i> (lxxx): <u>A Global Land Use and Biomass Approach to Reduce Greenhouse Gas Emissions, Fossil Fuel Use and to Preserve Biodiversity</u>
CCMP	62.2007	<i>Jordi Roca and Mònica Serrano</i> : <u>Atmospheric Pollution and Consumption Patterns in Spain: An Input-Output Approach</u>
CCMP	63.2007	<i>Derek W. Bunn and Carlo Fezzi</i> (lxxxi): <u>Interaction of European Carbon Trading and Energy Prices</u>

(lxxxix) This paper was presented at the EAERE-FEEM-VIU Summer School on "Computable General Equilibrium Modeling in Environmental and Resource Economics", held in Venice from June 25th to July 1st, 2006 and supported by the Marie Curie Series of Conferences "European Summer School in Resource and Environmental Economics".

(lxxxix) This paper was presented at the Workshop on "Climate Mitigation Measures in the Agro-Forestry Sector and Biodiversity Futures", Trieste, 16-17 October 2006 and jointly organised by The Ecological and Environmental Economics - EEE Programme, The Abdus Salam International Centre for Theoretical Physics - ICTP, UNESCO Man and the Biosphere Programme - MAB, and The International Institute for Applied Systems Analysis - IIASA.

2007 SERIES

CCMP	<i>Climate Change Modelling and Policy</i> (Editor: Marzio Galeotti)
SIEV	<i>Sustainability Indicators and Environmental Valuation</i> (Editor: Anil Markandya)
NRM	<i>Natural Resources Management</i> (Editor: Carlo Giupponi)
KTHC	<i>Knowledge, Technology, Human Capital</i> (Editor: Gianmarco Ottaviano)
IEM	<i>International Energy Markets</i> (Editor: Matteo Manera)
CSRM	<i>Corporate Social Responsibility and Sustainable Management</i> (Editor: Giulio Sapelli)
PRCG	<i>Privatisation Regulation Corporate Governance</i> (Editor: Bernardo Bortolotti)
ETA	<i>Economic Theory and Applications</i> (Editor: Carlo Carraro)
CTN	<i>Coalition Theory Network</i>