

Hille, Erik; Althammer, Wilhelm

**Conference Paper**

## Measuring climate policy stringency: A shadow price approach using energy prices

Beiträge zur Jahrestagung des Vereins für Socialpolitik 2015: Ökonomische Entwicklung - Theorie und Politik - Session: Modelling Energy Markets and Pollution, No. F17-V3

**Provided in Cooperation with:**

Verein für Socialpolitik / German Economic Association

*Suggested Citation:* Hille, Erik; Althammer, Wilhelm (2015) : Measuring climate policy stringency: A shadow price approach using energy prices, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2015: Ökonomische Entwicklung - Theorie und Politik - Session: Modelling Energy Markets and Pollution, No. F17-V3, ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften, Leibniz-Informationszentrum Wirtschaft

This Version is available at:

<https://hdl.handle.net/10419/112804>

**Standard-Nutzungsbedingungen:**

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

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

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

**Terms of use:**

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

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

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

# **Measuring climate policy stringency: A shadow price approach using energy prices**

## **Abstract**

To assess the effect of environmental policy on production structures, trade structures or foreign direct investment, a measure for the stringency of policy is necessary. Measures typically used in empirical studies share several disadvantages: They are not available on a sectoral basis to reflect concerns of industry competitiveness; they are not available for a wide range of countries to allow for international comparisons; or they are not broad enough to reflect the multidimensionality of environmental policy. This paper develops a thorough, internationally comparable, sector-specific measure of multidimensional climate policy stringency where a shadow price approach serves as a basis. The approach is applied to climate policy by determining sector-specific emission relevant energy costs on the basis of the sectors' usage of emission relevant energy carriers and the carriers' respective prices. The resulting shadow price estimates are heterogeneous and can be applied in future research to test for carbon leakage and pollution havens.

## **Keywords**

Environmental policy stringency; climate policy stringency; shadow price; energy price; pollution haven effect; carbon leakage

## 1 Introduction

A long-lasting debate in environmental economics concerns the question whether a more stringent environmental policy causes changes in trade structures and relocations of industry. The fear is that industries reduce domestic production or relocate to countries with less stringent regulations. If such pollution haven effects<sup>1</sup> exist, they can at least in the short run have adverse consequences, e.g. lower income and employment. Despite the fact that the empirical evidence for significant pollution haven effects is ambiguous (Levinson and Taylor 2008), fears that a stricter policy might reduce the competitiveness of regulated industries have a significant impact on policy. In the third phase of the European Union emission trading system from 2013 onwards competitiveness considerations were used to justify the special and favorable treatment of certain industries (Dröge 2009). Similarly, while the costs for supporting renewable energies in Germany are passed on to consumers, energy intensive industries have been granted generous exemptions to avoid rising energy costs and decreasing competitiveness (Dieckmann et al. 2012).

The fear that regulation has adverse impacts is especially pronounced in the field of energy policy as a part of climate policy. If carbon intensive production processes are shifted to countries with less strict mitigation policies, an additional negative consequence arises with carbon leakage and its impact on the effectiveness of unilateral climate policy regulation. While a broad body of literature analyzes the pollution haven effects for pollution with strong local effects (Bao et al. 2011; Ederington et al. 2004; He 2006), only little empirical evidence exists on how climate policy affects a country's competitiveness and growth through the policy's impact on trade flows or relocation of carbon intensive production. This lack of empirical research is at least partially the result of the unavailability of an internationally comparable sector-specific measure of climate policy stringency.

To evaluate pollution haven effects and carbon leakage empirically it is necessary to find a measure for the stringency of policy. The climate policy mix complicates the determination of a sector-specific climate policy stringency measure. Measures based on the direct assessment of single regulations in their mere nature cannot take interactions between several policies into account. Aggregate enforcement measures such as the number of implemented policies have a shortcoming in reflecting the characteristic of the policy as being, for instance, mandatory and restricting versus voluntary and supportive. This plurality of the implemented energy-related policies to reduce greenhouse gas emissions is reflected in *figure 1* for a set of 28 countries, which are analyzed in more detail in this paper.<sup>2</sup> As can be seen the United States are by far the country with the largest number of implemented policies, but a comparatively low share of policies included a regulatory instrument and the United States are generally not known as the forerunner in climate protection<sup>3</sup>. Hence, in order to credibly analyze carbon leakage, an economist would favor a policy stringency measure reflecting actual private sector abatement costs, which vary across countries, across industries, and over time (Brunel and Levinson 2013b).

Existing empirical literature merely uses measures, which cannot reflect this heterogeneity or face conceptual problems (Brunel and Levinson 2013b). In addition, the indicators of environmental policy stringency mostly do not allow for appropriate international

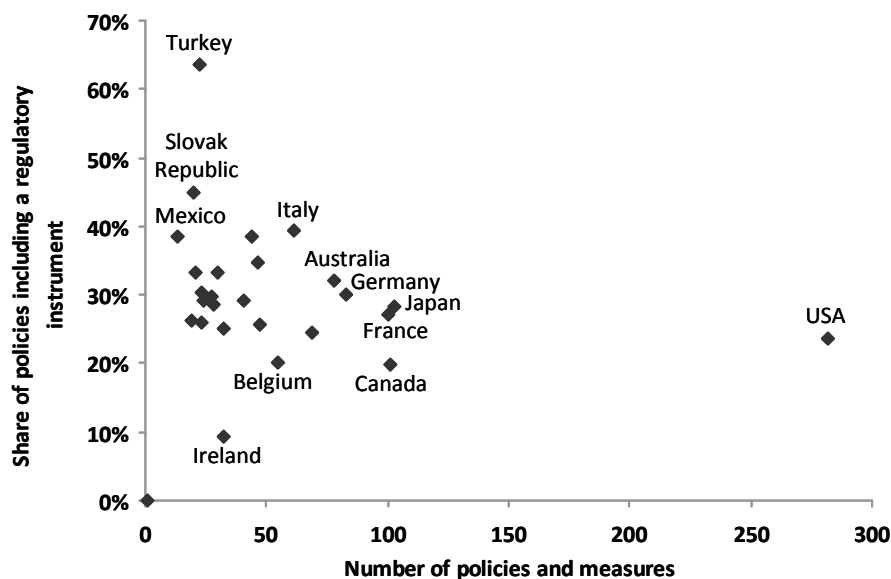
---

<sup>1</sup> While Ederington et al. (2004) distinguish between a direct and an indirect effect, Copeland and Taylor (2004) similarly differentiate between a pollution haven effect and a pollution haven hypothesis.

<sup>2</sup> For a detailed list of the included countries please see *table 1*.

<sup>3</sup> In general, the estimated sector-specific climate policy stringencies in this paper do not change this perception.

comparisons (van Soest et al. 2006). This may be one of the reasons why the majority of studies on pollution havens either are about the United States and other developed countries (Althammer and Mutz 2010; Keller and Levinson 2002) or are single country studies (Bao et al. 2011; He 2006). However, in order to further the findings that in particular the developing world and transition economies may suffer detrimental increases in emissions resulting from trade (Managi et al. 2009), it is of utmost importance that a climate policy stringency measure can also be determined for non-developed countries. The same holds true for implemented regulations to abate global greenhouse gas emissions. The majority of stringency indicators measure environmental policy in general but not climate policy in specific.<sup>4</sup>



**Figure 1:** Implemented energy-related policies and measures to reduce greenhouse gas emissions for a selected set of 28 countries in June 2013<sup>a</sup>

<sup>a</sup> Self-prepared using International Energy Agency 2013a

For these reasons, this paper develops a thorough, internationally comparable, sector-specific measure of multidimensional climate policy stringency. Thereby, van Soest et al.'s (2006) shadow price approach on environmental policy serves as a basis. They use economic theory and choices made by corporations to indirectly determine pollution abatement costs for two sectors and nine Western European countries from 1978 to 1996. The approach is applied to the topic of greenhouse gas emissions and climate policy by determining sector-specific emission relevant energy costs on the basis of the sectors' usage of emission relevant energy carriers and the carriers' respective prices. The resulting shadow price estimates are heterogeneous and can be applied in future research to test for carbon leakage and pollution havens. In this context a major advantage constitutes that the shadow prices are available for a large set of 28 OECD countries including also former transition economies and newly industrialized countries for the majority of primary, secondary, and tertiary sectors from 1995 to 2009. Hence, effects of the Kyoto Protocol and the transformation process after the fall of the Iron Curtain can be included in future analysis with a special emphasis on greenhouse gas emissions.

In the next section the existing literature on empirical measures of environmental and climate policy stringency is reviewed. Then in the sections 2.2 and 3 the general idea of the

<sup>4</sup> An overview of the environmental and climate policy stringency measures can be found in section 2.1.

shadow price approach and the applied methodology to the topic of climate policy are presented. After explaining the used data in section 4, the results of the seemingly unrelated regressions and the estimated shadow prices are provided, discussed, and compared to other measures in section 5. Section 6 concludes.

## **2 Literature**

### **2.1 Environmental and climate policy stringency**

There exist numerous approaches on the empirical measurement of environmental policy stringency as a whole and some on climate policy regulation in specific.<sup>5</sup> Brunel and Levinson (2013a) structure the environmental policy approaches into five groups, namely private sector abatement costs, the direct assessment of individual regulations, composite indices, measures based on pollution or energy use, and measures based on public sector efforts. While the five categories are not entirely mutually exclusive, they include the most important streams of literature. A similar overview is provided by Sauter (2013) for cross country measures that are available for at least 10 countries. Millimet and Roy (2011) review the research on instrumental variables used for environmental stringency. As to date only little research has been carried out exclusively on climate policy stringency, the categories of Brunel and Levinson (2013a) are adopted in the following and the selected articles on climate policy regulation are structured accordingly.

A common approach for measuring environmental policy stringency is to determine private sector pollution abatement costs, which reflect how much more costly firms' production in a given jurisdiction is relative to others as a result of complying with regulations. The data is often obtained with the help of surveys by directly asking industry managers about their pollution abatement expenditures. For instance Levinson (1996) and List and Co (2000) use the annual United States Pollution Abatement Costs and Expenditures (PACE) data, the earliest and most prominent example for this type of survey data. Pasurka (2008) provides a summary of estimates outside of the United States including European countries as well as the questionnaire of the Organisation for Economic Co-operation and Development (OECD). In general, the idea of the surveys of determining a cardinal cost number directly coincides with the data needed to measure stringency. However, the questionnaires face both the conceptual problem that respondents may not be capable to correctly separate corporate expenditures with an environmental intent from the ones with a profit motive and the weakness that all types of abatement costs, even those which cannot be directly attributed to environmental regulation, are included (Brunel and Levinson 2013b). Pasurka (2008) adds that it is difficult to make international comparisons based on the different surveys. As only expenditures of existing companies are represented, the questionnaires may also over- or understate the costs for new firms (Morgenstern et al. 2001). An alternative approach to measuring private sector abatement costs without using the expenditure questionnaires is the shadow price approach. The idea of the shadow price approach, which this paper follows, will be introduced from section 2.2 onwards.

In contrast to measuring the costs implied in all environmental regulation, the second stream of literature narrowly focuses on specific regulations. On the one hand, this is done by utilizing the existence of natural experiments such as the national ambient air quality

---

<sup>5</sup> An extensive overview of environmental policy stringency approaches can be found in Brunel and Levinson (2013b).

standards (NAAQS), which the Clean Air Act in the United States required to be set for six air pollutants. Henderson (1996) uses the NAAQS to analyze the effects of local regulation and finds that greater regulatory efforts in non-attainment counties improve the air quality and results in a relocation of polluting industries to avoid regulatory scrutiny. The launch of the emission trading scheme in the European Union is studied in Kettner et al. (2008) and Yu (2011). While the former measure the differences in stringency in the 24 member states and find that small installations are treated differently from big ones, the latter does not find significant impacts on Swedish energy firms' profits. On the other hand, the ratification and strictness of individual regulations is used as a measure of overall environmental or climate policy stringency. Nakada (2006) examines the relationship between income distribution and the timing of the ratification of the Kyoto Protocol. In order to test for pollution havens, Cole et al. (2006) use the allowed lead content in gasoline. These measures are sensitive to several obstacles, in particular to the multidimensionality of regulations as well as simultaneity (Brunel and Levinson 2013a). The narrow focus of individual regulations and natural experiments limits the generalizability of the results. Given that individual regulations are also dissimilar across countries makes it difficult to create a consistent regulation-based measure of stringency across countries.

The third type of measures rests on compressing the multidimensional regulatory environment down to one holistic index number. An extensive overview of composite indices evaluating country performance from an economic, political, social, and environmental viewpoint is given by Bandura (2008). In order to construct an environmental policy stringency index often surveys serve as a basis. In an early attempt Walter and Ugelow (1979) build an index, which ranks countries on a scale from one, referring to strict, to seven, referring to tolerant, based on the responses of the questionnaire collected by the United Nations Conference on Trade and Development (UNCTAD). Dasgupta et al. (2001) develop a more extensive index for 31 countries using 500 different observations per country from the reports prepared for the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. An environmental stringency index that includes a climate change sub-index is calculated in Cagatay and Mihci (2006) based on the pressure-state-response model of the OECD. Künkel et al. (2006) specifically develop a climate policy index to measure actual policy stringency at the national and the sectoral level for 1992, 1997, and 2005 using predominantly readily available data sources such as the OECD and the International Energy Agency (IEA). Even though these composite indices help to incorporate multiple regulations in one cardinal value, the assessment of the scales can be difficult.<sup>6</sup> Furthermore, the indices are often only available for one cross section and cannot be disaggregated by pollutant (Sauter 2013). While the weighting of the included factors is merely ad hoc limiting the robustness of the indices, the survey indices are based on perceptions and, thus, may be potentially biased.

Measures based on pollution or energy use make use of the relationship between these indicators and environmental regulation. While Xing and Kolstad (2002) as well as Costantini and Crespi (2008) interpret high levels of sulfur dioxide or carbon dioxide emissions on the country level as a sign of low stringency, McConnell and Schwab (1990) assume that high levels of air pollution on the county level force regulators to take actions and, hence, coincide with a high stringency. This inherent simultaneity constitutes a main disadvantage of indices based on pollution or energy use (Brunel and Levinson 2013b). Alternatively,

---

<sup>6</sup> List and Co (2000) solve this problem by ranking states based on their weighted public and private sector pollution abatement expenditures in Dollars.

percentage reductions in carbon dioxide emissions are used in Javorcik and Wei (2003) to measure environmental policy stringency. Cole and Elliot (2003) apply energy intensity data as a stringency index. However, these proxies only expose information on quantities consumed rather than expenditures taken, which at the same time require information on prices.

Lastly, in order to indirectly reflect the regulatory stringency, researchers sometimes use public sector efforts related to the environment, which has the advantage of including an enforcement dimension (Brunel and Levinson 2013b). Whereas Gray (1997) and Magnani (2000) respectively use public expenditures for environmental and natural resources in general and environmental protection in specific, Levinson (1996) includes the number of employees at state environmental agencies relative to the number of manufacturing plants. Analyzing a panel of 29 Chinese provinces between 1992 and 2004, Bao et al. (2010) use a combination of indicators including the government pollution abatement expenses and the number of employees in environmental protection related agencies. The mere shortcoming of these measures lies in their ambiguity as a proxy of stringency, because some types of public expenditures such as tax incentives relieve the private sector from costs. Moreover, given the relative differences in the size of the administrative body across countries complicates an international application.

## **2.2 The shadow price approach**

Like the PACE survey, the shadow price approach aims at determining private sector abatement expenditures as a measure for environmental policy stringency. There exist a number of articles, which calculate pollution abatement costs with the help of shadow prices by including pollutants either as inputs or outputs in the technology. Both Coggins and Swinton (1996) and Färe et al. (2005) determine the shadow price of sulfur dioxide emissions in the electricity generation sector. While the former analyzes 14 coal power plants in Wisconsin from 1990 to 1992, the latter looks at 209 fossil fuel power plants in the United States in the years 1993 and 1997. The phosphorus content of manure is considered as the polluting output in Huhtala and Marklund (2006), who measure its shadow price in the animal agricultural sector in Finland during the period from 1994 to 2002. Using a sample of 30 pulp and paper mills in Wisconsin and Michigan, Pittman (1981) represents an early approach to include pollutants as inputs in order to estimate marginal abatement costs. Van Soest et al. (2006) measure the shadow price of energy use for the heavy metals and the food processing industry for nine Western European countries from 1978 to 1996. By considering energy as the polluting input, which is certainly used in all sectors, their method has the potential to be applied as a measure of environmental policy stringency across a larger set of sectors and geographical coverage as well as over time.

The shadow price approach is based on microeconomic theory and the choices made by companies reflecting their profit maximization behavior. Van Soest et al. (2006, p. 1155) “define the shadow price of an input as the potential reduction in expenditures on other variable inputs that can be achieved by using an additional unit of the input under consideration (while maintaining the level of output).” Hence, in the case of no regulation the price for a polluting input is low and a profit-maximizing firm will use relatively more of the polluting input and less of other variable inputs to produce the same quantity of output. If the regulation is more stringent, e.g. because of a new tax or quota, the price of the polluting input will increase and the firm will use relatively less of the polluting input (Brunel

and Levinson 2013a). In other words, regulation drives a wedge  $\lambda_E$  between a companies' shadow price  $Z_E$  for an additional unit of the polluting input  $E$  and the input's undistorted market price  $p_E$  (Morrison Paul and MacDonald 2003; van Soest et al. 2006):<sup>7</sup>

$$(1) \quad Z_E = p_E + \lambda_E$$

Given that markets are sufficiently integrated internationally, the undistorted market price can be represented by the world price of the polluting input (van Soest et al. 2006). The wedge is then a measure of stringency reflecting either a stricter or a weaker environmental policy regulation than the world average. A positive wedge results in the shadow price being larger than the undistorted market price indicating that the company's or sector's usage of the polluting input is restricted. A negative wedge points at a low stringency and a subsidized usage of the polluting input.

The underlying shadow prices and wedges can be determined by assuming that firms are profit maximizing, which coincides with a cost minimization in the case of competition. This is done by estimating a firm's or sector's cost function with the help of the information revealed in firm's behavior, i.e. data on the level of output, the quantities of all inputs including the polluting input, and the prices of all inputs but the ones of the polluting input.

While having only few drawbacks, the shadow price approach overcomes several shortcomings of the other mentioned approaches.<sup>8</sup> By estimating the abatement costs for a certain pollutant the shadow prices summarize the hidden implications of all direct and indirect regulations in one cardinal cost measure. Therefore, the shadow prices and certainly the resulting wedges allow for comparing the actual policy stringency faced by firms in different sectors, across countries, and over time even if the policy instruments implemented differ. Although the estimates do not merely reflect the stringency faced by new entrants or investments, the shadow price approach controls for the industrial composition and capital vintage as all companies in the specific market are incorporated (Brunel and Levinson 2013a). The covered literature in the beginning of this section also shows that shadow prices can be determined for different kinds of pollutants. Nevertheless, the results are impacted by the selected functional form of the cost or production function as well as the choice of inputs and outputs (Brunel and Levinson 2013a). It should be noted that the shadow prices are a reflection of any policies or market impacts on the costs of the polluting input including government policies other than purely environmental ones and market failures. Yet, this may be seen as an advantage when it comes to assessing the location choice of certain industries from a more comprehensive view (van Soest et al. 2006). All things considered, the shadow price approach is the preferred method for determining the private sector abatement costs of climate policy regulation that are of relevance for the analysis of pollution havens and carbon leakage.

