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Cost Pass-Through in Strategic Oligopoly: Sectoral Evidence for the EU ETS

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Non-technical summary

The purpose of this paper is to analyse the cost pass-through potential, i.e. the ability of firms in German industrial sectors participating in the EU Emissions Trading Scheme (EU ETS) to adjust output prices to input cost shocks. The analysis is as comprehensive as the data permits and covers industrial branches paper and pulp, chemicals, rubber and plastic and non-metallic minerals. Although strategic interactions of domestic energy-intensive sectors with foreign competitors might be of importance, empirical cost pass-through literature does typically not take them into consideration. The stylised theoretical and empirical framework in this paper employs therefore a variant of the mark-up model of price determination which allows for strategic interactions between domestic and foreign firms. The key feature of the model is that the cost pass-through of domestic firms is limited by strategic considerations. The empirical section demonstrates that strategic pricing in the presence of the incomplete cost pass-through is by far the prevailing behaviour of German sectors within the EU ETS. We find that high market power of domestic firms in relatively homogenous product markets leads to lower cost pass-through rates and to the more pronounced adjustment towards the foreign producers' prices. The higher the market concentration of domestic firms in more heterogeneous product markets, the higher the cost pass-through potential and the lower strategic interactions with foreign enterprises.

Das Wichtigste in Kürze

Die vorliegende Arbeit untersucht das Kostenüberwälzungsverhalten deutscher Unternehmen (d.h. die Anpassung der Outputpreise an die Inputpreisveränderungen), welche am EU-Emissionshandel (EU EHS) teilnehmen. Die Analyse ist so umfassend wie die vorhandenen Daten für Deutschland es erlauben und betrachtet die Industriezweige Papier und Zellstoff, Chemie, Gummi und Kunststoff sowie die nicht-metallischen Mineralstoffe. Obwohl strategische Interaktionen von inländischen energieintensiven Sektoren mit ausländischen Wettbewerbern relevant sind, werden diese typischerweise von der empirischen Literatur zur Kostenweitergabe nicht berücksichtigt. Der stilisierte theoretische und empirische Rahmen des Papiers wendet daher eine Variante des Mark-up-Modells zur Preisbestimmung in strategischen Oligopolen an, wobei die strategischen Interaktionen zwischen inländischen und ausländischen Firmen das Kostenüberwälzungsverhalten deutscher Produzenten einschränkt. Der empirische Teil zeigt auf, dass die Mehrheit der deutschen Produzenten mit den ausländischen Wettbewerbern interagiert und somit eine unvollständige Kostenüberwälzung aufweist. Unsere Ergebnisse zeigen, dass hohe Marktmacht bei heimischen Produzenten auf relativ homogenen Produktmärkten zu geringeren Kostenüberwälzungsraten und einer stärkeren Ausrichtung auf die ausländischen Preise führt. Hingegen gilt: Je höher die Marktmacht bei heimischen Produzenten auf relativ heterogenen Produktmärkten ist, umso höher sind die Kostenüberwälzungsraten und umso weniger relevant sind die strategischen Interaktionen mit der ausländischen Konkurrenz.

Cost Pass-Through in Strategic Oligopoly:

Sectoral Evidence for the EU ETS

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Abstract

Price adjustments, particularly the cost pass-through relationships, are at the core of the analysis on how asymmetric climate change policy initiates two channels of carbon leakage: (decreasing) market shares and profit margins. Using advanced time-series techniques, this paper explores the pass-through relationships in an oligopoly setting. Under the condition of oligopolistic competition with strategic interactions, the cost pass-through of domestic firms is restricted by strategic interactions with foreign competitors. The empirical section demonstrates that strategic pricing in the presence of the incomplete cost pass-through is by far the prevailing behaviour of German energy-intensive sectors participating in the EU Emissions Trading Scheme (ETS). The relatively low cost pass-through rates in the long-run in most sectors in our sample – in comparison to studies which do not account for strategic interactions – are consistent with earlier findings. Additional costs induced by the EU ETS are therefore likely to be absorbed through a reduction of profit margin, creating incentives to relocate business abroad. Policy implications of the results are that strategic interactions between domestic and foreign firms could be a critical factor in applying offsetting instruments to address carbon leakage domestically. Accounting for oligopolistic structures – with and without strategic interactions – should therefore be a central issue within the broader context of how market structure affects climate change policies.

JEL Classification: F18, C22, L11

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

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1. Introduction

Climate policy in Europe has been increasingly designed to encourage energy-intensive companies to pursue low-carbon strategies in production process. The revised emissions trading scheme (ETS) in the EU foresees tightening emissions cap and introducing auctions as the basic principle for allocation of carbon allowances beyond 2012, with an auction rate of up to 100% in the power sector (EU 2008).

In the world with uneven carbon constraints, commitments to ambitious emissions targets give rise to multiple concerns, including the potentially adverse impact on competitiveness of European enterprises and the global environmental effectiveness. In the run-up to final consultations at the highest level in Brussels, heavy industry – in particular cement, steel, aluminium and chemical sectors – argued that the revised scheme would force them to move factories and jobs out of the EU's borders, leading to a 'leakage' of carbon emissions. Such concerns have been particularly extensive in Germany, the biggest player in the EU ETS (EurActive 2009).

Successful lobbying for preferential treatment of sectors potentially exposed to a significant risk of carbon leakage established the final compromise: EU leaders agreed that eligible sectors will be granted 100% of benchmarked emissions allowances free of charge after 2012. In following up this decision, the European Commission (EC) defined a rather simplified catalogue of exposure criteria and ascertained that 146 out of 258 sectors at the NACE 4-digit level have been meeting these criteria (EU 2009). The results in this paper cast some doubt on the usefulness of such a generous provision of benchmarked emissions allowances free of charge to energy-intensive sectors.

Given the importance of carbon leakage issues in current EU climate change policy, comprehensive research work has emerged over recent years. Assumptions on cost pass-through relationships determine the impact of asymmetric climate change policy on two channels of carbon leakage: (decreasing) market shares and profit margins. Numerical studies within a general equilibrium framework have focused on assessing carbon leakage and competitiveness effects associated with the implementation of the EU ETS (Böhringer and Lange 2005, Peterson 2006, Alexeeva-Talebi and Anger 2007). Assuming that an increase in marginal carbon costs is fully borne by consumers of the final good and consequently profit margins of producers remain unchanged, these studies quantify how domestic suppliers adjust market shares in both domestic and foreign markets. Cost increases are, however, not necessarily fully passed to consumers of energy-intensive goods through price increase but can be absorbed by the industry through a reduction of profit margins. In an extreme case, this might imply constant prices and sustaining output level but decreasing profit margins (Hourcade et al. 2007). Between both extremes, asymmetric climate change policy creates incentives to relocate business abroad by affecting both market shares and profit margins. Assuming a range of cost pass-through rates, i.e. shares of an increase in marginal costs that are passed on to output prices, global sectoral models quantify the impact of stringent environmental policies on both market shares and profit margins (Demailly and Quirion 2006, 2008, Smale et al. 2006). As a prominent example, Demailly and Quirion (2008) conduct a simulation analysis for the iron and steel sector. The authors conclude that pass-through rates are of major importance: Results related to competitiveness and carbon leakage crucially depend on the ability of the sector to pass-through additional costs to consumers.

Empirical evidence on cost pass-through relationships in sectors that are of special interest within the current EU climate change policy is rather scarce. Few studies analyse the scope and speed of output price adjustments in the event of input price shocks: Sijm (2005, 2006a, 2006b) and Zachmann and Hirschhausen (2008) estimate the potential to pass-through additional carbon costs in the power generation sector. Walker (2006) conducts a comparable study for the European cement sector. Controlling for labour costs, Gerald et al. (2009) estimate cost pass-through rates for European energy-intensive sectors at the relatively low level of sectoral disaggregation. More recently, Oberndorfer et al. (2010) analyse cost pass-through relationships in selected energy-intensive sectors in the UK. The other branch of literature focuses on determinants of the cost pass-through such as demand, trade and substitution elasticities. Welsch (2008) provided evidence for low substitution elasticities among imports and competing domestic goods (Armington elasticities) for few energy-intensive sectors in four European countries. Finally, some empirical evidence can be found in studies focusing on the ability of the EU exporters to pass-through exchange rate shocks into the foreign consumer prices (for German exporters: Knetter 1993, Clostermann 1996, Goldberg and Knetter 1997, Stahn 2006 and Gaulier et al. 2008).

This paper evaluates the exposure of German energy-intensive sectors to the risk of carbon leakage by estimating the long-run pass-through potential. It analyses the extent and the differences of cost pass-through rates across German energy-intensive sectors covered by the EU ETS. The empirical section employs a simple mark-up model of imperfect international competition (Dixit and Stiglitz 1977, Dornbusch 1987). The key feature of the estimated model is that each domestic firm's price depends on its labour, material and energy costs and its *flexible* mark-up which is in turn determined by industry characteristics and the price charged by foreign competitors. Strategic interactions between domestic and foreign firms limit thereby the impact of domestic cost shocks on price competitiveness on the part of large imperfectly competitive firms. Although strategic interactions in energy-intensive sectors might be very relevant, empirical literature on the cost pass-through does not typically take them into account (Gerald et al. 2009).

Our analysis is as comprehensive as the data permits and covers sub-sectors in German industrial branches paper and pulp, chemicals, rubber and plastic and non-metallic minerals. Using data at the high level of sectoral disaggregation (3- and 4-digit-level), the analysis overcomes the problem of high order aggregation which traditionally plagues empirical cost pass-through literature.

The regional focus is mainly motivated by two considerations: First, Germany represents the biggest emitter in the EU ETS and German energy-intensive sectors are expected to benefit most from preferential treatment in the third trading period beyond 2012. Second, it is plausible to apply the framework of strategic oligopoly to German energy-intensive sectors. Most importantly, German sectors participating in the EU ETS are typically dominated by few big companies (e.g. BASF, HeidelbergCement). According to the variant of the mark-up model applied in this paper, the existence of large companies is essential for strategic interactions to occur. All sectors in our sample, with only one exception, are equipped with the market power which lies above the median value in Germany.

This paper contributes to the existing literature on the climate change policy twofold: First, it evaluates the risk of carbon leakage in German energy-intensive sectors using advanced time-series techniques. The results of the estimation procedure yield estimates of cost pass-through rates in the long-run equilibrium varying across industries, from 0% to 75%. The less-than-complete pass-through implies that additional costs induced by the EU ETS are likely to be partly absorbed through a reduction of profit margins, but the severe risk of carbon leakage exists in few sectors only. It is mainly concentrated in parts of the paper industry and the chemical production, in which long-run pass-through elasticities range between roughly 0% and 15%. Sectors with medium to high cost pass-through rates might still be forced to move factories out of the EU's borders through the (decreasing) market share channel, but severe implications on profit margins are rather unlikely. Second, it explains the variation in pass-through across energy-intensive sub-sectors by industry characteristics and the price charged by foreign competitors. The analysis finds a significant role for included industrial characteristics like market power and product substitutability, but the impact on the pass-through is ultimately determined by the interplay of individual effects working in different directions. More importantly, most of the German EU ETS sectors have a *flexible* mark-up, which is outcome of strategic interactions between domestic and foreign firms. The higher the interaction with foreign producers is, the lower the pass-through potential of domestic firms. We conclude by emphasising that strategic interactions between German and foreign firms could be an additional critical factor for the design of appropriate countermeasures to delimitate carbon leakage in the EU.

The structure of the paper is as follows: Section 2 outlines the theoretical framework underpinning the model estimated in section 3. Section 4 presents and analyses the results. Section 5 concludes.

2. Theory of the cost pass-through in strategic oligopoly

To analyse the potential passing-through capacity of additional costs in German energy-intensive sectors, we employ a variant of the mark-up model of price determination built upon the work of Dixit and Stiglitz (1977) and Dornbusch (1987)[1]. Under the condition of imperfect competition in heterogeneous goods, this framework allows for strategic interaction between domestic and foreign firms. The key element of the model is that firms are in position to charge a *flexible* mark-up over marginal costs.

Assume that representative consumer maximises the following sub-utility function of the CES (constant elasticity of substitution) type:

$$U = \left(a \cdot X_d^{-\rho} + (1-a) \cdot X_f^{-\rho}\right)^{-\frac{1}{\rho}} \tag{1}$$

where $X_d = \left(\sum_{i=1}^{n^D} x_{di}^s\right)^{\frac{1}{s}}$ is a bundle of different brands x_{di} of the domestically produced commodity and $X_f = \left(\sum_{j=1}^{n^F} x_{fj}^t\right)^{\frac{1}{t}}$ is an index of different varieties x_{fj} of the same commodity produced abroad. It is assumed that there are n^D domestic firms and n^F foreign firms in (our)

[1] 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. Thereafter, we do not take exchange rate changes into consideration.

home market supplying some variant (brand) each. a is the share parameter ($0 \le a \le 1$), ρ is the outer substitution parameter defined by the elasticity of substitution, σ, as $\rho = \frac{\sigma - 1}{\sigma}$ with $-1 < \rho < 0$ (and hence $\sigma > 1$). To focus on the substitution between domestic and foreign bundles only, we assume $s = t = -\rho$ (see also Strauß 2004).

The profit maximisation yields the following demand for each individual domestic and foreign variant:

$$x_{di} = a^{\sigma} X \left(\frac{p_{di}}{P} \right)^{-\sigma} \quad (2) \qquad\qquad x_{fj} = (1-a)^{\sigma} X \left(\frac{p_{fj}}{P} \right)^{-\sigma} \quad (3)$$

with

$$P = \left[a^{\sigma} \sum_{i=1}^{n^D} p_{di}^{1-\sigma} + (1-a)^{\sigma} \sum_{j=1}^{n^F} p_{fj}^{1-\sigma} \right]^{1/1-\sigma} \quad (4)$$

as an index of all varieties' prices (industry price), while p_{di} and p_{fj} denote the prices of domestically produced and imported variants, respectively. Individual (domestic and foreign) firms face demand curve as in (2) and (3), where each firm's market share $\frac{x_{di}}{X}$ (with X as total demand) depends on its product price relative to the industry price $\frac{p_{di}}{P}$ and $\frac{p_{fj}}{P}$, respectively.

The profits of the domestic firm k which is identical to other $n^D - 1$ domestic firms but not to n^F foreign firms is given by:[2]

$$\pi_{dk} = \left(p_{dk} - c_{dk} \right) x_{dk} \quad (5)$$

where x_{dk} is the output quantity and c_{dk} are the unit costs of the domestic firm.

Under conditions of imperfect competition, assume now that individual firms are large enough to affect the industry price P, while strategic interactions between firms are introduced by means of a conjectural variation ω ($0 < \omega < 1$). The latter parameter indicates

[2] Assume further that there is an effective separation between home and foreign markets. In doing so, it is possible to discuss the pricing behaviour of foreign producers in our market separately.

that firms respond to a one-percentage-point rise in the industry price by increasing their prices by ω percent[3].

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

$$x_{dk} + \left[p_{dk} - c_{dk} \right] \left[\left(\partial x_{dk} / \partial p_{dk} \right) \right] + \left[\left(\partial x_{dk} / \partial P \right) \left(\partial P / \partial p_{dk} \right) \right] = 0 \qquad (6)$$

Thus, a single firm's production volume is affected directly via change in its individual price $\left[\partial x_{dk} / \partial p_{dk} \right]$ and indirectly via changes in the industry price index resulting from his own decision $\left[\left(\partial x_{dk} / \partial P \right) \left(\partial P / \partial p_{dk} \right) \right]$.

