Energy Cost Pass-Through and Strategic Pricing:

Sectoral Evidence for the EU ETS

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Abstract.

Price adjustments, particularly the pass-through relationships, are at the core of the analysis on how asymmetric climate change policy initiates two channels of carbon leakage in the energy-intensive sectors: (decreasing) market shares and profit margins. Under conditions of oligopolistic competition with strategic interactions, firms are in position to charge a flexible mark up over marginal costs to balance the negative impacts on both dimensions. Our empirical results demonstrate that strategic interactions of German producers with foreign competitors do matter in the EU ETS sectors. While energy cost shocks are largely born by the producers in the majority of the sectors, different patterns of asymmetric adjustment to the competitor's prices might increase or decrease profit losses induced by the incomplete pass-through rate. The policy implications of the results are that strategic interaction between domestic and foreign firms could be a critical factor in applying offsetting instruments to address carbon leakage domestically. Consequently, accounting for oligopolistic structures (with and without strategic interactions) should be a central issue within the broader context of how market structure affects the climate change policies.

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Keywords: Energy Cost Pass-Through, Strategic Oligopoly, Emissions Trading Scheme

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1. Introduction

In December 2008, the European Council decided upon the Energy and Climate Package – a comprehensive legislative initiative proposed by the European Commission to achieve the EU's target of emissions reductions by at least 20% by 2020 (EU, 2008, 2008a). Recognizing that asymmetric climate actions might lead to competitiveness distortions and carbon leakage, new legislation proposal foresees that installations from energy-intensive and export-oriented sectors receive preferential treatment in the third phase of the EU ETS from 2013 on. The main options to address competitiveness-driven carbon leakage include free allocation of allowances to existing and new facilities, financial compensation, border tax adjustments (BTAs) and global sectoral agreements, i.e. instruments encouraging sector-based activities in developing countries. After all, the European Council favoured free allocation to address competitiveness loss and carbon leakage issues in the European Union. But global sectoral approaches – as alternative option to reduce carbon leakage – might still apply to European facilities as Part of a Post 2012 Framework.

For policy-makers, the possibility of sector-specific carbon leakage is at the centre of discussions on how to effectively reduce emissions under domestic and international climate policies. Sound understanding of its drivers is indispensable for design of appropriate countermeasures. In the context of international climate policy, the issues of competitiveness-driven leakage have therefore triggered comprehensive research work. The CGE-related literature mainly focused on assessing competitiveness and leakage effects associated with the implementation of the EU ETS in the two first trading periods up to 2012 (Bollen et al., 2003; Klepper and Peterson, 2004; COWI, 2004; Reinaud, 2005; Peterson, 2006). Assuming that an increase in marginal carbon cost is fully borne by consumers[1] of the final good, these studies estimate how domestic suppliers adjust market shares on both domestic and foreign markets.[2] However, the cost pass-through literature suggests that cost increases under uneven carbon constraints would not necessary be fully passed onto the consumers of energy-intensive goods through product price increases but are rather absorbed by industry through a reduction of profit margin – in the extreme case, this might imply constant prices and sustaining output level but decreasing profit margins (Reinaud, 2005a and 2005b, Smale et al. 2006, McKinsey and Ecofys 2006, Hourcade et al. 2007, Öko-Institut

[1] In this case the profit margin of the producers remains unchanged.

[2] Reinaud (2008) refers to changes in international trade flows of carbon constrained products as a short-run leakage route (channel).

2008, CE Delft 2008). Differences in returns on capital between constrained and unconstrained producers give room for leakage by creating incentives to relocate the business abroad. Studies using detailed global sectoral models (e.g. Quirion 2003, Demailly and Quirion 2006a, Hidalgo, Szabo et al. 2005, Palmer et al. 2006) addressed sectoral carbon leakage referring explicitly to cost pass-behaviour of selected energy-intensive sectors. Assuming a range of cost-pass through rates (and other parameters such as trade elasticity), these studies estimated the impact of carbon price on both market share and profits of European energy-intensive industries. Given the fact that results crucially depend on the ability to pass-through additional costs, empirical foundation of such assumptions is fundamental for any conclusions on appropriate countermeasures. Surprisingly, ex-post studies providing evidence on the cost pass-through behaviour of European energy-intensive sectors other than power are at best scarce (see for example Walker et al. 2006 on cement).

The purpose of this paper is to analyse the potential passing through capacity of the additional energy cost in German energy-intensive industries covered by the European emission trading scheme (EU ETS). Within our stylized theoretical and empirical framework, we employ a variant of the mark-up model of price determination which allows for possible strategic interaction between domestic and foreign firms in the form of limiting the impact of cost shocks on price competitiveness. The key element of the model is that firms would be in position to charge a *flexible* mark up over marginal energy costs to earn profits and to protect market shares. In this setting, firm's decision on how to adjust market shares and profit margins is endogenous to a particular policy shock. Although strategic interactions in energy-intensive sectors might be very relevant, the empirical cost-pass through literature does not typically take such effects into consideration. The few studies accounting for the competitors' prices have been limited to the analysis of exchange rate pass-through for exporters in selected manufacturing industries (e.g. in automobile sector in Switzerland: Gross and Schmitt 2000, in ceramic tiles industry in Italy and Spain: Balaguer etr al. 2003). To our knowledge, there is no empirical study which analyses the capacity of German energy-intensive sectors to pass-through costs accounting for possible oligopolistic interactions with foreign competitors. The model is estimated for 17 energy-intensive sectors at the 3-digit-level – the corresponding sectors at the lower level of sectoral disaggregation are chemicals, paper, metals, refineries and non-metallic products. The focus on German energy-intensive sectors is to account for these industries being the biggest producer within the EU-27 (Eurostat, 2007).

The structure of the paper is as follows: Section 2 sets out the theoretical framework for measuring the incidence of energy price shocks in the presence of oligopolistic structures with strategic interactions. Section 3 discusses the econometric procedure and the data base. Section 4 presents and analyses the results. Section 5 concludes.

2. Model

To analyse the potential passing through capacity of additional energy costs in German energy-intensive sectors, we employ a variant of the mark-up model of price determination built upon the work of Dixit-Stiglitz (1977) and Dornbusch (1987)[3]. Under conditions of imperfect competition in heterogeneous goods, this framework allows for possible strategic interaction between domestic and foreign firms. The key element of the model is that firms would be in position to charge a *flexible* mark up over marginal energy costs to earn profits and to protect market shares even. The main purpose of this section is to give a theoretical underpinning to the empirical model estimated subsequently.

Assume that the representative consumer maximizes the following separable utility function:

$$u = U[z, V(x)] \tag{1}$$

where z and x are two commodities and x is an index of different brands of the same commodity. Suppose that there are n^D identical domestic firms and n^F foreign firms in (our) home market – the latter are identical to each other but not to the domestic firms.[4] The demand for each individual variant is obtained by maximizing the utility function:

$$x_d = x\left(P/p_d\right)^c ; \qquad c = \frac{1}{(1-\theta)} \tag{2}$$

The price index of the variants of x is given as:

$$P = \left[\left(\sum_{d=1}^{n^D} p_d^h\right) + \left(\sum_{f=1}^{n^F} p_f^h\right)\right]^{1/h} ; \qquad h = -\frac{\theta}{(1-\theta)} \tag{3}$$

where p_i denotes the price of a domestically produced variant and p_j denotes the price of an imported variant.

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[3] Dornbusch (1987) considers the Dixit-Stiglitz model (1977) to capture the effects of imperfect competition and product differentiation on the output price responses to exchange rate changes.

Under conditions of imperfect competition, assume too that individual firms are sufficiently large to affect the industry price P, while strategic interactions between the firms are introduced by way of a conjectural variation σ $(0 < \sigma < 1)$. The latter parameter indicates that firms respond to a one-percentage-point rise in the industry price by increasing their prices by σ percent[5]. The profits of the n^D domestic firms are given by:

$$\pi_d = (p_d - e_d)\, x_d \tag{4}$$

where x_i are the outputs, and e_i are the unit energy costs of the domestic firm.

The first-order condition of profit maximization for an individual domestic producer k becomes:

$$x_k + [p_k - e_k]\left[\left(\partial x_k / \partial p_k\right)\right] + \left[\left(\partial x_k / \partial P\right)\left(\partial P / \partial p_k\right)\right] = 0 \tag{5}$$

Thus, a single firm's production volume is affected directly via change in it's individual price $\left[\partial x_k / \partial p_k\right]$ and indirectly via changes in the output price index resulting from his own decision $\left[\left(\partial x_k / \partial P\right)\left(\partial P / \partial p_k\right)\right]$.