However, the results of van Soest et al. (2006) cannot be used directly as a measure of climate policy stringency mainly because of three reasons. From a technical point of view their shadow prices are rather a measure of energy policy as van Soest et al. do not look exclusively on emission relevant energy carriers but include all energy carriers, meaning also carbon-neutral ones, as polluting inputs in the analysis. In addition, little variability in the sector-specific shadow prices can be attributed to country-specific changes in the wedges.

---

<sup>7</sup> The interpretation of  $Z_E$  and  $p_E$  of van Soest et al. (2006) slightly differs to the one of Morrison Paul and MacDonald (2003), who differentiate between the observed price  $p$  and the effective/shadow price  $Z$ .

<sup>8</sup> For further discussion of advantages and disadvantages of the shadow price approach, see van Soest et al. (2006, pp. 1158-60).



The wedges are estimated for only three time periods and, thus, the shadow prices are strongly influenced by the development of the average market price. It also remains unclear whether the estimated wedge dummy coefficients truly compare to the market average, given that e.g. for the food and beverages industry only five wedges are positive compared to 20 negative ones, which are generally also at least as large in absolute values. Lastly, the data set focusing on only nine developed Western European countries and two industrial sectors can be widened by for instance including transition economies or newly industrialized countries and enlarging the sectoral coverage. More recent data, which includes the impacts of the Kyoto protocol and the multidimensional regulations of the last two decades, may also help increasing the validity of empirical studies working with this data.

### 3 Methodology

To determine each sector's climate policy stringency, the shadow price approach is applied to emission relevant energy costs. For this reason, the respective shadow prices along with a comparatively larger number of wedges are calculated. This is done by estimating a Generalized Leontief cost function and the shadow price equation (1) with the help of a system of seemingly unrelated regressions and by applying Shephard's lemma. The estimated coefficients are then in turn used for the quantification of the sector-specific shadow prices and the wedges.

This paper follows the estimation approach of Morrison Paul and MacDonald (2003), who directly include the shadow price of the input under consideration in the cost function.<sup>9</sup> Like van Soest et al. (2006) an extended version of Morrison's (1988) Generalized Leontief restricted variable cost function is used. The particular cost function facilitates the inclusion of additional inputs by simplifying the cost function developed in Diewert and Wales (1987), which adds technical change and returns to scale to the traditional Generalized Leontief cost function. The used variable cost function  $C$  reads as follows:

$$\begin{aligned}
 (2) \quad C = & y \left[ \sum_L \sum_M \alpha_{LL} p_L^{0.5} p_M^{0.5} + \sum_L \sum_E \alpha_{LE} p_L^{0.5} Z_E^{0.5} + \sum_E \sum_F \alpha_{EE} Z_E^{0.5} Z_F^{0.5} \right] \\
 & + y \left[ \sum_L \sum_A \delta_{LA} p_L s_A^{0.5} + \sum_L p_L \sum_A \sum_B \gamma_{AB} s_A^{0.5} s_B^{0.5} \right] \\
 & + y \left[ \sum_E \sum_A \delta_{EA} Z_E s_A^{0.5} + \sum_E Z_E \sum_A \sum_B \gamma_{AB} s_A^{0.5} s_B^{0.5} \right] \\
 & + y^{0.5} \left[ \sum_L \sum_K \delta_{LK} p_L x_K^{0.5} + \sum_L p_L \sum_A \sum_K \gamma_{AK} s_A^{0.5} x_K^{0.5} \right] \\
 & + y^{0.5} \left[ \sum_E \sum_K \delta_{EK} Z_E x_K^{0.5} + \sum_E Z_E \sum_A \sum_K \gamma_{AK} s_A^{0.5} x_K^{0.5} \right] \\
 & + \sum_L p_L \sum_K \sum_Q \gamma_{KK} x_K^{0.5} x_Q^{0.5} + \sum_E Z_E \sum_K \sum_Q \gamma_{KK} x_K^{0.5} x_Q^{0.5}
 \end{aligned}$$

<sup>9</sup> Looking at the U.S. food processing sector Morrison Paul and MacDonald (2003) found differences between the observed and the shadow price for capital and agricultural goods, but not for labor, energy, and two-materials inputs.

Thereby,  $p_L$  is the price of the variable input  $L$  and the subscripts  $L$  and  $M$  refer to variable inputs.  $Z_E$  is the shadow price of the polluting input  $E$  and the subscripts  $E$  and  $F$  denote variable inputs where the shadow price may be different to the market price. The stock of the quasi-fixed input  $K$  is given by  $x_K$  and the subscripts  $K$  and  $Q$  represent quasi-fixed inputs.  $S$ , which is enumerated by the subscripts  $A$  and  $B$ , stands for exogenous arguments in the cost function such as the output level  $y$  and time  $t$  as a proxy for the state of technology.<sup>10</sup> Finally, the respective coefficients are given by  $\alpha$ ,  $\gamma$ , and  $\delta$ .

In order to estimate the coefficients in the cost function, factor demand functions for both types of variable inputs can be derived based on Shephard's lemma. In addition, input-output ratios are employed to adjust for different sector sizes:<sup>11</sup>

$$(3) \quad x_L y^{-1} = y^{-1} \partial C(p, Z, x, y, \bullet) / \partial p_L$$

and

$$(4) \quad x_E y^{-1} = y^{-1} \partial C(p, Z, x, y, \bullet) / \partial Z_E$$

As consistent sector-specific data is only available for the relatively short time period of 15 years, which coincides with a limited number of degrees of freedom, further assumptions need to be implemented. Given that empirical researchers have found it difficult to isolate the independent impacts of technology, the factor inputs, and the returns to scale, long-run constant returns to scale are assumed to adapt the generality of the cost function (Morrison 1988). Hence, the long-run output elasticities for both variable and quasi-fixed inputs are set equal to one. Moreover, time trends are eliminated as they are normally found to be statistically insignificant (van Soest et al. 2006). Both assumptions translate into setting  $\delta_{LA} = \delta_{EA} = \gamma_{AB} = \gamma_{AK} = 0$ .

For the purpose of estimating the cost function three input factors are used. Labor  $L$  is considered as a fully variable input; emission relevant energy  $E$  is the variable input where due to causes such as climate regulation a wedge can be driven between the shadow price and the market price; and capital  $K$  is assumed to be a quasi-fixed input. As a result, the final specification of the variable cost function can be written as:

$$(5) \quad C = y [\alpha_{LL} p_L^{0.5} + \alpha_{LE} p_L^{0.5} Z_E^{0.5} + \alpha_{EE} Z_E^{0.5}] + y^{0.5} [\delta_{LK} p_L x_K^{0.5} + \delta_{EK} Z_E x_K^{0.5} + \gamma_{KK} p_L x_K^{0.5} + \gamma_{KK} Z_E x_K^{0.5}]$$

By taking the partial derivatives of equation (5) with respect to the price of labor  $p_L$  and the shadow price of energy  $Z_E$  and inserting it into the respective factor demand function, the detailed input-output ratios can be obtained. Furthermore, following Morrison (1988) the interaction effects are assumed to be specific for every sector  $i$  but common across all countries  $c$  and time  $t$ , whereas the direct effects represented by the coefficients  $\alpha_{EE}$  and  $\alpha_{LL}$  are set to be common across time but both sector- and country-specific:

$$(6) \quad x_L y^{-1} = 0.5 \alpha_{LL,i,c} p_L^{-0.5} + 0.5 \alpha_{LE,i} p_L^{-0.5} Z_E^{0.5} + \delta_{LK,i} y^{-0.5} x_K^{0.5} + \gamma_{KK,i} y^{-1} x_K^{0.5}$$

<sup>10</sup> For now, additional sub-subscripts are for clarity reasons left out. In the final estimating model each coefficient is also classified with regard to its country-, sector-, and time-specification.

<sup>11</sup> Other authors use the input-output specification to correct for potential heteroscedasticity, which this paper adjusts for by estimating robust standard errors (Morrison 1988; Morrison and Schwartz 1996; van Soest et al. 2006).

and

$$(7) \quad x_E y^{-1} = 0.5\alpha_{EE,i,c} Z_E^{-0.5} + 0.5\alpha_{LE,i} p_L^{0.5} Z_E^{-0.5} + \delta_{EK,i} y^{-0.5} x_K^{0.5} + \gamma_{KK,i} y^{-1} x_K^{0.5}$$

Besides the system of input-output equations, information about the shadow value of the variable input energy is included for estimation purposes. Therefore, the shadow price equation (1) is specified in more detail. The (undistorted) market price  $p_E$  is given by an average sector-specific (world) market price and its effect is allowed to differ across sectors (van Soest et al. 2006). In order to reconcile the limited number of degrees of freedom with an in-depth analysis of the climate policy stringency, sector- and country-specific wedges for five equally long time periods are estimated.<sup>12</sup> In other words, the wedges are estimated as a markup or markdown by including an interaction effect of the dummy variables  $D$  of each sector, each country, and the time periods 1995-1997, 1998-2000, 2001-2003, 2004-2006, and 2007-2009:

$$(8) \quad Z_E = \beta_{E,i} p_E + \lambda_{E,i,c,t} D_i D_c D_t$$

The final estimating model consists of three equations, namely the two input-output functions (6) and (7) as well as the detailed shadow price equation (8). The estimation is carried out by using seemingly unrelated regressions, a method that has been first specified by Zellner (1962) and allows for the estimation of common coefficients across a system of equations. In order to reflect possible fixed effects and given that each coefficient is at least sector-specific, the individual sectors are estimated independently reducing the complexity for the statistical program at the same time. Robust standard errors are determined to correct for potential heteroscedasticity. As a last step, the estimated coefficients are used to calculate the shadow prices and the wedges as the sector-specific, internationally comparable measure of climate policy stringency.

## 4 Data

### 4.1 Data sources and description

For the implementation of the described cost function estimation, price and quantity information on the production output, the capital and labor employed, and the energy consumption are required. The data is derived from the World Input Output Database (WIOD), the Penn World Tables (PWT), the IEA, and the OECD. Except for the energy price data from the IEA and the capital investment information from the PWT, which is needed for the capital stock estimation<sup>13</sup>, only existing variables from the WIOD are used. Exchange rates and country-specific price indices are taken from the OECD. Currency conversion has been applied to all monetary variables using the exchange rates as well as country- and sector-specific deflators. As the estimated shadow prices are in later research intended to be utilized as a thorough measure for climate policy in order to test for pollution haven or carbon leakage effects, all monetary units are calculated in 2005 prices but not in purchasing

<sup>12</sup> The results are robust to alternative time periods, which may be of the same or different length.

<sup>13</sup> Given that WIOD does not offer sector-specific capital stock information for the whole time period under consideration, the capital stock data is constructed using the methodology explained in appendix A.

power parity. In other words, the goal is to test for misdirecting incentives for investors or plant owners rather than to represent the point of view of a social planner.<sup>14</sup>

The final variables are:

- gross output  $y$  measured in billions of 2005 U.S. dollars
- the capital stock  $x_K$  in billions of 2005 U.S. dollars
- employment  $x_L$  in millions of man years worked
- the average wage  $p_L$  in thousands of 2005 U.S. dollars
- the emission relevant energy use  $x_E$  in millions of tons of oil equivalent
- the energy price  $Z_E$  and the sector-specific average market energy price  $p_E$  in thousands of 2005 U.S. dollars per ton of oil equivalent

With the exception of the average market energy price, all variables are time- and sector-specific at the country level. The set up database covers information on 28 countries disaggregated into 33 sectors<sup>15</sup> over a time period of 15 years from 1995 to 2009. This corresponds to more than 13,500 observations compared to roughly 300 observations on nine countries and two sectors in van Soest et al. (2006) and, therefore, allows for a more detailed application of the approach. *Table 1* provides an overview of all included nations.

---

<b>Asia and Oceania (4 countries)</b>
Australia, Japan, Korea, Turkey
<b>Americas (3 countries)</b>
Canada, Mexico, United States
<b>Eastern Europe (6 countries)</b>
Czech Republic, Estonia, Hungary, Poland, Slovak Republic, Slovenia
<b>European Union 1995 (15 countries)</b>
Austria, Belgium, Denmark, Finland, France, Germany, Great Britain, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden

---

**Table 1:** Country overview (in total 28 countries)

The 28 countries and 33 agricultural, industrial, and service sectors are in accordance with the structure of the main data source WIOD, which organizes the sectors based on the division-level ISIC Rev. 3.1<sup>16</sup> classifiers. Due to insufficient data on either energy prices or capital stocks, several countries from the original database and the sectors air transport (ISIC 62) and private households with employed personal (ISIC 95) are excluded. Nevertheless, the final data set covers the whole range of primary, secondary, and tertiary sectors as well as a comparatively large number of countries including former transition economies from Eastern Europe and the newly industrialized countries Mexico and Turkey. In addition, effects of the Kyoto protocol and of the integration of the former Eastern Block countries can be analyzed.

---

<sup>14</sup> Shadow prices have also been estimated using PPP units. This resulted in a tendency of higher shadow prices for poorer countries, which can be interpreted such that poorer economies spend a relatively higher share of income on emission relevant energy use or, in other words, on costs resulting from climate policy regulation.

<sup>15</sup> *Table B.1* in appendix B lists all included 33 sectors.

<sup>16</sup> ISIC refers to the International Standard Industrial Classification of All Economic Activities.

## 4.2 Energy price computation

One important reason why van Soest et al.'s (2006) approach – despite its advantages over other measures – has not yet been applied to a larger set of countries and industries is the lack of consistent data on energy prices on the sectoral level. Thus, a major innovation of this paper represents the determination and subsequent application of sector-specific energy prices across the comparatively large set of countries. The energy prices in this paper are in general calculated as a weighted average based on the prices of seven energy carriers used and the associated carriers' sector-specific volumes.

The country-specific data of the IEA on industry and household energy prices of seven energy carriers, namely electricity, coal, natural gas, diesel, gasoline, heavy fuel oil, and light fuel oil, is used as the foundation. In the first step, missing values of these energy prices are determined using the respective PAASCHE price indices. As the IEA also provides a country-specific total energy PAASCHE price index, the average energy price of the remaining energy sources  $Z_E^{REST}$  can be calculated with the help of this index, the derived prices of the seven energy carriers, and the associated gross energy uses  $x_{E^{Total}}$  given in WIOD<sup>17</sup>. In doing so, it is necessary to assume that the weighted average energy price  $Z_E^{KNOWN}$  of the seven energy carriers  $j$  in some (base) year 0 is equal to the price of the remaining sources in the same year and, consequently, also to the total average industry or household energy price  $\bar{Z}_E$ :

$$(9) \quad Z_{E_{0,c}}^{KNOWN} = \left( \sum_j Z_{E_{0,j,c}} x_{E_{0,j,c}}^{Total} \right) / \sum_j x_{E_{0,j,c}}^{Total} = Z_{E_{0,c}}^{REST} = \bar{Z}_{E_{0,c}}$$

For every country  $c$  the year with the highest explained share of the seven energy carriers in the total gross energy use is chosen as the (base) year.<sup>18</sup> The final energy prices, which are specific for every sector  $i$  and only include emission relevant energy use, are then given by a weighted average of the energy carriers' prices and their sector-specific emission relevant energy uses  $x_E$ :

$$(10) \quad Z_{E_{t,i,c}} = \left( \sum_j Z_{E_{t,j,c}} x_{E_{t,j,c}} + Z_{E_{t,c}}^{REST} x_{E_{t,i,c}}^{REST} \right) / \left( \sum_j x_{E_{t,j,c}} + x_{E_{t,i,c}}^{REST} \right) \\ = \left( \sum_j Z_{E_{t,j,c}} x_{E_{t,j,c}} + Z_{E_{t,c}}^{REST} x_{E_{t,i,c}}^{REST} \right) / x_{E_{t,i,c}}$$

For this computation the industry prices of the energy carriers have been assigned to all industry sectors and the household prices to the service and agricultural sectors.<sup>19</sup> Two exceptions constitute heavy fuel oil and gasoline, where only industry prices for the former

<sup>17</sup> The gross energy use includes the use of both energy carriers that are relevant for emissions and the ones that do not emit emissions.

<sup>18</sup> If all observations are included – also the ones that are not in the (base) year – the seven energy sources on average make up 86 percent of the total sectors' energy use, which is relevant for emissions and, hence, for climate policy issues. As for some years data is not available for all seven energy carriers, the explained share in the (base) years only is even higher and, therefore, considered a reasonable estimate for the respective year's average energy price. In the remaining years the total average energy price is determined by the total energy PASCHE price index.

<sup>19</sup> Table C.1 in appendix C summarizes the assignment of industry and household prices of the energy sources to the sectors.

and household prices for the later are available and are, therefore, assigned to all sectors. The rationale is that for the set of analyzed countries automobile gasoline is assumed to be primarily sold at publicly available gas stations, which serve customers from all sectors. Similarly, in the rare instances that a non-industry customer purchases heavy fuel oil, it is believed that they are likely to participate in the same market like industrial clients.

In addition, the (undistorted) market energy price needs to be determined. Following van Soest et al. (2006), who calculate an average market price across their nine analyzed European nations, a sector-specific average market price across all 28 countries  $c$ , which includes emission relevant energy use only, is employed. The average market energy price  $p_E$  is calculated as a weighted average of the individual sector- and country-specific energy prices in a particular year  $t$  and the respective emission relevant energy uses, which are used as weights:

$$(11) \quad p_{E_{t,i}} = \left( \sum_c Z_{E_{t,i},c} x_{E_{t,i},c} \right) / \sum_c x_{E_{t,i},c}$$

## 5 Results and discussion

In the following the estimated results from the cost function approach are presented for two exemplary sectors. Then, the characteristics of the measure are discussed in general and subsequently the results are compared to other measures.

### 5.1 Analysis of two exemplary sectors

Given the large size of the dataset including 33 sectors in 28 countries, first the results of two exemplary sectors are presented and discussed in more detail to analyze the structure of the estimated shadow prices and respective wedges. One potential application of the climate policy stringency measure is to determine whether pollution haven effects and carbon leakage exist. For this reason, based on the amended carbon leakage list of the European Commission (2012) the chemicals and chemical products sector as well as the inland transport sector are selected. While the former sector is potentially prone to carbon leakage, the latter one in theory should not be.

*Table 2* provides a selected part of the regression results of the chemicals and the inland transport sector. In order to account for the limited space, a complete overview of the estimated regression results can be found in *table D.1* in appendix D. The regression estimates of the remaining sectors are happily provided by the authors upon request.

With regards to the validity of the selected functional form an inspection of the estimated direct effects  $\alpha_{EE}$  and  $\alpha_{LL}$  of the variable inputs energy and labor reveals no significant negative coefficient for all countries. In other words, the estimated signs are as expected and a price increase in one of the variable inputs, ceteris paribus, generally results in a rise in variable costs. The global concavity condition concerning the variable input prices of energy and labor as well as the global convexity condition regarding the quasi-fixed input capital have been ensured by computing the second order partial derivatives of the variable cost function (5).