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

$$\varepsilon \equiv \left(dP/P \right) / \left(dp_{dk} / p_{dk} \right) \qquad (7)$$

Since individual firm has to take into consideration the extent to which its action affects the industry price index P, this term captures the strategic interaction between firms as perceived from the domestic firm k. Using the above definition for ε ($0 < \varepsilon < 1$), the first-order condition can be simplified to:

$$1 + (p_{dk} - c_{dk}) \cdot (\sigma) \cdot (\varepsilon - 1) / p_{dk} = 0 \qquad (8)$$

and solved for the optimal price under strategic interaction:

$$p_{dk} = \left[1 - \frac{1}{\sigma \cdot (1 - \varepsilon)} \right]^{-1} \cdot c_{dk} = \mu_{dk} \cdot c_{dk} \qquad (9)$$

Assuming that the conjectural variation for all firms i and j is given by:

$$\omega \equiv \left(dp_{di,fj} / p_{di,fj} \right) / \left(dP/P \right) \quad \text{with} \quad 0 < \omega < 1 \qquad (10)$$

one gets the following expression for the elasticity ε[4] if totally differentiating (4):

[3] 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 its market share. Firms with a high market share are considered to be able to charge higher prices (see for further details Menon 1996). 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 its market share but be conditioned by the anticipation of competitors' reaction to this strategy. This interrelation is expressed as the conjectural variation.

$$\varepsilon \equiv \frac{1}{\omega + (1-\omega)\left[n^D + \frac{(1-a)^\sigma}{a^\sigma} n^F \left(\frac{p_{di}}{p_{fj}} \right)^{1-\sigma} \right]} \tag{11}$$

This elasticity depends thereby on relative prices, the conjectural variation, the elasticity of substitution among variants and the number of domestic and foreign firms. The mark-up pricing equation (9) and equation (11) highlights the fact that firm's optimal price policy is no longer to charge a constant but rather a flexible mark-up μ_{dk} over margin costs (depending on the relative prices).

From equation (9) and (11), it is obvious that domestic firm's reaction function is given by $p_{dk} = f(p_{fj}/p_{di}, \sigma, \omega, n^D, n^F) \cdot c_{dk}$. By following similar steps one gets the following reaction function for the foreign firm: $p_{fj} = f^*(p_{di}/p_{fj}, \sigma, \omega, n^d, n^f) \cdot c_{fj}$.

The main theoretical implication of the model developed in this section for the subsequent empirical investigation is that strategic interactions between domestic and foreign producers under the condition of imperfect competition will limit the ability of domestic producers to pass-through cost shocks. This can be seen from the elasticity of domestic prices calculated with respect to domestic costs and industry price[5] from equation (9): this yields empirical coefficients ψ_1 and ψ_2 which are estimated in the subsequent section:

$$\psi_1 = \frac{dp_{dk}}{dc_{dk}} \cdot \frac{c_{dk}}{p_{dk}} = 1 - \frac{\varepsilon}{(1-\varepsilon)[1-\sigma(1-\varepsilon)]} \tag{14}$$

and

$$\psi_2 = \frac{dp_{dk}}{dP} \cdot \frac{p_{dk}}{P} = \frac{\varepsilon}{(1-\varepsilon)[1-\sigma(1-\varepsilon)]} \tag{15}$$

Equation (14) illustrates that the cost pass-through in strategic oligopoly is smaller than in the standard Dixit-Stiglitz framework where it is equal to 1. Equations (14) and (15) introduce the following adding-up restrictions on coefficients for domestic firm's price equation (in logarithms):

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

[5] Given the fact that domestic firms are identical this basically implies that domestic firm has to take foreign prices into consideration.

$$p_{dk} = (1-\psi_1)c_{dk} + \psi_1 p_{fj}, \qquad 0 \le \psi_1 \le 1 \tag{16}$$

where ψ_1 captures the intensity of competitive pressure in the respective sector k. If ψ_1 is zero, domestic prices are set exclusively with respect to the domestic producer's cost situation. This reflects constant mark-up over marginal domestic costs and complete cost pass-through rates for domestic producers. If ψ_1 is one, domestic prices are set exclusively with respect to the foreign producer's prices. In this case, increasing costs are fully absorbed by the profit margin of the domestic producer. If ψ_1 varies between zero and one, domestic prices react to both domestic unit costs and foreign competitors' prices. The higher substitutability between domestic and foreign goods, the higher number of competing enterprises in the sector and the higher conjectural variation, the lower is the cost pass-through potential of the domestic firm.

In the context of the unilateral EU climate change policy, this simple framework allows illustrating important insights. The main options to address competitiveness-driven carbon leakage includes free allocation of allowances to existing and new facilities, financial compensation, border tax adjustments (BTAs) or the inclusion of importers into the EU ETS and global sectoral agreements, i.e. instruments encouraging sector-based activities in developing countries. Figure 1 and Figure 2 demonstrate price adjustments for two different policy options which play a prominent role in the current EU discourse on climate policy: the inclusion of importers into the emissions trading scheme and the provision of benchmarked emissions allowances free of charge. The curves AA and A*A* are the price reaction functions of domestic and foreign firms, respectively. Assume without a loss of generality, that B is the initial equilibrium with carbon costs being already reflected in prices of domestic firms. Now consider the case (Figure 1) in which home country imposes an import tariff on foreign products in the domestic market or includes importers into the domestic emissions trading scheme (see for further details Alexeeva-Talebi et al. 2008). This policy will shift the foreign reaction function up and to the right due to the increased costs while leaving the domestic reaction function unchanged. The new equilibrium B' is characterised through higher domestic prices.

Figure 1: Increasing prices

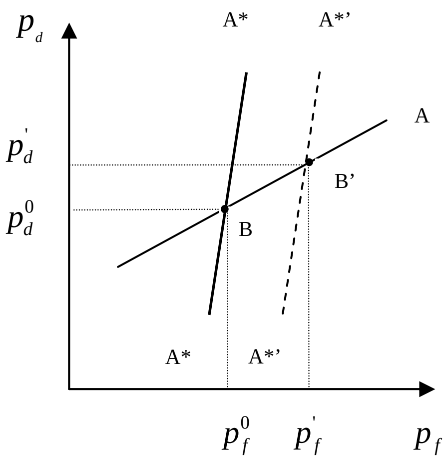
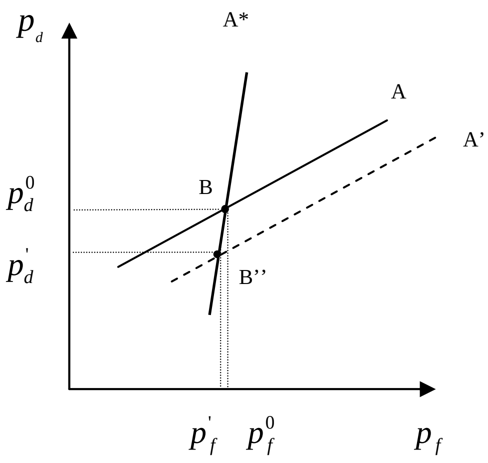


Figure 2: Decreasing prices



Alternatively, the government of the home country subsidises a fraction of the carbon costs which are reflected in the lower domestic costs (Figure 2) as it is intended by the free allocation provision. This policy will shift the domestic reaction function down and right while leaving the foreign country's price reaction function in place. The new equilibrium is therefore at B'' with lower foreign prices. From equations (2) and (3) is clear that consumers will react to changing prices and adjust their consumption quantities accordingly[6].

[6] It lies outside the scope of this paper to analyse the implications of given policy measures for production quantities and emissions level. At the single firm level, both policy measures are expected to have different impacts on both profit margins and market shares.

3. Empirical method, data and econometric procedure

Empirical method

The empirical section investigates to what extent German energy-intensive sectors covered by the EU ETS have a flexible mark-up over marginal costs, i.e. they set prices strategically when facing domestic cost shocks[7]. This focus allows estimating cost pass-through relationships for various energy-intensive sectors, while explicitly taking foreign competitors' prices into consideration.

Applying the theoretical framework of strategic oligopoly to German energy-intensive sectors is plausible for three reasons: First, anecdotic evidence suggests that German sectors participating in the EU ETS are dominated by big companies (e.g. BASF, HeidelbergCement). According to the theory in the previous section, the existence of large companies is essential for strategic interactions to occur. Second, the assumption of domestic and foreign goods being imperfect substitutes is widely used in numerical models which analyse climate change policies in the context of the EU ETS (the so-called Armington assumption, see further Armington 1969). Third, there is sporadic evidence that German producers in energy-intensive sectors compete with foreign companies in prices and not in quantities even in relatively homogenous markets such as cement sector.

We estimate a model that captures *long-run equilibrium* relationships between domestic producer prices, foreign producer prices and domestic costs in German energy-intensive sectors. More specifically, we broaden theoretical approach in previous section by assuming different types of input factors such as labour p_t^{lab}, material p_t^{mat} and electricity p_t^{ele} (see below). The inclusion of these variables, in particular input factor material, is important to avoid an omission of variable problems which leads to estimating biased pass-through coefficients (Gross and Schmitt 2000).

A linear combination of sectoral non-stationary variables (p_{it}^{dom}, p_{it}^{for}, p_{it}^{lab}, p_{it}^{mat} and p_{it}^{ele}) may thereby converge to a stationary process. The latter is referred to as a cointegration relationship and interpreted as a long-run equilibrium relationship between individual time series (Engle and Granger 1987). Letting x_{it} represent a vector of non-stationary endogenous

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[7] This is equivalent to empirically finding that $\psi_1 \neq 0$.

variables in the sector *i* $x_{it} = (p_{it}^{dom}, p_{it}^{for}, p_{it}^{lab}, p_{it}^{mat}, p_{it}^{ele})$, we assume that it follows a vector autoregressive (VAR) process of order *p*:

$$x_{it} = A_{i1}x_{it-1} + ... + A_{ip}x_{it-p} + By_{it} + \varepsilon_{it} \tag{14}$$

where y_{it} is a vector of exogenous variables (seasonal dummy variables), $A_1,...,A_p$ are matrices of coefficients to be estimated and ε_{it} is a vector of innovations. This VAR model may be rewritten as a vector-error-correction model (VECM) for each energy-intensive sector as:

$$\Delta x_{it} = \Pi_i x_{it-1} + \sum_{k=1}^{p-1} \Gamma_{ik}\Delta x_{it-p} + B_i y_{it} + \varepsilon_{it} \tag{15}$$

where Δ represents the first-difference operator and Π_i contains information about the long-run relationships among endogenous variables.

$\mathrm{Rank}(\Pi_i) = 1$ suggests the existence of a unique cointegration relationship among respective variables. The identification of cointegration rank(s) for each sectoral model depends on the form of the hypothesised cointegration equation. Johansen (1995) considers five deterministic trend cases. We always prefer the specification with a time trend in the cointegration equation over a specification with only an intercept in the cointegration equation if the time trend is significant:

$$\Pi_i x_{it-1} + B_i y_{it} = \partial_i(\beta_i^{'} x_{it-1} + \rho_{i0} + \rho_i t) + \alpha_i \gamma_{i0} \tag{16}$$

where ρ_{i0} is an intercept in the sectoral cointegration equation, t is a time trend in the cointegration equation and γ_{i0} is a deterministic term outside the cointegrating equation.

The suggested method allows capturing not only long-run interactions among the respective variables, but also the short-run dynamics through the past changes in these variables. In the cointegration system, the sectoral error-correction term ∂_i reflects the speed of an adjustment towards the long-run equilibrium.

We test the following two hypothesises:

- Hypothesis 1: Cost pass-through rates in German energy-intensive sectors are incomplete in the long-run equilibrium, albeit every sector is capable to pass-through at least one type of cost shocks.

- Hypothesis 2: Energy-intensive sectors in Germany have a flexible mark-up over domestic costs, i.e. they take foreign competitors' prices explicitly into consideration. The incentives to act strategically, by taking foreign prices into consideration are higher in relatively homogenous product markets with high market concentration.

Data

We start our analysis with data covering fifteen industries at the 4-digit and one sector at the 3-digit level based on the German commodity classification of production statistics (Version 2009, GP 2009). The selection of German energy-intensive sectors participating in the EU ETS is based on Graichen et al. (2008).[8] The analysis is as comprehensive as the data permits and covers sub-sectors in industrial branches including paper and pulp, chemicals, rubber and plastic and non-metallic minerals production. For our analysis, we use monthly data of the period from January 1995 to December 2008.

Both time series for domestic (P_i^{dom}) and foreign competitors' prices (P_i^{for}) are available in the required sectoral breakdown for the envisaged estimation period from the German Federal Statistical Office (Statistisches Bundesamt 2010a). The former is a domestic output price index for each product category which can be purchased in Germany; the latter measures the price development in the same product category imported to Germany from abroad.[9] Both time series refer to producer prices. For convenience, we use the subscript *i* to refer to sectoral affiliation in the GP 2009 classification: For example, P_{1712}^{dom} and P_{1712}^{for} are domestic and import prices in the sub-sector manufacture of paper and paperboard (GP09-1712), respectively.

[8] Graichen et al. (2008) list German energy-intensive sectors which participate in the EU ETS in accordance with the German "classification of economic activities" (WZ). With very few exceptions, time series of sectoral indices down to the 4-digit level of the WZ 2008 are identical to GP 2009 and NACE Rev. 2.

[9] The appropriate price is the C.I.F. price (cost, insurance, freight) at the German border which is converted to Euro.

By plotting sectoral producer prices in Figure 3[10] we observe a considerable heterogeneity in the movement of domestic and foreign price series across the sectors. The similar course of both series is observable in some sectors (e.g. manufacture of fertilisers and nitrogen compounds), while other industrial branches can be characterised through a pronounced divergence of domestic and foreign competitors' prices during the period 1995 – 2008 (e.g. manufacture of dyes and pigments).

Since no price data on a more frequent basis than monthly is available for sectors of interest and the EU ETS is still in an early stage, the pass-through capacity of additional carbon prices cannot be directly estimated. Instead, we assess the potential pass-through capacity of *domestic* type of cost shocks into sectoral producer prices using price indices for labour, material and energy. Table 1 contains the sector-specific input shares for 1995 and 2007, respectively.

Expenditures on labour and material represent a very significant fraction of the total production costs in all energy-intensive sectors, while energy inputs are much less important. Sectoral factors appear to significantly contribute to how the trend in energy intensity evolves over the time horizon from 1995 until 2008: The energy intensity (including electricity) remains roughly the same or slightly decreases in most sectors, while the production of all non-metallic mineral sub-sectors in Germany has become more energy-intensive over the last two decades.

Sectoral labour costs are not available in the same sectoral breakdown as the domestic and foreign producer price indices. In our analysis we, therefore, make use of sector-specific gross wages at the two-digit level (P_i^{lab}) which come from Eurostat (2010) since they are not available from the German Federal Statistical Office.

We are aware of the heterogeneity in terms of production structure across the energy-intensive sectors. The proper identification of applicable material and energy cost indices is therefore an important and challenging task. To identify the best proxy for material and energy at the sectoral level we rely on additional data source from the German Federal Statistical Office (Statistisches Bundesamt 2009) which provides very detailed information on input factors for German sectors at the 2-, 3- and 4-digit level of sectoral disaggregation in the WZ2003 classification[11]. Typically, the production structure includes more than a dozen material and

[10] We plot only data which will be subsequently included into our analysis.