Let now ε denote the elasticity of the aggregate price level with respect to the single supplier's own price:

$$\varepsilon \equiv \left(dP/P\right) / \left(dp_k / p_k\right) \tag{6}$$

Since the individual firm has to take into consideration the extent to which his action affects the output price index P, this term captures the strategic interaction between firms as perceived from the domestic firm k. Using the above definition for ε, the first-order condition can be simplified to:

$$1 + (p_k - e_k) \cdot c(\varepsilon - 1) / p_k = 0 \tag{7}$$

and solved for the optimal price under strategic interaction:

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[4] Assume further that there is an effective separation between the home and foreign markets. Thus, it's possible to separately discuss the pricing behaviour of foreign producers in our market.

[5] In the Cournot model of imperfect competition in homogenous goods (perfect substitutability between the domestic and imported goods), a firm's mark-up depends on it's market share. Firms with a high market share are considered to be able to charge higher prices. But in reality, this might be difficult if competitors are not expected to follow a firm's price increase. Hence, firm's optimal pricing strategy will not only depend on it's

$$p_k = \frac{e_k}{\left[1 - \frac{1}{c(1-\varepsilon)}\right]} \equiv \alpha e_k \tag{8}$$

The mark-up pricing equation (8) highlights the fact that firm's optimal price policy is no longer to charge a constant but rather a flexible mark-up over energy costs. Assuming that conjectural variation for all firms i and j other than k is given by:

$$\sigma \equiv \left(dp_{d\neq k,f} / p_{d\neq k,f}\right) \Big/ \left(dP/P\right) \tag{9}$$

one gets the following expression for the elasticity ε[6]:

$$\varepsilon \equiv \frac{1}{\sigma + (1-\sigma)[n^D + n^F (p_d / p_f)^h]} \tag{10}$$

The individual domestic firm's price reaction is then a function of relative prices, the conjectural variation and the elasticity of substitution among variants.

$$p_d = F(p_d / p_f, \sigma, c) e_d \tag{11}$$

By following similar steps (as in the case of the domestic firm) one gets the foreign firm's reaction function:

$$p_f = F(p_f / p_d, \sigma, c) e_f \tag{12}$$

From equations (11) and (12), it's clear that optimal pricing decisions of domestic and foreign firms are interdependent.

In the context of the unilateral EU climate change policy, this simple framework allows illustrating important insights for the aggregate price level. Figure 1 and Figure 2 demonstrate these implications for two alternative policy options being recently under consideration in the EU. The curves AA and A*A* are the price reaction functions of a representative domestic and foreign firm, respectively. B is the initial equilibrium with carbon costs being reflected in the energy prices of the domestic firm only. Now consider the case (Figure 1) where home country intends integrating foreign producers into the domestic emission trading scheme or imposing the import tariff on the foreign products in the domestic market (see for further details Alexeeva-Talebi et al. 2008). This policy option will shift the foreign reaction function

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market share but be conditioned by the anticipation of competitor's reaction to this strategy. This interrelation is expressed as conjectural variation.

[6] In the Dixit-Stiglitz model (1977) this elasticity is zero.

up and to the right while leaving the domestic reaction function unchanged. The new equilibrium B’ is characterized through an increase of the aggregate price level while the domestic firm responds with a higher price and mark-up to this policy chock. Alternatively, home government intends to subsidize a fraction of the carbon costs getting reflected in the lower domestic energy prices (Figure 2). Such a policy option will shift the domestic reaction function down and right while leaving the foreign country’s reaction function in place. The new equilibrium is therefore at B’’ with a lower aggregate price level.

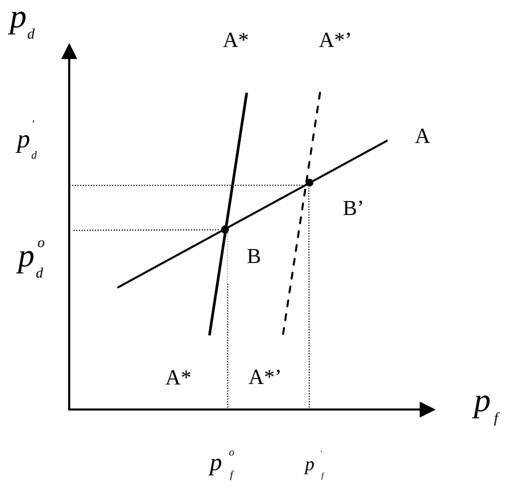

Figure 1: Increasing aggregate price

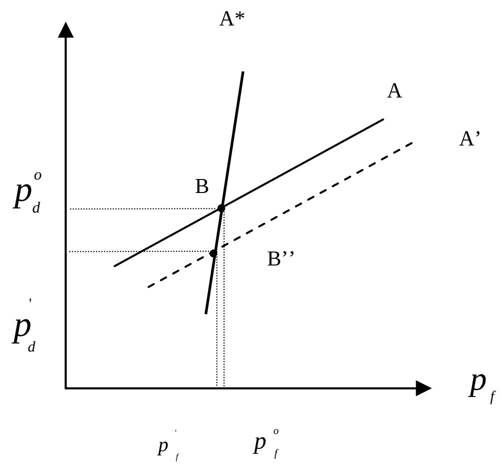

Figure 2: Decreasing aggregate price

This framework allows us to test if German energy-intensive sectors price strategically – through variation in their mark-ups – in the face of the energy cost shocks. Taking logarithms, we receive the solution out of equations (8) and (10) for the domestic supplier:

$$p_{it}^{d} = (1-\phi_i)e_{it} + \phi_i p_{it}^{f} \ , \ \ \varphi_i = \frac{\theta_i}{1+\theta_i} \tag{13}$$

If ϕ_i is zero, domestic prices are set exclusively with respect to the domestic producer’s cost situation. This would be exactly the case if the Dixit-Stiglitz model (1977) holds, reflecting the constant mark-up on domestic marginal energy costs. If ϕ_i is one, the domestic prices are set exclusively with respect to the foreign producer’s prices in the domestic market. If ϕ_i varies between zero and one, then domestic prices react to both domestic unit costs and foreign competitor’s prices. The larger the competitive pressure θ_i is, the higher substitutability between domestic products and foreign export goods, the larger ϕ_i is. In this particular case the domestic producers gear to a much higher extend to the competitor’s prices than to their own cost changes. The aim of the subsequent section is to determine the behavioural parameter of the in the domestic empirically.

3. Data and econometric procedure

The equilibrium price equation (13) is estimated for German energy-intensive sectors covered by the emissions trading scheme (EU ETS) with monthly data for the period January 2000 to December 2008. The analysis is carried out for 17 sub-categories at the 3-digit-level according to the German Product Classification for Production Statistics 2002 (GP 2002) – the corresponding sectors at the lower level of sectoral disaggregation are basic chemicals, rubber and plastic, paper and pulp, publishing, basic metals, refineries and non-metallic products. The selection of the respective energy-intensive sub-sectors is based on Graichen et al. (2008) – this publication specifies industrial branches participating in the emission trading scheme (EU ETS) in Germany[7] (see Table 1).

Time series for the sectoral domestic and foreign competitor's prices stem from German Statistical Office (Statistisches Bundesamt, 2009a). The former is domestic output price index (producer price index) for goods in respective sub-sectors sold on the German market. The latter measures the price development of the imported goods purchased in Germany from non-domestic producers.[8] Since more frequent price data (e.g. on the weakly base) are not available for these sectors and the EU ETS is still in an early stage (i.e. respective time series on carbon prices is relatively short), the passing-through capacity of additional carbon prices cannot be directly estimated. However, the carbon costs are likely to be incorporated in the electricity prices (Zachmann and Hirschhausen, 2008), while carbon regulations might have significant feedback effects on the international price development of the primary energy carriers coal, gas and oil (Böhringer and Vogt, 2003). Therefore, we analyse the potential passing through capacity of additional energy costs in German energy-intensive sectors, using energy price indices for electricity, natural gas, hard coal and crude mineral oil from German Statistical Office as proxies (Statistisches Bundesamt, 2009b). Due to the data availability, the prices for industrial customers are used for electricity only. The data for crude oil, natural gas

[7] Graichen et al. (2008) list industrial braches at the 4-digit level in NACE classification. Due to the data availability, the analysis has to be carried out at a lower level of disaggregation. Therefore, we assign industrial braches at the 4-digit level in NACE classification to the 3-digit level in GP 2002 classification. Due to the data lack, we do not, however, consider the sectors manufacture of coke oven products (231) and manufacture of bricks, tiles and construction products (264).

