First Evidence of Asymmetric Cost Pass-through of EU Emissions Allowances: Examining Wholesale Electricity Prices in Germany

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Abstract

This paper applies the literature on asymmetric price transmission to the emerging commodity market for EU emissions allowances (EUA). We utilize an error correction model and an autoregressive distributed lag model to measure the relationship between CO_2 *price changes and the development of wholesale electricity prices. Using data from the German market for electricity and EUAs, we find that the rising prices of EUAs have a stronger impact on wholesale electricity prices than falling prices -- the first empirical evidence of asymmetric cost pass-through for these new allowances.*

Keywords: Asymmetric cost pass-through, emissions allowances, electricity pricing

JEL: D43, C22, L13

1 Introduction

To fulfil its Kyoto greenhouse gas reduction targets, the EU implemented a European Emissions Trading Scheme (EU ETS) beginning in January 2005. The EU ETS allocates EU Emissions Allowances (EUAs) to about 12,000 "installations". Since electricity generation largely dominates the allocation of EUAs (~ 60%), the sector is significant when analyzing industrial and economic policies. Despite the free allocation of EUAs, economic theory suggests that they be considered opportunity costs in electricity prices; thus, during our research, we were not surprised to find a positive link between EUA and wholesale electricity prices. Due to the CO_2 intensity of different electricity production technologies, the influence of EUA prices on power prices is nonlinear.[1] Using data for 2005, Sijm et al. (2006) estimated that emissions costs have been almost fully (60-100%) passed through to consumers.

Despite the empirical evidence, power consumers soon complained about excessive increases in the price of electricity. One of their objections was based on anecdotal evidence that wholesale electricity prices occasionally reacted more to EUA price increases than to decreases. For example, a 60% drop in EUA prices in the last week of April 2006 was only met by an 8% decline in power prices (EEX 2007 Futures). This example, though somewhat unusual, indicated an asymmetric cost pass-through of price increases and decreases which the methodology of Sijm et al. (2006) was not designed to detect.

Studies of asymmetric pricing in various industries (e.g., Peltzmann, 2000)[2] chiefly have found evidence for *positive asymmetric pricing*, i.e. positive cost shocks are disseminated more strongly and/or quickly to the final prices than negative cost shocks. Explanations point to either the exercise of market power and/or industry-specific factors.[3] This paper applies an error correction and an autoregressive distributed lag model to identify asymmetric cost pass-through in the relationship between EUA and wholesale electricity prices. By rejecting the hypothesis of symmetric cost pass-through in favor of asymmetric pricing, the authors hope this paper will initiate a discussion of empirical evidence and theoretical explanations of this phenomenon.

Section 2 introduces the European emissions allowances market and the selected data; Section 3 describes the tests for asymmetric pricing and presents the results; and Section 4 concludes with two suggestions for further research.

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[1] The emergence of CO2 as a cost factor of electricity prices complicates the analysis of the competitive supply curve ("merit order"). Fuels vary in emissions, e.g. nuclear (0 t/MWh), natural gas (0.48t/MWh) and coal (0.85t/MWh). Therefore, peak electricity prices (generally determined by a marginal, CCGT plant) are likely to be less affected by CO2 prices than mid-load electricity prices (generally coal).