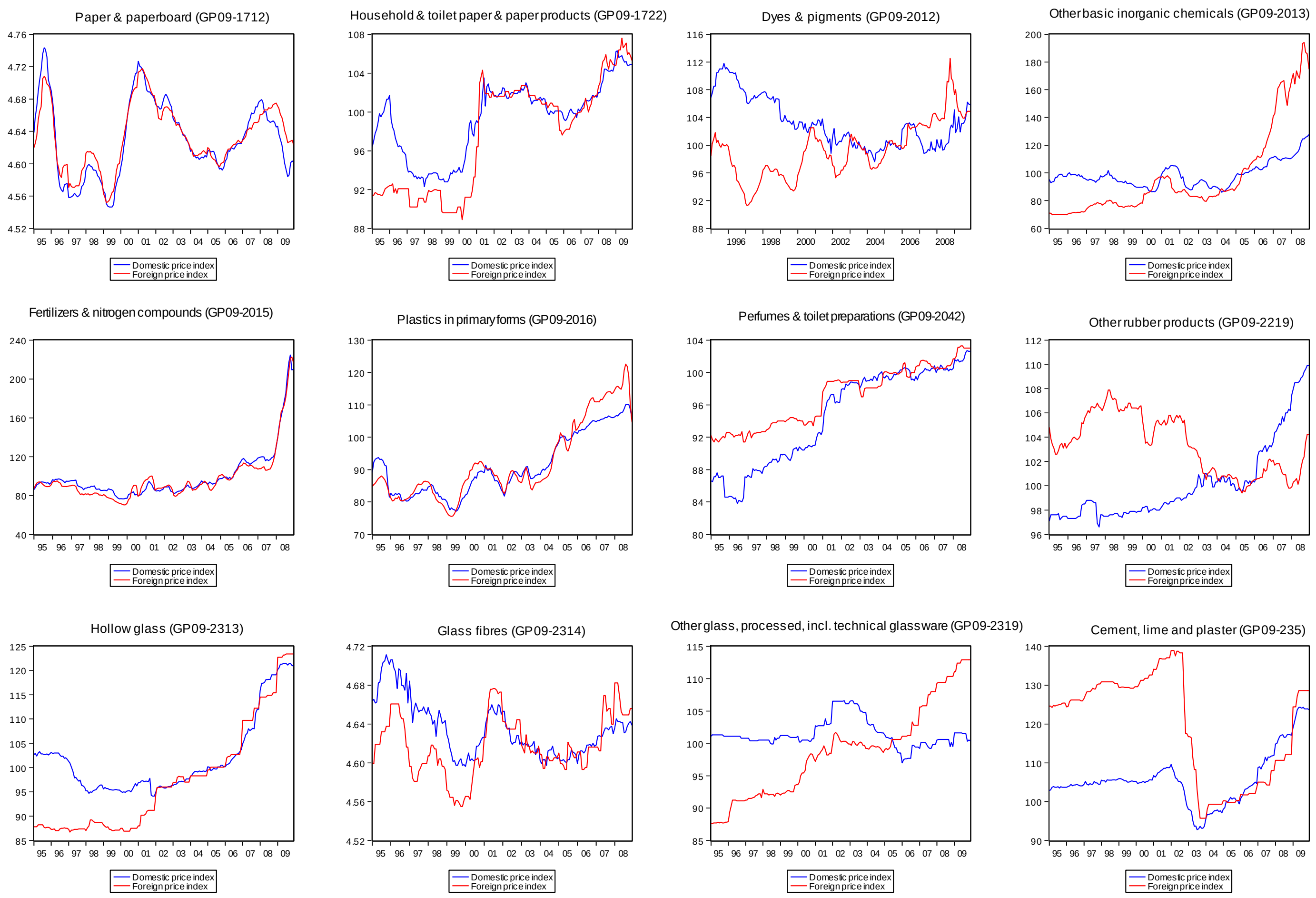
[11] We use concordance tables to assign the sectoral data in the WZ2003 to the GP2009 classification.

energy input factors, while the best proxy for the former and the latter can be identified as having the highest input share, respectively.[12] Domestic prices from the German Federal Statistical Office (Statistisches Bundesamt 2010a) are subsequently used to proxy sector-specific material input costs (P_i^{mat}) and energy input costs (P^{ele})[13]. Regarding the latter, electricity appears to be the most important input factor in most sub-sectors. All data series with the 2005 monthly average as the base value are in logarithms and seasonally unadjusted indexes except for the labour costs (Gross and Schmitt 2000).

[12] In some sectors, material and energy shares are not shown for reasons of confidentiality. We then test alternative proxies.

[13] For example, in order to model the domestic price in the sub-sector dyes and pigments (GP09-2012) P_{2012}^{dom}, we use the (domestic) price index for ferrous metals P_{27}^{mat} to proxy material costs and electricity prices P^{ele} to proxy energy costs since the German Federal Statistical Office (Statistisches Bundesamt 2009) identifies both input factors as most important in this sub-category.

Figure 3: Co-movement of domestic and import prices on German markets (monthly data from January 1995 to December 2008)



Source: German Federal Statistical Office (Statistisches Bundesamt 2010a).

Table 1: Labour, material and energy shares in German EU ETS sectors (% of the gross production value) in 1995 and 2007

Code GP 2002	Sector	Labour	Material	Energy	Labour	Material	Energy
		1995			2007		
17	**Manufacture of pulp, paper and paper products**						
1712	Manufacture of paper and paperboard				24.9	46.9	10.8
1722	Manufacture of household and toilet paper and paper products	38.8	33.5	3.6	33.1	34.5	4.6
20	**Manufacture of chemicals and chemical products**						
2012	Manufacture of dyes and pigments	30.9	52.8	4.8	30.7	40.3	6.4
2013	Manufacture of other basic inorganic chemicals	29.9	23.4	5.5	27.1	41.6	10.4
2015	Manufacture of fertilizers and nitrogen compounds	26.7	39.0	16.1	33.9	28.3	6.6
2016	Manufacture of plastics in primary forms	30.0	38.1	5.1	25.7	38.2	4.2
2042	Manufacture of perfumes and toilet preparations	53.3	26.6	0.6	41.7	36.6	0.7
22	**Manufacture of rubber and plastic products**						
2219	Manufacture of other rubber products	42.9	31.0	2.5	34.4	38.8	2.2
23	**Manufacture of non-metallic mineral products**						
2313	Manufacture of hollow glass	42.2	24.0	8.8	39.1	20.5	12.0
2314	Manufacture of glass fibres	37.0	24.9	6.5	36.3	26.9	8.1
2319	Manufacture of other glass, processed, incl. technical glassware	52.4	21.7	5.8	50.7	23.6	7.6
235	Manufacture of cement, lime and plaster	33.4	17.7	15.9	37.0	17.7	18.5

Source: German Federal Statistical Office (Statistisches Bundesamt 2010b)

Note: German Federal Statistical Office (Statistisches Bundesamt 2010b) provides data for labour, material and energy shares (% of the gross production value) for 1995 and 2007, respectively. Labour costs encompass wages for both permanently and temporally employed workers and social contributions. However, data is available at sectoral level in the WZ2003 classification only. Concordance tables have therefore been used to assign the sectoral data in the WZ2003 to the GP2009 classification which is subsequently used to estimate the cost pass-through rates. In 11 out of 16 sectors, the concordance is unique. For the remaining sectors in the GP2009 classificatoin the following assignments have been done:

GP2009 **2013** -> WZ2003 **24.13** [Manufacture of other basic inorganic chemicals];
GP2009 **2014** -> WZ2003 **24.14** [Manufacture of other basic organic chemical];
GP2009 **2042** -> WZ2003 **24.52** [Manufacture of perfumes and toilet preparations];
GP2009 **2219**-> WZ2003 **25.13** [Manufacture of other rubber products];
GP2009 **2229** -> WZ2003 **25.24** [Manufacture of other plastic products].

Econometric procedure

The first step of the econometric procedure is to test whether all price series are non-stationary: Unit root tests are performed following Dickey and Fuller (1979) and Phillips and Perron (1988). Table 6a.-c. (Appendix) display the results of two alternative versions of the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests with and without a trend for all domestic and foreign producer price series enumerated in Table 1 in (logs of) levels and first differences over the sample period from January 1995 to December 2008. It also includes sector-specific material input costs, labour and energy costs. There are 43 time series in total. If a unit root does not exists, the time series are said to be stationary or integrated of order zero (I(0)). The time series are considered to be integrated of order one (I(1)) if there is a unit root but differencing one time makes them stationary.

In 41 out of 43 cases, ADF and PP tests provide consistent results regarding the integration of order one I(1): The null hypothesis of a unit root in the (logs of) level data cannot be rejected in both models with and without trend at the 99% confidence level, while the null hypothesis of non-stationarity is rejected for each of these series after the first differencing at the 99% level. The variable P_{2229}^{dom} appears to be integrated of order zero I(0) according to both ADF and PP tests – it will be excluded from the cointegration analysis. Since the results for the remaining variable P_{20}^{lab} are less consistent, we additionally apply the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al. 1992). These results confirm that P_{20}^{lab} is non-stationary in levels but stationary in first differences at the reasonable confidence level.

We proceed now to the second step of the econometric analysis by testing whether the linear combination of the respective variables is stationary. In our case there are five I(1) variables in each sectoral model. If so, this finding implies that there is a long-run relationship between the variables. Following Johansen (1988) and Johansen and Juselius (1990), we apply trace and maximum eigenvalue tests to identify the number of cointegration relationships *r* among the respective variables. First, the selection of the deterministic components in the Johansen's co-integration analysis is important as the co-integration rank may depend on the form of the hypothesised co-integration equation. We, therefore, follow Johansen and Juselius (1992) by testing the joint hypothesis of both rank order and deterministic components and report the results for all deterministic trend cases (Table 8a.-c. in Appendix). Second, Stock and Watson (1993) show that Johansen's analysis is sensitive to the lag lengths used in the VAR models. The optimal lag length obtained with the Akaike information criterion (AIC) becomes, however, questionable if residuals remain autocorrelated, heteroscedastic or "deviate too much from Gaussian white noise” (Johansen, 1995)[14]. As a remedy, one may add one or more lags for each variable; alternatively or additionally, economically meaningful dummy variables (Table 7) may be needed (see further Strauß 2004, Farzanegan and Markwardt 2009). To minimise the effect of seasonal fluctuations, we make use of centred (orthogonalized) seasonal dummy variables which are factored in (Johansen 1995).

There is strong evidence – relying on a more powerful maximum eigenvalue tests (Johansen and Juselius 1990) – that in 12 out of 15 sectors, domestic output prices, foreign output prices, wages, material and energy input costs cointegrate with at least one co-integrating vector. The null hypothesis that the system’s rank is zero ($r = 0$) cannot be rejected at the 5% significance level for the following three sectors: manufacture of abrasive products, manufacture of other basic organic chemicals and manufacture of basic pharmaceutical products – these sectors will be excluded from the further analysis. In all sectors with the system’s rank of one, the more encompassing model with statistically significant time trend in the cointegration equation was selected (Table 8a.–c. in the Appendix, column five) except for producers of paper and paperboard, manufacturers of other basic inorganic chemicals and processed, including technical glassware. In the latter case, the model with only an intercept in the cointegration equation was preferred due to an insignificant time trend.

[14] These assumptions were clearly violated in our basis models (i.e. lag length obtained through the minimisation of the Akaike information criterion (AIC) and no (impulse) dummy variable).

4. Results

Cost pass-through estimates on labour, material and energy costs[15] from Table 2a.-b. provide empirical evidence for the hypothesis that total cost pass-through is incomplete for all energy-intensive sectors in the long-run equilibrium. Statistically significant cost pass-through coefficients outnumber by far coefficients with a wrong sign: 75% of all significant coefficients in the cointegration equations have the expected sign.

Stennek and Verboven (2001) point out that the long-run pass-through elasticities need to be adjusted by cost share of respective input factors. Otherwise, due to low values of corresponding coefficients, one could falsely conclude that individual pass-through rates are incomplete. Therefore, based on estimated sectoral cost pass-through coefficients and sector-specific data on input shares, we calculate the following normal distribution statistic for each cost pass-through coefficient (limiting to those with correct sign):

$$Z = (\bar{X} - \mu) / s \tag{17}$$

where $\bar{X}$ is an estimated cost pass-through coefficient and s is a standard error of the estimated parameter from Table 2a.-b., respectively; μ refers to the corresponding input share from Table 1 for the year 2007. The individual cost pass-through rate is considered to be full (=1), if the estimated coefficient has been found not to be statistically different from the respective input share for a 99% confidence interval. This is the case for 83% of all long-run cost pass-through coefficients. The last column in Table 3 provides individual and total cost pass-through rates for German energy-intensive sectors.

[15] For example, a 1% increase in wages lets the domestic producer price in the sub-sector manufacturing of dyes and pigments (GP09-2012) rise by 0.27%.

Table 2a.: Cost pass-through and strategic pricing coefficients in the long-run equilibrium

Manufacture of paper and paperboard (GP09-1712)				
P^{dom}_{1712}	P^{for}_{1712}	P^{mat}_{222}	P^{lab}_{17}	P^{ele}
-1.00	1.12 (0.09)***			
Manufacture of household and toilet paper and paper products (GP09-1722)				
P^{dom}_{1722}	P^{for}_{1722}	P^{mat}_{222}	P^{lab}_{17}	P^{ele}
-1.00	0.21 (0.09)***	-0.46 (0.19)***	2.03 (0.21)*** [16]	0.25 (0.03)***
Manufacture of dyes and pigments(GP09-2012)				
P^{dom}_{2012}	P^{for}_{2012}	P^{mat}_{27}	P^{lab}_{20}	P^{ele}
-1.00			0.27 (0.15)***	0.09 (0.02)***
Manufacture of other basic inorganic chemicals (GP09-2013)				
P^{dom}_{2013}	P^{for}_{2013}	P^{mat}_{27}	P^{lab}_{20}	P^{ele}
-1.00	0.33 (0.07)***	-0.31 (0.13)***		0.24 (0.08)***
Manufacture of fertilizers and nitrogen compounds (GP09-2015)				
P^{dom}_{2015}	P^{for}_{2015}	P^{mat}_{192}	P^{lab}_{20}	P^{ele}
-1.00	1.13 (0.10)***	- 0.23 (0.08)***		0.28 (0.06)***
Manufacture of plastics in primary forms (GP09-2016)				
P^{dom}_{2016}	P^{for}_{2016}	P^{mat}_{192}	P^{lab}_{20}	P^{ele}
-1.00	0.22 (0.14)*	0.15 (0.10)*		0.10 (0.05)**
Manufacture of perfumes and toilet preparations (GP09-2042)				
P^{dom}_{2042}	P^{for}_{2042}	P^{mat}_{222}	P^{lab}_{20}	P^{ele}
-1.00	0.64 (0.22)***	-0.35 (0.23)**		-0.10 (0.02)***
Manufacture of other rubber products (GP09-2219)				
P^{dom}_{2219}	P^{for}_{2219}	P^{mat}_{2017}	P^{lab}_{22}	P^{ele}
-1.00	0.47 (0.29)*	0.29 (0.08)***	0.66 (0.27)***	0.06 (0.04)*

[16] The pass-through ability of labour costs in the sector manufacturing of household and toilet paper and paper products (GP 1722) is with 2.03% disproportionally high. This is somewhat surprising but such a high elasticity of input factors with respect to the output prices is occasionally found in the empirical literature.

Table 2b.: Cost pass-through and strategic pricing coefficients in the long-run equilibrium

Manufacture of hollow glass (GP09-2313)				
P_{2313}^{dom}	P_{2313}^{for}	P_{201}^{mat}	P_{23}^{lab}	P^{ele}
-1.00	0.73 (0.12)***	0.48 (0.06)***	0.37 (0.10)***	

Manufacture of glass fibres (GP09-2314)				
P_{2314}^{dom}	P_{2314}^{for}	P_{201}^{mat}	P_{23}^{lab}	P^{ele}
-1.00	0.51 (0.07)***	0.25 (0.04)***		

Manufacture of other glass, processed, incl. technical glassware (GP09-2319)				
P_{2319}^{dom}	P_{2319}^{for}	P_{201}^{mat}	P_{23}^{lab}	P^{ele}
-1.00		0.43 (0.12)***		-0.14 (0.05)***

Manufacture of cement, lime and plaster (GP09-235)				
P_{235}^{dom}	P_{235}^{for}	P_{20}^{mat}	P_{23}^{lab}	P^{ele}
-1.00	0.37 (0.03)***	0.11 (0.07)**	0.39 (0.08)***	0.18 (0.02)***

Note: Numbers in parenthesis are standard error of the estimated parameters. *** (**, *) denotes significance at the 1% (5%, 10%) level.

Table 3: Cost pass-through rates in the long-run equilibrium

Code GP 2009	**Sector**	**Labour cost pass-through rates**	**Material cost pass-through rates**	**Energy cost pass-through rates**	**Total cost pass-through rates**
1712	Manufacture of paper and paperboard				**0.00**
1722	Manufacture of household and toilet paper	>1		>1	**>0.38**
2012	Manufacture of dyes and pigments	=1		=1	**0.37**
2013	Manufacture of other basic inorganic chemicals			=1	**0.10**
2015	Manufacture of fertilizers and nitrogen compounds			=1[17]	**0.16**
2016	Manufacture of plastics in primary forms		=1	=1	**0.42**
2042	Manufacture of perfumes and toilet preparations				**0.00**
2219	Manufacture of other rubber products	=1	=1	=1	**0.75**
2313	Manufacture of hollow glass	=1	>1		**>0.60**
2314	Manufacture of glass fibres		=1		**0.27**
2319	Manufacture of other glass, processed, incl.		=1		**0.24**
235	Manufacture of cement, lime and plaster	=1	=1	=1	**0.73**

[17] With the energy intensity in the year 1995.