[8] The appropriate price is the C.I.F. price (cost, insurance, freight) at the border.

and hard coal are import indices. All data series are (seasonally unadjusted) indexes with the 2000 monthly average as the base value.

Table: Industrial braches participating in the EU ETS in Germany

Sector	Code GP 2002
Manufacture of pulp, paper and paper products	**21**
Manufacture of pulp, paper and paperboard	211
Manufacture of articles of paper and paperboard	212
Publishing, printing, reproduction of recorded media	**22**
Printing and service activities related to printing	222
Manufacture of coke, refined petroleum products and nuclear fuel	**23**
Manufacture of refined petroleum products	232
Manufacture of chemicals and chemical products	**24**
Manufacture of basic chemicals	241
Manufacture of pharmaceuticals, medicinal chemicals and botanical products	244
Manufacture of soap, detergents, cleaning, polishing	245
Manufacture of other chemical products	246
Manufacture of rubber and plastic products	**25**
Manufacture of rubber products	251
Manufacture of plastic products	252
Manufacture of non-metallic mineral products	**26**
Manufacture of glass and glass products	261
Manufacture of non-refractory ceramic products	262
Manufacture of ceramic tiles and flags	263
Manufacture of cement, lime and plaster	265
Manufacture of other non-metallic mineral products	268
Manufacture of basic metals	**27**
Manufacture of basic iron and steel and of ferrous-alloys	271
Manufacture of basic precious and non-ferrous metals	274

We start our econometric procedure by testing the properties of the time series. The results from the Dickey-Fuller unit root test suggest that none of the dependent and explanatory variables are stationary in levels. Achieving the stationarity after differencing once implies that they are non-stationary processes of order one (I(1)).[9] Subsequently, we tested for the existence of a long-run relationship using the Johansen maximum likelihood procedure. The existence of cointegration relationship between domestic and foreign prices has been rejected for few product categories, making the estimation in first differences necessary for all time

[9] The results are available upon the request.

series. This might be due to the fact that the data set is relatively small so that the probability to identify the long-run properties of the data is reduced. Under this approach, the long-run effects of the determinants are captured by summing up the coefficient of the current and lagged first differences. Thus, the choice of the numbers of lags included in the regression might be crucial for the results. According to the Schwartz' Bayesian Information Criteria (BIC), the appropriate number of lags is one for all time series. Akaike's Information Criterion (AIC) suggests specifying the model with a one lag for each explanatory variable for the most but not for all time series. In few sectors, the latter suggests specifying the model with a higher number of lags (up to six). Obviously, the firms may delay adjustments of their producer prices to the cost shocks. To keep the degree of freedom as high as possible, the number of the lags has been restricted to four. Model specifications including one and four lags are reported in the Appendix. The model specification with a high number of lags is used to check the model robustness.

The autoregressive distributed lag representation of equation (13) has been estimated for 17 sub-sectors using the energy prices for electricity, crude oil, natural gas and hard coal. In order to asses the vulnerability of domestic energy-intensive sectors to the foreign competitors, we account for possible asymmetric reactions of German producers to the foreign competitor's price separating the months with positive and negative price changes:

$$\triangle p_t^{f+} = \begin{cases} \triangle p_t^f, if \triangle p_t^f > 0 \\ 0, otherwise \end{cases} \qquad \triangle p_t^{f-} = \begin{cases} \triangle p_t^f, if \triangle p_t^f < 0 \\ 0, otherwise \end{cases}$$

and estimate the following equation in first differences including up to the fourth lag:

$$\triangle p_{i,t}^d = \alpha_i + \delta_{i,l} \sum_{l=1}^{n} \Delta p_{i,t-l}^d + \lambda_{i,l} \sum_{l=1}^{n} p_{i,t-l}^{f+} + \rho_{i,l} \sum_{l=1}^{n} p_{i,t-l}^{f-} + \zeta_{i,y} \sum_{y=0}^{n} \triangle e'_{t-y} + \varepsilon_{i,t} \tag{14}$$

$$\text{with } e_t^{'} = (p_t^o, p_t^c, p_t^e, p_t^g),$$

where α_i is the constant, $\varepsilon_{i,t}$ is the error term and $e_t^{'}$ is the vector of energy prices with $p_t^o, p_t^c, p_t^e, p_t^g$ being the price for oil, coal, electricity and gas, respectively.

4. Results

The results from the model specification with one lag (Tables 2 and 3) and four lags (Tables 4 and 5) together with diagnostic statistics are presented in the Appendix. To check the robustness of our results, we additionally estimated for every sub-sector a model with a higher number of lags (up to six) – those results will be reported only if additional insights have been obtained.[10] To emphasise the heterogeneity in the price-setting behaviour – and therefore the value of analysing the cost pass-through relationships at the highest possible level of disaggregation – we report the results for all sub-sectors.

Paper and pulp (21) and printing (22)

Our results on the ability to pass-through additional energy costs and strategic pricing are rather heterogeneous in both goods categories.

For the manufacturers of articles of pulp and paper (212), Tables 2 and 4 indicate that passing-through additional energy costs is being completed within few months: In the model specification including four lags, the respective coefficients – with one exemption – have expected sign and are significant on the 5% significance level. Given the fact that coal is not used in the production process (Table 1), any price increases of this input factor are not reflected in the output prices. Empirical evidence has been found for the existence of the flexible mark-up as domestic producers decrease own prices in the event the competitor's increase them. In the model specification with a higher number of lags, the weak evidence (at the 10% significance level) for adjustments to the negative price shocks of the competitors has been also received. Thus, this sub-sector lets profits bear the brunt of adjustments to the competitor's price changes as increasing market share comes at the expense of the decreasing profit margin.

In contrast, the ability of the producers of paper and pulp (211) to pass-through cost shocks is more limited: According to our estimates in the specification including one and four lags, output prices of these products rise due to the increased gas prices. Data on the energy intensity with respect to the input factor gas suggest, however, that pass-through rate of these cost shocks is complete (Table 1). Evidence for complete passing-through oil price increases has been found in model specification with a higher number of lags, but price shocks of the most important energy input factor electricity are born by the producers even within a time horizon of six months. The domestic firms appear to partly offset these losses in profit margin

[10] Results in the model specification with a higher number of lags (up to six lags) are available upon request.

via increasing prices in the event the competitor's increase own prices: Following the 1%-positive competitor's price shock, manufacturers of paper and pulp increase the domestic prices immediately (within one month) by up to 0.47%.

For the printing sector (222), we do not find the evidence that any types of energy cost shocks might be passes-through to the consumer in the short-run (within four months). According to the model specification with a higher number of lags (up to six lags), this sector is capable to more than completely pass-through gas price shocks, while price increases of two other energy input factors (oil and electricity) are born by the producers. The latter model specification provides evidence on strategic pricing of the firms, i.e. there are price adjustments to both competitor's price increases and decreases. Obviously, such price-setting strategy might be suitable to maintain the market share in the domestic market. Adjusting to increasing and decreasing competitor's prices will, however, differently affect the profit margin of the respective firms, albeit the scope to compensate the incomplete pass-though rate appears to be limited in this sub-sector. Finally, own price adjustment appears also to be an important driver of the price-setting strategy in this sub-sector.

Basis chemicals products (24)

None of the sub-sectors producing chemical products are capable to completely pass-through all types of relevant energy prices shocks within the time horizon of six months. The speed and scope of adjustments differs across those sectors. However, the most of the sub-sectors are capable to pass-through a substantial fraction of additional energy price increases over this time horizon.

Manufactures of basic chemicals (241) rapidly – within one month – pass-through a considerable part of energy price shocks to the consumers. The corresponding coefficients are highly significant for electricity and oil price increases and weak significant for coal price increases. We have not found any evidence that gas price shocks – with gas being one of the major energy inputs in the production – cannot be passed-through over this time horizon (Table 1). The model specification with one lag provides also strong evidence on the strategic interactions with foreign competitors: Domestic producers let the profit margin bear the brunt of adjustments to the competitor's prices decreasing the prices in the event the competitors let them fall. The model specification with a higher number of lags does not significantly change our results.