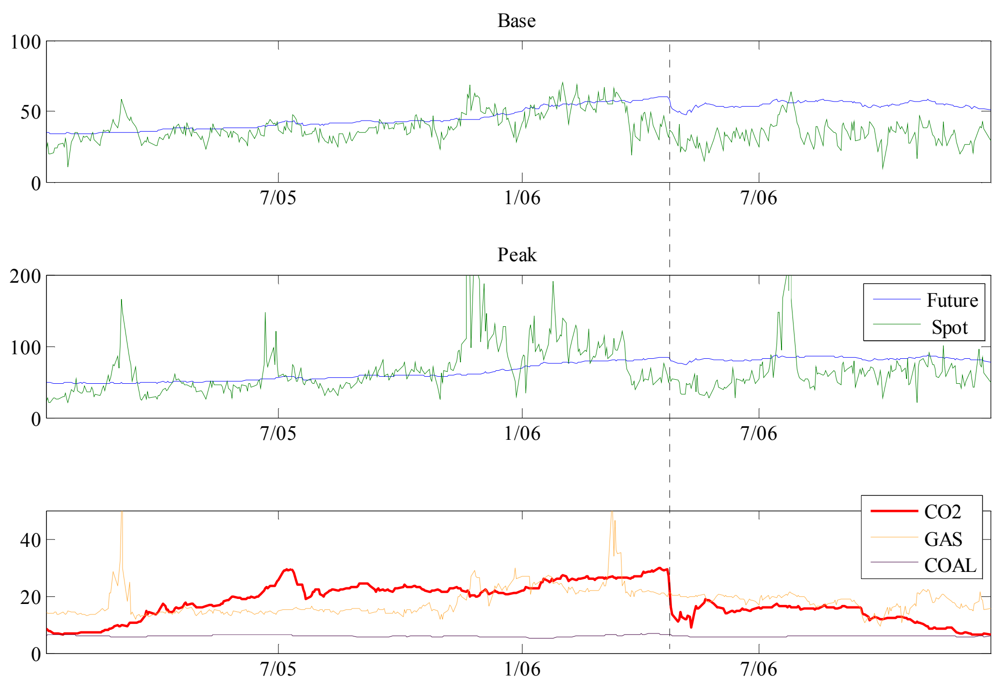
[2] The literature of energy economics has intensively investigated the asymmetric link between crude oil and gasoline prices. See Geweke (2004), Manera and Frey (2005) and Kaufmann and Laskowski (2005) for a survey of the literature on asymmetric gasoline pricing. Other industrial and agricultural products as well as services (banking) feature the same phenomenon.

[3] Borenstein et al. (1997) for example suggest three explanations for their finding of short-run asymmetric pricing in the gasoline market: (1) a model of tacit collusion with imperfect monitoring, (2) a model with finite inventories and (3) a model of consumer search cost. Balke et al. (1998) considers signalling in tacit collusion and accounting methods such as "first-in-first-out" as explanation for asymmetric pricing. Asymmetric menu cost could also induce asymmetric pricing (Meyer and v.C-Taubadel, 2004).

2 Data

In 2005 a total of 350 million tonnes of CO_2 (~€9 billion) were traded at the European Climate Exchange (London), various European electricity exchanges and over-the-counter (OTC). We are mainly interested in the German market, and will therefore use the data provided by the European Energy Exchange (EEX) in Leipzig. We chose to use data for the EUA spot market because there is less financial risk and there is no interest rate compared to the futures and forward markets.[4] We also obtained spot market electricity prices as well as prices for electricity futures with delivery in 2007 from the EEX for the entire sample period (workdays of 2005-2006).[5]

Figure 1: Electricity Future and Spot Prices and CO_2, Coal and Natural Gas Prices in €/MWh 2005-06



The EEX EUA spot prices as well as EEX electricity futures and spot prices for the years 2005-2006 are depicted in Figure 1. The most outstanding event - the price crash in spring 2006[6] - is highlighted by a dotted vertical line. Electricity futures and spot prices differ significantly in almost all statistical measures (e.g. mean, variance). The higher volatility of electricity spot prices is due to the fact that they are based on more information (e.g. weather, demand, and power plant availability) and that electricity future prices capture a longer delivery period, smoothing the effects on individual demand and supply shocks. Since hourly demand and supply factors are less important for the price formation

[4] Usually, futures are traded with a contango reflecting the interest rate.
[5] Prices at the EEX are often considered as reference and usually track the more liquid OTC prices sufficiently well.
[6] In the end of April 2006 information leaked to the traders that some countries (Netherlands, Czech Republic, Walloon, Spain, France) emitted significantly less CO2 than expected which created an overall long position in the market causing EUA prices to drop from around €30 to €10. For more details see CEAG (2006).

in electricity futures markets, the main price drivers are fuel and EUA prices. This is illustrated by the significantly higher correlation of EUA price changes with electricity futures than with electricity spot price changes (see Table 1).[7] Due to this structure, we limit our analysis to the EEX electricity futures prices.