Pass-through elasticities on input costs vary significantly across industries from 0% to 75%. Producers of cement, lime and plaster, other rubber products and hollow glass are capable to pass-through a very significant fraction of domestic cost shocks to consumer (up to roughly 75% of the total costs) in the long-run equilibrium. In contrast, producers of paper and paperboard, other basic inorganic chemicals, fertilizers and nitrogen compounds and, finally, perfumes and toilet preparations are capable to pass-through only a small fraction of domestic cost shocks, if any at all. While both groups might build extremes on the vulnerability scale, remaining industrial branches take an intermediate position with cost pass-through rates varying between roughly 25% and 40% in the long-run equilibrium. Additional costs induced by the EU ETS are therefore likely to be absorbed through a reduction of profit margins in most energy-intensive sectors, creating incentives to relocate business abroad.

Turning now to the strategic component in our estimations, empirical evidence illustrates that all German EU ETS sectors, except for producers of dyes and pigments and other glassware, have a *flexible* mark-up over marginal costs. Pass-through rates can therefore be considered as outcome of interaction between domestic and foreign firms in a particular industrial and market environment. In the presence of the incomplete pass-through domestic firms “capitalize” on the opportunity to increase their own prices if foreign competitors start charging higher prices. For example, following a 1% competitors’ price increase, manufacturers of cement, lime and plaster increase domestic prices by 0.37%. Alternatively, one might interpret these elasticities as “willingness” to alter mark-up if facing domestic price shocks (Clostermann 1996).

In section 2 we argued that strategic interactions between domestic and foreign producers under conditions of imperfect competition will limit the ability of producers to pass-through domestic cost shocks. Contrary to expectations from equations (14) and (15), the adding-up restrictions on estimated elasticities are not always fulfilled in practice. This might occur due to the index aggregation problem which plagues both domestic and foreign price series. If domestic prices are set exclusively with respect to foreign producers’ prices – as in the sectors producing paper and paperboard and fertilizers and nitrogen compounds – increasing costs are fully absorbed by the profit margin of the domestic producer. The potential to pass-through domestic costs is clearly very limited in this case. In the remaining sectors, the evidence is somewhat inconclusive but for most sectors the following interrelationship holds: the higher the impact of foreign prices, the lower the ability to pass-through the domestic cost shocks, and vice versa.

Table 4: Market shares for domestic and foreign producers, the level of product homogeneity and market concentration in German energy-intensive sectors

Code GP 2009	Sector	Import value relative to the revenues of German producers in domestic market[18]	Number of sub-sectors at the NACE 9-digit level	Herfindahl-Hirschman index[19]
17	**Manufacture of pulp, paper and paper products**			
1712	Manufacture of paper and paperboard	0,38	11	344.86
1722	Manufacture of household & toilet paper and paper products	0,36	11	849.53
20	**Manufacture of chemicals and chemical products**			
2012	Manufacture of dyes and pigments	1,18	4	903.03
2013	Manufacture of other basic inorganic chemicals	2,03	14	549.10
2015	Manufacture of fertilizers and nitrogen compounds	0,92	5	4013.88
2016	Manufacture of plastics in primary forms	0,83	14	2606.04
2042	Manufacture of perfumes and toilet preparations	0,94	12	861.38
22	**Manufacture of rubber and plastic products**			
2219	Manufacture of other rubber products	0,78	7	533.14
23	**Manufacture of non-metallic mineral products**			
2313	Manufacture of hollow glass	0,44	4	701.75
2314	Manufacture of glass fibres	1,55	3	1902.67
2319	Manufacture of other glass, processed, incl. technical glassware	0,72	4	1625.59
235	Manufacture of cement, lime and plaster	0,08	3	898.49

Source: Own calculations based on data from the Monopolies Commission (Monopolkommission 2007) and the German Federal Statistical Office (Statistisches Bundesamt 2010c, d).

[18] The data for this level of sectoral disaggregation are available for the year 2008 only.

[19] Concentration degree as measured by the Herfindahl-Hirschman index (in absolute values multiplied by 10.000). The reference year is 2005.

Now we are interested in explaining the differences across sectors in terms of cost pass-through rates and strategic interactions with foreign competitors. Theoretical framework in section 2 (equation 9, 11 and 14) suggests that cost pass-through rate in strategic oligopoly depends on the following four factors: the substitutability between domestic and foreign varieties, market shares of domestic and foreign firms, relative prices of domestic and foreign firms and the conjectural variation.

Additional data on industrial characteristics as reported in Table 4 are used to explain the variation in pass-through across sub-sectors. First, the substitutability between domestic and foreign varieties is difficult to proxy. We, therefore, make use of a more general approach measuring the level of product homogeneity in each sector. To account for the degree of product homogeneity across the sectors, we report the number of subsectors at the NACE 9-digit level for each sector in our sample. We assume that the higher the number of sub-sectors, the more heterogeneous (at the lower level of sectoral disaggregation) the product markets are. Second, to measure how the German market is split between domestic and foreign producers we calculate the quotient of import values in each sector over the revenues of domestic firms gained in German market in the same sector. Third, the conjectural variation is hard to measure too. We, therefore, rely only on the data from the Monopolies Commission (Monopolkommission, 2007) on the concentration degree in German energy-intensive sectors. According to Table 5 which describes the distribution of the Herfindahl-Hirschman index in German sectors at the NACE 4-digit level, each of sectors in our sample possesses a significant degree of market concentration: The sectoral Herfindahl-Hirschman indices in our sample are well above the median value (495.21) in all sectors except for producers of paper and paper board. Fourth, relative prices of domestic and foreign prices are not explicitly reported in Table 4 but the corresponding plots can be found in Figure 3.

Table 4 illustrates that the impact on the pass-through is ultimately determined by the interplay of individual effects working in different directions.

Table 5: Distribution of the Herfindahl-Hirschman index in German sectors as the NACE 4-digit level

	Percentiles	*Smallest*		
1%	2.33	1.28	Number of observations	333
5%	21.68	1.99	Sum of wgt.	333
10%	46.27	2.31		
25%	125.86	2.33	Mean	928.944
50%	495.21	*Largest*	Std. Dev.	1285.953
75%	1128.45	6133.18		
90%	2585.00	6245.16	Variance	1653676
95%	3142.59	8601.72	Skewness	3.002952
99%	6133.18	9761.61	Kurtosis	15.46499

Source: Own calculations based on data from the Monopolies Commission (Monopolkommission 2007)

We find that in more homogenous product markets – dyes and pigments, fertilizers and nitrogen compounds, glass fibres and other glass, processed, incl. technical glassware – the higher the market power, the lower the cost pass-through and the more pronounced the adjustment towards the foreign producers. Drawing on the specific example from the manufacturing of fertilizers and nitrogen compounds, a sector with the highest degree of concentration in our sample and among the most concentrated industrial sectors in Germany (among 5% of most concentrated sectors in Germany), domestic prices can even be set exclusively with respect to foreign producers' prices. According to Table 4, this is particularly likely to occur if the market is split almost equally between domestic and foreign producers (0.92, third column). It is worth stressing that all remaining sectors in the category of homogenous product markets have lower market power and higher cost pass-through rates (between 24% and 37%) than producers of fertilizers and nitrogen compounds (16%) with the highest market power.

Cement, lime and plaster, other rubber products and hollow glass fall into the category of relatively homogenous products too. In contrast to the previous group of sub-sectors, additional factors are likely to determine relatively high cost pass-through rate in these sectors (between 60% and 75%). The graphical inspection of the plots in Figure 3 depicts that in first two sectors the prices of foreign competitors were above the domestic prices over a long period of time – this might have significantly facilitating the pass-through of domestic costs to consumers in the past as indicated by high cost pass-through rates. Given the fact that foreign producers serve a relatively small fraction of German market in the cement, lime and plaster sector and despite the fact that the price gap has recently disappeared, the significant potential to pass-through domestic costs might still persist in the future. In contrast, the domestic producers of other rubber products might be exposed to a significant competitive pressure from foreign producers limiting the potential to pass-through domestic costs.

In the more heterogeneous product markets – paper and paperboard, household and toilet paper and paper products, plastics in primary forms and perfumes and toilet preparations – the higher market concentration of domestic firms is, the higher the cost pass-through rate and the less pronounced the orientation towards the foreign producers' prices. Consider manufacturers of plastics in primary forms and perfumes and toilet preparations which are exposed to a high penetration rate of foreign producers (0.83 and 0.92, respectively). The former industry is the second most concentrated sector in our sample (10% of most concentrated sectors in Germany). It is capable to pass-through more than 40% of total domestic costs to consumers in the long-run with a moderate orientation towards the price development of foreign producers. The latter sector is much less concentrated – this results in much higher orientation towards the competitors' prices and the disability to pass-through costs in the long-run. The observation that market concentration in heterogeneous markets leads to higher cost pass-through rates is confirmed for the manufacturers of paper and paperboard and household and toilet paper and paper products. The relatively low cost pass-through rate by producers of other basic inorganic chemicals (GP 2013) seems to be driven rather by the extreme high penetration of the market by the foreign producers (import/domestic revenue ratio: 2.03) than by the level of product homogeneity and the market power.

Finally, we notice that short-run cost pass-through coefficients are reported in Table 9a.-d. in the Appendix. We observe a considerable heterogeneity with respect to the magnitude and the speed of the pass-through potential (column one) across sectors. Even in industries with high pass-through rates, the short-run cost pass-through potential varies substantially: While producers of cement, lime and plaster and other rubber products appear to bear a very significant fraction of cost increases over a long-time horizon, German manufacturers of hollow glass are found to rapidly pass-through costs to consumers. Moreover, there is a difference between the short-run and the long-run degree of the pass-through: Sectors which are not able to pass-through costs in the long-run appear to be capable to pass-through at least a fraction of cost increases in the short run (e.g. manufacturers of paper and paperboard).

Diagnostic statistics and Granger causality

Diagnostic statistics suggest that sectoral VEC models are reasonably specified (Table 10): All specifications pass the autocorrelation and heteroscedasticity tests except for manufacturing of paper and paperboard. However, the Jarque-Bera (JB) test rejects the null hypothesis of normality of the residuals in most cases: The decomposition of the JB statistic into tests using separate measures of skewness and kurtosis demonstrate that the deviation from normality is due to excess kurtosis. In the applied work, VEC residuals are apparently found to be non-normally distributed (Johansen and Juselius 1990, Juselius and MacDonald 2000, Bjørnland and Hungnes 2002). Since the properties of the VEC models are not very sensitive to deviations from the normality due to excess kurtosis, we consider our results to be still valid (see further Gonzalo 1994).

The existence of one cointegrating vector suggests that there must be Granger causality in at least one direction in each sectoral VEC model. While the direction of causation is not evident, we tested it by reviewing the significance of the error-correction terms (long-run causality) and by observing the significance of the lagged differences of the respective variables (short-run causality). The following patterns emerged: All estimated error correction terms which are reported in the ECM for domestic prices (Table 9a.-d., first column) have the correct sign and are statistically significant. In 5 out of 12 sectors our findings suggest a uni-directional long-run causality running from input factor prices and foreign output prices to domestic prices. Those sectors are manufacture of paper and paper boar, manufacture of household, toilet paper and paper products, manufacture of other basic inorganic chemicals, manufacture of other rubber products and manufacture of cement, lime and plaster. Obviously, domestic prices in these sectors are Granger-caused in the long-run by competitors' prices (and input factor prices). Hence, the latter can be treated as exogenous within a given VEC framework. The results for manufacturing of other rubber products, hollow glass and other glass, processed reinforce the bi-directional long-run causality between domestic and foreign prices.

5. Conclusions and suggestions for further research

For the EU policy-makers, the risk of sector-specific carbon leakage is at the centre of discussions on how to design effective climate policy under globally asymmetric carbon constraints. The results in this paper cast some doubt on the usefulness of too generous provision of benchmarked emissions allowances free of charge after 2012 to energy-intensive sectors. Moreover, the current proposal of the European Commission to possibly introduce "additional and alternative means" to address the risk of carbon leakage, most notably through the inclusion of imports into the EU ETS, needs to be put into perspective (EU 2010). Strategic interactions between domestic and foreign firms could be a critical factor for the design of appropriate countermeasures to delimitate carbon leakage.

To asses the exposure of energy-intensive sectors to the risk of carbon leakage in this paper, we have combined time series of producer prices of German and foreign firms with data on industry characteristics to estimate the pass-through potential of domestic cost shocks. Results for 12 German energy-intensive sectors provide evidence for a significant role of included industrial characteristics in explaining the extent of cost pass-through rates, but the impact of foreign firms' prices appears to be just as important. The estimated cost pass-through relationships differ from the traditional approach in the empirical research: The inclusion of the foreign competitor' price as the dependent variable in the respective pass-through equation zoom in the analysis on pass-through rates as outcome of interaction between domestic and foreign firms in a particular industrial and market environment (Gangnes 1993).

Facing domestic cost shocks, German firms raise prices less than proportionally. Hence, additional costs induced by the EU ETS are likely to be absorbed through a reduction of profit margin in the long-run, rather than through decreasing market shares. However, the impact on the mark-ups varies significantly across the sectors. In 6 out of 12 cases, empirical results give support for medium to high pass-through rates ranging between roughly 40% and 75%. Producers of paper and paperboard, basic inorganic chemicals, fertilizers and nitrogen compounds and perfumes and toilet preparations are found to pass only a small fraction of domestic cost shocks (if any at all!) , with long-run cost pass-through rates varying between 0% and 15%. Remaining sectors take an intermediate position with cost pass-through rates of about 25%.

The relatively low long-run cost pass-through rates in our sample – in comparison to studies which do not consider strategic interactions – are consistent with both predictions from the theoretical model and earlier findings of Gross and Schmitt (2000). Contrary to the study by

Gerald and al. (2009), the extent of cost pass-through varies not only across energy-intensive sectors, but also within the respective industry at the sub-sectors level. This illustrates the necessity to consider data at the higher level of sectoral disaggregation.

The variation in the pass-through across sub-sectors is explained by industry characteristics including the import penetration, the level of product homogeneity, the market power of domestic firms and the price charged by foreign competitors in German markets. Perhaps the most interesting result in this paper is that most of the German EU ETS sectors have a *flexible* mark-up over marginal costs: Strategic interactions with foreign competitors limit the impact on the domestic cost pass-through rates. Reversely, domestic firms "capitalize" on the opportunity to increase their own prices if foreign competitors start charging higher prices. The detected impacts are generally consistent with the predictions of the model of strategic oligopoly employed in this paper. But the overall impact on the pass-through is ultimately determined by the interplay of individual effects working in different directions.

In most theoretical and empirical papers, market concentration reduces the pass-through potential. This result holds in our sample for homogenous product markets only. High market power of domestic firms on relatively homogenous product markets leads to lower cost pass-through rates and to the more pronounced orientation towards the foreign producers' prices. Drawing on the specific example from manufacturing of fertilizers and nitrogen compounds, a sector with the highest degree of concentration in our sample and among the most concentrated industrial sectors in Germany, domestic prices can even be set exclusively with respect to foreign producers' prices. The higher the market concentration of domestic firms in more heterogeneous product markets, the higher the cost pass-through potential and the less pronounced the adjustment towards the foreign producers' prices.

Using these findings as a criterion to asses the vulnerability of German EU ETS sectors, we conclude that sectors with low cost pass-through rates might be shortlisted to receive preferential treatment in the third phase of the EU ETS from 2013 on. Additional costs induced by the EU ETS are likely to be absorbed through a reduction of profit margins, creating incentives to relocate business abroad in few sectors only. Remaining sectors with medium to high cost pass-through rates might still be forced to move factories out of the EU's borders due to an adverse impact on market shares, but severe implications on profit margins are rather unlikely.