The manufacturers of soap & cleaning (245) and other chemical products (246) are capable to pass-through a substantial fraction of additional energy costs too but over a longer time horizon: In the model specification with one lag, the respective coefficients in the former sub-sector are insignificant. In the model specification with a higher number of lags (up to six), producers of soap & cleaning products are able to pass-through the biggest fraction of energy price shocks – i.e. increasing electricity and gas prices – to the consumers. Oil price increases are thereby born by the producers. Strategic pricing in this sub-sector enclose maintaining the market share via adjustments to both positive and negative price movements of the competitors. For the latter sub-sector, we have found robust empirical evidence – i.e. in the model specifications with a different number of lags – for potential to pass-through additional gas prices. But our results regarding the ability to pass-through additional electricity prices are less clear and depend on the number of lags included in the model specification. According to the Table 1, only these both types of energy are being used in the production process. Thus, the ability of the producers in this sub-sector to pass-though the energy price shocks varies from being substantial and to being complete. The results regarding the existence of the flexible mark-up in this sub-sector are ambiguous too as respective coefficients differ in model specifications with an alternative number of lags.

In contrast, the ability to pass-through energy cost shocks in the production of pharmaceuticals (244) remains rather limited even over a time horizon of six months. This sub-sector is capable to completely pass-through the gas price increases only, while other price increases – i.e. electricity, oil and coal – are born by the producers. In the model with a higher number of lags, our results indicate that producers of pharmaceuticals follow negative price shocks of the competitors. Obviously, such strategic price adjustments put an additional burden on the profit margin in this sub-sector.

Rubber and plastic products (25)

Within this sub-sector, we find even a more pronounces heterogeneity: Producers of rubber (251) are able to more than completely pass-through all relevant types of energy price shocks in the short-run, within four months (Tables 2 and 4). Adjustments to the positive price shocks of the competitor’s are weak significant in the model specification with four lags (at the 10% significance level) and significant in the model specification with a higher number of lags (at the 5% significance level), indicating that producers might be able to get additional profits at the expenses of decreasing market shares. In contrast, producers of plastic (252) are much more limited in their ability to pass-through energy price shocks. In the model specification with a higher number of lags, the biggest fraction of the energy price shocks is born by the producers even 6 months after the price shocks – the electricity and gas price shocks cannot be passed-through. We find a weak evidence for passing-though oil price increases. In the model specification with 6 lags, the adjustments to the decreasing competitor's prices (in the fifth month after the price shock) alleviate the negative implications for the profit margin.

Non-metallic mineral products (26)

Our results in Tables 3 and 5 suggest that only one sub-sector – i.e. manufactories of non-refractory ceramic products (262) – completely passes-through all energy costs increases in the short-run, while other sectors are capable to pass-through at least a (significant) fraction of the energy price shocks.

Three out of five sub-sectors in this product category – manufactures of non-refractory ceramics (262), ceramic tiles & flags (263) and cement & lime (265) – are able to pass-through electricity price shocks to the domestic consumers within few months, albeit the results for the producers of ceramic tiles and flags are significant in the model specification with one lag only. The corresponding coefficients are significant on the 5% significance level, with the highest value of up to 0.55% in the sub-sector manufacture of cement & lime. Table 1 suggests further that those producers are able to pass-through more than 100% of the electricity price increases. Surprisingly, we do not find – with an exception in the model specification with one lag for the producers of non-refractory ceramic goods and a model specification with a higher number of lags (up to six) for the glass producers (261) – any evidence for passing-through gas price shocks, although gas constitutes one of the most important energy production factors (Table 1). The (weak) evidence for passing-through oil price changes has been found for manufactures of non-refractory ceramics and other non-metallic products. Finally, two sub-sectors – producers of glass and cement & lime – pass-through additionally coal price shocks, with coefficients ranging between 0.04% and 0.06%. This is remarkable as – at least in 2002 – this production factor has not been used in both sectors, while the change in the production function might deliver an explanation for this result.

To sum-up, producers of non-refractory ceramic goods are capable to completely pass-though all energy price shocks within four months. Producers of cement & lime pass-through the biggest fraction of energy price increases in the short-run: The results are robust for the passing-through electricity and – in the model specification with a higher number of lags – oil price increases. We have also found evidence for passing-through gas and oil prices to the consumers, albeit these results are not robust, i.e. they depend on the number of lags included in the model specification. In contrast, producers of glass products and ceramic tiles & flags bear the biggest fraction of energy price increases even within the time horizon of six months. The results for producers of other non-metallic products (268) are ambiguous, depending on alternative model specifications.

Our results in Table 3b indicate further that domestic price-setting of German non-metallic mineral producers might be affected by the negative price movement of the competitors in two sub-sectors: Those sectors are manufactures of cement, lime and plaster and glass producers. Such price adjustment puts an additional pressure on the profits reducing the profit margins in the respective sub-sectors. In the model specification with a higher number of lags (up to six lags) the adjustment to the negative price movements has been found for the manufactures of other non-metallic mineral products. Our hypothesis about the existence of the strategic interactions within the extended Dixit-Stiglitz framework (i.e. existence of the flexible mark-up) in Section 2 cannot be confirmed for the remaining sub-sector (263 and 262), as the respective coefficients (competitor’s prices) are not statistically significant. In the standard version of the Dixit-Stiglitz model (1977) the oligopolistic firms are significant small – they are not capable to make any impact on the aggregate (industry) price level and therefore do no explicitly consider the prices of the competitors. Thus, one reason for competitor’s prices being non-significant in this sector might be that printing firms are significant small and do not possess market power.

Ferrous and non-ferrous metals (27)

According to the Tables 3 and 5, manufacturers of ferrous (271) and non-ferrous metals (274) are capable to completely pass-through only a limited amount of energy price increases in the short-run. Producers of ferrous metals pass-through coal price shocks – this appears to be important as Table 1 suggests that coal represents the most significant energy input factor in this sub-sector – and oil price increases. Given the energy intensities in the Table 1, the biggest fraction of energy costs – gas and electricity – is being born by the producers even within the time horizon of six month. Producers of non-ferrous metals are capable to pass-through even a smaller fraction of additional energy prices, namely oil price shocks only. Thus, the biggest fraction of price increases – particularly of the most important energy input factor electricity – is born by the producers in this sub-sector. Further experimental runs – model specification including up to six lags – do not significantly change our results indicating that a significant fraction of energy price shocks is born by the producers of both sub-sectors even within the time horizon of up to six months.

Further, Tables 3 and 5 provide strong evidence that price-setting behaviour of German producers of ferrous and non-ferrous metals is largely determined by the evolution of competitor's prices. Thereby, these sectors adjust to both types of competitor's price shocks, i.e. to the positive and negative price movements. For both sectors, our estimation results report positive asymmetric short-run pricing behaviour with respect to the competitor's prices: Positive competitor's price shocks have a stronger positive influence on prices of producers of ferrous metals, than negative shocks (i.e. competitor's prices decrease). The estimated (lagged) coefficient for positive competitor's price changes is larger than those for negative ones ($\hat{\lambda}_{t-1} > \hat{\rho}_{t-1}$), while the values amount 0.98% and 0.56%, respectively. Thereby, prices are adjusted almost immediately, i.e. within one month (Table 5). For producers of non-ferrous metals, we have found even a more pronounced positive asymmetric pricing. Following the 1%-positive competitor's price shock, manufacturers of non-ferrous metals increase the domestic prices by 1.14%. Domestic prices of these products decrease by 0.92% only, if competitor's prices drop by 1% (Table 5). Obviously, such price-setting strategy might be suitable to maintain the market share in the domestic market. Adjusting to increasing and decreasing competitor's prices will, however, differently affect the profit margin of the respective firms. Adjusting to increasing prices of the competitor's prices allows German producers to partly offset the profit losses induced by the incomplete pass-through rate.

Manufactures of refined petroleum products (23)

According to our results, the producers can pass-through the 1% increase of the oil prices by 0.39% to the consumers immediately within one month. In the model specification with four lags, the manufactures are capable to pass-through up to 0.71% of the oil price increase. The latter model specification provides also a weak evidence for passing-through electricity and coal price increases. Given the fact that Table 1 does not provide the energy intensities for this sub-sector for the confidentiality reasons, the energy cost pass-through rate cannot be estimated. Finally, the results on strategic pricing are not robust with respect to the model specification.