		Chemicals and chemical products			Inland transport		
		Coefficient <sup>a</sup>		(SE)	Coefficient <sup>a</sup>		(SE)
Common coefficients	$\alpha_{LE}$	-0.001	***	(0.000)	0.000		(0.000)
	$\delta_{LK}$	0.000		(0.000)	-0.001	***	(0.000)
	$\delta_{EK}$	0.015	***	(0.003)	0.006	***	(0.001)
	$\gamma_{KK}$	0.001	***	(0.000)	0.005	***	(0.001)
	$\beta_E$	1.341	***	(0.076)	1.287	***	(0.056)
Netherlands	$\alpha_{LL}$	0.017	***	(0.001)	0.058	***	(0.003)
	$\alpha_{EE}$	0.047	***	(0.002)	0.021	***	(0.002)
	$\lambda_{E,95-97}$	-0.131	***	(0.009)	0.827	***	(0.105)
	$\lambda_{E,98-00}$	-0.128	***	(0.008)	0.490	***	(0.034)
	$\lambda_{E,01-03}$	-0.130	***	(0.009)	0.377	***	(0.019)
	$\lambda_{E,04-06}$	-0.114	***	(0.011)	0.467	***	(0.025)
	$\lambda_{E,07-09}$	-0.019		(0.019)	0.496	***	(0.056)

**Table 2:** Selected regression results

<sup>a</sup> Significance codes: \* p<.10, \*\* p<.05, \*\*\* p<.01

The estimated wedge coefficients  $\lambda_E$  can serve as a first indicator for the stringency of climate regulation. For instance, in the case of the Netherlands the coefficient is negative and highly significant for the chemicals sector until the year 2006 and positive and highly significant for the inland transport sector for every time period. This hints at an initial subsidization and subsequent reduction of the preferential treatment of the chemicals sector and a restrictive climate policy for the inland transport sector.

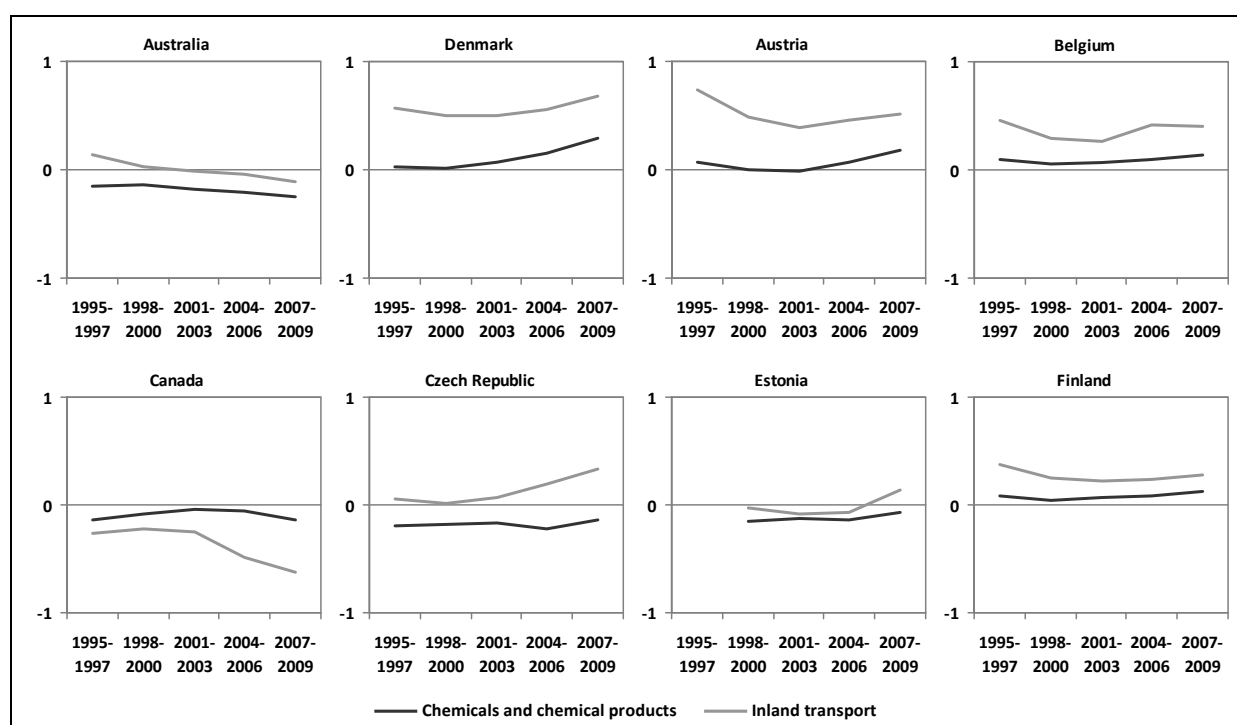
Based on the estimated coefficients the sector-specific shadow prices can be quantified. In *table 3* the ranking of the 28 countries according to their average shadow price is shown for the two exemplary sectors.<sup>20</sup> Likewise, *table E.1* in appendix E provides the rankings for the 31 remaining sectors. The shadow prices are compared to the end-1970s to the mid-1990s environmental policy stringency estimates of van Soest et al. (2006) in a similar range but larger, which affirms the credibility of the results and may be explained by generally higher regulatory efforts since then and by the later base year in this paper. The average shadow prices also support the first impression of the wedge coefficients. In particular the ranking for the inland transport sector confirms popular opinions about climate policy stringency with Germany along with the majority of the other Western European countries having the strictest regulations and the Northern American countries the weakest. This reflects the different emission relevant energy costs borne by the transport sector in each country, i.e. predominantly cost differences in the fuels caused by regulation. Interestingly, the regional distribution for the chemicals sector is much more diverse. While the Netherlands is among the Western European forerunners regarding climate policy stringency in the inland transport sector, it is the only Western European nation placed in the fourth quartile in the chemicals industry. Moreover, four out of the five countries with the lowest climate policy stringency in the chemicals sector are either a former transition economy or a newly industrialized country proving potential incentives for carbon leakage. *Table 3* also displays the minimum and maximum levels of the shadow prices between 1995 and 2009, which show large differences and are a first indication for large variation inherited in the measure over time. This picture is confirmed by the temporal development of the estimated wedges for the two sectors presented in *figure 2*. A heterogeneous development seems to exist not only internationally, but also within the same country and over time.

<sup>20</sup> The rankings look the same based on the wedge coefficients.

Chemicals and chemical products					Inland transport				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Italy	0.894	(0.276)	0.615	1.363	1 Germany	1.657	(0.309)	1.319	2.293
2 Slovenia	0.886	(0.195)	0.610	1.139	2 Denmark	1.434	(0.317)	1.137	2.115
3 Japan	0.802	(0.077)	0.685	0.911	3 Sweden	1.431	(0.206)	1.150	1.880
4 Luxembourg	0.783	(0.294)	0.480	1.280	4 Netherlands	1.403	(0.266)	1.047	1.931
5 Portugal	0.715	(0.128)	0.540	0.927	5 Great Britain	1.402	(0.254)	1.039	1.852
6 Ireland	0.713	(0.126)	0.582	0.967	6 Austria	1.390	(0.265)	1.061	1.953
7 Germany	0.635	(0.131)	0.488	0.877	7 Italy	1.306	(0.341)	0.983	1.990
8 Denmark	0.627	(0.200)	0.424	0.990	8 Belgium	1.239	(0.299)	0.929	1.839
9 Belgium	0.610	(0.130)	0.457	0.845	9 France	1.193	(0.312)	0.906	1.836
10 Finland	0.594	(0.125)	0.447	0.826	10 Ireland	1.188	(0.285)	0.902	1.772
11 Hungary	0.588	(0.202)	0.366	0.933	11 Turkey	1.182	(0.486)	0.744	2.105
12 Sweden	0.583	(0.130)	0.444	0.817	12 Slovenia	1.179	(0.375)	0.664	1.766
13 Austria	0.577	(0.166)	0.395	0.881	13 Finland	1.144	(0.257)	0.887	1.715
14 Greece	0.540	(0.116)	0.417	0.768	14 Portugal	1.119	(0.387)	0.794	1.910
15 Korea	0.530	(0.079)	0.419	0.686	15 Luxembourg	1.111	(0.213)	0.868	1.606
16 Great Britain	0.509	(0.125)	0.370	0.735	16 Hungary	1.108	(0.350)	0.737	1.741
17 France	0.493	(0.110)	0.362	0.679	17 Japan	1.093	(0.141)	0.937	1.472
18 Spain	0.485	(0.106)	0.367	0.689	18 Poland	1.018	(0.408)	0.609	1.799
19 Slovak Republic	0.462	(0.219)	0.245	0.863	19 Czech Republic	1.008	(0.378)	0.656	1.773
20 Mexico	0.447	(0.137)	0.270	0.657	20 Greece	0.990	(0.359)	0.670	1.723
21 Canada	0.423	(0.087)	0.316	0.565	21 Spain	0.967	(0.346)	0.627	1.639
22 United States	0.419	(0.042)	0.364	0.493	22 Estonia	0.912	(0.338)	0.588	1.571
23 Netherlands	0.411	(0.140)	0.274	0.680	23 Slovak Republic	0.892	(0.373)	0.499	1.683
24 Estonia	0.405	(0.139)	0.260	0.636	24 Korea	0.882	(0.353)	0.546	1.549
25 Turkey	0.396	(0.163)	0.258	0.717	25 Australia	0.871	(0.198)	0.661	1.325
26 Poland	0.341	(0.095)	0.216	0.510	26 United States	0.589	(0.176)	0.409	1.004
27 Czech Republic	0.334	(0.111)	0.227	0.558	27 Mexico	0.518	(0.113)	0.354	0.777
28 Australia	0.330	(0.068)	0.227	0.454	28 Canada	0.504	(0.114)	0.388	0.810

**Table 3:** Country ranking for the two exemplary sectors based on the average shadow price<sup>a</sup>

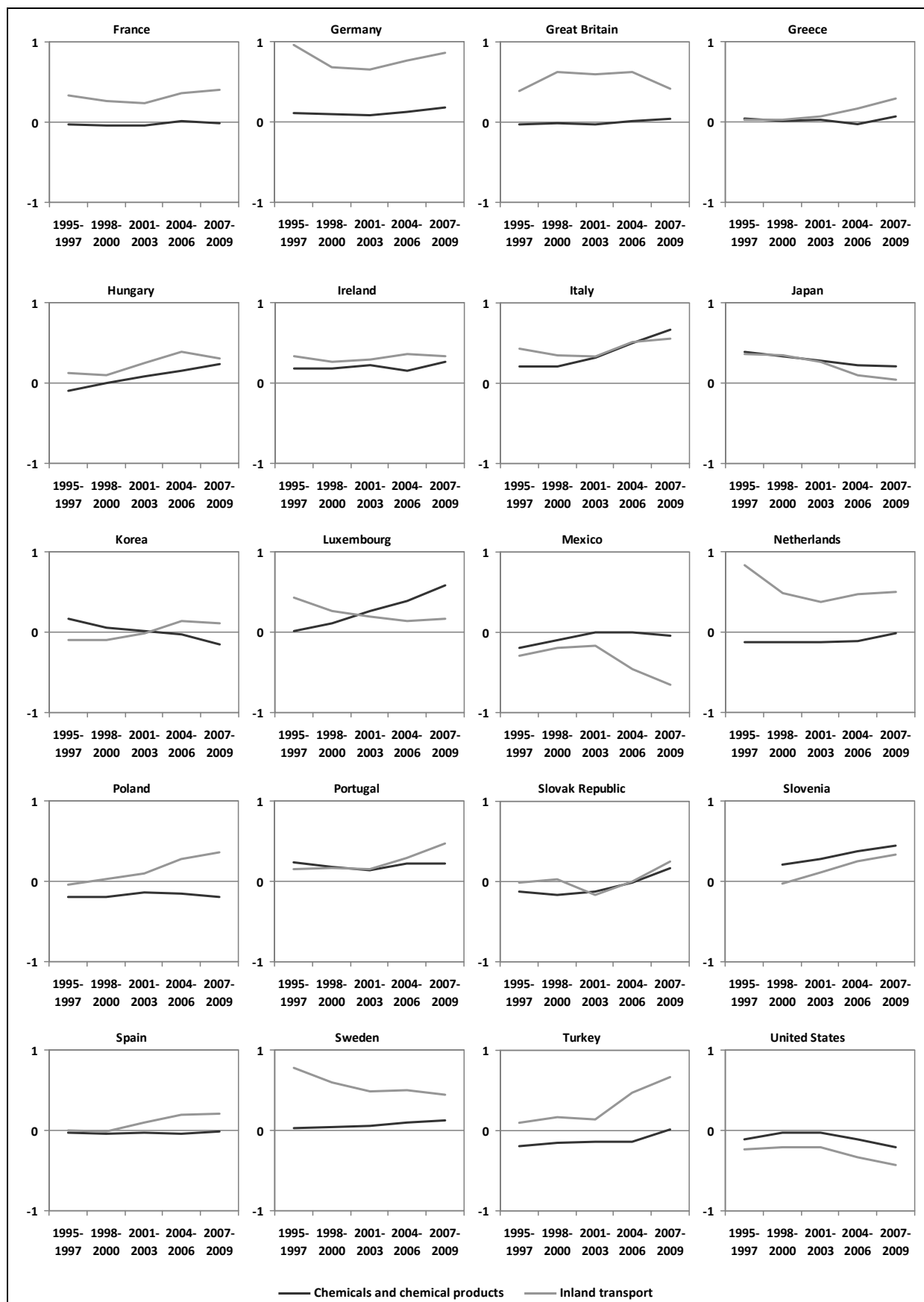
<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent



**Figure 2:** Country-wise overview of wedges<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent





**Figure 2 (cont.):** Country-wise overview of wedges<sup>a</sup>  
<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

## 5.2 General characteristics of the shadow prices and the wedges

Three deductions can be derived from the analysis of the two exemplary sectors, which also hold true for the estimates of the remaining sectors. Firstly and most obviously, countries lay different weight on climate policy regulation. Whereas e.g. the United States has a relatively low stringency across all 33 sectors with 97 percent of the sectors being in either the third or fourth quartile of the rankings, Germany as a representative of the Western European countries has a comparatively high stringency with 94 percent of the sectors being in first and second quartile. This impression is validated by *table 4*, which shows the country ranking of the shadow prices on an aggregated level across all sectors as well as across manufacturing and service sectors only. Taking all sectors into account the United States has on average the 25<sup>th</sup> highest shadow price as opposed to Germany that places sixth among the 28 analyzed countries.

	All sectors					Manufacturing sectors			Service sectors		
	Rank	AVG	(SD)	MIN	MAX	Rank	AVG	(SD)	Rank	AVG	(SD)
Denmark	1	1,715	(0,881)	0,193	3,313	7	0,708	(0,195)	1	2,110	(0,681)
Italy	2	1,291	(0,455)	0,387	2,500	1	0,978	(0,428)	5	1,479	(0,378)
Sweden	3	1,261	(0,502)	0,363	2,052	11	0,640	(0,127)	2	1,569	(0,302)
Japan	4	1,260	(0,446)	0,141	2,110	3	0,857	(0,213)	4	1,492	(0,365)
Austria	5	1,205	(0,529)	0,225	2,387	12	0,595	(0,217)	3	1,501	(0,390)
Germany	6	1,136	(0,460)	0,147	2,364	8	0,707	(0,172)	6	1,393	(0,419)
Portugal	7	1,131	(0,409)	0,296	2,162	6	0,721	(0,234)	7	1,337	(0,367)
Luxembourg	8	1,107	(0,310)	0,292	1,606	5	0,762	(0,256)	13	1,168	(0,273)
Netherlands	9	1,063	(0,477)	0,175	2,133	23	0,502	(0,191)	8	1,337	(0,345)
Ireland	10	1,057	(0,366)	0,370	1,943	4	0,811	(0,221)	10	1,205	(0,369)
Great Britain	11	1,038	(0,399)	0,194	1,870	13	0,591	(0,169)	9	1,212	(0,327)
Slovenia	12	0,999	(0,274)	0,429	1,766	2	0,902	(0,229)	18	1,053	(0,299)
Spain	13	0,994	(0,383)	0,249	1,956	15	0,582	(0,161)	11	1,188	(0,353)
Belgium	14	0,968	(0,352)	0,171	1,839	10	0,647	(0,203)	14	1,130	(0,333)
Greece	15	0,944	(0,328)	0,277	1,723	16	0,579	(0,193)	17	1,060	(0,299)
France	16	0,892	(0,325)	0,255	1,836	21	0,520	(0,151)	19	1,041	(0,263)
Finland	17	0,886	(0,308)	0,294	1,715	14	0,591	(0,140)	15	1,084	(0,231)
Turkey	18	0,884	(0,386)	0,035	2,105	18	0,557	(0,230)	16	1,065	(0,316)
Korea	19	0,866	(0,372)	0,140	1,549	20	0,541	(0,167)	12	1,180	(0,266)
Australia	20	0,805	(0,316)	0,227	1,502	27	0,453	(0,185)	20	0,956	(0,224)
Estonia	21	0,757	(0,285)	0,237	1,571	22	0,515	(0,146)	22	0,883	(0,250)
Slovak Republic	22	0,744	(0,423)	0,172	2,519	19	0,553	(0,253)	23	0,876	(0,476)
Hungary	23	0,714	(0,298)	0,275	1,741	9	0,649	(0,227)	26	0,762	(0,339)
Poland	24	0,709	(0,343)	0,088	1,799	28	0,413	(0,169)	21	0,915	(0,307)
United States	25	0,683	(0,207)	0,232	1,203	24	0,467	(0,133)	25	0,764	(0,182)
Czech Republic	26	0,619	(0,344)	0,152	1,773	26	0,455	(0,257)	24	0,766	(0,351)
Mexico	27	0,614	(0,171)	0,201	1,004	17	0,567	(0,163)	27	0,672	(0,146)
Canada	28	0,580	(0,159)	0,254	0,993	25	0,462	(0,125)	28	0,649	(0,154)

**Table 4:** Country ranking for aggregated sectors based on the weighted average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

At the same time, *table 4* reveals regional differences in stringency. The majority of Western European countries can be found in the first and second quartile not only on average across all sectors, but also when analyzing the aggregated manufacturing and service sectors separately. The opposite holds true for the Northern American along with the Eastern European countries that on average place in the third and fourth quartile. Moreover, on the sectoral level some regions show similar developments in stringency as can be seen in *tables*

*F.1* and *F.2* in appendix F for the two exemplary sectors. The wedges of the inland transport sector of the Northern American countries are very highly positively correlated with each other and at the same time negative correlation coefficients are displayed between the Northern American countries and the Eastern European as well as the majority of Western European countries. This indicates regionally integrated markets in the inland transport sector and that North America is heading a different road with regard to climate policy stringency than Europe during the analyzed time period. Similarly, in the chemicals sector the wedges of the Western European countries are, apart from minor exceptions for France, all positively correlated between each other and negatively correlated with the wedges of Canada and the United States.