In the oligopolistic framework with strategic interactions firms' decisions on how to adjust market shares *and* profit margins are endogenous to a particular shock. The main insight from the empirical part is that the hypothesis of strategic interactions with foreign competitors holds for the most of the EU ETS sectors in Germany. Introducing additional offsetting instruments – e.g. the inclusion of importers into the EU ETS – is likely to produce an opportunity for domestic firms to “capitalize” on increasing prices of foreign competitors. This finding is directly related to the recent discussion on appropriate countermeasures to delimitate carbon leakage in the energy-intensive sectors in the EU.

We close with limitations of our study and suggestions on future work. First, a shortcoming of the used data set refers to the small number of energy-intensive sectors with a sufficient time horizon for which domestic producer prices and matching foreign price series exist. The limited industry sample does not allow regressing estimates of pass-through elasticities on a number of industry characteristics to receive robust empirical results. Second, since no price data on a more frequent basis than monthly is available for sectors of interest and the EU ETS is still in an early stage, the pass-through capacity of additional carbon prices cannot be directly estimated. Using labour, material and energy costs as proxy for carbon costs has practical advantage of estimating long-run cost pass-through relationships for few energy-intensive sectors. But firms’ response to carbon costs might differ from their response to other costs. We will therefore leave the empirical estimation of carbon cost pass-through and the design of optimal offsetting instruments to reduce carbon leakage in strategic oligopolies to future research.

References

Alexeeva-Talebi, V. and N. Anger (2007), Developing Supra-European Emissions Trading Schemes: An efficiency and international trade analysis, ZEW Discussion Paper No. 07-038, ZEW, Mannheim.

Alexeeva-Talebi, V., A. Löschel and T. Mennel (2008), Climate policy and the problem of competitiveness: Border Tax Adjustments or Integrated Emission Trading?, ZEW Discussion Paper No. 08-061, ZEW, Mannheim.

Armington, P.S. (1969), A theory of demand for products distinguished by place of production, *International Monetary Fund Staff Papers* No.16, 159–178.

Bjørnland, H.C. and H. Hungnes (2002), Fundamental determinants of the long run real exchange rate: The case of Norway, Discussion Papers No. 326, Statistics Norway, Research Department, Kongsvinger.

Böhringer, C. and A. Lange (2005), Economic implications of alternative allocation schemes for emission allowances, *Scandinavian Journal of Economics* 107(3), 563–581.

Clostermann, J. (1996), Der Einfluss des Wechselkurses auf die deutsche Handelsbilanz, Diskussionspapier No. 7/96, Volkswirtschaftliche Forschungsgruppe der Deutschen Bundesbank, Frankfurt.

Demailly, D. and P. Quirion (2006), CO2 abatement, competitiveness and leakage in the European cement industry under the EU-ETS: grandfathering vs. output-based allocation, *Climate Policy* 6(1), 93–113.

Demailly D. and P. Quirion (2008), European Emission Trading Scheme and competitiveness: A case study on the iron and steel industry, *Energy Economics* 30(4), 2009–2027.

Dickey, D. and W. Fuller (1979), Distribution of the estimators for autoregressive time series with a unit root, *Journal of the American Statistical Association* 74(366), 427–431.

Dixit A.K. and J.E. Stiglitz (1977), Monopolistic competition and optimum product diversity, *American Economic Review* 67(3), 297–308.

Dornbusch, R. (1987), Exchange rates and prices, *American Economic Review* 77 (1), 93–106.

Engle, R.F. and C.W.J. Granger (1987), Cointegration and error correction: Representation, estimation, and testing, *Econometrica* 55(2), 251–276.

EU (2008), Proposal for a Directive of the European Parliament and of the Council amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading system of the Community, Communication COM(2008) 30 final, European Commission, Brussels.

EU (2009), Commission decision of determining, pursuant to Directive 2003/87/EC of the European Parliament and of the Council, a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage, Brussels.

EU (2010), Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage: Background information and analysis, Commissions Staff Working Document accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Brussels.

EurActive, EU industry and the 'carbon leakage' threat. 27 January 2009. Available at: http://www.euractiv.com/en/climate-change/carbon-leakage-challenge-eu-industry/article-176591.

Eurostat (2010), Short-term business statistics – Industry labour input index, http://epp.eurostat.ec.europa.eu/portal/page/portal/short_term_business_statistics/data/database.

Farzanegan, M.R. and G. Markwardt (2009), The effects of oil price shocks on the Iranian economy, *Energy Economics* 31(1), 134–151.

Gangnes B. (1993), Industry structure and exchange rate pass-through, Working paper No. 93-11, University of Hawaii.

Gaulier G., A. Lahrèche-Révil and I. Méjean (2008), Exchange-rate pass-through at the product level, *Canadian Journal of Economics* 41(2), 425–449.

Gerald, J.F., M. Keeney and S. Scott (2009), Assessing vulnerability of selected sectors under environmental tax reform: The issue of pricing power, *Journal of Environmental Planning and Management* 52(3), 413–433.

Goldberg, P.K. and M.M. Knetter (1997), Goods prices and exchange rates: what have we learned?, *Journal of Economic Literature* 35(3), 1243–1272.

Gonzalo, J. (1994), Five alternative methods of estimating long-run equilibrium relationships, *Journal of Econometrics* 60(1-2), 203–233.

Graichen, V., K. Schumacher, F.C. Matthes, L. Mohr, V. Duscha, J. Schleich and J. Diekmann (2008), Impacts of the EU Emissions Trading Scheme on the industrial competitiveness in Germany, Report 3707 41 501/UBA-FB 001177, Federal Environment Agency, Dessau-Roßlau.

Gross, D.M. and N. Schmitt (2000), Exchange rate pass-through and dynamic oligopoly: an empirical investigation, *Journal of International Economics* 52(1), 89–112.

Hourcade, J.-C., D. Demailly, K. Neuhoff, M. Sato, M. Grubb, F. Matthes and V. Graichen (2007), Differentiation and dynamics of EU-ETS industrial competitiveness impacts: Final Report, Climate Strategies, Cambridge.

Johansen, S. (1988), Statistical analysis of cointegrating vectors, *Journal of Economic Dynamics and Control* 12(2-3), 231–254.

Johansen, S. and K. Juselius, K. (1990), Maximum likelihood estimation and inference on cointegration - With applications to the demand for money, *Oxford Bulletin of Economics and Statistics* 52(2), 169–210.

Johansen, S. and K. Juselius (1992), Testing structural hypotheses in a multivariate cointegration analysis of the PPP and the UIP for UK, *Journal of Econometrics* 53(1-3), 211–244.

Johansen, S. (1995), Likelihood-based inference in cointegrated vector autoregressive models, Oxford University Press.

Juselius, K. and R. MacDonald (2000), International parity relationships between Germany and the United States: A joint modeling approach, Discussion Paper No. 00/10, University of Copenhagen, Institute of Economics, Copenhagen.

Knetter, M. (1993), International comparisons of pricing-to-market behavior, *American Economic Review* 83(3), 473–486.

Kwiatkowski, D., P.C.B. Phillips, P. Schmidt and S. Yongcheol (1992), Testing the null hypothesis of stationary against the alternative of a unit root, *Journal of Econometrics* 54(1-3), 159–178.

Menon, J. (1996), The degree and determinants of exchange rate pass-through: Market structure, non-tariff barriers and multinational corporations, *The Economic Journal* 106 (435), 434–444.

Monopolkommission (2008), Hauptgutachten 2006/2007, Anlagen zu den Kapiteln I, II und III, http://www.monopolkommission.de/haupt_17/anlagen_h17.pdf

Oberndorfer, U., Alexeeva-Talebi, V. und A. Löschel (2010), Understanding the competitiveness implications of future phases of EU ETS on the industrial sectors, ZEW Discussion Paper No. 10-044, ZEW, Mannheim.

Peterson, S. (2006), The European Emissions Trading Scheme and its competitiveness effects for European business - Results from the CGE Model DART. Antes, R., Hansjürgens, B., Lemathe, P. (eds), Emissions Trading and Business 1. Physika/ Springer, Heidelberg.

Phillips, P.C.B. and P. Perron (1988), Testing for a unit root in time series regression, *Biometrika* 75(2), 335–346.

Sijm J.P.M., S.J.A. Bakker, Y. Chen, H.W. Harmsen and W. Lise (2005), CO2 price dynamics: The implications of EU emissions trading for the price of electricity, ECN-C-05-081, Energy Research Centre of the Netherlands, Petten.

Sijm, J.P.M., Y. Chen, M. ten Donkelaar, S. Hers and M.J.J. Scheepers (2006a), CO2 price dynamics: A follow-up analysis of the implications of EU Emissions Trading for the price of electricity, ECN-C–06-015, Energy Research Centre of the Netherlands, Petten.

Sijm, J., K. Neuhoff, and Y. Chen (2006b), CO2 cost pass-through and windfall profits in the power sector, *Climate Policy* 6(1), 49–72.

Smale, R., M. Hartley, C. Hepburn, J. Ward and M. Grubb (2006), The impact of CO2 emissions trading on firm profits and market prices, *Climate Policy* 6(1), 29 – 46.

Stahn, K. (2006), Has the export pricing behaviour of German enterprises changed? Empirical evidence from German sectoral export prices, Discussion Paper, Series 1: Economic Studies No. 37/2006, Deutsche Bundesbank, Frankfurt.

Statistisches Bundesamt (2009), Produzierendes Gewerbe: Material- und Wareneingangserhebung im Verarbeitenden Gewerbe sowie im Bergbau und in der Gewinnung von Steinen und Erden, Wiesbaden.

Statistisches Bundesamt (2010a), Index der Erzeugerpreise gewerblicher Produkte (Code: 61241), Index der Einfuhrpreise (Code: 61411), https://www-genesis.destatis.de/genesis/online.

Statistisches Bundesamt (2010b), Kostenstrukturerhebung im Verarbeitenden Gewerbe, Bergbau (Code: 42251), https://www-genesis.destatis.de/genesis/online.

Statistisches Bundesamt (2010c), Aus- und Einfuhr (Außenhandel): Deutschland, Monate, Warensystematik, (Code: 51000), https://www-genesis.destatis.de/genesis/online.

Statistisches Bundesamt (2010d), Code (42111), Beschäftigte und Umsatz der Betriebe im Verarbeitenden Gewerbe: Deutschland, Jahre, Wirtschaftszweige (WZ2008 2-4-Steller Hierarchie) (Code: 42111), https://www-genesis.destatis.de/genesis/online.

Stennek, J. and F. Verboven (2001), Merger control and enterprise competitiveness – Empirical analysis and policy recommendations, IUI Working Paper No. 556, Research Institute of Industrial Economics, Stockholm.

Stock, J.H. and M.W. Watson (1993), A simple estimator of cointegrating vectors in higher-order integrated system, *Econometrica* 61(4), 783–820.

Strauß, H.M. (2004), Demand and supply of aggregate exports of goods and services: Multivariate cointegration analysis for the United States, Canada, and Germany, Springer-Verlag, Berlin, Heidelberg.

Walker, N. (2006), Concrete Evidence? An empirical approach to quantify the impact of EU Emissions Trading on cement industry competitiveness, Working Paper PEP 06/10, School of Geography Planning and Environmental Policy, University College Dublin.

Welsch, H. (2008), Armington elasticities for energy policy modeling: Evidence from four European countries, *Energy Economics* 30(5), 2252–2264.

Zachmann, G. and C. v. Hirschhausen (2008), First evidence of asymmetric cost pass-through of EU Emissions allowances: Examining wholesale electricity prices in Germany, *Economics Letters* 99(3), 465–469.

Mathematical Appendix

Equation (2) and (3)

In order to derive the demand functions (2) for each variant of the composite good x_i, $i = 1, ..., n^D$, the utility function is being maximised under the respective budget constraint (i.e. the fraction of the budget used for these goods):

$$\max_{x_{di}, x_{fj}, \lambda} \; L = \sum_{i=1}^{n^D} p_{di} x_{di} + \sum_{j=1}^{n^F} p_{fj} x_{fj} - \lambda [\overline{U}^{-\rho} - a \sum_{i=1}^{n^D} x_{di}^{-\rho} - (1-a) \sum_{j=1}^{n^F} x_{fj}^{-\rho}] \tag{1A}$$

The first order condition (FOC) for the variant x_{di} is given as:

$$\frac{\partial L}{\partial x_{di}} = p_{di} - \lambda \rho a x_{di}^{-\rho-1} \overset{!}{=} 0 \tag{2A}$$

In analogy, one receives the following FOC for the variant x_{fj}:

$$\frac{\partial L}{\partial x_{fj}} = p_{fj} - \lambda \rho a x_{fj}^{-\rho-1} \overset{!}{=} 0 \tag{3A}$$

Solving for λ and plugging into (2A) and (3A) yields the following demand functions:

$$x_{di} = p_{di}^{-\frac{1}{\rho+1}} a^{\frac{1}{\rho+1}} [a^{\frac{1}{\rho+1}} \sum_{i=1}^{n^D} p_{di}^{\frac{\rho}{\rho+1}} + (1-a)^{\frac{1}{\rho+1}} \sum_{j=1}^{n^F} p_{fj}^{\frac{\rho}{\rho+1}}]^{\frac{1}{\rho}} \cdot \overline{U} \tag{4A}$$

and

$$x_{fj} = p_{fj}^{-\frac{1}{\rho+1}} (1-a)^{\frac{1}{\rho+1}} [a^{\frac{1}{\rho+1}} \sum_{i=1}^{n^D} p_{di}^{\frac{\rho}{\rho+1}} + (1-a)^{\frac{1}{\rho+1}} \sum_{j=1}^{n^F} p_{fj}^{\frac{\rho}{\rho+1}}]^{\frac{1}{\rho}} \cdot \overline{U} \tag{5A}$$

The expenditure function is given by:

$$\begin{aligned} E = \sum_{i=1}^{n^D} p_{di} x_{di} + \sum_{j=1}^{n^F} p_{fj} x_{fj} = \sum_{i=1}^{n^D} p_{di}^{\frac{\rho}{\rho+1}} a^{\frac{1}{\rho+1}} [a^{\frac{1}{\rho+1}} \sum_{i=1}^{n^D} p_{di}^{\frac{\rho}{\rho+1}} + (1-a)^{\frac{1}{\rho+1}} \sum_{j=1}^{n^F} p_{fj}^{\frac{\rho}{\rho+1}}]^{\frac{1}{\rho}} \cdot \overline{U} + \\ \sum_{j=1}^{n^F} p_{di}^{\frac{\rho}{\rho+1}} (1-a)^{\frac{1}{\rho+1}} [a^{\frac{1}{\rho+1}} \sum_{i=1}^{n^D} p_{di}^{\frac{\rho}{\rho+1}} + (1-a)^{\frac{1}{\rho+1}} \sum_{j=1}^{n^F} p_{fj}^{\frac{\rho}{\rho+1}}]^{\frac{1}{\rho}} \cdot \overline{U} \end{aligned} \tag{6A}$$

$$E = PX = \underbrace{\left[a^{\sigma} \sum_{i=1}^{n^D} p_{di}^{1-\sigma} + (1-a)^{1-\sigma} \sum_{j=1}^{n^F} p_{fj}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}}_{P} \cdot \underbrace{\left[a \sum_{i=1}^{n^D} x_{di}^{\frac{\sigma-1}{\sigma}} + (1-a) \sum_{j=1}^{n^F} x_{fj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}}_{X} \tag{7A}$$

Plugging P and X from (7A) in (4A) and (5A) yields the demand function for domestic and foreign varieties:

$$x_{di} = a^{\sigma} X \left[\frac{p_{di}}{P} \right]^{-\sigma} \tag{2}$$

and

$$x_{fj} = (1-a)^{\sigma} X \left[\frac{p_{fj}}{P} \right]^{-\sigma} \tag{3}$$

Equation 9

The profits of the domestic firm k which is identical to other $n^D - 1$ domestic firms but not to n^F foreign firms is given by:

$$\max_{p_{dk}} \pi_{dk} = \left(p_{dk} - c_{dk} \right) x_{dk} \tag{5}$$

$$\frac{\partial \pi_{dk}}{\partial p_{dk}} = x_{dk} + \left(p_{dk} - c_{dk} \right) \left[-\sigma a^{\sigma} p_{dk}^{-\sigma-1} X P^{\sigma} + \sigma a^{\sigma} X p_{dk}^{-\sigma} P^{\sigma-1} \frac{\partial P}{\partial p_{dk}} \right] \overset{!}{=} 0 \tag{8A}$$