5. Conclusions

This paper analyses the potential passing-through capacity of the additional energy cost shocks in German energy-intensive industries covered by the EU ETS within a theoretical and empirical framework. It appears to be important to account for the price-setting behaviour of the producers at the lowest possible level of sectoral disaggregated. Our results indicate that sub-sectors might be rather heterogeneous in price adjustments (including cost-pass-through relationships). Our main findings might be summarized in the following way:

- First, manufacturers of three (out of seventeen) product sub-categories – that are articles of paper and pulp, rubber and non-refractory ceramics – are capable to completely pass-through *all* types of relevant energy price increases in the short-run. In nine sub-sectors – that are paper and pulp, refined petroleum, basic chemicals, other chemical products, soap & cleaning, glass, ceramic & tiles, other non-metallic mineral products, iron & steel – producers are capable to pass-through a significant fraction of energy price within this time horizon. In all remaining energy-intensive sectors, the potential to pass-through electricity, coal, gas and oil price increases is rather limited, albeit every sector is capable to completely pass-through *one* type of energy price shocks in the short-run. Thus, those four sub-sectors – that are manufacturers of printing service, pharmaceuticals, plastic and non-ferrous metals – bear the biggest fraction of energy price increases even within the time horizon of six months. Competitive pressure from the foreign competitors and the existence of long-term contracts with suppliers might provide the explanation for these results. The latter appears to be plausible as none of these sub-sectors passes-through the price increases of the most important energy input factors in the respective production process.
- Second, the most of the German EU ETS sectors appear to have a *flexible* mark-up over marginal (energy) costs – thus, strategic interactions with foreign competitors do matter to balance negative implications for profit margin *and* market shares. Strong evidence for existence of a flexible mark-up has been found for the producers of basic metals, paper and pulp, printing services and basic chemicals. Strong evidence is given if respective coefficients are statistically significant at the 5% level and results are robust in the model specifications with different number of lags. Weak evidence for flexible mark-up exists for producers of articles of paper, refined petroleum, pharmaceuticals, soap & cleaning, other chemical products, rubber, plastic, glass, cement and other non-metallic products. In our setting, there is weak evidence if

coefficients are statistically significant at the 10% level and/or sensitive to the number of included lags within the model specification. Manufacturers of non-refractory ceramics and ceramic tiles & flags appear to have a *fixed* mark-up as they do not take into consideration the prices of the foreign competitors. However, our theoretical framework suggests that strategic interactions between domestic and foreign producers under conditions of imperfect competition will limit the ability of a producer to pass-through the energy cost shocks. Energy cost shocks cannot be completely passed-through in (almost) all sectors (see above), while sectors where strategic interactions exist do not perform significantly different in this respect as sectors without any strategic interactions. One of the explanations for this result might be a different time horizon: While our data allows performing a short-run analysis only, the theoretical model is a long-run framework.

- Third, industries with strategic interactions demonstrate different patterns of asymmetric adjustments to the competitor's prices: Adjusting to negative competitor's price changes might additionally decrease profit losses induced by the incomplete pass-through rate, while adjusting to positive competitor's price changes might decrease profit losses. The price reactions towards the competitor's prices might be therefore used as an additional criterion for the vulnerability of the EU ETS sectors.

Our main insight is that hypothesis of strategic interactions under oligopolistic competition holds for the most of the EU ETS sectors in Germany. In this respect, our results are very much related to the findings of Quirion (2008) who conducted a simulation analysis for iron and steel producers. Assuming oligopolistic competition (without strategic interactions and thus with constant mark-ups), the study assesses the implications of the EU ETS on the production level (market share). Under conditions of oligopolistic competition with strategic interactions, however, firms are in position to charge a flexible mark up over marginal costs to balance the negative impacts on market share and profitability. In this setting, firm's decision on how to adjust market shares *and* profit margins is endogenous to a particular shock (see again section 2). The policy implications of the results are that strategic interaction between domestic and foreign firms could be a critical factor in applying offsetting instruments to improve competitiveness of domestic energy-intensive industries. Consequently, accounting for oligopolistic structures (with and without strategic interactions) should be a central issue within the broader context of how market structure affects the climate change policies. Particularly, our results suggest that sector-specific choice of the instruments to address the leakage problem might be a promising approach.

The further research might therefore focus on the following issues: (i) better understanding of implications of the existence of flexible mark-up for alternative offsetting measures – simulation models might provide an appropriate methodological framework, (ii) cost-pass though issues in the long-term perspective and (iii) better understanding why particular price shocks (types of energy) are passed-through in some sectors in the short-run but not in the others.

6. References

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Table 1: Energy intensity in German EU ETS sectors (% of total production costs in 2002)

Code GP 2002	Sector	Coal	Gas	Oil	Electricity	Total[11]
21	**Manufacture of pulp, paper and paper products**					
211	Manufacture of pulp, paper and paperboard	0.8	5.1	0.4	5.7	13.0
212	Manufacture of articles of paper and paperboard	0.0	1.5	0.4	1.8	4.3
22	**Publishing, printing. reproduction of recorded media**					
222	Printing and service activities related to printing	0.0	0.8	0.4	2.4	3.6
23	**Manufacture of coke, refined petroleum products and nuclear fuel**					
232	Manufacture of refined petroleum products	n/a	n/a	n/a	n/a	n/a
24	**Manufacture of chemicals and chemical products**					
241	Manufacture of basic chemicals	0.1	2.5	0.6	3.5	8.7
244	Manufacture of pharmaceuticals. medicinal chemicals and botanical products	0.1	0.7	0.4	0.8	2.3
245	Manufacture of soap, detergents, cleaning. polishing	0.0	0.8	0.3	1.2	2.6
246	Manufacture of other chemical products	0.0	0.9	0.0	1.4	3.2
25	**Manufacture of rubber and plastic products**					
251	Manufacture of rubber products	0.0	0.8	0.0	1.7	3.1
252	Manufacture of plastic products	0.0	0.6	0.4	2.4	3.5
26	**Manufacture of non-metallic mineral products**					
261	Manufacture of glass and glass products	0.0	5.2	1.5	4.5	11.3
262	Manufacture of non-refractory ceramic products	0.0	5.3	0.5	2.6	8.5
263	Manufacture of ceramic tiles and flags	0.0	15.1	0.0	5.8	21.4
265	Manufacture of cement. lime and plaster	0.0	4.5	5.8	17.4	43
268	Manufacture of other non-metallic mineral products	0.5	2.3	1.5	2.2	6.5
27	**Manufacture of basic metals**					
271	Manufacture of basic iron and steel and of ferrous-alloys	7.5	4.4	0.9	5.2	18.3
274	Manufacture of basic precious and non-ferrous metals	0.1	1.2	0.2	3.2	5.1

[11] Total includes energy and other energy-related inputs (i.e. district heating). Source: Statistisches Bundesamt (2005) .

Table 2: Regression results in the energy-intensive EU ETS sectors: GP code 21 - 24 (1 lag)