Secondly, within countries sectors are in parts treated differently. In *table 5* both high positive and high negative correlation coefficients are found between the wedges of the chemicals and the inland transport sector inside the same country. A similar picture appears for intra-country correlations among other sectors. This may be the result of different policy regulation faced by the sectors, e.g. in order to protect certain sectors from international competition or to restrain carbon leakage, but can also indicate that the impact of regulation varies across sectors. Interestingly, on the aggregated level, as displayed in *table 4*, it can be observed that on average for each country the abatement costs per emission relevant energy unit are higher for service sectors than for manufacturing sectors. In other words, service sectors seem to face stricter relative climate policy regulation. Yet, as energy-intense industries use higher amounts of emission relevant energy, their total abatement costs are higher. In this respect the shadow price measure seems to closely reflect reality given that manufacturing sectors in general or energy-intense industries in specific are occasionally relieved from the costs of (climate) policy regulation and that large industrial consumers are likely to have a higher bargaining power.<sup>21</sup>

Australia	0.997	Great Britain	-0.681	Poland	-0.182
Austria	0.723	Greece	0.509	Portugal	0.855
Belgium	0.794	Hungary	0.783	Slovak Republic	0.803
Canada	0.639	Ireland	-0.005	Slovenia	0.998
Czech Republic	0.319	Italy	0.956	Spain	0.363
Denmark	0.975	Japan	0.993	Sweden	-0.816
Estonia	0.867	Korea	-0.778	Turkey	0.800
Finland	0.558	Luxembourg	-0.766	United States	0.994
France	0.677	Mexico	-0.197		
Germany	0.990	Netherlands	0.515		

**Table 5:** Country-wise correlation coefficients between the wedges of the chemicals and the inland transport sector

Thirdly, the sector-specific climate policy stringency is heterogeneous over time. In the most extreme cases some countries change within the 15 year time period from relatively subsidizing a certain sector to a restrictive policy and vice versa. For instance for the chemicals sector Korea starts with a positive and highly significant wedge for the period 1995 to 1997 and ends with a negative and highly significant wedge for the period 2007 to 2009. For the inland transport sector the picture is the opposite. While this variability over time is likely to be in parts attributed to changes in the regulatory environment, it seems unlikely that the heterogeneity of the shadow price measure can be matched with an equal

<sup>21</sup> There exist quite a number of examples for the differentiated treatment of sectors including the implementation of the European Union Emission Trading System and the distribution of the costs of the German Renewable Energy Act.

variability of the individual regulations. Hence, the estimated measure allows analyzing the actual stringency faced by firms and private investors in the market. This is seen to be of utmost importance to facilitate testing for misdirecting incentives of climate policy regulation.

### 5.3 Comparison to alternative measures

As the last step of the discussion the estimates of the shadow price indicator are compared to other measures of environmental and climate policy stringency. For this reason, additional indicators are derived by extending the data with supplementary information from the environmental accounts of the main data source WIOD. The 18 sector-specific indicators, that all fall into the category of measures based on pollution or energy use as reviewed in section 2.1, can be classified into three groups, namely gross energy use per output, greenhouse gas emissions per output, and reductions in greenhouse gas emissions or in gross energy use per output. Gross energy use per output is commonly used as a measure of sector-specific energy efficiency. Besides the price of energy, energy use is one of the determinants of the energy costs and a production input. By arguing that strict regulation may limit the consumption of polluting energy carriers and result in increased energy efficiency, research has used energy intensity as a measure of environmental policy stringency before. Greenhouse gas emissions as a polluting output are a direct result of using emission relevant energy carriers such as fossil fuels. As indicated before both high and low levels of emissions have been used as a measure of stringency. For the following eight gases emission intensities are calculated: Carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), mono-nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), and ammonia (NH<sub>3</sub>). In addition, reductions in emission intensities and in energy intensities are determined. Earlier researchers interpret relatively large reductions as a reaction to stricter regulatory constraints. In general, data is available for the whole time period from 1995 to 2009 for all 28 countries and 33 sectors included in the dataset.<sup>22</sup> For the reductions in intensities values can be calculated from 1996 to 2009.

The *tables F.3* and *F.4* in appendix F show the correlation coefficients between the different measures for the chemicals and the inland transport sector. On the one hand, some moderate and high correlations can be observed between indicators of the same group and between energy intensity and the emission intensities. For instance for both sectors the shadow prices are highly correlated to the wedges and correlation coefficients above 0.50 can be found between the carbon dioxide emission intensity and both the energy intensity and the intensity of mono-nitrogen oxides. Not surprisingly, this reconfirms the significant relationship between the wedges and the shadow prices and indicates that the use of energy entails polluting a mix of emissions. On the other hand, there exist no high correlations between measures of different groups, i.e. the shadow prices and the wedges are not highly correlated to any other measure and the gross intensities are not highly correlated to the reduction in intensities. Thus, the high variability of the shadow price indicator, which is derived using both energy price and quantity information, cannot be matched by measures focusing on only one of the two dimensions or their effects.

---

<sup>22</sup> Nevertheless, the dataset contains some missing data points.

The findings are supported by van Soest et al. (2006), who compare a methodologically similar sector-specific shadow price measure of environmental policy stringency to four other country-wide indicators and find no high correlations between the indicators. Namely the share of environmental tax revenues of the total revenues from taxes and social contributions, the ratio of public environmental R&D expenditures to the GDP, the per capita membership in environmental organizations, and the lead content in gasoline are compared to the shadow prices of energy. Van Soest et al. (2006) conclude that countrywide measures are not good indicators in explaining variations in international competitiveness between sectors as differences in regulatory stringency exist both between countries and between sectors within one country.

## 6 Conclusion

Given the need for a theoretically consistent, internationally comparable, sector-specific measure of multidimensional climate policy stringency, this paper for the first time applies the shadow price approach of environmental policy stringency to the topic of climate policy. Annual shadow prices and the respective wedges, which indicate the regulatory stringency, are estimated based on sector-specific emission relevant energy costs. For this reason, sector-specific energy prices are determined with the help of the prices of seven common emission relevant energy carriers and their corresponding sector-specific usage. The high degree of detail incorporated in the data as well as the focus on shorter three year time periods for the wedges allow for estimating a heterogeneous measure with increased variability over time. The climate policy stringency is computed for 33 primary, secondary, and tertiary sectors for a comparatively large set of 28 OECD countries between 1995 and 2009. Not only highly developed countries, but also former transition economies from Eastern Europe and the newly industrialized countries Mexico and Turkey are included in the analysis. These are potential locations for outsourcing activities in the 1990s and the beginning of the 21<sup>st</sup> century for Western European and Northern American companies and, therefore, of interest for applying the measure in future research.

Despite the large coverage of the dataset, the study leaves room for improvement predominantly owing to the unavailability of data. First, the limited number of non-highly developed economies can be further increased by also including developing and non-OECD countries allowing for an even greater applicability of the measure. Prospects for this are good, because the United Nations Statistical Division has launched a project to extend the main data source WIOD in both geographical and time coverage (Sauter 2013). Thus, the estimation of the shadow prices and wedges can then be continued for the years after 2009, which is considered to be important to examine the future development of climate policy stringency while fighting climate change.<sup>23</sup> As a result of the limited number of 28 included countries, the average market price may not necessarily reflect the world market average in the case of insufficiently internationally integrated input markets. Hence, the wedges may merely represent a comparative measure of climate policy stringency across the included set of countries.<sup>24</sup> However, this does not limit the applicability as a relative measure of stringency, because the international ranking of and the differences between the shadow

---

<sup>23</sup> In other words, the measure is likely not to become another one that cannot be further extended due to the unavailability of data. Examples for this are the indices of Dasgupta et al. (2001) and Eliste and Fredriksson (2002).

<sup>24</sup> For instance a negative estimated wedge may only indicate that the country is subsidizing the usage of the polluting input relative to the rest of the included countries.

prices as well as the wedges are not altered. A second disadvantage is that the energy prices are like in van Soest et al. (2006) measured in average terms. Certainly marginal prices of energy would be preferred, but in order to determine them additional information e.g. about substitution possibilities are required. Moreover, the estimated climate policy stringency measure does not solve the above mentioned general weaknesses of shadow price approaches, namely the focus on cost data for existing firms and the dependence on the selected functional form of the cost function.<sup>25</sup>

All in all, it is believed that the estimated shadow prices and wedges are a strong cardinal measure of climate policy stringency. Consequently, an extension of the timeframe and the geographical coverage is, subject to the availability of the data, regarded as one of the tasks of future research. Given that the measure reflects sector-specific private compliance costs and is available for primary, secondary, and tertiary sectors it may help to clarify how climate policy abatement efforts influence economic activity. Potential applications are not limited to the discussion about the existence of carbon leakage and pollution havens. One may also test for impacts of climate policy stringency on greenhouse gas emissions, labor markets, and innovation or for implications of historic events like the fall of the iron curtain and the Kyoto protocol. This paper provides estimates of a thorough relative measure of climate policy stringency to analyze these different policy concerns.

## References

- Althammer, W., Mutz, C., 2010. Pollution havens: Empirical evidence for Germany. Paper presented at the Fourth World Congress of Environmental and Resource Economists in Montreal, Canada.
- Bandura, R., 2008. A survey of composite indexes measuring country performance: 2008 update. UNDP/ODS Working paper, United Nations Development Programme.
- Bao, Q., Chen, Y., Song, L., 2011. Foreign direct investment and environmental pollution in China: A simultaneous equations estimation. *Environment and Development Economics*, 16(1), 71-92. <http://dx.doi.org/10.1017/S1355770X10000380>
- Brunel, C., Levinson, A., 2013a. Evaluating measures of environmental regulatory stringency. Working paper, August 7, 2013, Georgetown University.
- Brunel, C., Levinson, A., 2013b. Measuring environmental regulatory stringency. OECD Trade and Environment Working Papers, No. 2013/05, OECD Publishing. <http://dx.doi.org/10.1787/5k41t69f6f6d-en>
- Cagatay, S., Mihci, H., 2006. Degree of environmental stringency and the impact on trade patterns. *Journal of Economic Studies*, 33(1), 30-51. <http://dx.doi.org/10.1108/01443580610639884>
- Caselli, F., 2005. Accounting for cross-country income differences. In P. Aghion and S. N. Durlauf (Eds.), *Handbook of Economic Growth* (pp. 679-741). Amsterdam, The Netherlands: Elsevier B. V. . [http://dx.doi.org/10.1016/S1574-0684\(05\)01009-9](http://dx.doi.org/10.1016/S1574-0684(05)01009-9)

---

<sup>25</sup> With regard to the cost function explained in section 3 this paper follows the approach of van Soest et al. (2006), who take all cost information as exogenously given and, hence, cannot explain changes in explanatory variables of the cost function.

- Coggins, J. S., Swinton, J. R., 1996. The price of pollution: a dual approach to valuing SO<sub>2</sub> allowances. *Journal of Environmental Economics and Management*, 30(1), 58-72. <http://dx.doi.org/10.1006/jeem.1996.0005>
- Cole, M. A., Elliot, R. J. R., 2003. Do environmental regulations influence trade patterns? Testing old and new trade theories. *The World Economy* 26(8), 1163-1186. <http://dx.doi.org/10.1111/1467-9701.00567>
- Cole, M. A., Elliot, R. J. R., Fredriksson, P. G., 2006. Endogenous pollution havens: Does FDI influence environmental regulations?. *Scandinavian Journal of Economics*, 108(1), 157-178. <http://dx.doi.org/10.1111/j.1467-9442.2006.00439.x>
- Costantini, V., Crespi, F., 2008. Environmental regulation and the export dynamics of energy technologies. *Ecological Economics*, 66(2-3), 447-460. <http://dx.doi.org/10.1016/j.ecolecon.2007.10.008>
- Copeland, B. R., Taylor, M. S., 2004. Trade, growth, and the environment. *Journal of Economic Literature*, 42(1), 7-71. <http://dx.doi.org/10.1257/002205104773558047>
- Dasgupta, S., Mody, A., Roy, S., Wheeler, D., 2001. Environmental regulation and development: A cross-country empirical analysis. *Oxford Development Studies*, 29(2), 173-187. <http://dx.doi.org/10.1080/13600810125568>
- Diekmann, J.; Kemfert, C., Neuhoﬀ, K., 2012. The proposed adjustment of Germany's renewable energy law: A critical assessment. *DIW Economic Bulletin*, 6, 3-9.
- Diewert, W. E., Wales T. J., 1987. Flexible functional forms and global curvature conditions. *Econometrica*, 55(1), 43-68. <http://dx.doi.org/10.2307/1911156>
- Dröge, S., 2009. Tackling leakage in a world of unequal carbon prices. Project report, Climate Strategies.
- Ederington, J., Levinson, A., Minier, J., 2004. Trade liberalization and pollution havens. *Advances in Economic Analysis & Policy*, 4(2), 1330-1330. <http://dx.doi.org/10.2202/1538-0637.1330>
- Eliste, P., Fredriksson, P. G., 2002. Environmental regulations, transfers, and trade: Theory and evidence. *Journal of Environmental Economics and Management*, 43(2), 234-250. <http://dx.doi.org/10.1006/jeem.2000.1176>
- European Commission, 2012. Commission Decision of 24 December 2009 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 (notified under document C(2009) 10251) (Text with EEA relevance), amended by Commission Decision 2011/745/EU of 11 November 2011 and Commission Decision 2012/498/EU of 17 August 2012. Treaty on the functioning of the European Union.
- Färe, R., Grosskopf, S., Noh, D.-W., Weber, W., 2005. Characteristics of a polluting technology: Theory and practice. *Journal of Econometrics*, 126(2), 469-492. <http://dx.doi.org/10.1016/j.jeconom.2004.05.010>
- Gray, W., 1997. Manufacturing plant location: Does state pollution regulation matter?. NBER Working Paper Series, No. 5880.
- He, J., 2006. Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emission of sulfur dioxide (SO<sub>2</sub>) in Chinese provinces. *Ecological Economics*, 60(1), 228-245. <http://dx.doi.org/10.1016/j.ecolecon.2005.12.008>

Henderson, V., 1996. Effects of air quality regulation. *American Economic Review*, 86, 789-813. <http://www.jstor.org/stable/2118305>

Huhtala, A., Marklund, P.-O., 2006. Stringency of environmental targets in animal agriculture: shedding light on policy with shadow prices. *European Review of Agricultural Economics*, 35(2), 193-217. <http://dx.doi.org/10.1093/erae/jbn025>

International Energy Agency, 2013a. Addressing climate change. Policies and Measures Database.

International Energy Agency, 2013b. Energy prices and taxes: End-use prices. Data Services.

Javorcik, B. S., Wei, S.-J., 2003. Pollution havens and foreign direct investment: dirty secret or popular myth?. *The B.E. Journal of Economic Analysis and Policy*, 3(2), 8. <http://dx.doi.org/10.2202/1538-0645.1244>

Keller, W., Levinson, A., 2002. Pollution abatement costs and foreign direct investment inflows to U.S. states. *Review of Economics and Statistics*, 84(4), 691-703. <http://dx.doi.org/10.1162/003465302760556503>

Kettner, C., Köppl, A., Schleicher, S. P., Thenius, G., 2008. Stringency and distribution in the EU Emissions Trading Scheme: First evidence. *Climate Policy*, 8(1), 41-61. <http://dx.doi.org/10.3763/cpol.2007.0394.8.1.41>

Künkel, N., Jacob, K., Busch, P.-O., 2006. Climate policies: (The feasibility of) a statistical analysis of their determinants. Paper presented at the 2006 Berlin Conference on the Human Dimensions of Global Environmental Change in Berlin, Germany.

Levinson, A., 1996. Environmental regulations and manufacturers' location choices: Evidence from the census of manufactures. *Journal of Public Economics*, 62(1-2), 5-29. [http://dx.doi.org/10.1016/0047-2727\(96\)01572-1](http://dx.doi.org/10.1016/0047-2727(96)01572-1)

Levinson, A., Taylor, M. S., 2008. Unmasking the pollution haven effect. *International Economic Review*, 49(1), 223-254. <http://dx.doi.org/10.1111/j.1468-2354.2008.00478.x>

List, J. A., Co, C. Y., 2000. The effects of environmental regulations on foreign direct investment. *Journal of Environmental Economics and Management*, 40(1), 1-20. <http://dx.doi.org/10.1006/jeem.1999.1095>

Magnani, E., 2000. The environmental Kuznets curve, environmental protection policy and income distribution. *Ecological Economics*, 32(3), 431-443. [http://dx.doi.org/10.1016/S0921-8009\(99\)00115-9](http://dx.doi.org/10.1016/S0921-8009(99)00115-9)

Managi, S., Hibiki, A., Tsurumi, T., 2009. Does trade openness improve environmental quality?. *Journal of Environmental Economics and Management*, 58(3), 346-63. <http://dx.doi.org/10.1016/j.jeem.2009.04.008>

McConnell, V. D., Schwab, R. M., 1990. The impact of environmental regulation on industry location decisions: The motor vehicle industry. *Land Economics*, 66(1), 67-81. <http://dx.doi.org/10.2307/3146684>

Millimet, D. L., Roy, J., 2011. Three new tests of the pollution haven hypothesis when environmental regulation is endogenous. IZA Discussion Paper, No. 5911.

Morgenstern, R. D., Pizer, W. A., Shih, J.-S., 2001. The cost of environmental protection. *The Review of Economics and Statistics*, 83(4), 732-738. <http://dx.doi.org/10.1162/003465301753237812>



Morrison, C. J., 1988. Quasi-fixed inputs in U.S. and Japanese manufacturing: A generalized Leontief restricted cost function approach. *Review of Economics and Statistics*, 70(2), 275-287. <http://dx.doi.org/10.2307/1928312>

Morrison, C. J., Schwartz, A. E., 1996. State infrastructure and productive performance. *American Economic Review*, 86(5), 1095-1111. <http://www.jstor.org/stable/2118280>

Morrison Paul, C. J., MacDonald, J. M., 2003. Tracing the effects of agricultural commodity prices on food processing costs. *American Journal of Agricultural Economics*, 85(3), 633-646. <http://www.jstor.org/stable/1244988>

Nakada, M., 2006. Distributional conflicts and the timing of environmental policy. *International Environmental Agreements: Politics, Law and Economics*, 6(1), 29-38. <http://dx.doi.org/10.1007/s10784-004-7861-2>

Organisation for Economic Co-operation and Development, 2012a. 4. PPPs and exchange rates dataset. OECD.StatExtracts.

Organisation for Economic Co-operation and Development, 2012b. Monthly monetary and financial statistics (MEI) dataset. OECD.StatExtracts.

Pasurka, C., 2008. Perspectives on pollution abatement and competitiveness: Theory, data, and analyses. *Review of Environmental Economics and Policy*, 2(2), 194-218. <http://dx.doi.org/10.1093/reep/ren009>

Pittman, R. W., 1981. Issue in pollution control: Interplant cost differences and economies of scale. *Land Economics*, 57(1), 1-17. <http://dx.doi.org/10.2307/3145748>

Penn World Tables, 2011. Extended Penn World Tables: Economic growth data assembled from the Penn World Tables and other sources. Extended Penn World Tables Database Version 4.0. Released August 2011.

Penn World Tables, 2012. Penn World Table Version 7.1. Database of the Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania. Released November 2012.

Sauter, C., 2013. Measuring greenhouse-gas policies: A new methodology. Paper presented at the SSES Annual Congress 2013 in Neuchâtel, Switzerland.

van Soest, D. P., List, J. A., Jeppesen, T., 2006. Shadow prices, environmental stringency, and international competitiveness. *European Economic Review*, 50(5), 1151-1167. <http://dx.doi.org/10.1016/j.eurocorev.2005.02.002>

Walter, I., Ugelow, J. L., 1979. Environmental policies in developing countries. *Ambio*, 8(2/3), 102-109. <http://www.jstor.org/stable/4312437>

World Input Output Database, 2012a. The world input-output database (WIOD): Contents, sources and methods. The World Input-Output Database (WIOD): Environmental Accounts. Released March 2012.