Using (7), the equation (8A) can be restated as:

$$1 + \left(p_{dk} - c_{dk} \right) \cdot (\sigma) \cdot (\varepsilon - 1) / p_{dk} \overset{!}{=} 0 \tag{8}$$

Solving (8) for p_{dk} we obtain the first order condition:

$$p_{dk} = \left[1 - \frac{1}{\sigma \cdot (1-\varepsilon)} \right]^{-1} \cdot c_{dk} = \mu_{dk} \cdot c_{dk} \tag{9}$$

Equation (10)

Let α be defined as follows:

$$\beta \equiv \left(a^{\sigma} p_{dk}^{1-\sigma} + \sum_{i}^{n^D - 1} p_{di \neq k}^{1-\sigma} + (1-a)^{\sigma} \sum_{j}^{n^F} p_{f}^{1-\sigma} \right) \tag{9A}$$

Totally differentiating (4), we obtain:

$$dP = \frac{\partial P}{\partial p_{dk}} dp_{dk} + \sum_{i}^{n^D - 1} \frac{\partial P}{\partial p_{di \neq k}} dp_{di \neq k} + \sum_{j}^{n^F} \frac{\partial P}{\partial p_{df}} dp_{df} \tag{10A}$$

$$dP = \frac{\alpha^{\sigma} p_{dk}^{1-\sigma} \beta^{\frac{1}{1-\sigma}} dp_{dk}}{\beta\, p_{dk}} + \frac{\alpha^{\sigma} \beta^{\frac{1}{1-\sigma}} \sum_{i}^{n^D - 1} p_{di \neq k}^{1-\sigma} dp_{di \neq k}}{\beta \sum_{i}^{n^D - 1} p_{di \neq k}} + \frac{(1-\alpha)^{\sigma} \beta^{\frac{1}{1-\sigma}} \sum_{j}^{n^F} p_{fj}^{1-\sigma} dp_{fj}}{\alpha \sum_{j}^{n^F} p_{fj}} \tag{11A}$$

$$\varepsilon = \frac{dP}{P} \cdot \frac{p_{dk}}{dp_{dk}} = \frac{1}{1 + (n^d - 1)[1-\omega] + \frac{(1-a)^{\sigma}}{a^{\sigma}} n^F [1-\omega] \left(\frac{p_{fj}}{p_{di}} \right)^{1-\sigma}}$$

Using that $p_{dk} = p_{di \neq k}$ one obtains the equation (10):

$$\varepsilon \equiv \frac{1}{\omega + (1-\omega) \left[n^D + \frac{(1-a)^{\sigma}}{a^{\sigma}} n^F \left(\frac{p_{fj}}{p_{di}} \right)^{1-\sigma} \right]} \tag{10}$$

Table 6a.: Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Unit Root Test on domestic output prices

Variables	**ADF**				**PP**			
	Level		First-diff.		Level		First-diff.	
	Model				*Model*			
	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend
P^{dom}_{1712}	-3.40**	-3.52**	-4.17***	-4.19***	-2.22	-2.26	-5.77***	-5.76***
P^{dom}_{1722}	-0.54	-1.39	-11.94***	-11.96***	-0.82	-1.65	-12.04***	-12.04***
P^{dom}_{2012}	-1.53	-1.97	-14.57***	-14.57***	-1.44	-1.91	-14.59***	-14.60***
P^{dom}_{2013}	-0.88	-1.64	-5.62***	-5.73***	-0.30	-1.16	-9.97***	-10.03***
P^{dom}_{2014}	-1.87	-3.75**	-3.96***	-3.90**	-1.04	-2.83	-9.03***	-8.95***
P^{dom}_{2015}	1.84	0.44	-5.32***	-8.27***	2.58	1.03	-7.87***	-8.27***
P^{dom}_{2016}	-0.64	-3.27*	-8.94***	-9.08***	-0.52	-2.41	-8.92***	-9.07***
P^{dom}_{2042}	-0.64	-1.72	-12.50***	-12.46***	-0.65	-1.80	-12.50***	-12.46***
P^{dom}_{2110}	-0.97	-2.21	-14.26***	-14.22***	-0.90	-2.21	-14.53***	-14.50***
P^{dom}_{2219}	2.11	0.04	-12.39***	-10.85***	2.13	0.04	-12.38***	-12.88***
P^{dom}_{2229}	-3.7***	-3.52**	-13.35***	-13.39***	-3.72***	-3.55**	-13.38***	-13.42***
P^{dom}_{2313}	2.72	0.61	-4.90***	-12.29***	1.84	0.47	-11.62***	-12.34***
P^{dom}_{2314}	-1.59	-1.41	-15.73***	-15.72***	-1.76	-1.80	-15.54***	-15.56***
P^{dom}_{2319}	-1.28	-1.34	-13.35***	-13.34***	-1.28	-1.34	-13.35***	-13.34***
P^{dom}_{2391}	-1.65	-1.63	-12.85***	-12.83***	-1.67	-1.65	-12.85***	-12.83***
P^{dom}_{235}	-0.42	-0.56	-6.52***	-6.69***	-0.44	-0.56	-10.86***	-10.97***

Notes: The sample period is from January 1995 to December 2008. The MacKinnon critical values across the sample are -3.47*** / -2.88**/ -2.58* for the model with a constant and -4.01*** / -3.44** / -3.14* for a model with a constant and a trend at the 1% / 5% / 10% levels of significance. The optimum lag lengths are SIC-based. Test critical values for the PP test are -3.47***/-2.88**/-2.58* for a model with a constant and -4.01***/-3.44**/ -3.14* for a model with a constant and a trend at the 1% / 5% / 10% levels of significance.

The notation * (**, ***) means the rejection of the hypothesis at the 10% (5% or 1%) significance level, respectively.

Acronyms of the variables: The superscripts *dom* and *for* indicate domestic and foreign output prices, respectively. For labour, electricity and material we use the superscripts *lab*, *ele* and *mat*. The subscripts represent the number of a sub-sector in the GP 2009 classification at the 2-, 3- and 4-digit level. The corresponding sectors are enumerated in Table 1.

Table 6b.: Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Unit Root Test on foreign output prices

Variables	ADF				PP			
	Level		First-diff.		Level		First-diff.	
	Model				*Model*			
	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend
P_{1712}^{for}	-2.70*	-2.80	-4.82***	-4.83***	-2.14	-2.20	-7.95***	-7.92***
P_{1722}^{for}	-1.11	-2.30	-6.55***	-6.54***	-0.89	-1.97	-12.22***	-12.19***
P_{2012}^{for}	-1.68	-3.48**	-6.11***	-6.27***	-0.85	-2.11	-11.03***	-11.11***
P_{2013}^{for}	0.75	-1.05	-9.46***	-9.61***	1.13	-0.85	-9.44***	-9.60***
P_{2014}^{for}	-1.38	-3.21*	-7.19***	-7.19***	-1.06	-2.85	-7.14***	-7.15***
P_{2015}^{for}	0.36	-1.08	-6.90***	-7.23***	3.38	1.54	-6.62***	-6.72***
P_{2016}^{for}	-1.21	-3.16*	-6.12***	-6.08***	-0.89	-2.21	-4.60***	-4.56***
P_{2042}^{for}	-0.47	-2.84	-12.16***	-12.13***	-0.48	-2.96	-12.15***	-12.11***
P_{2110}^{for}	-1.75	-1.97	-10.53***	-10.52***	-1.81	-1.91	-10.54***	-10.53***
P_{2219}^{for}	-1.40	-1.75	-9.27***	-9.25***	-1.48	-1.52	-9.34***	-9.32***
P_{2229}^{for}	-2.44	-2.43	-9.85***	-9.82***	-2.35	-2.35	-9.85***	-9.82***
P_{2313}^{for}	1.67	-1.49	-10.94***	-11.24***	1.57	-1.53	-10.92***	-11.13***
P_{2314}^{for}	-1.86	-1.98	-11.41***	-11.38***	-2.11	-2.22	-11.41***	-11.38***
P_{2319}^{for}	0.03	-1.63	-11.70***	-11.67***	-0.05	-1.80	-11.65***	-11.63***
P_{2391}^{for}	-1.62	-1.65	-11.47***	-11.44***	-1.80	-1.83	-11.47***	-11.44***
P_{235}^{for}	-1.10	-1.72	-7.83***	-7.80***	-1.09	-1.51	-7.76***	-7.74***

Table 6c.: Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Unit Root Test on input prices

Variables	**ADF**				**PP**			
	Level		First-diff.		Level		First-diff.	
	Model				*Model*			
	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend	Constant	Constant & trend
P_{17}^{lab}	-0.79	-1.99	-11.34***	-11.30***	-1.57	-3.51**	-26.98***	-27.62***
P_{20}^{lab}	-1.48	-1.16	-11.59***	-11.71***	-4.29***	-4.27***	-27.59***	-31.11***
P_{22}^{lab}	-0.51	-2.48	-6.62***	-6.58***	-0.86	-2.70	-17.60***	-17.52***
P_{23}^{lab}	-1.84	-0.87	-13.00***	-13.17***	-1.53	-1.97	-19.15***	-19.24***
P^{ele}	0.01	-0.84	-9.61***	-10.21***	-0.10	-0.76	-9.75***	-10.21***
P_{222}^{mat}	-0.56	-2.13	-7.12***	-7.08***	0.18	-1.58	-7.03***	-6.82***
P_{27}^{mat}	-0.91	-2.68	-4.18***	-9.74***	0.06	-1.99	-10.11***	-10.15***
P_{2017}^{mat}	0.72	-0.84	-10.55***	-10.78***	0.32	-1.45	-11.18***	-11.24***
P_{192}^{mat}	-1.40	-2.82	-9.21***	-9.20***	-1.26	-2.53	-9.23***	-9.20***
P_{201}^{mat}	-0.35	-2.91	-7.20***	-7.44***	-0.07	-2.13	-7.29***	-7.38***
P_{20}^{mat}	0.02	-2.74	-7.26***	-7.58***	0.40	-1.92	-7.45***	-7.68***

Sectoral assignment for input factors material and labour

Price index for input factor material[20]		**Wages**	
P_{222}^{mat}	*Manufacture of plastics products (GP 222)*	P_{17}^{lab}	*Manufacture of paper and paper products (GP 17)*
P_{27}^{mat}	*Manufacture of basic metals (GP 27)*	P_{20}^{lab}	*Manufacture of chemical products (GP 20)*
P_{2017}^{mat}	*Manufacture of synthetic rubber in primary forms (GP 2017)*	P_{22}^{lab}	*Manufacture of rubber and plastic products (GP 22)*
P_{192}^{mat}	*Manufacture of refined petroleum products (GP 192)*	P_{23}^{lab}	*Manufacture of other non-metallic mineral products (GP 23)*
P_{201}^{mat}	*Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms (GP 201)*		
P_{20}^{mat}	*Manufacture of chemicals (GP20)*		

[20] We use also input factors which can be found in Table 1.

Table 7: List of dummy variables

d96_01: The German “Electricity Feed Law“ (Stromeinspeisegesetz) which guarantees premium prices for producers of electricity from renewable resources was approved by the German Federal Constitutional Court (Bundesverfassungsgericht). The input factor electricity is used in all sectoral models to proxy the input factor energy. This seems to be the most parsimonious way to achieve the normality (skewness) of residuals in sectoral VEC models.

d97_01: Sharp increase of the steel price following an exceptionally strong growth in demand. The input factor basic metals (GP09-27) is intensively employed in the production of both dyes and pigments (GP09-2012) and other basic inorganic chemicals (GP09-2013) and used in sectoral models to proxy material input, respectively. This seems to be the most parsimonious way to avoid the residual heteroscedasticity in both sectoral VEC models.

d01_01: The dummy is needed to address a price increase of foreign producers of other basic inorganic chemicals (GP 2042) and to achieve the normality of residuals in sectoral VEC model (GP09-2042).

d07_01: Strong price increase by foreign manufacturers of hollow glass (GP09-2313). Dummy was used to achieve the normality (skewness) of residuals in sectoral VEC models.

d06_08: Strong price increase by foreign manufacturers of glass fibres (GP09-2314). Dummy was used to achieve the normality (skewness) of residuals in sectoral VEC models.

d02_10: Strong price decrease by foreign producers of cement, lime and plaster (GP09-235) after a cartel has been discovered. This seems to be the most parsimonious way to achieve the normality in the sectoral VEC model.

Table 8a.: Number of cointegrating relations at the 0.05 level (GP09 1712 – 2015)

Manufacture of paper and paperboard (GP09-1712)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	2	2	2	2	2
Max-Eig	2	2	1	2	1

Endogenous variables: P_{1712}^{dom}, P_{1712}^{for}, P_{17}^{lab}, P_{222}^{mat} and P^{ele}; number of selected lags: 5 (AIC: 3); exogenous variables: centred seasonal dummies, d96_01

Manufacture of household and toilet paper and paper products (GP09-1722)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	2	2	2	2	2
Max-Eig	1	1	1	1	1

Endogenous variables: P_{1722}^{dom}, P_{1722}^{for}, P_{17}^{lab}, P_{222}^{mat} and P^{ele}; number of selected lags: 7 (AIC: 4); exogenous variables: centred seasonal dummies, d96_01

Manufacture of dyes and pigments (GP09-2012)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	1	1	1	2
Max-Eig	1	1	1	1	2

Endogenous variables: P_{2012}^{dom}, P_{2012}^{for}, P_{20}^{lab}, P_{27}^{mat} and P^{ele}; number of selected lags: 3 (AIC: 3); exogenous variables: centred seasonal dummies, d96_01, d_97_01

Manufacture of other basic inorganic chemicals (GP09-2013)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	1	1	0	1
Max-Eig	1	1	1	1	1

Endogenous variables: P_{2013}^{dom}, P_{2013}^{for}, P_{20}^{lab}, P_{27}^{mat} and P^{ele}; number of selected lags: 4 (AIC: 2); exogenous variables: centred seasonal dummies, d96_01, d97_01

Manufacture of other basic organic chemicals (GP09-2014)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	0	0	1	2	2
Max-Eig	0	0	0	0	0

Endogenous variables: P_{2014}^{dom}, P_{2014}^{for}, P_{20}^{lab}, P_{2013}^{mat} and P^{ele}; number of lags: 5 (AIC:2); exogenous variables: centred seasonal dummies, d96_01

Manufacture of other basic inorganic chemicals (GP09-2015)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	1	1	1	1
Max-Eig	1	1	1	0[21]	1

Endogenous variables: P_{2015}^{dom}, P_{2015}^{for}, P_{20}^{lab}, P_{192}^{mat} and P^{ele}; number of selected lags: 6 (AIC: 2); exogenous variables: centred seasonal dummies, d96_01

[21] The hypothesis that there is at least one cointegration relationship cannot be rejected at the 0.1 level.