Dependent variable:								
Sectors	*Paper and Pulp*		*Printing*	*Refineries*	*Basic Chemicals*			
Code GP 2002	**211**	**212**	**222**	**232**	**241**	**244**	**245**	**246**
Constant	-0.00** (0.00)	0.00** (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Own price$_{-1}$	0.35*** (0.10)	0.37*** (0.10)	-0.11 (0.10)	-0.35*** (0.13)	0.05 (0.18)	0.09 (0.11)	0.03 (0.11)	-0.21** (0.10)
Competitor's price $_{t=-1. positive}$	0.47*** (0.10)	0.02 (0.08)	0.07 (0.06)	0.24** (0.10)	0.27 (0.19)	-0.04 (0.16)	0.02 (0.12)	-0.03 (0.20)
Competitor's price $_{t=-1. negative}$	0.02 (0.11)	0.30 (0.23)	0.01 (0.05)	0.24** (0.10)	0.43** (0.17)	-0.03 (0.19)	-0.12 (0.22)	0.40 (0.27)
Electricity price $_{t=0}$	0.07 (0.06)	-0.01 (0.05)	-0.03 (0.03)	-0.27 (0.25)	0.00 (0.11)	0.04 (0.07)	-0.06 (0.05)	0.14 * (0.08)
Electricity price $_{t=-1}$	-0.01 (0.06)	-0.04 (0.05)	-0.02 (0.03)	0.42 (0.26)	0.28** (0.11)	0.01 (0.07)	0.08 (0.05)	-0.02 (0.08)
Gas price $_{t=0}$	0.05*** (0.02)	0.01 (0.02)	0.01 (0.01)	0.02 (0.09)	0.04 (0.04)	0.04 (0.02)	0.00 (0.02)	0.04 (0.03)
Gas price $_{t=-1}$	-0.04 ** (0.01)	0.00 (0.02)	0.00 (0.01)	-0.03 (0.09)	0.02 (0.04)	-0.02 (0.02)	0.01 (0.02)	0.00 (0.03)
Oil price $_{t=0}$	-0.01* (0.01)	0.00 (0.00)	0.00 (0.00)	0.39*** (0.02)	0.01 (0.01)	0.00 (0.01)	0.00 (0.00)	-0.01 (0.01)
Oil price $_{t=-1}$	0.00 (0.01)	0.00 (0.00)	0.00 (0.00)	-0.02 (0.06)	0.04*** (0.01)	-0.01 (0.01)	0.00 (0.00)	0.01 (0.01)
Coal price $_{t=0}$	0.00 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.04 (0.06)	0.01 (0.03)	-0.02 (0.02)	0.01 (0.01)	0.00 (0.02)
Coal price $_{t=-1}$	-0.01 (0.01)	-0.01 (0.01)	0.01 (0.01)	-0.02 (0.06)	0.05* (0.03)	0.02 (0.02)	0.01 (0.01)	-0.01 (0.02)
EU ETS dummy	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.02)	0.00 (0.00)	0.00*** (0.00)
Observation	106	106	106	106	106	106	106	106
R^2	0.58	0.23	0.10	0.81	0.57	0.09	0.13	0.24
F-Test	10.59***	2.35***	0.92	33.01***	10.32***	0.79	1.11	2.46***
AIC	-8.13	-8.42	-9.43	-5.02	-6.75	-7.59	-8.44	-7.36
BIC	-7.80	-8.09	-9.11	-4.69	-6.43	-7.26	-8.11	-7.03

Note: *. ** and *** show significance at the 10%-. 5%-. and 1%-level. respectively. Standard errors are indicated in brackets.

Table 3: Regression results in the energy-intensive EU ETS sectors: GP code 25 -27 (1 lag)

Dependent variable:									
Sectors	***Rubber and Plastic***		***Non-metallic mineral products***					***Basic Metals***	
Code GP 2002	**251**	**252**	**261**	**262**	**263**	**265**	**268**	**271**	**274**
Constant	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Own price$_{-1}$	-0.05 (0.11)	0.35*** (0.12)	0.05 (0.10)	0.02 (0.11)	-0.05 (0.10)	0.14 (0.12)	-0.38*** (0.10)	-0.18 (0.17)	-0.66*** (0.17)
Competitor's price $_{t=-1. positive}$	0.06 (0.14)	-0.09 (0.17)	0.24 (0.17)	0.03 (0.14)	0.14 (0.19)	-0.03 (0.14)	0.23 (0.38)	0.90*** (0.21)	0.90*** (0.19)
Competitor's price $_{t=-1. negative}$	0.12 (0.17)	0.34 (0.22)	0.74* (0.42)	0.03 (0.20)	0.01 (0.28)	0.14** (0.06)	0.49 (0.73)	0.33 (0.23)	0.74*** (0.19)
Electricity price $_{t=0}$	0.09* (0.05)	-0.01 (0.04)	0.05 (0.06)	0.11* (0.05)	0.21*** (0.07)	0.38*** (0.10)	0.05 (0.14)	0.13 (0.22)	-0.09 (0.28)
Electricity price $_{t=-1}$	0.03 (0.05)	0.00 (0.04)	-0.07 (0.07)	-0.07 (0.06)	-0.08 (0.07)	-0.11 (0.12)	-0.03 (0.15)	-0.14 (0.23)	0.42 (0.29)
Oil price $_{t=0}$	0.00 (0.02)	0.01 (0.01)	-0.01 (0.02)	-0.04 (0.02)	-0.02 (0.02)	-0.05 (0.04)	0.03 (0.05)	0.06* (0.08)	0.13*** (0.10)
Oil price $_{t=-1}$	0.00 (0.02)	0.01 (0.01)	0.01 (0.02)	0.04 (0.02)	0.01 (0.02)	0.00 (0.04)	0.01*** (0.05)	-0.04 (0.08)	-0.09 (0.10)
Gas price $_{t=0}$	0.00 (0.00)	0.00 (0.00)	0.00 (0.01)	-0.01** (0.00)	-0.01 (0.01)	0.00 (0.01)	0.04 (0.01)	0.04 (0.02)	0.09 (0.03)
Gas price $_{t=-1}$	0.00 (0.00)	0.00 (0.00)	-0.01 (0.01)	0.00* (0.01)	0.00 (0.01)	0.00 (0.01)	0.01 (0.01)	0.01 (0.02)	-0.03 (0.03)
Coal price $_{t=0}$	0.00 (0.01)	0.03*** (0.01)	0.05*** (0.02)	0.01 (0.01)	0.01 (0.02)	0.04* (0.02)	-0.03 (0.03)	0.08 (0.05)	0.04 (0.07)
Coal price $_{t=-1}$	0.02* (0.01)	-0.01 (0.01)	-0.04** (0.02)	-0.01 (0.01)	-0.03* (0.02)	-0.01 (0.03)	-0.02 (0.03)	-0.07 (0.06)	-0.01 (0.07)
EU ETS dummy	0.00 (0.00)	0.00 (0.00)	0.00* (0.00)	0.00 (0.00)	0.00** (0.00)	0.00** (0.00)	0.00*** (0.00)	0.00 (0.00)	0.00 (0.00)
Observation	106	106	106	106	106	106	106	106	106
R2	0.11	0.26	0.22	0.10	0.22	0.33	0.26	0.43	0.42
F-Test	1.00	2.75***	2.19**	0.90	2.16**	3.85***	2.71***	5.89***	5.62***
AIC	-8.39	-8.92	-7.79	-8.10	-7.66	-6.88	-6.23	-5.31	-4.81
BIC	-8.06	-8.59	-7.46	-7.77	-7.34	-6.55	-5.91	-4.99	-4.48

Note: *. ** and *** show significance at the 10%-. 5%-. and 1%-level. respectively. Standard errors are indicated in brackets.

Table 4: Regression results in the energy-intensive EU ETS sectors: GP code 21 -24 (4 lag)