World Input Output Database, 2012b. The world input-output database (WIOD): Contents, sources and methods. The World Input-Output Database (WIOD): Socio-Economic Accounts. Released February 2012.

Xing, Y., Kolstad, C. D., 2002. Do lax environmental regulations attract foreign investment?. *Environmental and Resource Economics*, 21(1), 1-22. <http://hdl.handle.net/10.1023/A:1014537013353>

Yu, H., 2011. The EU ETS and firm profits: An ex-post analysis for Swedish energy firms. Working Paper Series, No. 2011/2, Uppsala University. <http://nbn-resolving.de/urn:nbn:se:uu:diva-144938>

Zellner, A., 1962. An efficient method of estimating seemingly unrelated regressions and tests of aggregation bias. Journal of the American Statistical Association, 57(298), 348-68. <http://dx.doi.org/10.2307/2281644>

## Appendix A: Capital stock computation

The WIOD only offers sector-specific capital stock information until 2007. For this reason, the capital stock data is constructed by applying the perpetual inventory method to the PWT data and disaggregating the country-level estimates with the help of the information in WIOD on the shares of each sector in the total national capital stock.

The capital stock  $x_K$  is constructed using the perpetual inventory method explained in Caselli (2005), who computes the capital stock in time  $t$  as the sum of the real aggregate capital investments  $I_t$  in the respective year and the depreciated capital stock of the previous year<sup>27</sup>:

$$(A.1) \quad x_{K_t} = I_t + (1 - \delta)x_{K_{t-1}}$$

Here,  $\delta$  refers to the depreciation rate. The initial capital stock in the year 1995 is determined following common practice by dividing the investments in 1995 by the sum of the depreciation rate and geometric mean growth rate  $g$  of the investments for the whole time period from 1995 to 2009:

$$(A.2) \quad x_{K_{1995}} = I_{1995} (g + \delta)^{-1}$$

As the PWT capital investments data is available on the country-level only, a disaggregation scheme, which is derived from the WIOD sector-specific real fixed capital stock data, is used to disaggregate the capital stock estimates. The WIOD data is not used in the first place, because the WIOD offers no capital stock information for the years 2008 as well as 2009 and updating the WIOD data using prior growth rates seems to be problematic owing to expected negative consequences of the financial dept crisis that started in 2008. Therefore, the missing sector shares for 2008 and 2009 are replaced by the information given for the last available year in WIOD, namely 2007.

---

<sup>27</sup> The constructed capital stock measure has also been compared to the one reported in the Extended Penn World Tables 4.0. for all countries in WIOD and shows a very high correlation coefficient of 0.995.

## Appendix B: Sector overview

ISIC Rev. 3.1	Sector
AtB (01t05)	Agriculture, hunting, forestry, and fishing
C (10t14)	Mining and quarrying
15t16	Food, beverages, and tobacco
17t18	Textiles and textile products
19	Leather, leather and footwear
20	Wood and products of wood and cork
21t22	Pulp, paper, printing, and publishing
23	Coke, refined petroleum, and nuclear fuel
24	Chemicals and chemical products
25	Rubber and plastics
26	Other non-metallic mineral
27t28	Basic metals and fabricated metal
29	Machinery, nec
30t33	Electrical and optical equipment
34t35	Transport equipment
36t37	Manufacturing, nec; recycling
E (40t41)	Electricity, gas and water supply
F (45)	Construction
50	Sale, maintenance, and repair of motor vehicles and motorcycles; retail sale of fuel
51	Wholesale trade and commission trade, except for motor vehicles and motorcycles
52	Retail trade, except for motor vehicles and motorcycles; repair of household goods
H (55)	Hotels and restaurants
60	Inland transport
61	Water transport
63	Other supporting and auxiliary transport activities; activities of travel agencies
64	Post and telecommunications
J (65t67)	Financial intermediation
70	Real estate activities
71t74	Renting of M&Eq and other business activities
L (75)	Public admin and defence; compulsory social security
M (80)	Education
N (85)	Health and social work
O (90t93)	Other community, social, and personal services

**Table B.1:** Included sectors and the respective division-level ISIC Rev. 3.1

## Appendix C: Distribution of industry and household prices

	Electricity	Coal	Natural gas	Diesel	Gasoline	Heavy fuel oil	Light fuel oil
<b>Agricultural sector</b>	Household prices	Household prices	Household prices	Household prices	Household prices	Industry prices	Household prices
<b>Industry sector</b>	Industry prices	Industry prices	Industry prices	Industry prices	Household prices	Industry prices	Industry prices
<b>Service sector</b>	Household prices	Household prices	Household prices	Household prices	Household prices	Industry prices	Household prices

**Table C.1:** Distribution of industry and household prices of the seven energy carriers to the primary, secondary, and tertiary sector

## Appendix D: Regression results

		Chemicals and chemical products				Inland transport			
		Coefficient <sup>a</sup>		(SE)		Coefficient <sup>a</sup>		(SE)	
Common coefficients	$\alpha_{LE}$	-0.001	***	(0.000)		0.000		(0.000)	
	$\delta_{LK}$	0.000		(0.000)		-0.001	***	(0.000)	
	$\delta_{EK}$	0.015	***	(0.003)		0.006	***	(0.001)	
	$\gamma_{KK}$	0.001	***	(0.000)		0.005	***	(0.001)	
	$\beta_{\bar{E}}$	1.341	***	(0.076)		1.287	***	(0.056)	
Australia	$\alpha_{LL}$	0.020	***	(0.001)		0.061	***	(0.003)	
	$\alpha_{EE}$	0.030	***	(0.001)		0.017	***	(0.001)	
	$\lambda_{E,95-97}$	-0.158	***	(0.016)		0.136	***	(0.025)	
	$\lambda_{E,98-00}$	-0.143	***	(0.009)		0.029		(0.025)	
	$\lambda_{E,01-03}$	-0.177	***	(0.011)		-0.009		(0.022)	
	$\lambda_{E,04-06}$	-0.203	***	(0.011)		-0.047		(0.029)	
	$\lambda_{E,07-09}$	-0.244	***	(0.024)		-0.110	**	(0.049)	
Austria	$\alpha_{LL}$	0.019	***	(0.001)		0.057	***	(0.004)	
	$\alpha_{EE}$	0.037	***	(0.002)		0.008	**	(0.002)	
	$\lambda_{E,95-97}$	0.066	**	(0.028)		0.731	***	(0.043)	
	$\lambda_{E,98-00}$	0.006		(0.022)		0.490	***	(0.070)	
	$\lambda_{E,01-03}$	-0.009		(0.018)		0.390	***	(0.022)	
	$\lambda_{E,04-06}$	0.065	***	(0.013)		0.463	***	(0.022)	
	$\lambda_{E,07-09}$	0.182	***	(0.026)		0.519	***	(0.027)	
Belgium	$\alpha_{LL}$	0.021	***	(0.001)		0.051	***	(0.004)	
	$\alpha_{EE}$	0.035	***	(0.002)		0.014	***	(0.002)	
	$\lambda_{E,95-97}$	0.103	***	(0.014)		0.459	***	(0.048)	
	$\lambda_{E,98-00}$	0.050	**	(0.024)		0.295	***	(0.031)	
	$\lambda_{E,01-03}$	0.071	***	(0.022)		0.259	***	(0.029)	
	$\lambda_{E,04-06}$	0.103	***	(0.009)		0.420	***	(0.025)	
	$\lambda_{E,07-09}$	0.146	***	(0.019)		0.404	***	(0.042)	
Canada	$\alpha_{LL}$	0.020	***	(0.001)		0.062	***	(0.003)	
	$\alpha_{EE}$	0.040	***	(0.001)		0.027	***	(0.001)	
	$\lambda_{E,95-97}$	-0.139	***	(0.012)		-0.257	***	(0.030)	
	$\lambda_{E,98-00}$	-0.090	***	(0.015)		-0.228	***	(0.030)	
	$\lambda_{E,01-03}$	-0.039	***	(0.009)		-0.248	***	(0.036)	
	$\lambda_{E,04-06}$	-0.060	***	(0.008)		-0.479	***	(0.039)	
	$\lambda_{E,07-09}$	-0.134	***	(0.028)		-0.624	***	(0.067)	
Czech Republic	$\alpha_{LL}$	0.017	***	(0.001)		0.057	***	(0.002)	
	$\alpha_{EE}$	0.044	***	(0.001)		0.005	*	(0.001)	
	$\lambda_{E,95-97}$	-0.190	***	(0.023)		0.053	***	(0.016)	
	$\lambda_{E,98-00}$	-0.179	***	(0.031)		0.020		(0.032)	
	$\lambda_{E,01-03}$	-0.172	***	(0.016)		0.071	***	(0.024)	
	$\lambda_{E,04-06}$	-0.222	***	(0.012)		0.199	***	(0.024)	
	$\lambda_{E,07-09}$	-0.141	***	(0.033)		0.338	***	(0.052)	
Denmark	$\alpha_{LL}$	0.021	***	(0.001)		0.048	***	(0.004)	
	$\alpha_{EE}$	0.031	***	(0.002)		0.007	*	(0.002)	
	$\lambda_{E,95-97}$	0.024		(0.019)		0.570	***	(0.023)	
	$\lambda_{E,98-00}$	0.018	**	(0.008)		0.500	***	(0.030)	
	$\lambda_{E,01-03}$	0.067	***	(0.020)		0.507	***	(0.038)	
	$\lambda_{E,04-06}$	0.159	***	(0.016)		0.556	***	(0.025)	
	$\lambda_{E,07-09}$	0.291	***	(0.029)		0.681	***	(0.037)	
Estonia	$\alpha_{LL}$	0.011	***	(0.001)		0.031	***	(0.003)	
	$\alpha_{EE}$	0.058	***	(0.002)		0.015	***	(0.002)	
	$\lambda_{E,98-00}$	-0.146	***	(0.019)		-0.022		(0.040)	
	$\lambda_{E,01-03}$	-0.123	***	(0.031)		-0.082	***	(0.030)	
	$\lambda_{E,04-06}$	-0.132	***	(0.020)		-0.071	***	(0.026)	
	$\lambda_{E,07-09}$	-0.062		(0.056)		0.136	**	(0.066)	

**Table D.1 (1/4):** Regression results of the chemicals and the inland transport sector

<sup>a</sup> Significance codes: \* p<.10, \*\* p<.05, \*\*\* p<.01

		Chemicals and chemical products			Inland transport					Chemicals and chemical products			Inland transport		
		Coefficient <sup>a</sup>		(SE)	Coefficient <sup>a</sup>		(SE)			Coefficient <sup>a</sup>		(SE)	Coefficient <sup>a</sup>		(SE)
Finland	$\alpha_{LL}$	0.017	***	(0.001)	0.049	***	(0.004)	Greece	$\alpha_{LL}$	0.024	***	(0.001)	0.105	***	(0.004)
	$\alpha_{EE}$	0.043	***	(0.002)	0.006	*	(0.002)		$\alpha_{EE}$	0.027	***	(0.001)	0.022	***	(0.002)
	$\lambda_{E,95-97}$	0.079	***	(0.020)	0.381	***	(0.053)		$\lambda_{E,95-97}$	0.044		(0.027)	0.033		(0.025)
	$\lambda_{E,98-00}$	0.041	***	(0.011)	0.253	***	(0.025)		$\lambda_{E,98-00}$	0.011		(0.016)	0.033		(0.038)
	$\lambda_{E,01-03}$	0.068	***	(0.013)	0.216	***	(0.016)		$\lambda_{E,01-03}$	0.023	*	(0.012)	0.069	**	(0.027)
	$\lambda_{E,04-06}$	0.082	***	(0.009)	0.233	***	(0.019)		$\lambda_{E,04-06}$	-0.022	**	(0.009)	0.172	***	(0.027)
	$\lambda_{E,07-09}$	0.127	***	(0.021)	0.280	***	(0.040)		$\lambda_{E,07-09}$	0.069	*	(0.039)	0.288	***	(0.050)
France	$\alpha_{LL}$	0.021	***	(0.001)	0.060	***	(0.003)	Hungary	$\alpha_{LL}$	0.021	***	(0.001)	0.066	***	(0.002)
	$\alpha_{EE}$	0.037	***	(0.002)	0.024	***	(0.002)		$\alpha_{EE}$	0.034	***	(0.001)	0.017	***	(0.002)
	$\lambda_{E,95-97}$	-0.025	**	(0.011)	0.329	***	(0.021)		$\lambda_{E,95-97}$	-0.104	***	(0.019)	0.132	***	(0.027)
	$\lambda_{E,98-00}$	-0.044	***	(0.015)	0.270	***	(0.026)		$\lambda_{E,98-00}$	0.006		(0.010)	0.101	***	(0.021)
	$\lambda_{E,01-03}$	-0.035	***	(0.010)	0.239	***	(0.026)		$\lambda_{E,01-03}$	0.077	***	(0.018)	0.255	***	(0.038)
	$\lambda_{E,04-06}$	0.012		(0.016)	0.366	***	(0.023)		$\lambda_{E,04-06}$	0.152	***	(0.021)	0.388	***	(0.031)
	$\lambda_{E,07-09}$	-0.020		(0.021)	0.402	***	(0.036)		$\lambda_{E,07-09}$	0.234	***	(0.021)	0.306	***	(0.041)
Germany	$\alpha_{LL}$	0.023	***	(0.001)	0.063	***	(0.003)	Ireland	$\alpha_{LL}$	0.016	***	(0.001)	0.033	***	(0.004)
	$\alpha_{EE}$	0.037	***	(0.002)	0.005		(0.002)		$\alpha_{EE}$	0.028	***	(0.002)	0.015	***	(0.002)
	$\lambda_{E,95-97}$	0.107	***	(0.035)	0.963	***	(0.059)		$\lambda_{E,95-97}$	0.175	***	(0.012)	0.328	***	(0.019)
	$\lambda_{E,98-00}$	0.101	***	(0.022)	0.683	***	(0.071)		$\lambda_{E,98-00}$	0.176	***	(0.017)	0.266	***	(0.025)
	$\lambda_{E,01-03}$	0.084	***	(0.015)	0.653	***	(0.062)		$\lambda_{E,01-03}$	0.217	***	(0.018)	0.287	***	(0.028)
	$\lambda_{E,04-06}$	0.127	***	(0.012)	0.770	***	(0.048)		$\lambda_{E,04-06}$	0.151	***	(0.013)	0.362	***	(0.025)
	$\lambda_{E,07-09}$	0.178	***	(0.018)	0.859	***	(0.031)		$\lambda_{E,07-09}$	0.268	***	(0.020)	0.337	***	(0.060)
Great Britain	$\alpha_{LL}$	0.022	***	(0.001)	0.055	***	(0.003)	Italy	$\alpha_{LL}$	0.020	***	(0.001)	0.071	***	(0.004)
	$\alpha_{EE}$	0.030	***	(0.001)	0.008	**	(0.002)		$\alpha_{EE}$	0.032	***	(0.002)	0.010	***	(0.002)
	$\lambda_{E,95-97}$	-0.031	***	(0.010)	0.394	***	(0.055)		$\lambda_{E,95-97}$	0.203	***	(0.023)	0.425	***	(0.028)
	$\lambda_{E,98-00}$	-0.020	**	(0.009)	0.628	***	(0.018)		$\lambda_{E,98-00}$	0.209	***	(0.021)	0.346	***	(0.029)
	$\lambda_{E,01-03}$	-0.034	**	(0.013)	0.593	***	(0.017)		$\lambda_{E,01-03}$	0.315	***	(0.035)	0.339	***	(0.035)
	$\lambda_{E,04-06}$	0.018		(0.022)	0.619	***	(0.040)		$\lambda_{E,04-06}$	0.502	***	(0.018)	0.509	***	(0.021)
	$\lambda_{E,07-09}$	0.036		(0.028)	0.418	***	(0.118)		$\lambda_{E,07-09}$	0.664	***	(0.041)	0.556	***	(0.031)

**Table D.1 (cont., 2/4):** Regression results of the chemicals and the inland transport sector

<sup>a</sup> Significance codes: \* p< .10, \*\* p<.05, \*\*\* p<.01

		Chemicals and chemical products			Inland transport		
		Coefficient <sup>a</sup>		(SE)	Coefficient <sup>a</sup>		(SE)
Japan	$\alpha_{LL}$	0.019	***	(0.001)	0.080	***	(0.003)
	$\alpha_{EE}$	0.037	***	(0.002)	0.003		(0.002)
	$\lambda_{E,95-97}$	0.393	***	(0.046)	0.357	***	(0.042)
	$\lambda_{E,98-00}$	0.327	***	(0.043)	0.354	***	(0.036)
	$\lambda_{E,01-03}$	0.281	***	(0.016)	0.266	***	(0.030)
	$\lambda_{E,04-06}$	0.223	***	(0.022)	0.094	**	(0.041)
	$\lambda_{E,07-09}$	0.209	***	(0.040)	0.038		(0.077)
Korea	$\alpha_{LL}$	0.020	***	(0.001)	0.076	***	(0.003)
	$\alpha_{EE}$	0.030	***	(0.001)	0.033	***	(0.001)
	$\lambda_{E,95-97}$	0.169	***	(0.018)	-0.098	**	(0.040)
	$\lambda_{E,98-00}$	0.061	***	(0.021)	-0.091	**	(0.039)
	$\lambda_{E,01-03}$	0.015		(0.018)	-0.010		(0.022)
	$\lambda_{E,04-06}$	-0.025	*	(0.014)	0.136	**	(0.062)
	$\lambda_{E,07-09}$	-0.147	***	(0.037)	0.115	*	(0.069)
Luxembourg	$\alpha_{LL}$	0.005		(0.002)	0.002		(0.008)
	$\alpha_{EE}$	0.035	***	(0.002)	0.008	**	(0.002)
	$\lambda_{E,95-97}$	0.010		(0.021)	0.430	***	(0.040)
	$\lambda_{E,98-00}$	0.105	***	(0.019)	0.258	***	(0.048)
	$\lambda_{E,01-03}$	0.257	***	(0.026)	0.198	***	(0.025)
	$\lambda_{E,04-06}$	0.385	***	(0.022)	0.140	***	(0.027)
	$\lambda_{E,07-09}$	0.581	***	(0.029)	0.172	***	(0.036)
Mexico	$\alpha_{LL}$	0.019	***	(0.001)	0.060	***	(0.002)
	$\alpha_{EE}$	0.026	***	(0.001)	0.007	***	(0.001)
	$\lambda_{E,95-97}$	-0.200	***	(0.028)	-0.292	***	(0.040)
	$\lambda_{E,98-00}$	-0.097	***	(0.031)	-0.196	***	(0.018)
	$\lambda_{E,01-03}$	-0.007		(0.012)	-0.162	***	(0.041)
	$\lambda_{E,04-06}$	0.002		(0.011)	-0.458	***	(0.029)
	$\lambda_{E,07-09}$	-0.042		(0.030)	-0.658	***	(0.071)
Netherlands	$\alpha_{LL}$	0.017	***	(0.001)	0.058	***	(0.003)
	$\alpha_{EE}$	0.047	***	(0.002)	0.021	***	(0.002)
	$\lambda_{E,95-97}$	-0.131	***	(0.009)	0.827	***	(0.105)
	$\lambda_{E,98-00}$	-0.128	***	(0.008)	0.490	***	(0.034)
	$\lambda_{E,01-03}$	-0.130	***	(0.009)	0.377	***	(0.019)
	$\lambda_{E,04-06}$	-0.114	***	(0.011)	0.467	***	(0.025)
	$\lambda_{E,07-09}$	-0.019		(0.019)	0.496	***	(0.056)
Poland	$\alpha_{LL}$	0.024	***	(0.001)	0.051	***	(0.002)
	$\alpha_{EE}$	0.055	***	(0.002)	0.028	***	(0.002)
	$\lambda_{E,95-97}$	-0.197	***	(0.025)	-0.037		(0.056)
	$\lambda_{E,98-00}$	-0.191	***	(0.023)	0.033		(0.035)
	$\lambda_{E,01-03}$	-0.135	***	(0.010)	0.100	***	(0.033)
	$\lambda_{E,04-06}$	-0.158	***	(0.020)	0.274	***	(0.091)
	$\lambda_{E,07-09}$	-0.189	***	(0.036)	0.364	***	(0.089)
Portugal	$\alpha_{LL}$	0.016	***	(0.001)	0.046	***	(0.004)
	$\alpha_{EE}$	0.029	***	(0.002)	0.029	***	(0.002)
	$\lambda_{E,95-97}$	0.235	***	(0.045)	0.149	***	(0.029)
	$\lambda_{E,98-00}$	0.178	***	(0.014)	0.166	***	(0.048)
	$\lambda_{E,01-03}$	0.137	***	(0.023)	0.148	***	(0.029)
	$\lambda_{E,04-06}$	0.220	***	(0.010)	0.297	***	(0.037)
	$\lambda_{E,07-09}$	0.228	***	(0.018)	0.476	***	(0.056)
Slovak Republic	$\alpha_{LL}$	0.015	***	(0.001)	0.025	***	(0.002)
	$\alpha_{EE}$	0.057	***	(0.002)	0.018	***	(0.002)
	$\lambda_{E,95-97}$	-0.128	***	(0.030)	-0.017		(0.066)
	$\lambda_{E,98-00}$	-0.161	***	(0.021)	0.035		(0.074)
	$\lambda_{E,01-03}$	-0.126	***	(0.022)	-0.171	***	(0.042)
	$\lambda_{E,04-06}$	-0.013		(0.028)	0.006		(0.085)
	$\lambda_{E,07-09}$	0.164	***	(0.044)	0.248	***	(0.053)