Table 8b.: Number of cointegrating relations at the 0.05 level (GP09 2016 – 2314)

Manufacture of plastics in primary forms (GP09-2016)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	2	2	2	1
Max-Eig	0	0	0	1	1
Endogenous variables: P_{2016}^{dom}, P_{2016}^{for}, P_{20}^{lab}, P_{2014}^{mat} and P^{ele}; number of lags: 5 (AIC:2); exogenous variables: centred seasonal dummies, d96_01					

Manufacture of other basic inorganic chemicals (GP09-2042)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	2	2	2	1	1
Max-Eig	0	0	0	1	1
Endogenous variables: P_{2042}^{dom}, P_{2042}^{for}, P_{20}^{lab}, P_{222}^{mat} and P^{ele}; number of lags: 6 (AIC:2); exogenous variables: centred seasonal dummies, d96_01, d01_01					

Manufacture of basic pharmaceutical products (GP09-2110)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	1	0	0	0
Max-Eig	0	0	0	0	0
Endogenous variables: P_{2110}^{dom}, P_{2110}^{for}, P_{20}^{lab}, P_{2014}^{mat} and P^{ele}; number of lags: 4 (AIC:4); exogenous variables: centred seasonal dummies, d96_01					

Manufacture of other rubber products (GP09-2219)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	1	1	1	1
Max-Eig	1	1	1	1	1
Endogenous variables: P_{2219}^{dom}, P_{2219}^{for}, P_{22}^{lab}, P_{2017}^{mat} and P^{ele}; number of lags: 10 (AIC:2); exogenous variables: centred seasonal dummies, d96_01					

Manufacture of hollow glass (GP09-2313)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	3	3	3	4	1
Max-Eig	3	2	1	1	1
Endogenous variables: P_{2313}^{dom}, P_{2313}^{for}, P_{23}^{lab}, P_{201}^{mat} and P^{ele}; number of lags: 8 (AIC:4); exogenous variables: centred seasonal dummies, d96_01, d07_01					

Manufacture of glass fibres (GP09-2314)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	1	1	2	2
Max-Eig	1	1	1	2[22]	2
Endogenous variables: P_{2314}^{dom}, P_{2314}^{for}, P_{23}^{lab}, P_{201}^{mat} and P^{ele}; number of lags: 6 (AIC:2); exogenous variables: centred seasonal dummies, d96_01, d06_08					

[22] Max eigenvalue statistic which fails to reject the hypothesis of 2 cointegrating equations (in favour of 1 cointegration equitation) is very close to the critical value of 0.05.

Table 8c.: Number of cointegrating relations at the 0.05 level (GP09 2319 – 2391)

Manufacture of other glass, processed, incl. (GP09-2319)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	5	5	2	1	1
Max-Eig	1	1	1	0	0
Endogenous variables: P_{2319}^{dom}, P_{2319}^{for}, P_{23}^{lab}, P_{201}^{mat} and P^{ele}; number of lags: 6 (AIC:2); exogenous variables: centred seasonal dummies					

Manufacture of cement, lime and plaster (GP09-235)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	1	1	1	1	1
Max-Eig	1	0	0	1	1
Endogenous variables: P_{235}^{dom}, P_{235}^{for}, P_{23}^{lab}, P_{20}^{mat} and P^{ele}; number of lags: 5 (AIC: 4); exogenous variables: centred seasonal dummies, d96_01, d02_10					

Manufacture of other rubber products (GP09-2391)					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Trace	5	4	1	0	0
Max-Eig	1	1	0	0	0
Endogenous variables: P_{2391}^{dom}, P_{2391}^{for}, P_{23}^{lab}, P_{20}^{mat} and P^{ele}; number of lags: 5 (AIC: 2); exogenous variables: centred seasonal dummies, d96_01, d00_04					

Note: In parentheses we indicate the lag length suggested by the Akaike information criterion (AIC).

Table 9a.: Short-run relationship between output and input prices (GP09 1712 – 2012)

Manufacture of paper and paperboard (GP09-1712)					
	$\Delta P^{dom}_{1712,\ t}$	$\Delta P^{for}_{1712,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{17,\ t}$	$\Delta P^{mat}_{222,\ t}$
ec_{t-1}	-0.15 (0.05)***	0.04 (0.05)	0.29 (0.12)**	-0.09 (0.10)	0.01 (0.10)
$\Delta P^{dom}_{1712,\ t-i}$	i=1 0.32 (0.11)*** i=2 0.30 (0.13)**				i=1 0.11 (0.05)**
$\Delta P^{for}_{1712,\ t-i}$	i=1 0.17 (0.11)* i=4 -0.28 (0.11)***	i=1 0.25 (0.13)** i=2 0.19 (0.13)*			i=1 0.07 (0.05)**
ΔP^{ele}_{t-i}	i=4 0.04 (0.03)* i=5 - 0.08 (0.03)*	i=5 -0.07 (0.03)**	i=1 0.24 (0.08)*** i=3 0.20 (0.08) ***	i=1 -0.09 (0.06)*	i=1 0.02 (0.01)** i=2 0.04 (0.03)* i=3 -0.03 (0.01)***
$\Delta P^{lab}_{17,\ t-i}$	i=5 -0.08 (0.05)**			i=1 -0.70 (0.10)*** i=2 -0.52 (0.11)*** i=3 -0.41 (0.11)*** i=4 -0.26 (0.11)***	
$\Delta P^{mat}_{222,\ t-i}$	i=4 0.37 (0.23)* i=5 -0.31 (0.23)*	i=3 0.59 (0.26)** i=5 -0.48 (0.25)**	i=1 -0.77 (0.57)* i=3 0.83 (0.60)*	i=5 -1.05 (0.46)**	i=1 0.39 (0.10)*** i=2 0.17 (0.10)** i=3 -0.17 (0.10)** i=5 -0.20 (0.10)**

Manufacture of household and toilet paper and paper products (GP09-1722)					
	$\Delta P^{dom}_{1722,\ t}$	$\Delta P^{for}_{1722,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{17,\ t}$	$\Delta P^{mat}_{222,\ t}$
ec_{t-1}	-0.16 (0.05)***	0.12 (0.06)**	0.50 (0.11)***	0.23 (0.08)***	-0.01 (0.02)
$\Delta P^{dom}_{1722,\ t-i}$		i=7 0.39 (0.12)***		i=1 0.26 (0.17)* i=3 0.25 (0.17)* i=5 -0.70 (0.16)*** i=7 0.39 (0.17)**	i=2 0.07 (0.04)** i=4 0.07 (0.04)**
$\Delta P^{for}_{1722,\ t-i}$	i=3 0.12 (0.07)** i=4 -0.13 (0.07)** i=5 0.16 (0.07)** i=7 0.09 (0.07)*	i=2 0.27 (0.09)*** i=3 -0.16 (0.10)*	i=4 -0.37 (0.18)** i=5 -0.28 (0.18)*	i=6 -0.26 (0.13)** i=7 0.18 (0.13)*	i=7 -0.05 (0.03)**
ΔP^{ele}_{t-i}	i=7 -0.07 (0.03)**	i=2 0.10 (0.04)** i=4 -0.06 (0.05)*	i=1 0.27 (0.08)*** i=3 0.24 (0.08)*** i=6 0.18 (0.09)**	i=1 -0.08 (0.06)*	i=2 0.03 (0.01)** i=5 -0.03 (0.02)** i=6 -0.02 (0.02)*
$\Delta P^{lab}_{17,\ t-i}$	i=1 -0.22 (0.08)*** i=2 -0.12 (0.08)* i=3 -0.20 (0.08)*** i=4 -0.14 (0.08)** i=5 -0.13 (0.07)** i=6 -0.16 (0.06)*** i=7 -0.09 (0.05)**	i=1 0.18 (0.12)* i=2 0.24 (0.12)**	i=1 0.85 (0.22)*** i=2 0.81 (0.23)*** i=3 0.76 (0.22)*** i=4 0.71 (0.21)*** i=5 0.55 (0.19)*** i=6 0.39 (0.16)*** i=7 0.19 (0.12)*	i=6 0.23 (0.12)** i=7 0.18 (0.09)**	
$\Delta P^{mat}_{222,\ t-i}$	i=1 0.27 (0.20)* i=7 0.55 (0.21)***	i=3 0.49 (0.34)*	i=1 -1.18 (0.56)**	i=1 0.78 (0.41)** i=5 -0.87 (0.46)** i=7 -0.60 (0.42)*	i=1 0.46 (0.10)*** i=2 0.23 (0.11)** i=3 -0.21 (0.11)**

Manufacture of dyes and pigments (GP09-2012)					
	$\Delta P^{dom}_{2012,\ t}$	$\Delta P^{for}_{2012,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{20,\ t}$	$\Delta P^{mat}_{27,\ t}$
ec_{t-1}	-0.16 (0.05)***	-0.03 (0.05)	0.09 (0.09)	0.23 (0.10)**	-0.23 (0.07)***
$\Delta P^{dom}_{2012,\ t-i}$			i=1 -0.29 (0.16)**	i=2 -0.25 (0.18)*	i=1 0.21 (0.12)** i=3 0.19 ((0.12)*
$\Delta P^{for}_{2012,\ t-i}$	i=2 0.14 (0.08)** i=3 0.22 (0.09)***	i=1 0.15 (0.09)** i=2 0.28 (0.09)***		i=2 -0.32 (0.17)**	i=2 -0.19 ((0.12)*
ΔP^{ele}_{t-i}	i=1 0.05 (0.04)*	i=1 0.10 (0.04)*** i=2 -0.05 (0.04)*	i=1 0.30 (0.07)*** i=3 0.14 (0.07)**	i=1 0.12 (0.08)*	
$\Delta P^{lab}_{20,\ t-i}$	i=1 0.07 (0.04)**		i=2 0.23 (0.09)*** I=3 0.13 (0.08)**	i=1 -0.60 (0.08)*** i=2 -0.33 (0.09)*** i=3 -0.22 (0.08)***	
$\Delta P^{mat}_{27,\ t-i}$		i=1 0.07 (0.04)** i=3 0.06 (0.04)*	i=2 -0.12 (0.08)* i=3 0.21 (0.08)***	i=1 -0.12 (0.08)* i=2 0.14 (0.08)** i=3 0.27 (0.08)***	i=1 0.15 (0.05)*** i=2 0.13 (0.05)** i=3 0.19 (0.06)***

Table 9b.: Short-run relationship between output and input prices (GP09 2013 – 2016)

Manufacture of other basic inorganic chemicals (GP09-2013)

	$\Delta P^{dom}_{2013,\ t}$	$\Delta P^{for}_{2013,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{20,\ t}$	$\Delta P^{mat}_{27,\ t}$
ec_{t-1}	-0.10 (0.03)***	-0.01 (0.05)	0.06 (0.03)**	-0.01 (0.03)	-0.08 (0.02)***
$\Delta P^{dom}_{2013,\ t-i}$	i=1 0.20 (0.08)*** i=2 0.29 (0.08)*** i=3 0.14 (0.09)* i=4 0.13 (0.09)*		i=4 -0.22 (0.09)***	i=3 0.18 (0.10)**	
$\Delta P^{for}_{2013,\ t-i}$		i=1 0.18 (0.09)**			i=2 -0.08 (0.04)** i=4 -0.07 (0.04)**
ΔP^{ele}_{t-i}	i=2 0.12 (0.07)*	i=4 -0.16 (0.12)*	i=1 0.29 (0.07)*** i=3 0.13 (0.07)**	i=1 0.13 (0.08)*	
$\Delta P^{lab}_{20,\ t-i}$	i=3 0.12 (0.09)*	i=1 0.21 (0.13)* i=2 0.21 (0.15)* i=4 0.19 (0.13)*	i=2 0.23 (0.09)*** i=3 0.17 (0.09)**	i=1 -0.61 (0.09)*** i=2 -0.36 (0.10)*** i=3 -0.29 (0.10)***	i=1 0.08 (0.06)*
$\Delta P^{mat}_{27,\ t-i}$		i=2 0.21 (0.13)** i=3 0.25 (0.13)**	i=2 -0.15 (0.08)** i=3 0.20 (0.08)***	i=1 -0.14 (0.08)** i=2 0.15 (0.09)** i=3 0.20 (0.09)**	i=1 0.15 (0.06)*** i=2 0.15 (0.06)*** i=3 0.19 (0.06)***

Manufacture of other basic inorganic chemicals (GP09-2015)

	$\Delta P^{dom}_{2015,\ t}$	$\Delta P^{for}_{2015,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{20,\ t}$	$\Delta P^{mat}_{192,\ t}$
ec_{t-1}	-0.12 (0.07)**	0.21 (0.07)***	-0.04 (0.05)	-0.12 (0.05)**	0.08 (0.11)
$\Delta P^{dom}_{2015,\ t-i}$	i=1 0.18 (0.10)** i=2 0.37 (0.12)***	i=2 0.60 (0.12)*** i=6 0.26 (0.13)**	i=1 0.12 (0.08)* i=4 0.14 (0.08)** i=5 -0.17 (0.09)**	i=1 0.12 (0.09)* i=2 0.18 (0.10)** i=6 -0.17 (0.10)*	i=4 0.29 (0.20)* i=5 -0.70 (0.21)***
$\Delta P^{for}_{2015,\ t-i}$	i=2 -0.20 (0.11)** i=5 0.13 (0.08)* i=6 -0.20 (0.09)**	i=1 0.55 (0.10)*** i=3 0.21 (0.10)** i=4 -0.18 (0.10)** i=5 0.21 (0.09)*** i=6 -0.13 (0.09)*	i=3 0.10 (0.07)*	i=2 -0.15 (0.09)** i=3 -0.11 (0.08)* i=5 -0.10 (0.07)*	i=4 0.24 (0.16)*
ΔP^{ele}_{t-i}	i=1 0.14 (0.10)* i=4 -0.20 (0.11)**	i=1 0.15 (0.11)* i=6 0.21 (0.11)**	i=1 0.24 (0.08)***		
$\Delta P^{lab}_{20,\ t-i}$		i=1 -0.18 (0.13)* i=2 -0.22 (0.15)*	i=2 0.16 (0.10)* i=3 0.17 (0.10)* i=6 0.17 (0.09)**	i=1 -0.61 (0.09)*** i=2 -0.41 (0.11)*** i=3 -0.33 (0.12)*** i=5 -0.16 (0.12)*	
$\Delta P^{mat}_{192,\ t-i}$	i=1 0.13 (0.06)** i=2 0.17 (0.06)***	i=1 0.10 (0.06)** i=4 0.13 (0.06)** i=5 -0.08 (0.06)*	i=1 0.06 (0.04)*	i=6 0.07 (0.05)*	i=1 0.21 (0.10)**

Manufacture of plastics in primary forms (GP09-2016)

	$\Delta P^{dom}_{2016,\ t}$	$\Delta P^{for}_{2016,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{20,\ t}$	$\Delta P^{mat}_{2014,\ t}$
ec_{t-1}	-0.14 (0.04)***	-0.04 (0.04)	0.14 (0.06)***	0.13 (0.06)**	-0.15 (0.06)**
$\Delta P^{dom}_{2016,\ t-i}$	i=1 0.21 (0.09)** i=5 0.13 (0.09)*	i=1 0.17 (0.11)*		i=1 -0.33 (0.16)**	i=1 0.26 (0.17)* i=4 -0.24 (0.17)* i=5 -0.23 (0.16)*
$\Delta P^{for}_{2016,\ t-i}$	i=1 0.30 (0.08)***	i=1 0.62 (0.10)*** i=4 - 0.26 (0.13)**	i=1 -0.19 (0.13)*	i=2 -0.23 (0.18)*	i=1 0.48 (0.15)***
ΔP^{ele}_{t-i}	i=1 0.09 (0.05)**	i=1 -0.09 (0.07)*	i=1 0.25 (0.07)*** i=3 0.17 (0.08)**		
$\Delta P^{lab}_{20,\ t-i}$	i=1 0.09 (0.05)*		i=2 0.13 (0.10)*	i=1 -0.66 (0.09)*** i=2 -0.42 (0.11)*** i=3 -0.31 (0.11)*** i=4 -0.14 (.011)* i=5 -0.14 (0.09)*	i=1 0.17 (0.09)**
$\Delta P^{mat}_{2014,\ t-i}$		i=3 0.12 (0.07)**	i=1 0.21 (0.09)***	i=1 0.22 (0.10)**	i=2 -0.22 (0.10)** i=3 0.42 (0.10)**** i=5 0.19 (0.10)**

Table 9c.: Short-run relationship between output and input prices (GP09 2042 – 2313)

Manufacture of other basic inorganic chemicals (GP09-2042)