Dependent variable:																
Sectors	*Paper and Pulp*				*Printing*		*Refineries*		*Basic Chemicals*							
Code GP 2002	**211**		**212**		**222**		**232**		**241**		**244**		**245**		**246**	
Constant	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.01	(0.01)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Own price$_{-1}$	0.11	(0.13)	0.19*	(0.11)	-0.16	(0.11)	-0.21	(0.16)	0.17	(0.21)	-0.05	(0.12)	-0.10	(0.13)	-0.15	(0.12)
Own price$_{-2}$	0.18	(0.13)	0.18	(0.11)	0.15	(0.11)	-0.30*	(0.16)	-0.12	(0.22)	-0.07	(0.11)	-0.07	(0.13)	-0.20	(0.12)
Own price$_{-3}$	0.10	(0.12)	0.16	(0.11)	0.24**	(0.11)	0.06	(0.16)	0.15	(0.22)	-0.11	(0.11)	-0.14	(0.13)	0.00	(0.11)
Own price$_{-4}$	0.12	(0.12)	0.14	(0.10)	0.15	(0.11)	-0.11	(0.16)	-0.36*	(0.19)	-0.06	(0.11)	0.00	(0.13)	-0.09	(0.11)
Competitor's price $_{t=-1.\ positive}$	0.35**	(0.15)	0.09	(0.11)	0.05	(0.07)	0.15	(0.12)	0.29	(0.22)	-0.19	(0.19)	-0.01	(0.16)	-0.15	(0.23)
Competitor's price $_{t=-2.\ positive}$	0.11	(0.12)	0.14	(0.10)	0.04	(0.06)	-0.03	(0.12)	0.00	(0.23)	-0.12	(0.20)	0.14	(0.16)	0.02	(0.23)
Competitor's price $_{t=-3.\ positive}$	0.14	(0.12)	0.02	(0.08)	-0.16**	(0.06)	-0.03	(0.11)	0.08	(0.22)	0.15	(0.19)	0.11	(0.15)	-0.53**	(0.23)
Competitor's price $_{t=-4.\ positive}$	-0.18	(0.13)	-0.26***	(0.09)	-0.07	(0.07)	-0.10	(0.12)	0.22	(0.20)	0.17	(0.19)	0.03	(0.15)	0.22	(0.23)
Competitor's price $_{t=--1.\ negative}$	-0.01	(0.13)	0.22	(0.21)	0.09	(0.07)	0.09	(0.13)	0.22	(0.20)	0.13	(0.23)	-0.06	(0.25)	0.33	(0.29)
Competitor's price $_{t=--1.\ negative}$	0.06	(0.14)	-0.27	(0.21)	0.07	(0.06)	-0.01	(0.12)	0.11	(0.23)	0.18	(0.24)	-0.07	(0.25)	-0.01	(0.29)
Competitor's price $_{t=--3.\ negative}$	0.01	(0.14)	0.00	(0.21)	0.07	(0.06)	0.09	(0.11)	-0.12	(0.24)	0.56	(0.23)	0.09	(0.26)	0.36	(0.31)
Competitor's price $_{t=--4.\ negative}$	-0.17	(0.13)	-0.19	(0.22)	-0.01	(0.05)	-0.09	(0.12)	0.29	(0.23)	0.25**	(0.24)	-0.08	(0.28)	0.50	(0.31)
Electricity price $_{t=0}$	0.09	(0.06)	0.12***	(0.05)	-0.01	(0.03)	-0.51*	(0.28)	0.04	(0.12)	0.12	(0.08)	-0.06	(0.06)	0.04	(0.09)
Electricity price $_{t=-1}$	0.06	(0.06)	0.01	(0.05)	-0.05	(0.03)	0.21	(0.28)	0.39***	(0.12)	0.10	(0.08)	0.10*	(0.06)	-0.01	(0.09)
Electricity price $_{t=-2}$	-0.04	(0.06)	-0.07	(0.05)	-0.03	(0.03)	0.51*	(0.30)	-0.05	(0.13)	0.08	(0.09)	0.05	(0.06)	0.01	(0.09)
Electricity price $_{t=-3}$	-0.12*	(0.06)	-0.08	(0.05)	-0.01	(0.03)	0.20	(0.29)	-0.06	(0.12)	0.02	(0.09)	0.03	(0.07)	0.08	(0.09)
Electricity price $_{t=-4}$	-0.06	(0.06)	0.06	(0.05)	-0.01	(0.03)	-0.38	(0.30)	-0.13	(0.12)	-0.05	(0.09)	-0.04	(0.06)	-0.11	(0.09)

Code GP 2002	211	212	222	232	241	244	245	246
Gas price $_{t=0}$	0.05* (0.03)	-0.04* (0.02)	0.00 (0.01)	0.00 (0.12)	0.06 (0.05)	0.04 (0.03)	-0.01 (0.02)	0.08** (0.04)
Gas price $_{t=-1}$	-0.05** (0.03)	-0.03 (0.02)	0.01 (0.01)	0.10 (0.12)	-0.03 (0.05)	-0.05 (0.03)	-0.02 (0.02)	-0.01 (0.04)
Gas price $_{t=-2}$	-0.02 (0.02)	0.01 (0.02)	0.01 (0.01)	-0.19 (0.11)	-0.02 (0.05)	-0.01 (0.03)	0.03 (0.02)	0.04 (0.03)
Gas price $_{t=-3}$	-0.01 (0.03)	0.04** (0.02)	0.00 (0.01)	0.19 (0.12)	0.03 (0.05)	-0.02 (0.03)	0.00 (0.02)	-0.07* (0.04)
Gas price $_{t=-4}$	0.02 (0.02)	-0.01 (0.02)	-0.01 (0.01)	-0.05 (0.11)	-0.01 (0.04)	0.07** (0.03)	0.02 (0.02)	0.03 (0.04)
Oil price $_{t=-0}$	0.00 (0.01)	0.00 (0.00)	0.00 (0.00)	0.43*** (0.03)	0.02* (0.01)	0.00 (0.01)	0.01 (0.01)	0.00 (0.01)
Oil price $_{t=-1}$	-0.01 (0.01)	0.00 (0.00)	0.00 (0.00)	0.01 (0.08)	0.02** (0.01)	-0.02** (0.01)	-0.01 (0.01)	0.01 (0.01)
Oil price $_{t=-2}$	0.01 (0.01)	0.01*** (0.00)	0.00 (0.00)	0.14* (0.08)	0.01 (0.01)	0.00 (0.01)	0.00 (0.01)	-0.01 (0.01)
Oil price $_{t=-3}$	0.01 (0.01)	0.01** (0.01)	-0.01* (0.00)	-0.05 (0.07)	0.01 (0.01)	-0.01 (0.01)	0.00 (0.01)	-0.01 (0.01)
Oil price $_{t=-4}$	0.00 (0.01)	0.01** (0.01)	0.00 (0.00)	0.14* (0.08)	0.01 (0.01)	0.00 (0.01)	0.00 (0.01)	0.01 (0.01)
Coal price $_{t=0}$	0.00 (0.01)	-0.01 (0.01)	-0.01 (0.01)	0.00 (0.07)	0.01 (0.03)	0.00 (0.02)	0.00 (0.01)	0.00 (0.02)
Coal price $_{t=-1}$	0.00 (0.02)	-0.01 (0.01)	0.00 (0.01)	-0.08 (0.08)	0.05 (0.03)	0.04 (0.02)	0.00 (0.02)	-0.02 (0.02)
Coal price $_{t=-2}$	0.00 (0.02)	-0.02 (0.01)	0.00 (0.01)	-0.10 (0.08)	-0.02 (0.03)	0.02 (0.02)	0.01 (0.01)	0.01 (0.02)
Coal price $_{t=-3}$	-0.01 (0.02)	0.00 (0.01)	0.00 (0.01)	0.14* (0.08)	0.05 (0.03)	-0.04* (0.02)	0.00 (0.01)	0.04* (0.02)
Coal price $_{t=-4}$	0.02 (0.02)	0.01 (0.01)	0.00 (0.01)	0.03 (0.07)	-0.04 (0.03)	0.00 (0.02)	0.00 (0.01)	0.00 (0.02)
EU ETS dummy	0.00 (0.00)	0.00 (0.01)	0.00 (0.00)	0.00 (0.12)	0.00 (0.00)	0.00** (0.00)	0.00 (0.00)	0.00** (0.00)
Observation	103	103	103	103	103	103	103	103
R^2	0.64	0.52	0.40	0.87	0.71	0.38	0.26	0.47
F-Test	3.69***	2.30***	1.40	13.67***	5.06***	1.26	0.77	1.86**
AIC	-8.06	-8.66	-9.48	-4.95	-6.78	-7.53	-8.18	-7.31
BIC	-7.19	-7.80	-8.61	-4.08	-5.91	-6.66	-7.83	-6.44

Note: *. ** and *** show significance at the 10%-. 5%-. and 1%-level. respectively. Standard errors are indicated in brackets.