Table 1: Correlation of CO_2 and EEX Price Changes

	Spot (X-day averages)				Future 2007 (X-day averages)			
	1 day	7-days	14-days	21-days	1 day	7-days	14-days	21-days
Peak	0%	-1%	4%	16%	63%**	69%**	67%**	63%**
Base	-4%	5%	15%	27%	72%**	80%**	83%**	81%**

3 Methodology and Results

3.1 Error Correction Model

Following Borenstein et al. (1997) the asymmetric diffusion pattern of positive and negative cost shocks can be estimated using Error Correction Models (ECM). These models assume a long run (symmetric) relation between prices and cost:

$$EEX_{t-1} = \phi_0 + \phi_1 TIME_t + \sum_{i=0}^{n} \left(\phi_{2,i} X_{t-i}\right) + \phi_3 CO2_{t-1} \tag{1}$$

but allow for short run systematic deviations:

$$\begin{aligned} \Delta EEX_t &= -\theta\phi_0 - \theta\phi_1 TIME_t + \sum_{i=0}^{n} \left(\beta_i^{+} \Delta CO2_{t-i}^{+} + \beta_i^{-} \Delta CO2_{t-i}^{-}\right) \\ &- \sum_{i=1}^{n} \left(\gamma_i \, \Delta EEX_{t-i}\right) - \sum_{i=0}^{n} \left(\theta\phi_{2,i} X_{t-i}\right) + \theta EEX_{t-1} - \theta\phi_3 CO2_{t-1} + \varepsilon_t \end{aligned} \tag{2}$$

where EEX_t is the electricity price, $CO2_t$ the EUA price, ΔEEX_t the period to period electricity price change, $\Delta CO2_t^{+}$ the positive period to period EUA price change (or zero if $\Delta CO2_t < 0$), X_t the considered exogenous variables like fuel prices or demand, and ε_t the iid estimation error. To reduce the number of variables (and because of a lack of significance) the asymmetric reaction to past electricity prices suggested by Borenstein et al. (1997) are deleted. The response in time $t+k$ to a one-time, 1%-positive CO_2 price shock in t is given by

$$B_k^{+} = B_{k-1}^{+} + \hat{\beta}_k^{+} + \theta\left(B_{k-1}^{+} - \hat{\phi}_1\right) + \sum_{i=1}^{k} \left(\hat{\gamma}_i \left(B_{k-i}^{+} - B_{k-i-1}^{+}\right)\right).^{8} \tag{3}$$

[7] Note, that there is no significant correlation of the changes of average spot electricity and EUA spot prices.
[8] Note, that the long run symmetry condition (1) implies $\lim_{k\to\infty}\left(B_k^{+} = B_k^{-}\right)$.

Because of the limited sample length (2 years), only a few specific combinations of lag length and data-frequency can be reasonably considered. Thus, we estimate (2) separately for weekly average base and peak futures prices using four lags in both cases. To control for gas price developments, we included Dutch TTF gas spot prices since no comparably liquid corresponding German market exists.[9]

Table 2: Error Correction Model Results

Variable	Base	Peak
R^2 ($\overline{R}^2$)	74% (69%)	61% (52%)
σ^2	0.48	0.88
Durbin-Watson	1.92	1.94
Constant	0.48	0.48
Time trend	0.01	0.02
$dCO2^+_t$	0.12	0.05
$dCO2^+_{t-1}$	0.14	0.03
$dCO2^+_{t-2}$	-0.16	-0.30 *
$dCO2^+_{t-3}$	0.51 ***	0.72 ***
$dCO2^-_t$	0.01	0.05
$dCO2^-_{t-1}$	-0.18 **	-0.20 *
$dCO2^-_{t-2}$	0.17 *	0.10
$dCO2^-_{t-3}$	0.54 ***	0.45 ***
$dEEX_{t-1}$	0.00	0.08
$dEEX_{t-2}$	-0.04	-0.07
$dEEX_{t-3}$	0.14	0.21 *
GAS_t	-0.01	-0.01
GAS_{t-1}	0.03	0.04
GAS_{t-2}	0.00	-0.01
GAS_{t-3}	0.04 *	0.06 *
EEX_t	-0.04	-0.03
$CO2_t$	0.04 **	0.05 **
F(H_0: $CO2_{sym}$ vs. H_1: $CO2_{asym}$)	2.7 **	1.7