	$\Delta P^{dom}_{2042,\ t}$	$\Delta P^{for}_{2042,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{20,\ t}$	$\Delta P^{mat}_{222,\ t}$
ec_{t-1}	-0.24 (0.05)***	0.06 (0.03)**	0.06 (0.13)	0.22 (0.15)*	-0.03 (0.02)
$\Delta P^{dom}_{2042,\ t-i}$		i=2 0.09 (0.06)*	i=3 -0.72 (0.24)*** i=6 -0.36 (0.21)**	i=4 -0.47 (0.25)**	
$\Delta P^{for}_{2042,\ t-i}$			i=1 0.43 (0.28)* i=2 0.60 (0.29)**	i=2 0.61 (0.33)** i=5 -0.56 (0.32)**	i=1 -0.10 (0.05)**
ΔP^{ele}_{t-i}	i=1 0.05 (0.03)* i=3 0.08 (0.03)*** i=5 0.07 (0.03)**	i=3 0.04 (0.02)** i=4 -0.03 (0.02)* i=6 -0.04 (0.02)*	i=1 0.21 (0.07)*** i=3 0.15 (0.08)**		i=1 0.02 (0.01)* i=2 0.03 (0.01)**
$\Delta P^{lab}_{20,\ t-i}$	i=5 -0.06 (0.04)*	i=6 -0.03 (0.029*	i=2 0.19 (0.09)** i=3 0.21 (0.10)** i=6 0.13 (0.08)*	i=1 -0.64 (0.09)*** i=2 -0.44 (0.11)*** i=3 -0.33 (0.11)***	
$\Delta P^{mat}_{222,\ t-i}$	i=5 0.34 (0.23)* i=6 -0.31 (0.22)*	i=6 -0.24 (0.15)*	i=2 -1.09 (0.61)**	i=2 1.10 (0.70)*	i=1 0.46 (0.10)*** i=2 0.22 (0.11)** i=3 -0.19 (0.11)**

Manufacture of other rubber products (GP09-2219)

	$\Delta P^{dom}_{2219,\ t}$	$\Delta P^{for}_{2219,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{22,\ t}$	$\Delta P^{mat}_{2017,\ t}$
ec_{t-1}	-0.06 (0.02)***	-0.04 (0.02)**	-0.24 (0.07)***	0.15 (0.05)***	0.10 (0.09)
$\Delta P^{dom}_{2219,\ t-i}$	i=2 -0.26 (0.09)*** i=7 0.16 (0.10)*	i=9 0.20 (0.10)**	i=1 -0.73 (0.40)** i=3 -0.90 (0.40)**	i=2 0.33 (0.24)*	
$\Delta P^{for}_{2219,\ t-i}$	i=5 -0.15 (0.11)* i=8 -0.16 (0.10)* i=9 0.32 (0.11)***	i=1 0.40 (0.10)*** i=10 0.26 (0.11)**	i=8 -1.00 (0.42)** i=9 -0.84 (0.43)**	i=9 0.38 (0.26)*	i=10 -0.73 (0.49)*
ΔP^{ele}_{t-i}	i=2 0.03 (0.02)* i=3 0.03 (0.02)* i=9 -0.04 (0.02)*	i=8 0.04 (0.02)**	i=1 0.20 (0.08)*** i=3 0.20 (0.10)** i=6 0.12 (0.10)*	i=4 0.11 (0.06)** i=5 -0.08 (0.06)* i=6 -0.08 (0.06)*	
$\Delta P^{lab}_{22,\ t-i}$	i=1 0.07 (0.05)*	i=4 0.10 (0.05)** i=10 -0.10 (0.04)**	i=4 0.37 (0.19)**	i=1 -0.39 (0.11)*** i=3 0.29 (0.12)*** i=5 0.19 (0.12)* i=10 -0.31 (0.11)***	
$\Delta P^{mat}_{2017,\ t-i}$		i=5 -0.04 (0.02)* i=8 -0.03 (0.02)*	i=1 -0.15 (0.09)* i=6 -0.13 (0.10)*	i=8 0.08 (0.06)*	i=3 0.26 (0.11)** i=4 0.18 (0.11)**

Manufacture of hollow glass (GP09-2313)

	$\Delta P^{dom}_{2313,\ t}$	$\Delta P^{for}_{2313,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{23,\ t}$	$\Delta P^{mat}_{201,\ t}$
ec_{t-1}	-0.10 (0.03)***	-0.08 (0.03)***	-0.25 (0.09)***	0.05 (0.07)	0.20 (0.05)
$\Delta P^{dom}_{2313,\ t-i}$	i=3 0.27 (0.09)***	i=3 -0.26 (0.09)*** i=6 0.14 (0.09)*	i=6 0.40 (0.26)*	i=3 0.26 (0.20)* i=4 0.57 (0.22)*** i=6 -0.40 (0.21)** i=7 -0.44 (0.21)**	i=6 -0.24 (0.15)*
$\Delta P^{for}_{2313,\ t-i}$	i=3 -0.12 (0.09)* i=5 -0.17 (0.09)** i=7 -0.29 (0.09)*** i=8 -0.13 (0.09)*		i=1 -0.32 (0.24)* i=2 -0.34 (0.25)* i=3 -0.37 (0.25)* i=7 -0.34 (0.23)*	i=1 0.37 (0.20)**	i=2 0.34 (0.15)** i=7 0.18 (0.13)* i=8 0.21 (0.14)*
ΔP^{ele}_{t-i}		i=8 -0.05 (0.03)**	i=1 0.22 (0.09)*** i=3 0.14 (0.09)**	i=1 -0.14 (0.07)** i=2 0.13 (0.07)** i=6 -0.15 (0.08)**	i=1 0.09 (0.05)**
$\Delta P^{lab}_{23,\ t-i}$	i=1 -0.13 (0.05)** i=2 -0.10 (0.06)* i=7 0.13 (0.05)***	i=3 -0.13 (0.06)** i=4 -0.09 (0.05)** i=6 0.08 (0.05)* i=8 0.10 (0.04)**	i=1 -0.19 (0.14)*	i=1 -0.61 (0.11)*** i=2 0.28 (0.13)** i=5 0.28 (0.12)**	i=3 0.16 (0.09)* i=5 0.17 (0.09)**
$\Delta P^{mat}_{201,\ t-i}$	i=8 -0.10 (0.06)*	i=4 0.12 (0.07)** i=5 -0.11 (0.07)* i=7 -0.10 (0.06)*			i=1 0.58 (0.08)*** i=3 0.26 (0.11)** i=7 0.23 (0.11)**

Table 9d.: Short-run relationship between output and input prices (GP 2314 – 235)

Manufacture of fertilizers & nitrogen compounds (GP09-2314)

	$\Delta P^{dom}_{2314,\ t}$	$\Delta P^{for}_{2314,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{23,\ t}$	$\Delta P^{mat}_{201,\ t}$
ec_{t-1}	-0.44 (0.09)***	-0.03 (0.13)	-0.17 (0.20)	0.30 (0.17)*	0.31 (0.12)***
$\Delta P^{dom}_{2314,\ t-i}$	i=1 -0.17 (0.09)** i=3 0.13 (0.08)* i=6 -0.13 (0.07)**	i=1 0.20 (0.14)* i=3 0.33 (0.12)*** i=5 0.20 (0.12)**		i=1 -0.28 (0.18)*	i=1 -0.27 (0.13)** i=5 -0.14 (0.11)*
$\Delta P^{for}_{2314,\ t-i}$	i=4 -0.12 (0.06)** i=6 -0.13 (0.06)**	i=3 -0.17 (0.10)* i=5 -0.16 (0.09)**	i=3 -0.21 (0.16)* i=6 0.30 (0.14)**	i=1 0.36 (0.14)*** i=2 0.24 (0.13)**	i=5 0.15 (0.09)**
ΔP^{ele}_{t-i}	i=1 -0.07 (0.03)** i=4 0.10 (0.04)***	I=1 -0.08 (0.05)*	i=1 0.23 (0.08)*** i=3 0.18 (0.08)**	i=2 0.14 (0.07)** i=6 -0.10 (0.07)*	i=1 0.08 (0.05)** i=5 -0.08 (0.05)*
$\Delta P^{lab}_{23,\ t-i}$	i=4 0.16 (0.06)*** i=5 0.14 (0.05)*** i=6 0.11 (0.05)**	i=1 -0.15 (0.07)** i=4 0.12 (0.09)* i=5 0.12 (0.08)* i=6 0.19 (0.07)***		i=1 -0.53 (0.10)*** i=2 -0.24 (0.11)** i=5 0.15 (0.11)*	
$\Delta P^{mat}_{201,\ t-i}$	i=3 -0.19 (0.08)***	I=2 0.28 (0.12)**		i=1 0.17 (0.12)* i=6 0.21 (0.13)*	i=1 0.63 (0.09)*** i=3 0.24 (0.11)**

Manufacture of other glass, processed, incl. (GP09-2319)

	$\Delta P^{dom}_{2319,\ t}$	$\Delta P^{for}_{2319,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{23,\ t}$	$\Delta P^{mat}_{201,\ t}$
ec_{t-1}	-0.03 (0.02)**	-0.06 (0.01)***	-0.11 (0.05)**	-0.00 (0.04)	0.05 (0.02)***
$\Delta P^{dom}_{2319,\ t-i}$	i=4 -0.12 (0.09)* i=5 0.23 (0.09)** i=6 0.22 (0.09)***	I=1 0.12 (0.09)*	i=4 -0.49 (0.30)**	i=4 0.40 (0.21)** i=5 0.35 (0.22)*	i=3 0.23 (015)* i=4 -0.24 (0.15)** i=6 -0.39 (0.16)***
$\Delta P^{for}_{2319,\ t-i}$	i=2 -0.12 (0.09)* i=5 -0.21 (0.10)** i=6 0.14 (0.10)*	i=2 -0.13 (0.09)* i=2 -0.16 (0.10)**	i=2 -0.71 (0.31)**	i=3 0.52 (0.24)**	i=2 0.43 (0.15)*** i=3 -0.33 (0.16)** i=4 0.40 (0.16)*** i=5 0.36 (0.17)**
ΔP^{ele}_{t-i}	i=3 -0.07 (0.03)** i=6 -0.05 (0.03)*	i=1 -0.07 (0.03)*** i=3 -0.07 (0.03)*** i=6 -0.04 (0.03)*	i=1 0.19 (0.09)**	i=2 0.12 (0.07)*	i=1 0.06 (0.05)* i=6 0.07 (0.05)*
$\Delta P^{lab}_{23,\ t-i}$	i=4 -0.08 (0.05)**		i=1 -0.33 (0.14)*** i=2 -0.25 (0.16)*	i=1 -0.51 (0.10)*** i=2 -0.23 (0.11)*** i=5 0.19 (0.11)**	i=3 0.10 (0.08)* i=5 0.10 (0.07)*
$\Delta P^{mat}_{201,\ t-i}$	i=3 -0.10 (0.06)*				i=1 0.69 (0.09)*** i=3 0.24 (0.10)** i=4 -0.18 (0.10)**

Manufacture of cement, lime and plaster (GP09-235)

	$\Delta P^{dom}_{235,\ t}$	$\Delta P^{for}_{235,\ t}$	ΔP^{ele}_{t}	$\Delta P^{lab}_{23,\ t}$	$\Delta P^{mat}_{20,\ t}$
ec_{t-1}	-0.19 (0.05)***	0.14 (0.08)**	-0.09 (0.14)	-0.08 (0.11)	0.10 (0.05)**
$\Delta P^{dom}_{235,\ t-i}$	i=1 0.17 (0.09)** i=2 0.25 (0.09)*** i=3 0.18 (0.09)** i=4 0.15 (0.09)**	i=1 -0.21 (0.14)* i=2 0.22 (0.14)* i=4 0.25 (0.13)**	i=4 0.33 (0.24)*	i=1 0.35 (0.21)**	i=3 -0.12 (0.09)*
$\Delta P^{for}_{235,\ t-i}$	i=1 0.13 (0.05)*** i=3 0.14 (0.05)*** i=4 -0.14 (0.05)*** i=5 0.07 (0.05)*	i=1 0.53 (0.07)*** i=2 -0.34 (0.08)*** i=3 0.28 (0.08)*** i=4 -0.20 (0.08)*** i=5 0.11 (0.07)*	i=3 -0.20 (0.14)*	i=1 -0.14 (0.10)*	i=2 -0.07 (0.05)* i=4 -0.10 (0.05)**
ΔP^{ele}_{t-i}	i=3 -0.11 (0.03)***		i=1 0.21 (0.08)*** i=3 0.20 (0.09)**	i=1 -0.12 (0.07)**	
$\Delta P^{lab}_{23,\ t-i}$				i=1 -0.52 (0.11)*** i=2 -0.32 (0.12)*** i=5 0.13 (0.10)*	i=5 0.06 (0.04)*
$\Delta P^{mat}_{20,\ t-i}$		i=1 0.25 (0.16)*		i=1 0.40 (0.20)** i=4 -0.36 (0.23)*	i=1 0.52 (0.09)*** i=3 0.31 (0.10)***

Note: ec_{t-1} is an error correction term. We report significant coefficients only. Numbers in parenthesis are standard error of the estimated parameters. *** (**, *) denotes significance at the 1% (5%, 10%) level. Optimal lag length was set as indicated in Table 8a.-c., respectively.

Table 10: Diagnostic tests for sectoral VEC models

Sectoral VEC model		Autocorrelation				Normality			Heterosc.
		LM (3)	LM (6)	LM (9)	LM (12)	Skewness	Kurtosis	JB	WHn
1712	Manufacture of paper and paperboard	18.53 [0.82]	15.44 [0.93]	20.39 [0.72]	26.36 [0.55]	12.77 [0.03]	12.09 [0.03]	24.87 [0.01]	1096 [0.00]
1722	Manufacture of household and toilet paper & paper products	31.32 [0.17]	18.01 [0.84]	21.23 [0.68]	26.65 [0.37]	8.81 [0.12]	43.04 [0.00]	51.85 [0.00]	1327 [0.09]
2012	Manufacture of dyes and pigments	23.84 [0.53]	22.83 [0.59]	18.51 [0.82]	48.97 [0.00]	3.93 [0.56]	16.40 [0.01]	20.33 [0.03]	719 [0.12]
2013	Manufacture of other basic inorganic chemicals	35.13 [0.09]	15.84 [0.92]	35.12 [0.09]	45.16 [0.01]	2.93 [0.71]	13.42 [0.02]	16.36 [0.09]	878 [0.10]
2015	Manufacture of fertilizers and nitrogen compounds	17.34 [0.87]	18.48 [0.82]	22.99 [0.58]	37.01 [0.06]	8.47 [0.13]	16.23 [0.01]	24.70 [0.01]	1175 [0.15]
2016	Manufacture of plastics in primary forms	14.18 [0.96]	17.95 [0.84]	13.14 [0.97]	28.33 [0.29]	10.85 [0.05]	20.06 [0.00]	30.91 [0.00]	1043 [0.03]
2042	Manufacture of perfumes and toilet preparations	24.17 [0.51]	8.88 [0.99]	19.31 [0.78]	26.47 [0.38]	8.89 [0.11]	13.95 [0.02]	22.84 [0.01]	1156 [0.36]
2219	Manufacture of other rubber products	45.03 [0.01]	16.29 [0.91]	21.59 [0.66]	35.34 [0.08]	4.28 [0.51]	51.27 [0.00]	55.55 [0.00]	1702 [0.55]
2313	Manufacture of hollow glass	31.25 [0.18]	13.81 [0.96]	34.20 [0.10]	38.05 [0.05]	11.44 [0.04]	43.60 [0.00]	55.04 [0.00]	1389 [0.75]
2314	Manufacture of glass fibres	13.23 [0.97]	19.52 [0.77]	17.40 [0.87]	28.27 [0.30]	10.49 [0.06]	11.93 [0.04]	22.42 [0.01]	1178 [0.21]
2319	Manufacture of other glass, processed, incl. technical glassware	14.64 [0.95]	19.38 [0.78]	14.84 [0.95]	26.86 [0.36]	35.37 [0.00]	172.1 [0.00]	207.5 [0.00]	1154 [0.17]
235	Manufacture of cement, lime and plaster	30.11 [0.22]	15.53 [0.93]	19.84 [0.76]	24.04 [0.52]	8.37 [0.14]	9.14 [0.10]	17.51 [0.07]	1044 [0.07]

Note: The table reports test statistics and probability values for rejecting the null hypothesis of the following tests: Lagrange Multiplier (LM) autocorrelation test up to the 3^{rd}, 6^{th} and 12^{th} lag (H0: no serial correlation at lag order h); Jarque-Bera normality test (orthogonalisation: Cholesky (Lutkepohl), H0: residuals are multivariate normal); White heteroskedasticity test without cross terms (WHn) (H0: residuals are homoskedastic).