Table 5: Regression results in the energy-intensive EU ETS sectors: GP code 25 -27 (4 lag)

Dependent variable:									
Sectors	***Rubber and Plastic***		***Non-metallic mineral products***					***Basic Metals***	
Code GP 2002	**251**	**252**	**261**	**262**	**263**	**265**	**268**	**271**	**274**
Constant	0.00 (0.00)	0.00* (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.01)
Own price$_{-1}$	-0.07 (0.12)	0.28** (0.13)	0.01 (0.13)	0.06 (0.12)	-0.04 (0.12)	0.00 (0.12)	-0.33*** (0.12)	-0.22 (0.17)	-0.87*** (0.20)
Own price$_{-2}$	-0.20 (0.12)	0.16 (0.13)	0.19 (0.12)	0.10 (0.11)	-0.24** (0.12)	0.17 (0.12)	-0.03 (0.14)	-0.21 (0.18)	-0.08 (0.24)
Own price$_{-3}$	-0.08 (0.12)	-0.26* (0.13)	0.09 (0.13)	0.00 (0.11)	0.19 (0.12)	-0.03 (0.12)	-0.02 (0.14)	0.21 (0.18)	0.10 (0.24)
Own price$_{-4}$	0.01 (0.13)	0.04 (0.14)	0.10 (0.13)	0.08 (0.12)	0.11 (0.12)	0.12 (0.12)	-0.01 (0.14)	-0.13 (0.19)	-0.07 (0.22)
Competitor's price $_{t=-1.\ positive}$	0.17 (0.17)	0.04 (0.19)	0.25 (0.21)	0.06 (0.15)	0.15 (0.23)	0.00 (0.15)	0.27 (0.48)	0.98*** (0.23)	1.14*** (0.24)
Competitor's price $_{t=-2.\ positive}$	0.33* (0.17)	-0.20 (0.22)	0.02 (0.19)	0.10 (0.15)	0.02 (0.22)	-0.06 (0.15)	-0.67 (0.49)	0.22 (0.27)	-0.07 (0.27)
Competitor's price $_{t=-3.\ positive}$	0.06 (0.17)	-0.04 (0.22)	-0.06 (0.20)	-0.20 (0.16)	-0.05 (0.23)	0.06 (0.15)	0.31 (0.48)	0.31 (0.27)	0.42 (0.27)
Competitor's price $_{t=-4.\ positive}$	0.10 (0.17)	-0.30 (0.22)	-0.10 (0.20)	0.00 (0.16)	-0.03 (0.23)	-0.06 (0.15)	-0.19 (0.45)	-0.17 (0.27)	-0.20 (0.24)
Competitor's price $_{t=--1.\ negative}$	0.29 (0.28)	0.25 (0.25)	0.07 (0.48)	-0.03 (0.22)	0.09 (0.38)	0.07 (0.07)	0.32 (0.87)	0.57* (0.31)	0.92*** (0.23)
Competitor's price $_{t=--1.\ negative}$	0.00 (0.27)	0.12 (0.25)	-0.49 (0.49)	-0.20 (0.22)	-0.33 (0.38)	0.02 (0.08)	0.02 (0.82)	-0.22 (0.38)	0.10 (0.25)
Competitor's price $_{t=--3.\ negative}$	0.00 (0.22)	0.13 (0.25)	0.42 (0.46)	0.23 (0.21)	-0.12 (0.35)	0.22*** (0.08)	1.29 (0.84)	-0.25 (0.37)	-0.33 (0.25)
Competitor's price $_{t=--4.\ negative}$	-0.12 (0.22)	0.08 (0.25)	0.84* (0.48)	-0.06 (0.21)	-0.35 (0.41)	-0.16** (0.08)	-1.26 (0.90)	0.01 (0.34)	0.33 (0.24)
Electricity price $_{t=0}$	0.12** (0.06)	0.03 (0.04)	0.03 (0.07)	0.14** (0.06)	0.14 (0.09)	0.55*** (0.11)	0.08 (0.17)	0.01 (0.24)	-0.04 (0.32)
Electricity price $_{t=-1}$	0.03 (0.06)	0.01 (0.04)	-0.04 (0.08)	-0.07 (0.06)	-0.10 (0.09)	0.01 (0.13)	-0.13 (0.17)	0.00 (0.25)	0.49 (0.31)
Electricity price $_{t=-2}$	0.01 (0.06)	-0.02 (0.04)	-0.01 (0.08)	0.01 (0.07)	0.02 (0.08)	-0.07 (0.13)	-0.18 (0.18)	0.13 (0.26)	-0.22 (0.33)
Electricity price $_{t=-3}$	0.06 (0.06)	-0.01 (0.04)	-0.20** (0.08)	0.18*** (0.06)	-0.10 (0.09)	-0.09 (0.12)	0.18 (0.18)	0.15 (0.25)	0.19 (0.31)
Electricity price $_{t=-4}$	0.08 (0.07)	-0.05 (0.04)	0.04 (0.08)	-0.16** (0.07)	0.03 (0.09)	-0.10 (0.12)	0.05 (0.18)	-0.25 (0.24)	0.23 (0.32)
Gas price $_{t=0}$	-0.02 (0.02)	-0.01 (0.02)	-0.02 (0.03)	-0.09*** (0.02)	-0.01 (0.03)	-0.09** (0.04)	0.03 (0.07)	0.14 (0.10)	0.04 (0.13)

Gas price $_{t=-1}$	-0.01 (0.02)	0.02 (0.02)	0.01 (0.03)	0.03 (0.03)	0.01 (0.03)	-0.06 (0.05)	-0.02 (0.08)	-0.02 (0.10)	-0.13 (0.14)
Gas price $_{t=-2}$	0.00 (0.02)	0.00 (0.02)	-0.03 (0.03)	0.05 (0.02)	-0.01 (0.03)	0.01 (0.04)	0.01 (0.07)	-0.03 (0.09)	0.01 (0.12)
Gas price $_{t=-3}$	0.04* (0.02)	0.00 (0.02)	0.05 (0.03)	0.00 (0.03)	0.03 (0.03)	0.06 (0.04)	-0.02 (0.08)	-0.10 (0.10)	0.07 (0.13)
Gas price $_{t=-4}$	-0.03 (0.02)	0.01 (0.02)	-0.02 (0.03)	0.00 (0.02)	-0.03 (0.03)	0.03 (0.04)	0.03 (0.07)	0.06 (0.09)	0.05 (0.12)
Oil price $_{t=-0}$	0.00 (0.01)	0.00 (0.00)	-0.01 (0.01)	0.00 (0.01)	-0.01 (0.01)	0.01 (0.01)	0.04*** (0.02)	0.05** (0.02)	0.06* (0.03)
Oil price $_{t=-1}$	0.00 (0.01)	0.00 (0.00)	-0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.00 (0.01)	0.01 (0.02)	-0.01 (0.03)	-0.04 (0.03)
Oil price $_{t=-2}$	0.00 (0.01)	0.01* (0.00)	0.00 (0.01)	0.01* (0.01)	0.00 (0.01)	0.01 (0.01)	0.00 (0.02)	-0.01 (0.02)	-0.01 (0.03)
Oil price $_{t=-3}$	0.01 (0.01)	0.01 (0.00)	0.00 (0.01)	0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	0.00 (0.02)	-0.02 (0.03)	0.01 (0.04)
Oil price $_{t=-4}$	0.01 (0.01)	0.00 (0.00)	0.00 (0.01)	0.01 (0.01)	-0.02* (0.01)	0.00 (0.01)	0.01 (0.02)	-0.01 (0.03)	0.07* (0.04)
Coal price $_{t=0}$	0.00 (0.01)	0.02 (0.01)	0.06*** (0.02)	0.01 (0.01)	0.01 (0.02)	0.04* (0.02)	-0.02 (0.04)	0.05 (0.06)	0.08 (0.07)
Coal price $_{t=-1}$	0.01 (0.01)	-0.01 (0.01)	-0.05** (0.02)	-0.01 (0.02)	-0.04** (0.02)	-0.03 (0.03)	-0.02 (0.04)	-0.07 (0.06)	-0.06 (0.09)
Coal price $_{t=-2}$	-0.01 (0.01)	0.00 (0.01)	0.02 (0.02)	-0.01 (0.02)	0.03 (0.02)	0.01 (0.03)	-0.01 (0.04)	-0.02 (0.06)	0.11 (0.08)
Coal price $_{t=-3}$	0.00 (0.02)	0.00 (0.01)	-0.01 (0.02)	0.02 (0.02)	0.00 (0.02)	0.05* (0.03)	0.00 (0.05)	0.12* (0.07)	-0.20** (0.09)
Coal price $_{t=--4}$	0.00 (0.01)	0.00 (0.01)	-0.02 (0.02)	-0.01 (0.02)	0.01 (0.02)	0.02 (0.03)	0.03 (0.04)	-0.10* (0.06)	-0.03 (0.09)
EU ETS dummy	-0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00** (0.00)	0.00* (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Observation	103	103	103	103	103	103	103	103	103
R2	0.28	0.45	0.40	0.39	0.41	0.58	0.39	0.63	0.59
F-Test	0.82	1.73**	1.42	1.34	1.43	2.92***	1.31	3.57***	2.97***
AIC	-8.16	-8.79	-7.63	-8.05	-7.51	-6.91	-6.00	-5.31	-4.71
BIC	-7.29	-7.92	-6.77	-7.18	-6.64	-6.04	-5.13	-4.44	-3.84

Note: *. ** and *** show significance at the 10%-. 5%-. and 1%-level. respectively. Standard errors are indicated in brackets.