**Table D.1 (cont., 3/4):** Regression results of the chemicals and the inland transport sector

<sup>a</sup> Significance codes: \* p<.10, \*\* p<.05, \*\*\* p<.01

		Chemicals and chemical products			Inland transport					Chemicals and chemical products			Inland transport		
		Coefficient <sup>a</sup>		(SE)	Coefficient <sup>a</sup>		(SE)			Coefficient <sup>a</sup>		(SE)	Coefficient <sup>a</sup>		(SE)
Slovenia	$\alpha_{LL}$	0.016	***	(0.001)	0.023	***	(0.004)	Turkey	$\alpha_{LL}$	0.020	***	(0.001)	0.045	***	(0.002)
	$\alpha_{EE}$	0.021	***	(0.002)	0.015	***	(0.002)		$\alpha_{EE}$	0.028	***	(0.002)	-0.004		(0.002)
	$\lambda_{E,98-00}$	0.203	***	(0.009)	-0.026		(0.038)		$\lambda_{E,95-97}$	-0.188	***	(0.018)	0.098	***	(0.037)
	$\lambda_{E,01-03}$	0.280	***	(0.034)	0.108	***	(0.036)		$\lambda_{E,98-00}$	-0.148	***	(0.021)	0.166	***	(0.039)
	$\lambda_{E,04-06}$	0.374	***	(0.010)	0.244	***	(0.027)		$\lambda_{E,01-03}$	-0.136	***	(0.017)	0.141	**	(0.065)
	$\lambda_{E,07-09}$	0.440	***	(0.024)	0.331	***	(0.042)		$\lambda_{E,04-06}$	-0.142	***	(0.021)	0.476	***	(0.065)
Spain	$\alpha_{LL}$	0.021	***	(0.001)	0.049	***	(0.002)	United States	$\lambda_{E,07-09}$	0.018		(0.053)	0.671	***	(0.073)
	$\alpha_{EE}$	0.038	***	(0.002)	0.028	***	(0.002)		$\alpha_{LL}$	0.023	***	(0.001)	0.071	***	(0.003)
	$\lambda_{E,95-97}$	-0.029	*	(0.016)	-0.003		(0.023)		$\alpha_{EE}$	0.040	***	(0.002)	0.025	***	(0.001)
	$\lambda_{E,98-00}$	-0.040	***	(0.010)	-0.010		(0.017)		$\lambda_{E,95-97}$	-0.106	***	(0.025)	-0.236	***	(0.025)
	$\lambda_{E,01-03}$	-0.026	***	(0.008)	0.094	***	(0.031)		$\lambda_{E,98-00}$	-0.031	***	(0.009)	-0.205	***	(0.026)
	$\lambda_{E,04-06}$	-0.045	***	(0.012)	0.193	***	(0.025)		$\lambda_{E,01-03}$	-0.025	*	(0.013)	-0.206	***	(0.038)
Sweden	$\lambda_{E,07-09}$	-0.010		(0.015)	0.204	***	(0.034)		$\lambda_{E,04-06}$	-0.113	***	(0.015)	-0.336	***	(0.023)
	$\alpha_{LL}$	0.016	***	(0.002)	0.052	***	(0.004)		$\lambda_{E,07-09}$	-0.206	***	(0.017)	-0.431	***	(0.049)
	$\alpha_{EE}$	0.025	***	(0.002)	-0.005		(0.002)								
	$\lambda_{E,95-97}$	0.030		(0.020)	0.782	***	(0.034)								
	$\lambda_{E,98-00}$	0.038	**	(0.015)	0.596	***	(0.021)								
	$\lambda_{E,01-03}$	0.057	***	(0.017)	0.480	***	(0.021)								
	$\lambda_{E,04-06}$	0.095	***	(0.012)	0.493	***	(0.019)								
	$\lambda_{E,07-09}$	0.118	***	(0.029)	0.446	***	(0.066)								

**Table D.1 (cont., 4/4):** Regression results of the chemicals and the inland transport sector

<sup>a</sup> Significance codes: \* p< .10, \*\* p<.05, \*\*\* p<.01



## Appendix E: Country ranking for all remaining sectors

Agriculture, hunting, forestry and fishing					Mining and quarrying					Food, beverages and tobacco				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Denmark	1.618	(0.357)	1.264	2.208	1 Hungary	1.007	(0.266)	0.730	1.498	1 Italy	0.880	(0.286)	0.624	1.408
2 Sweden	1.559	(0.234)	1.189	1.938	2 Slovenia	0.965	(0.226)	0.658	1.288	2 Luxembourg	0.863	(0.289)	0.582	1.381
3 Austria	1.469	(0.354)	1.108	2.102	3 Portugal	0.791	(0.121)	0.638	0.982	3 Slovenia	0.801	(0.222)	0.547	1.124
4 Italy	1.412	(0.364)	1.073	2.071	4 Luxembourg	0.765	(0.285)	0.477	1.251	4 Japan	0.748	(0.062)	0.652	0.873
5 Germany	1.401	(0.311)	1.103	1.953	5 Ireland	0.748	(0.168)	0.564	1.066	5 Ireland	0.684	(0.125)	0.558	0.936
6 Turkey	1.255	(0.467)	0.835	2.066	6 Italy	0.723	(0.225)	0.521	1.165	6 Belgium	0.668	(0.145)	0.504	0.963
7 Portugal	1.181	(0.227)	0.844	1.634	7 Greece	0.663	(0.181)	0.493	1.015	7 Portugal	0.659	(0.155)	0.502	0.948
8 Korea	1.070	(0.186)	0.828	1.358	8 Spain	0.650	(0.141)	0.498	0.916	8 Germany	0.629	(0.146)	0.469	0.910
9 Slovak Republic	1.039	(0.589)	0.572	2.150	9 Sweden	0.607	(0.115)	0.472	0.837	9 Sweden	0.613	(0.106)	0.484	0.818
10 Ireland	1.010	(0.341)	0.686	1.635	10 Germany	0.580	(0.184)	0.331	0.877	10 Denmark	0.612	(0.149)	0.465	0.902
11 Japan	0.971	(0.120)	0.801	1.233	11 Belgium	0.549	(0.225)	0.326	0.952	11 Finland	0.574	(0.129)	0.438	0.830
12 Australia	0.956	(0.204)	0.715	1.342	12 Austria	0.537	(0.104)	0.389	0.740	12 Mexico	0.571	(0.123)	0.371	0.787
13 Greece	0.929	(0.254)	0.684	1.408	13 Estonia	0.496	(0.137)	0.355	0.732	13 Korea	0.555	(0.072)	0.442	0.667
14 Slovenia	0.914	(0.241)	0.627	1.286	14 Denmark	0.490	(0.138)	0.363	0.772	14 Hungary	0.554	(0.183)	0.401	0.910
15 Netherlands	0.904	(0.300)	0.624	1.475	15 Turkey	0.489	(0.159)	0.326	0.812	15 Greece	0.542	(0.163)	0.397	0.865
16 Spain	0.843	(0.253)	0.602	1.335	16 Finland	0.436	(0.150)	0.294	0.727	16 Great Britain	0.528	(0.125)	0.388	0.766
17 Luxembourg	0.813	(0.270)	0.464	1.260	17 Slovak Republic	0.396	(0.158)	0.252	0.703	17 Austria	0.526	(0.167)	0.343	0.837
18 Hungary	0.800	(0.301)	0.565	1.427	18 Korea	0.383	(0.275)	0.140	0.824	18 Slovak Republic	0.521	(0.198)	0.360	0.916
19 France	0.777	(0.226)	0.543	1.213	19 Canada	0.355	(0.068)	0.282	0.479	19 Spain	0.514	(0.145)	0.360	0.796
20 Finland	0.765	(0.167)	0.581	1.098	20 Australia	0.345	(0.075)	0.256	0.496	20 Turkey	0.478	(0.168)	0.321	0.801
21 Estonia	0.757	(0.245)	0.475	1.193	21 Mexico	0.328	(0.088)	0.212	0.458	21 France	0.478	(0.127)	0.344	0.739
22 United States	0.722	(0.117)	0.579	0.972	22 United States	0.327	(0.052)	0.261	0.416	22 Estonia	0.468	(0.143)	0.321	0.718
23 Mexico	0.698	(0.127)	0.477	0.888	23 France	0.322	(0.062)	0.256	0.466	23 Netherlands	0.466	(0.151)	0.330	0.769
24 Poland	0.689	(0.123)	0.531	0.970	24 Poland	0.321	(0.115)	0.219	0.565	24 United States	0.416	(0.041)	0.350	0.498
25 Czech Republic	0.671	(0.284)	0.412	1.209	25 Netherlands	0.297	(0.126)	0.175	0.562	25 Czech Republic	0.396	(0.197)	0.200	0.770
26 Canada	0.637	(0.163)	0.479	0.965	26 Great Britain	0.290	(0.094)	0.194	0.470	26 Australia	0.379	(0.095)	0.272	0.565
27 Belgium	0.629	(0.284)	0.393	1.182	27 Czech Republic	0.230	(0.074)	0.156	0.390	27 Poland	0.351	(0.134)	0.212	0.614
28 Great Britain	0.603	(0.177)	0.431	0.959	28 Japan	0.217	(0.049)	0.141	0.312	28 Canada	0.342	(0.067)	0.264	0.469

**Table E.1 (1/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

Textiles and textile products					Leather, leather- and footwear					Wood and products of wood and cork				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Italy	0.980	(0.274)	0.730	1.519	1 Italy	0.983	(0.267)	0.726	1.518	1 Italy	1.514	(0.556)	0.966	2.500
2 Japan	0.886	(0.143)	0.740	1.184	2 Japan	0.901	(0.140)	0.753	1.166	2 Slovenia	1.047	(0.273)	0.666	1.440
3 Slovenia	0.829	(0.145)	0.642	1.067	3 Ireland	0.869	(0.162)	0.724	1.218	3 Luxembourg	0.917	(0.322)	0.536	1.514
4 Hungary	0.801	(0.189)	0.611	1.170	4 Hungary	0.848	(0.147)	0.689	1.169	4 Japan	0.858	(0.100)	0.720	1.014
5 Belgium	0.794	(0.135)	0.618	1.053	5 Belgium	0.847	(0.142)	0.632	1.106	5 Portugal	0.750	(0.158)	0.527	1.069
6 Ireland	0.786	(0.180)	0.660	1.180	6 Slovenia	0.843	(0.272)	0.529	1.242	6 Germany	0.719	(0.132)	0.539	0.965
7 Denmark	0.763	(0.209)	0.555	1.169	7 Portugal	0.823	(0.151)	0.624	1.088	7 Belgium	0.719	(0.248)	0.449	1.199
8 Luxembourg	0.667	(0.152)	0.458	0.932	8 Denmark	0.802	(0.231)	0.571	1.260	8 Spain	0.706	(0.166)	0.476	1.029
9 Mexico	0.646	(0.096)	0.442	0.775	9 Turkey	0.766	(0.237)	0.471	1.190	9 Austria	0.677	(0.136)	0.505	0.966
10 Turkey	0.644	(0.168)	0.462	0.951	10 United States	0.666	(0.071)	0.577	0.847	10 Great Britain	0.661	(0.122)	0.524	0.938
11 Sweden	0.630	(0.117)	0.503	0.858	11 Mexico	0.654	(0.103)	0.448	0.798	11 Hungary	0.650	(0.177)	0.404	0.993
12 Germany	0.630	(0.164)	0.459	0.959	12 Slovak Republic	0.644	(0.219)	0.437	1.099	12 Greece	0.645	(0.187)	0.415	1.021
13 Greece	0.627	(0.172)	0.467	0.974	13 Sweden	0.640	(0.118)	0.470	0.882	13 Ireland	0.641	(0.072)	0.535	0.833
14 Austria	0.614	(0.209)	0.386	0.996	14 Germany	0.639	(0.156)	0.468	0.967	14 Finland	0.617	(0.131)	0.455	0.903
15 Slovak Republic	0.603	(0.234)	0.394	1.064	15 Great Britain	0.629	(0.116)	0.441	0.878	15 Denmark	0.611	(0.134)	0.422	0.886
16 Portugal	0.588	(0.101)	0.449	0.783	16 Czech Republic	0.618	(0.317)	0.322	1.219	16 Netherlands	0.601	(0.116)	0.439	0.830
17 Finland	0.574	(0.113)	0.434	0.812	17 Greece	0.610	(0.186)	0.433	1.002	17 Slovak Republic	0.581	(0.184)	0.373	0.947
18 Korea	0.565	(0.122)	0.429	0.824	18 Finland	0.596	(0.109)	0.441	0.830	18 Korea	0.574	(0.080)	0.437	0.694
19 Great Britain	0.557	(0.117)	0.392	0.792	19 Spain	0.581	(0.172)	0.399	0.934	19 France	0.565	(0.113)	0.427	0.779
20 Spain	0.551	(0.145)	0.395	0.842	20 Korea	0.578	(0.116)	0.423	0.789	20 Sweden	0.557	(0.079)	0.429	0.716
21 Estonia	0.534	(0.156)	0.381	0.820	21 Canada	0.574	(0.110)	0.449	0.786	21 Estonia	0.479	(0.134)	0.296	0.739
22 Poland	0.529	(0.155)	0.341	0.841	22 France	0.557	(0.172)	0.345	0.920	22 Canada	0.478	(0.130)	0.319	0.753
23 France	0.516	(0.167)	0.314	0.852	23 Austria	0.538	(0.198)	0.348	0.930	23 Czech Republic	0.406	(0.163)	0.194	0.712
24 United States	0.500	(0.045)	0.427	0.601	24 Netherlands	0.522	(0.190)	0.325	0.906	24 Turkey	0.385	(0.239)	0.035	0.716
25 Netherlands	0.499	(0.177)	0.317	0.847	25 Poland	0.500	(0.138)	0.361	0.806	25 Poland	0.383	(0.107)	0.238	0.626
26 Czech Republic	0.494	(0.237)	0.228	0.947	26 Estonia	0.494	(0.091)	0.394	0.686	26 United States	0.381	(0.067)	0.284	0.553
27 Canada	0.466	(0.102)	0.343	0.664	27 Australia	0.457	(0.090)	0.297	0.597	27 Mexico	0.377	(0.100)	0.201	0.560
28 Australia	0.456	(0.084)	0.327	0.622						28 Australia	0.358	(0.098)	0.227	0.571