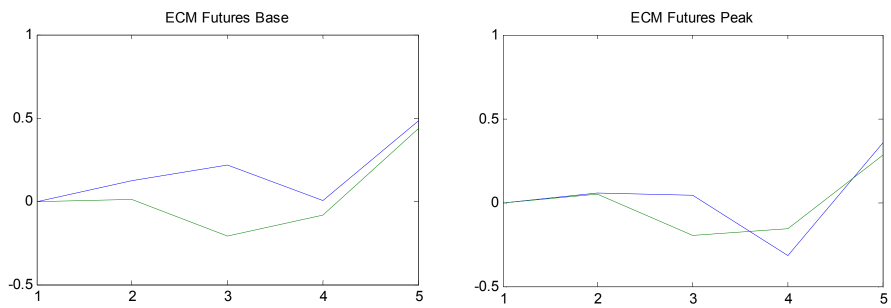
*, **, *** coefficient different from zero on the 10%, 5%, 1% confidence interval, respectively. Weekly average 2005-2006 data (99 observations).

The R^2 above 60% and the Durbin-Watson statistic of almost 2 indicate that the model is reasonably well specified.[10] In the base and the peak cases, we find the typical characteristic of positive asymmetric cost pass-through: while in the first two weeks, positive EUA price shocks had a stronger positive influence on EEX prices, negative shocks (i.e. EUA price decreases) catch up in the third and fourth weeks ($\hat{\beta}^+_t > \hat{\beta}^-_t$ and $\hat{\beta}^+_{t-1} < \hat{\beta}^-_{t-1}$). The B^+ and B^- values calculated according to (3) confirm the quicker pass-through of positive EUA price shocks to electricity future prices (see Figure 3). While the null hypothesis of symmetric cost pass-through cannot be rejected for the peak case, it can be rejected on the 5% confidence level for base case. The latter is evidence for positive asymmetric cost pass-through.

[9] Since including time trend, constant, coal prices or load as well as controlling for the market crash in April 2006 does not alter the asymmetry results significantly, we only present the results for the most parsimonious specification. Detailed results might be obtained from the authors upon request.
[10] Note that including coal prices and electricity demand as explanatory variables did not prove significant.

One additional finding merits notice: The last lag of the asymmetric coefficient is in all cases high (~0.5) and highly significant while most other lags are not. This indicates that the imposed error correction forces the model back to the equilibrium in the last period. Although it may be possible to detect additional dynamics by including more lags, this is infeasible because the ratio of variables over observations is already critical.[11]

Figure 2: Impact of EUA price changes on electricity price changes estimated using an ECM and data from the German electricity and emissions markets 2005-2007 (B^+ blue, B^- green)



3.2 Autoregressive Distributed Lag Model

One way to circumvent the difficulties of the ECM model is to drop the error correction term and thus deviate from the idea of a long-run equilibrium. By doing so, the forced upward trend in the last lag and the number of estimated coefficients can be greatly reduced.[12] Following Karrenbrock (1991) our autoregressive distributed lag (ADL) model is:

$$\Delta EEX_t = \phi_0 + \phi_1 t + \sum_{i=0}^{n}\left(\beta_i^+ \Delta CO2_{t-i}^+ + \beta_i^- \Delta CO2_{t-i}^-\right) + \sum_{i=0}^{p}\left(\gamma_i \Delta X_{t-i}\right) + \varepsilon_t \qquad (4)$$

In (4), we can test the hull hypothesis of symmetric cost pass-through against the alternative hypothesis of asymmetric cost pass-through by finding whether $\beta_i^+ = \beta_i^-$ for all i.

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[11] The number of variables equal $(3+x)\times n+3$, where x is the number of exogenous variables and n is the number of lags. This is critical since the data sample consists of only two years and correspondingly only 104-n weekly observations are available.

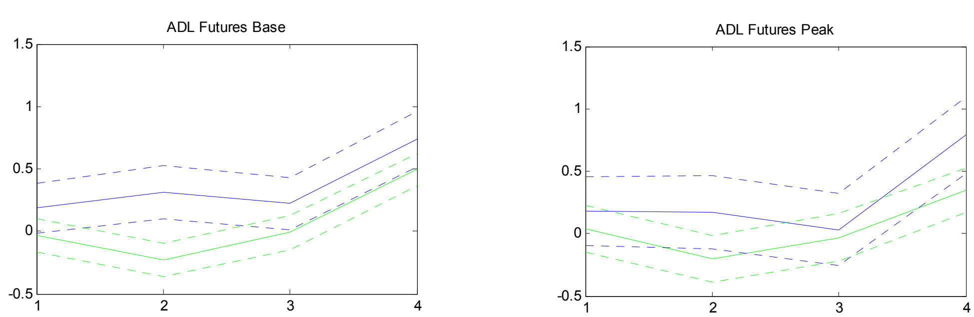
[12] Note that Geweke (2004) criticizes (4) since it implies the gap between prices and cost will grow indefinitely in the long-run. In our case, however, this argument does not hold because the length of our sample does not allow the prices to return sufficiently often to the long-run equilibrium.