**Table E.1 (cont., 2/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

Pulp, paper, printing and publishing					Coke, refined petroleum and nuclear fuel					Rubber and plastics				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Ireland	0.917	(0.191)	0.731	1.294	1 Slovenia	1.194	(0.332)	0.429	1.533	1 Italy	1.439	(0.417)	1.040	2.193
2 Italy	0.898	(0.277)	0.641	1.401	2 Japan	0.794	(0.078)	0.679	0.963	2 Ireland	1.158	(0.167)	0.963	1.513
3 Japan	0.852	(0.060)	0.753	0.963	3 Germany	0.703	(0.127)	0.558	0.950	3 Japan	1.125	(0.171)	0.916	1.491
4 Slovenia	0.845	(0.130)	0.681	1.050	4 Belgium	0.608	(0.180)	0.428	0.962	4 Portugal	1.056	(0.146)	0.910	1.359
5 Luxembourg	0.843	(0.245)	0.575	1.283	5 Italy	0.603	(0.125)	0.462	0.850	5 Slovenia	0.888	(0.182)	0.681	1.183
6 Belgium	0.741	(0.159)	0.550	1.047	6 Spain	0.571	(0.196)	0.373	0.933	6 Luxembourg	0.818	(0.242)	0.577	1.283
7 Denmark	0.728	(0.166)	0.570	1.065	7 Denmark	0.566	(0.117)	0.407	0.800	7 Austria	0.810	(0.247)	0.520	1.262
8 Germany	0.675	(0.151)	0.506	0.976	8 Canada	0.556	(0.144)	0.417	0.837	8 Germany	0.771	(0.182)	0.581	1.122
9 Great Britain	0.649	(0.125)	0.488	0.896	9 Estonia	0.548	(0.119)	0.377	0.762	9 Greece	0.767	(0.168)	0.579	1.108
10 Hungary	0.609	(0.140)	0.459	0.879	10 Sweden	0.528	(0.092)	0.363	0.673	10 Hungary	0.743	(0.244)	0.365	1.171
11 Finland	0.596	(0.120)	0.446	0.832	11 Ireland	0.502	(0.048)	0.443	0.613	11 Denmark	0.735	(0.198)	0.500	1.117
12 Turkey	0.582	(0.200)	0.394	0.959	12 Portugal	0.501	(0.121)	0.362	0.756	12 Netherlands	0.718	(0.194)	0.541	1.112
13 Canada	0.577	(0.127)	0.465	0.832	13 Finland	0.490	(0.095)	0.365	0.694	13 Australia	0.691	(0.163)	0.527	0.993
14 Greece	0.566	(0.169)	0.409	0.909	14 France	0.488	(0.119)	0.352	0.698	14 Great Britain	0.671	(0.181)	0.495	1.030
15 Sweden	0.561	(0.086)	0.449	0.731	15 Greece	0.469	(0.125)	0.337	0.736	15 Finland	0.667	(0.140)	0.495	0.923
16 Portugal	0.556	(0.146)	0.407	0.831	16 Hungary	0.461	(0.146)	0.302	0.732	16 Slovak Republic	0.660	(0.279)	0.364	1.204
17 Spain	0.556	(0.160)	0.401	0.871	17 Turkey	0.441	(0.176)	0.262	0.760	17 Korea	0.651	(0.114)	0.509	0.890
18 Mexico	0.545	(0.110)	0.381	0.740	18 Austria	0.437	(0.080)	0.348	0.627	18 Sweden	0.643	(0.125)	0.490	0.889
19 Korea	0.532	(0.079)	0.418	0.666	19 Slovak Republic	0.394	(0.120)	0.260	0.653	19 Mexico	0.637	(0.117)	0.374	0.807
20 France	0.504	(0.125)	0.382	0.757	20 Korea	0.378	(0.079)	0.283	0.542	20 Belgium	0.630	(0.198)	0.397	0.981
21 Austria	0.503	(0.125)	0.375	0.761	21 Netherlands	0.368	(0.116)	0.255	0.612	21 Estonia	0.626	(0.139)	0.475	0.896
22 Estonia	0.459	(0.136)	0.330	0.702	22 Great Britain	0.364	(0.061)	0.293	0.493	22 France	0.617	(0.159)	0.469	0.962
23 Slovak Republic	0.458	(0.134)	0.303	0.722	23 Mexico	0.326	(0.055)	0.230	0.441	23 United States	0.616	(0.081)	0.496	0.780
24 Netherlands	0.455	(0.135)	0.329	0.732	24 Australia	0.323	(0.080)	0.230	0.494	24 Spain	0.594	(0.104)	0.441	0.789
25 Australia	0.418	(0.107)	0.310	0.632	25 Czech Republic	0.294	(0.089)	0.193	0.475	25 Turkey	0.567	(0.171)	0.412	0.931
26 Czech Republic	0.409	(0.115)	0.303	0.632	26 United States	0.292	(0.051)	0.232	0.413	26 Czech Republic	0.555	(0.361)	0.212	1.235
27 United States	0.384	(0.040)	0.334	0.485	27 Poland	0.280	(0.087)	0.181	0.481	27 Poland	0.508	(0.149)	0.350	0.818
28 Poland	0.361	(0.068)	0.293	0.523						28 Canada	0.443	(0.098)	0.289	0.637

**Table E.1 (cont., 3/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

Other non-metallic mineral					Basic metals and fabricated metal					Machinery, nec				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Slovenia	0.832	(0.216)	0.522	1.129	1 Slovenia	0.965	(0.152)	0.755	1.168	1 Japan	1.131	(0.045)	1.056	1.200
2 Italy	0.655	(0.180)	0.487	0.991	2 Portugal	0.854	(0.167)	0.630	1.121	2 Italy	1.047	(0.306)	0.761	1.605
3 Luxembourg	0.644	(0.187)	0.448	0.972	3 Denmark	0.795	(0.143)	0.635	1.042	3 Portugal	0.959	(0.133)	0.782	1.202
4 Japan	0.590	(0.062)	0.494	0.716	4 Luxembourg	0.735	(0.197)	0.560	1.091	4 Slovenia	0.925	(0.191)	0.679	1.214
5 Sweden	0.582	(0.098)	0.470	0.758	5 Italy	0.710	(0.214)	0.493	1.089	5 Ireland	0.904	(0.123)	0.759	1.112
6 Canada	0.582	(0.147)	0.433	0.842	6 Spain	0.662	(0.171)	0.458	0.965	6 Belgium	0.886	(0.211)	0.645	1.279
7 Ireland	0.562	(0.067)	0.467	0.708	7 Greece	0.623	(0.167)	0.451	0.933	7 Denmark	0.805	(0.160)	0.635	1.108
8 Germany	0.550	(0.146)	0.411	0.826	8 Estonia	0.600	(0.148)	0.448	0.840	8 Germany	0.757	(0.155)	0.556	1.056
9 Greece	0.529	(0.136)	0.400	0.800	9 Sweden	0.593	(0.096)	0.466	0.759	9 Great Britain	0.748	(0.137)	0.552	1.006
10 Belgium	0.519	(0.147)	0.370	0.792	10 Germany	0.574	(0.157)	0.391	0.842	10 Sweden	0.734	(0.128)	0.582	0.976
11 Turkey	0.513	(0.143)	0.332	0.771	11 Netherlands	0.568	(0.140)	0.435	0.826	11 Austria	0.728	(0.225)	0.486	1.161
12 Spain	0.506	(0.137)	0.374	0.775	12 Turkey	0.547	(0.146)	0.394	0.807	12 Korea	0.724	(0.142)	0.558	1.024
13 Portugal	0.502	(0.152)	0.353	0.775	13 Hungary	0.539	(0.148)	0.380	0.777	13 Luxembourg	0.712	(0.193)	0.482	1.071
14 Austria	0.495	(0.126)	0.365	0.731	14 Japan	0.537	(0.072)	0.427	0.680	14 Hungary	0.704	(0.214)	0.497	1.113
15 Denmark	0.480	(0.122)	0.362	0.727	15 Belgium	0.534	(0.202)	0.334	0.898	15 Greece	0.702	(0.252)	0.445	1.135
16 Hungary	0.465	(0.192)	0.275	0.803	16 Ireland	0.516	(0.100)	0.411	0.704	16 Slovak Republic	0.674	(0.319)	0.366	1.260
17 Finland	0.451	(0.123)	0.328	0.700	17 Canada	0.504	(0.092)	0.394	0.663	17 Finland	0.666	(0.125)	0.518	0.912
18 Great Britain	0.440	(0.091)	0.312	0.616	18 Finland	0.494	(0.152)	0.350	0.769	18 Mexico	0.664	(0.086)	0.483	0.809
19 France	0.431	(0.102)	0.325	0.627	19 Mexico	0.490	(0.131)	0.292	0.683	19 Spain	0.664	(0.155)	0.478	0.957
20 Estonia	0.427	(0.119)	0.313	0.638	20 Slovak Republic	0.479	(0.212)	0.291	0.861	20 Australia	0.633	(0.140)	0.479	0.883
21 Slovak Republic	0.419	(0.179)	0.238	0.748	21 United States	0.471	(0.058)	0.370	0.563	21 France	0.625	(0.159)	0.477	0.944
22 Netherlands	0.414	(0.139)	0.291	0.698	22 Great Britain	0.448	(0.131)	0.314	0.667	22 Turkey	0.536	(0.286)	0.250	1.084
23 Mexico	0.398	(0.087)	0.253	0.547	23 Australia	0.424	(0.102)	0.316	0.605	23 Czech Republic	0.504	(0.264)	0.210	0.971
24 Czech Republic	0.362	(0.159)	0.196	0.660	24 France	0.385	(0.102)	0.292	0.588	24 United States	0.504	(0.038)	0.449	0.578
25 United States	0.323	(0.051)	0.242	0.425	25 Austria	0.360	(0.134)	0.225	0.605	25 Poland	0.502	(0.189)	0.270	0.852
26 Australia	0.317	(0.078)	0.233	0.472	26 Poland	0.349	(0.136)	0.197	0.592	26 Estonia	0.500	(0.120)	0.391	0.728
27 Korea	0.296	(0.061)	0.207	0.401	27 Korea	0.326	(0.059)	0.244	0.424	27 Netherlands	0.491	(0.128)	0.368	0.745
28 Poland	0.285	(0.111)	0.164	0.505	28 Czech Republic	0.323	(0.149)	0.152	0.585	28 Canada	0.459	(0.089)	0.340	0.639

**Table E.1 (cont., 4/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

Electrical and optical equipment					Transport equipment					Manufacturing, nec; recycling				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Japan	1.168	(0.065)	1.088	1.306	1 Italy	1.349	(0.473)	0.926	2.190	1 Italy	1.358	(0.412)	0.957	2.096
2 Italy	1.118	(0.331)	0.787	1.694	2 Japan	0.993	(0.179)	0.854	1.379	2 Slovenia	1.024	(0.232)	0.731	1.368
3 Portugal	1.006	(0.136)	0.835	1.229	3 Luxembourg	0.896	(0.281)	0.601	1.383	3 Portugal	0.970	(0.208)	0.755	1.363
4 Ireland	0.969	(0.080)	0.852	1.106	4 Slovenia	0.887	(0.168)	0.664	1.136	4 Ireland	0.908	(0.116)	0.798	1.187
5 Slovenia	0.920	(0.189)	0.695	1.188	5 Portugal	0.883	(0.155)	0.718	1.177	5 Hungary	0.871	(0.206)	0.620	1.236
6 Luxembourg	0.913	(0.261)	0.631	1.371	6 Ireland	0.819	(0.129)	0.689	1.082	6 Germany	0.811	(0.202)	0.598	1.215
7 Denmark	0.834	(0.160)	0.646	1.112	7 Denmark	0.809	(0.161)	0.641	1.104	7 Denmark	0.787	(0.165)	0.614	1.113
8 Germany	0.802	(0.147)	0.645	1.074	8 Germany	0.802	(0.161)	0.589	1.088	8 Austria	0.769	(0.171)	0.568	1.093
9 Great Britain	0.779	(0.140)	0.597	1.016	9 Mexico	0.779	(0.090)	0.570	0.924	9 Greece	0.747	(0.187)	0.546	1.099
10 Sweden	0.770	(0.123)	0.602	0.957	10 Turkey	0.766	(0.216)	0.556	1.167	10 Slovak Republic	0.731	(0.313)	0.427	1.324
11 Austria	0.769	(0.211)	0.520	1.124	11 Greece	0.745	(0.178)	0.549	1.073	11 Turkey	0.700	(0.210)	0.482	1.130
12 Hungary	0.758	(0.217)	0.483	1.118	12 Hungary	0.714	(0.247)	0.463	1.161	12 Korea	0.698	(0.110)	0.543	0.902
13 Slovak Republic	0.748	(0.291)	0.477	1.264	13 Austria	0.708	(0.188)	0.493	1.049	13 Japan	0.696	(0.107)	0.550	0.896
14 Korea	0.737	(0.150)	0.588	1.072	14 Sweden	0.679	(0.122)	0.517	0.903	14 Sweden	0.688	(0.124)	0.514	0.918
15 Belgium	0.734	(0.171)	0.540	1.013	15 Australia	0.675	(0.172)	0.460	0.972	15 Australia	0.687	(0.172)	0.512	1.002
16 Netherlands	0.719	(0.200)	0.529	1.089	16 Belgium	0.671	(0.195)	0.477	1.039	16 Spain	0.683	(0.108)	0.533	0.911
17 Greece	0.688	(0.220)	0.436	1.014	17 Finland	0.655	(0.147)	0.511	0.940	17 Netherlands	0.679	(0.202)	0.513	1.103
18 Spain	0.675	(0.134)	0.494	0.896	18 Great Britain	0.640	(0.126)	0.472	0.876	18 United States	0.661	(0.071)	0.580	0.839
19 Mexico	0.665	(0.104)	0.433	0.783	19 Netherlands	0.635	(0.172)	0.471	0.963	19 Finland	0.616	(0.156)	0.428	0.928
20 Australia	0.664	(0.157)	0.485	0.918	20 Korea	0.623	(0.138)	0.458	0.916	20 Great Britain	0.602	(0.146)	0.439	0.904
21 United States	0.654	(0.059)	0.551	0.761	21 Spain	0.596	(0.163)	0.415	0.894	21 Poland	0.599	(0.180)	0.401	0.952
22 Finland	0.636	(0.116)	0.511	0.849	22 France	0.589	(0.163)	0.418	0.909	22 Luxembourg	0.598	(0.159)	0.416	0.930
23 Turkey	0.619	(0.266)	0.354	1.081	23 Estonia	0.562	(0.132)	0.428	0.807	23 Belgium	0.580	(0.189)	0.366	0.939
24 France	0.617	(0.166)	0.451	0.935	24 Slovak Republic	0.543	(0.274)	0.314	1.076	24 France	0.577	(0.101)	0.454	0.793
25 Estonia	0.597	(0.169)	0.396	0.871	25 United States	0.517	(0.044)	0.420	0.590	25 Czech Republic	0.568	(0.381)	0.190	1.258
26 Czech Republic	0.572	(0.335)	0.164	1.123	26 Czech Republic	0.508	(0.259)	0.258	0.986	26 Canada	0.498	(0.105)	0.387	0.736
27 Poland	0.560	(0.196)	0.302	0.901	27 Poland	0.501	(0.133)	0.353	0.769	27 Estonia	0.482	(0.147)	0.329	0.750
28 Canada	0.483	(0.098)	0.335	0.660	28 Canada	0.410	(0.084)	0.285	0.571	28 Mexico	0.474	(0.067)	0.325	0.598

**Table E.1 (cont., 5/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

Electricity, gas and water supply					Construction					Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Slovenia	1.122	(0.222)	0.847	1.437	1 Sweden	1.476	(0.212)	1.206	1.840	1 Denmark	2.068	(0.320)	1.693	2.551
2 Japan	0.961	(0.167)	0.797	1.275	2 Denmark	1.450	(0.308)	1.125	2.018	2 Japan	1.729	(0.109)	1.525	1.904
3 Belgium	0.798	(0.197)	0.594	1.180	3 Italy	1.425	(0.381)	0.973	2.053	3 Italy	1.512	(0.315)	1.200	2.072
4 Spain	0.704	(0.128)	0.549	0.934	4 Germany	1.293	(0.286)	0.980	1.822	4 Sweden	1.497	(0.204)	1.173	1.789
5 France	0.691	(0.180)	0.507	1.023	5 Austria	1.264	(0.295)	0.963	1.804	5 Germany	1.496	(0.336)	1.113	2.076
6 Slovak Republic	0.686	(0.279)	0.392	1.213	6 Korea	1.246	(0.173)	0.989	1.519	6 Korea	1.326	(0.114)	1.117	1.474
7 Germany	0.667	(0.147)	0.517	0.942	7 Netherlands	1.240	(0.257)	0.962	1.708	7 Portugal	1.320	(0.322)	0.995	1.899
8 Hungary	0.644	(0.197)	0.424	1.015	8 Ireland	1.231	(0.242)	0.941	1.671	8 Spain	1.277	(0.280)	0.946	1.773
9 Austria	0.631	(0.197)	0.404	0.995	9 Japan	1.201	(0.090)	1.062	1.366	9 Austria	1.271	(0.306)	0.921	1.811
10 Canada	0.628	(0.078)	0.534	0.793	10 Portugal	1.148	(0.255)	0.843	1.648	10 Netherlands	1.230	(0.259)	0.937	1.679
11 Italy	0.612	(0.183)	0.445	0.971	11 Spain	1.091	(0.296)	0.749	1.634	11 Great Britain	1.218	(0.242)	0.894	1.590
12 Sweden	0.610	(0.106)	0.473	0.803	12 Great Britain	1.088	(0.213)	0.793	1.423	12 Greece	1.197	(0.249)	0.887	1.631
13 Luxembourg	0.597	(0.131)	0.396	0.801	13 Luxembourg	1.056	(0.218)	0.756	1.429	13 Ireland	1.164	(0.345)	0.821	1.724
14 Finland	0.551	(0.112)	0.412	0.777	14 Belgium	0.960	(0.330)	0.597	1.536	14 Luxembourg	1.118	(0.248)	0.774	1.524
15 Greece	0.492	(0.139)	0.341	0.761	15 Slovak Republic	0.948	(0.482)	0.519	1.857	15 Turkey	1.094	(0.154)	0.819	1.374
16 Ireland	0.470	(0.083)	0.370	0.644	16 Hungary	0.927	(0.298)	0.565	1.451	16 France	1.058	(0.199)	0.829	1.400
17 Korea	0.463	(0.112)	0.371	0.715	17 Slovenia	0.913	(0.270)	0.535	1.317	17 Finland	1.054	(0.200)	0.779	1.405
18 Great Britain	0.455	(0.075)	0.339	0.594	18 Poland	0.910	(0.244)	0.587	1.373	18 Australia	1.053	(0.238)	0.766	1.465
19 Portugal	0.426	(0.103)	0.296	0.648	19 Australia	0.910	(0.200)	0.680	1.282	19 Belgium	1.050	(0.215)	0.694	1.417
20 Turkey	0.416	(0.104)	0.280	0.608	20 France	0.868	(0.252)	0.596	1.337	20 Slovenia	1.044	(0.269)	0.733	1.429
21 Mexico	0.410	(0.094)	0.272	0.595	21 Finland	0.853	(0.195)	0.570	1.223	21 Estonia	0.955	(0.257)	0.692	1.358
22 Estonia	0.408	(0.133)	0.237	0.642	22 Greece	0.849	(0.212)	0.583	1.203	22 Poland	0.911	(0.219)	0.628	1.314
23 Netherlands	0.375	(0.127)	0.241	0.635	23 Estonia	0.749	(0.263)	0.508	1.220	23 Slovak Republic	0.883	(0.469)	0.421	1.686
24 Czech Republic	0.363	(0.171)	0.177	0.687	24 Czech Republic	0.739	(0.322)	0.435	1.328	24 Hungary	0.818	(0.312)	0.492	1.372
25 Denmark	0.347	(0.094)	0.231	0.541	25 United States	0.705	(0.080)	0.580	0.884	25 United States	0.795	(0.102)	0.644	0.976
26 Australia	0.333	(0.079)	0.244	0.498	26 Mexico	0.664	(0.121)	0.425	0.854	26 Czech Republic	0.769	(0.371)	0.413	1.419
27 United States	0.322	(0.031)	0.271	0.399	27 Canada	0.660	(0.157)	0.487	0.973	27 Mexico	0.668	(0.148)	0.388	0.852
28 Poland	0.166	(0.061)	0.088	0.289	28 Turkey	0.416	(0.135)	0.264	0.707	28 Canada	0.660	(0.123)	0.507	0.893