Table 3: Autoregressive Distributed Lag Model Results

Variable	Base	Peak
R^2 ($\overline{R}^2$)	71% (67%)	52% (46%)
σ^2	0.5	1
Durbin-Watson	1.47	1.33
$dCO2^+_t$	0.18 *	0.18
$dCO2^+_{t-1}$	0.13	-0.01
$dCO2^+_{t-2}$	-0.09	-0.14
$dCO2^+_{t-3}$	0.52 ***	0.76 ***
$dCO2^-_t$	-0.04	0.03
$dCO2^-_{t-1}$	-0.19 ***	-0.23 **
$dCO2^-_{t-2}$	0.22 ***	0.17 *
$dCO2^-_{t-3}$	0.51 ***	0.38 ***
$\sum dCO2^+$	**0.79**	**0.74**
$\sum dCO2^-$	**0.35**	**0.50**
GAS_t	-0.01	0.00
GAS_{t-1}	0.03	0.04
GAS_{t-2}	0.01	0.01
GAS_{t-3}	0.04 *	0.06 *
F(H_0: $CO2_{sym}$ vs. H_1: $CO2_{asym}$)	**4.1** ***	**3.4** **
*,**,*** coefficient different from zero on the 10%, 5%, 1% confidence interval, respectively. Weekly average 2005-2006 data (99 observations).		

Therefore, we estimate (4) using a specification comparable to the presented ECM model. The ADL model results indicate a slightly inferior "fit" compared to the EC model in terms of adjusted R^2 and Durbin-Watson statistics. Nevertheless, the results in Table 3 provide strong evidence for positive asymmetric cost pass-through of EUA prices: The cumulated sums of the lagged coefficients for positive EUA price changes in both cases are larger than those for negative ones (see Figure 3). Further, the hypothesis of EUA symmetric cost pass-through to electricity futures prices is rejected in favor of the asymmetric version on the 5% confidence level.

Figure 3: CPT of EUAs in Base and Peak Future 2007 Prices 2005-2006



Moreover, assuming asymmetric gas price pass-through does not prove significant in general (see Table 4). This is evidence that asymmetric pricing is not a universal phenomenon in electricity futures markets but is specific to the EUA price pass-through.

Table 4: F-Test for asymmetric cost pass-through in the ADL model

	Future Base	Future Peak
F(H0: $CO2_{sym}$ vs. H1: $CO2_{asym}$) given GAS_{asym}	4.1***	2.9**
F(H0: GAS_{sym} vs. H1: GAS_{asym}) given $CO2_{asym}$	1.8	1.9
F(H0: $CO2\&GAS_{sym}$ vs. H1: $CO2\&GAS_{asym}$)	3.0***	2.7**
F(H0: $CO2_{sym}$ vs. H1: $CO2_{asym}$) given GAS_{sym}	4.1***	3.4**
F(H0: GAS_{sym} vs. H1: GAS_{asym}) given $CO2_{sym}$	1.7	2.3*

4 Conclusions

This paper has analyzed asymmetric cost pass-through between EUA and electricity future prices in Germany. We applied an error correction and an autoregressive distributed lag model to analyze this link. We find convincing evidence that emissions prices are passed through asymmetrically to electricity futures prices in Germany.

We observe that since most industry-specific explanations for asymmetric pricing (search cost, inventories, menu cost, signalling, and the like) do not apply for electricity wholesale electricity markets, two intuitive explanations arise, although neither is fully convincing: First, asymmetric cost pass-through may be a sign of an early market phase, where the knowledge about how to handle a newly introduced cost factor develops over time. Second, finding evidence of asymmetric pricing could indicate the exercise of market power by German electricity generators.

With longer series becoming available, the inclusion of more lags and variables will shortly allow for more detailed analyses. We suggest that two subjects for future research are: undertaking an international comparison, and developing a consistent theoretical model.

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