**Table E.1 (cont., 6/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

Wholesale trade and commission trade, except for motor vehicles and motorcycles					Retail trade, except for motor vehicles and motorcycles; repair of household goods					Hotels and restaurants				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Denmark	2.199	(0.368)	1.822	2.751	1 Denmark	2.591	(0.435)	2.148	3.225	1 Denmark	2.604	(0.394)	2.148	3.109
2 Italy	1.540	(0.311)	1.234	2.094	2 Netherlands	1.608	(0.323)	1.291	2.106	2 Japan	1.697	(0.095)	1.529	1.873
3 Sweden	1.479	(0.181)	1.196	1.747	3 Japan	1.590	(0.103)	1.404	1.754	3 Sweden	1.680	(0.220)	1.323	2.052
4 Germany	1.464	(0.345)	1.107	2.077	4 Sweden	1.544	(0.221)	1.204	1.851	4 Austria	1.512	(0.218)	1.218	1.847
5 Portugal	1.362	(0.242)	0.988	1.789	5 Austria	1.533	(0.299)	1.178	2.051	5 Italy	1.508	(0.310)	1.185	2.084
6 Austria	1.360	(0.323)	1.014	1.942	6 Italy	1.516	(0.298)	1.213	2.047	6 Germany	1.485	(0.285)	1.162	2.001
7 Japan	1.356	(0.098)	1.168	1.503	7 Portugal	1.432	(0.326)	1.138	2.008	7 Portugal	1.451	(0.323)	1.143	2.052
8 Korea	1.316	(0.135)	1.120	1.517	8 Germany	1.425	(0.299)	1.062	1.951	8 Belgium	1.299	(0.248)	1.007	1.772
9 Netherlands	1.280	(0.174)	1.030	1.581	9 Spain	1.324	(0.294)	1.005	1.843	9 Ireland	1.275	(0.347)	0.927	1.875
10 Spain	1.257	(0.305)	0.941	1.814	10 Ireland	1.257	(0.383)	0.877	1.882	10 Luxembourg	1.250	(0.236)	0.887	1.558
11 Great Britain	1.174	(0.273)	0.775	1.580	11 Belgium	1.203	(0.277)	0.928	1.704	11 Korea	1.248	(0.115)	1.086	1.457
12 Turkey	1.111	(0.179)	0.835	1.404	12 Luxembourg	1.192	(0.231)	0.844	1.550	12 Netherlands	1.220	(0.293)	0.913	1.723
13 Greece	1.074	(0.276)	0.801	1.560	13 Turkey	1.184	(0.166)	0.893	1.403	13 Great Britain	1.188	(0.232)	0.860	1.570
14 Finland	1.046	(0.169)	0.833	1.343	14 Korea	1.183	(0.142)	0.990	1.435	14 Greece	1.177	(0.206)	0.897	1.565
15 Ireland	1.045	(0.334)	0.713	1.589	15 Slovenia	1.163	(0.292)	0.817	1.560	15 Spain	1.171	(0.258)	0.788	1.607
16 Belgium	1.042	(0.242)	0.794	1.494	16 Great Britain	1.151	(0.249)	0.850	1.545	16 Slovenia	1.139	(0.269)	0.832	1.548
17 Slovenia	1.019	(0.267)	0.723	1.411	17 Finland	1.122	(0.195)	0.862	1.447	17 Turkey	1.125	(0.158)	0.839	1.373
18 Australia	0.966	(0.242)	0.724	1.388	18 France	1.069	(0.192)	0.836	1.395	18 Finland	1.123	(0.107)	0.952	1.306
19 France	0.898	(0.215)	0.666	1.280	19 Greece	1.060	(0.265)	0.817	1.531	19 France	1.103	(0.173)	0.875	1.418
20 Luxembourg	0.881	(0.215)	0.642	1.270	20 Estonia	0.942	(0.252)	0.669	1.345	20 Poland	0.994	(0.205)	0.723	1.405
21 Estonia	0.863	(0.213)	0.635	1.222	21 Poland	0.887	(0.225)	0.622	1.314	21 Australia	0.983	(0.215)	0.757	1.381
22 Slovak Republic	0.854	(0.473)	0.377	1.672	22 Slovak Republic	0.871	(0.532)	0.183	1.669	22 Estonia	0.961	(0.195)	0.762	1.306
23 Poland	0.833	(0.237)	0.551	1.289	23 Czech Republic	0.802	(0.311)	0.522	1.375	23 Slovak Republic	0.838	(0.453)	0.333	1.574
24 United States	0.748	(0.087)	0.602	0.911	24 Australia	0.776	(0.184)	0.540	1.077	24 United States	0.803	(0.090)	0.649	0.987
25 Czech Republic	0.736	(0.358)	0.371	1.375	25 Hungary	0.762	(0.297)	0.491	1.319	25 Czech Republic	0.740	(0.392)	0.339	1.457
26 Mexico	0.715	(0.141)	0.439	0.893	26 United States	0.760	(0.106)	0.597	0.943	26 Hungary	0.731	(0.314)	0.434	1.333
27 Hungary	0.701	(0.337)	0.393	1.349	27 Canada	0.687	(0.175)	0.497	0.979	27 Canada	0.718	(0.139)	0.570	0.993
28 Canada	0.653	(0.146)	0.488	0.926	28 Mexico	0.659	(0.102)	0.461	0.788	28 Mexico	0.682	(0.195)	0.343	0.965

**Table E.1 (cont., 7/11):** Country ranking based on the average shadow price (in thousands of 2005 U.S. dollars per ton of oil equivalent)

Water transport					Other supporting and auxiliary transport activities; activities of travel agencies					Post and telecommunications				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Slovak Republic	1.098	(0.670)	0.435	2.519	1 Denmark	2.407	(0.377)	2.030	3.122	1 Denmark	2.503	(0.511)	1.968	3.313
2 Australia	0.943	(0.198)	0.716	1.357	2 Japan	1.875	(0.145)	1.692	2.110	2 Austria	1.769	(0.332)	1.401	2.382
3 Turkey	0.865	(0.391)	0.508	1.607	3 Netherlands	1.538	(0.332)	1.208	2.133	3 Japan	1.570	(0.089)	1.377	1.699
4 Hungary	0.826	(0.411)	0.377	1.683	4 Sweden	1.491	(0.203)	1.165	1.846	4 Sweden	1.450	(0.213)	1.117	1.794
5 Estonia	0.823	(0.189)	0.628	1.204	5 Austria	1.456	(0.303)	1.133	2.084	5 Italy	1.425	(0.346)	1.067	2.035
6 Austria	0.757	(0.386)	0.387	1.502	6 Germany	1.422	(0.285)	1.111	1.978	6 Germany	1.421	(0.305)	1.060	1.942
7 Sweden	0.726	(0.275)	0.380	1.197	7 Italy	1.361	(0.344)	1.048	2.021	7 Portugal	1.380	(0.355)	1.003	2.012
8 Mexico	0.689	(0.158)	0.443	0.995	8 Great Britain	1.264	(0.280)	0.876	1.756	8 Spain	1.292	(0.368)	0.919	1.956
9 Netherlands	0.687	(0.181)	0.488	1.070	9 Turkey	1.185	(0.488)	0.714	2.078	9 Netherlands	1.231	(0.339)	0.860	1.749
10 Ireland	0.638	(0.262)	0.371	1.173	10 Portugal	1.162	(0.384)	0.782	1.899	10 Great Britain	1.224	(0.286)	0.851	1.665
11 Portugal	0.622	(0.136)	0.455	0.949	11 Ireland	1.141	(0.346)	0.807	1.802	11 Ireland	1.195	(0.340)	0.820	1.769
12 Italy	0.604	(0.180)	0.387	0.975	12 Belgium	1.103	(0.288)	0.800	1.694	12 Luxembourg	1.157	(0.218)	0.807	1.487
13 Luxembourg	0.561	(0.214)	0.292	0.996	13 France	1.073	(0.271)	0.821	1.620	13 Finland	1.130	(0.171)	0.908	1.448
14 Czech Republic	0.545	(0.109)	0.351	0.750	14 Finland	1.072	(0.173)	0.859	1.458	14 Belgium	1.112	(0.298)	0.775	1.659
15 Finland	0.516	(0.170)	0.325	0.892	15 Korea	1.056	(0.127)	0.835	1.308	15 France	1.084	(0.255)	0.782	1.525
16 Spain	0.457	(0.198)	0.249	0.864	16 Luxembourg	1.040	(0.261)	0.718	1.553	16 Greece	1.077	(0.256)	0.807	1.553
17 Korea	0.456	(0.135)	0.297	0.754	17 Greece	1.031	(0.298)	0.765	1.641	17 Slovenia	1.067	(0.306)	0.678	1.484
18 France	0.449	(0.189)	0.255	0.862	18 Slovenia	1.026	(0.330)	0.586	1.534	18 Turkey	1.046	(0.274)	0.737	1.541
19 Greece	0.440	(0.135)	0.277	0.761	19 Spain	1.009	(0.332)	0.707	1.675	19 Estonia	0.980	(0.304)	0.605	1.459
20 Canada	0.418	(0.152)	0.254	0.756	20 Slovak Republic	0.990	(0.463)	0.511	1.882	20 Korea	0.976	(0.127)	0.764	1.150
21 Great Britain	0.408	(0.191)	0.217	0.821	21 Australia	0.956	(0.237)	0.711	1.444	21 Poland	0.969	(0.340)	0.599	1.542
22 United States	0.374	(0.127)	0.234	0.670	22 Estonia	0.923	(0.253)	0.657	1.401	22 Australia	0.910	(0.242)	0.636	1.338
23 Denmark	0.363	(0.141)	0.193	0.698	23 Poland	0.910	(0.361)	0.569	1.617	23 Slovak Republic	0.891	(0.474)	0.381	1.697
24 Japan	0.344	(0.147)	0.191	0.689	24 Czech Republic	0.874	(0.404)	0.513	1.660	24 Czech Republic	0.848	(0.368)	0.478	1.506
25 Belgium	0.329	(0.138)	0.171	0.655	25 Hungary	0.872	(0.374)	0.447	1.537	25 Hungary	0.703	(0.344)	0.374	1.356
26 Poland	0.287	(0.095)	0.174	0.541	26 United States	0.675	(0.184)	0.412	1.068	26 United States	0.688	(0.113)	0.523	0.865
27 Germany	0.275	(0.109)	0.147	0.551	27 Canada	0.567	(0.121)	0.427	0.856	27 Mexico	0.634	(0.126)	0.403	0.813
					28 Mexico	0.520	(0.126)	0.293	0.797	28 Canada	0.578	(0.175)	0.392	0.899

**Table E.1 (cont., 8/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent



Financial intermediation					Real estate activities					Renting of M&Eq and other business activities				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Denmark	2.590	(0.386)	2.153	3.078	1 Denmark	2.115	(0.351)	1.705	2.664	1 Denmark	2.347	(0.351)	1.954	2.789
2 Netherlands	1.660	(0.266)	1.371	2.082	2 Austria	1.863	(0.287)	1.473	2.387	2 Sweden	1.529	(0.205)	1.210	1.812
3 Sweden	1.657	(0.224)	1.296	1.969	3 Germany	1.794	(0.303)	1.424	2.364	3 Italy	1.503	(0.320)	1.182	2.076
4 Portugal	1.555	(0.316)	1.262	2.103	4 Japan	1.668	(0.103)	1.484	1.840	4 Japan	1.481	(0.102)	1.300	1.622
5 Japan	1.501	(0.105)	1.329	1.677	5 Sweden	1.666	(0.212)	1.317	1.951	5 Austria	1.439	(0.301)	1.109	1.976
6 Italy	1.496	(0.317)	1.171	2.048	6 Portugal	1.629	(0.272)	1.252	2.162	6 Portugal	1.380	(0.279)	0.988	1.883
7 Austria	1.442	(0.351)	1.099	2.058	7 Italy	1.516	(0.310)	1.131	2.132	7 Netherlands	1.370	(0.269)	1.069	1.835
8 Spain	1.292	(0.285)	0.969	1.780	8 Great Britain	1.442	(0.282)	1.067	1.870	8 Korea	1.343	(0.144)	1.129	1.531
9 Germany	1.288	(0.207)	1.027	1.638	9 Netherlands	1.437	(0.278)	1.087	1.929	9 Great Britain	1.266	(0.254)	0.946	1.649
10 Belgium	1.278	(0.245)	0.997	1.713	10 Spain	1.313	(0.322)	0.896	1.938	10 Spain	1.257	(0.266)	0.972	1.743
11 Luxembourg	1.220	(0.220)	0.891	1.539	11 Ireland	1.214	(0.420)	0.739	1.943	11 Germany	1.246	(0.259)	0.960	1.699
12 Korea	1.209	(0.168)	0.921	1.385	12 Luxembourg	1.201	(0.246)	0.861	1.606	12 Ireland	1.229	(0.338)	0.888	1.798
13 Great Britain	1.196	(0.255)	0.886	1.575	13 Turkey	1.186	(0.198)	0.853	1.570	13 Turkey	1.195	(0.180)	0.875	1.484
14 Ireland	1.187	(0.385)	0.809	1.821	14 Belgium	1.163	(0.302)	0.782	1.777	14 Finland	1.168	(0.200)	0.918	1.519
15 Slovenia	1.141	(0.307)	0.779	1.565	15 Greece	1.158	(0.217)	0.874	1.603	15 Greece	1.130	(0.273)	0.847	1.592
16 Greece	1.115	(0.245)	0.849	1.546	16 Finland	1.127	(0.122)	0.914	1.388	16 Luxembourg	1.094	(0.230)	0.790	1.497
17 France	1.109	(0.192)	0.866	1.429	17 United States	1.111	(0.058)	1.024	1.203	17 Belgium	1.061	(0.252)	0.810	1.524
18 Turkey	1.104	(0.149)	0.834	1.335	18 France	1.106	(0.150)	0.841	1.405	18 France	1.051	(0.214)	0.808	1.433
19 Finland	1.101	(0.173)	0.881	1.395	19 Slovenia	1.104	(0.391)	0.653	1.665	19 Slovenia	1.022	(0.355)	0.586	1.493
20 Estonia	0.983	(0.309)	0.624	1.427	20 Korea	1.057	(0.199)	0.796	1.440	20 Australia	1.009	(0.216)	0.770	1.397
21 Australia	0.929	(0.219)	0.698	1.300	21 Australia	1.047	(0.233)	0.744	1.502	21 Estonia	0.888	(0.230)	0.655	1.274
22 Slovak Republic	0.891	(0.525)	0.308	1.739	22 Poland	1.045	(0.280)	0.716	1.607	22 Slovak Republic	0.862	(0.476)	0.372	1.669
23 Poland	0.852	(0.207)	0.629	1.232	23 Mexico	0.790	(0.150)	0.558	1.004	23 Czech Republic	0.792	(0.342)	0.448	1.411
24 Czech Republic	0.777	(0.361)	0.434	1.418	24 Estonia	0.773	(0.201)	0.535	1.174	24 United States	0.709	(0.098)	0.584	0.895
25 United States	0.758	(0.123)	0.589	0.968	25 Slovak Republic	0.734	(0.509)	0.172	1.674	25 Hungary	0.704	(0.355)	0.308	1.339
26 Hungary	0.751	(0.291)	0.455	1.290	26 Czech Republic	0.635	(0.322)	0.304	1.285	26 Poland	0.699	(0.165)	0.553	1.046
27 Mexico	0.681	(0.143)	0.433	0.846	27 Hungary	0.625	(0.329)	0.304	1.302	27 Canada	0.694	(0.153)	0.531	0.977
28 Canada	0.642	(0.137)	0.506	0.884	28 Canada	0.564	(0.109)	0.377	0.801	28 Mexico	0.664	(0.169)	0.403	0.918

**Table E.1 (cont., 9/11): Country ranking based on the average shadow price<sup>a</sup>**

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

Public admin and defence; compulsory social security					Education					Health and social work				
	AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX		AVG	(SD)	MIN	MAX
1 Denmark	2.112	(0.309)	1.781	2.561	1 Denmark	2.543	(0.384)	2.073	3.022	1 Denmark	2.557	(0.365)	2.130	3.013
2 Austria	1.679	(0.340)	1.341	2.297	2 Sweden	1.664	(0.210)	1.301	2.013	2 Sweden	1.654	(0.204)	1.323	1.944
3 Japan	1.645	(0.130)	1.499	1.859	3 Japan	1.661	(0.124)	1.463	1.917	3 Japan	1.582	(0.093)	1.420	1.726
4 Sweden	1.629	(0.188)	1.362	1.895	4 Austria	1.496	(0.425)	1.115	2.213	4 Austria	1.528	(0.260)	1.199	1.994
5 Italy	1.504	(0.310)	1.187	2.071	5 Italy	1.473	(0.327)	1.154	2.038	5 Italy	1.495	(0.312)	1.173	2.045
6 Germany	1.337	(0.237)	1.057	1.764	6 Portugal	1.391	(0.330)	1.089	1.968	6 Germany	1.292	(0.320)	0.930	1.825
7 Spain	1.311	(0.295)	0.993	1.842	7 Ireland	1.311	(0.374)	0.940	1.930	7 Belgium	1.258	(0.241)	0.985	1.687
8 Netherlands	1.283	(0.364)	0.852	1.827	8 Great Britain	1.294	(0.265)	0.919	1.675	8 Great Britain	1.226	(0.205)	0.960	1.543
9 Great Britain	1.217	(0.222)	0.988	1.583	9 Belgium	1.237	(0.241)	0.908	1.646	9 Finland	1.185	(0.147)	0.998	1.433
10 Korea	1.216	(0.121)	1.052	1.421	10 Korea	1.213	(0.133)	1.036	1.488	10 Korea	1.180	(0.144)	0.970	1.418
11 Portugal	1.206	(0.280)	0.954	1.707	11 Finland	1.172	(0.152)	0.956	1.419	11 Portugal	1.170	(0.244)	0.938	1.626
12 Luxembourg	1.188	(0.218)	0.940	1.580	12 Spain	1.172	(0.291)	0.873	1.681	12 Ireland	1.168	(0.398)	0.774	1.856
13 Belgium	1.172	(0.215)	0.941	1.576	13 Netherlands	1.163	(0.277)	0.906	1.630	13 Luxembourg	1.162	(0.218)	0.883	1.504
14 Finland	1.155	(0.129)	0.993	1.386	14 Turkey	1.140	(0.196)	0.842	1.482	14 Spain	1.152	(0.272)	0.859	1.633
15 Ireland	1.146	(0.400)	0.744	1.809	15 France	1.130	(0.176)	0.911	1.419	15 Netherlands	1.149	(0.274)	0.864	1.602
16 Greece	1.140	(0.217)	0.931	1.563	16 Germany	1.124	(0.302)	0.774	1.605	16 France	1.145	(0.185)	0.909	1.456
17 Slovenia	1.129	(0.330)	0.748	1.577	17 Greece	1.117	(0.258)	0.801	1.560	17 Greece	1.112	(0.223)	0.871	1.507
18 Turkey	1.032	(0.256)	0.745	1.506	18 Luxembourg	1.100	(0.243)	0.799	1.504	18 Turkey	1.105	(0.205)	0.828	1.486
19 Australia	0.971	(0.217)	0.754	1.361	19 Poland	1.098	(0.256)	0.760	1.545	19 Slovenia	1.077	(0.260)	0.783	1.448
20 Poland	0.955	(0.190)	0.755	1.341	20 Slovenia	1.085	(0.278)	0.765	1.470	20 Poland	1.053	(0.267)	0.745	1.504
21 France	0.950	(0.138)	0.763	1.186	21 Australia	1.014	(0.238)	0.767	1.412	21 Estonia	0.946	(0.217)	0.734	1.305
22 Estonia	0.887	(0.245)	0.610	1.298	22 Estonia	0.956	(0.253)	0.689	1.355	22 Australia	0.928	(0.226)	0.684	1.305
23 Slovak Republic	0.832	(0.460)	0.341	1.559	23 United States	0.892	(0.093)	0.748	1.063	23 Slovak Republic	0.879	(0.441)	0.436	1.575
24 Czech Republic	0.745	(0.381)	0.353	1.424	24 Slovak Republic	0.849	(0.417)	0.418	1.595	24 Hungary	0.760	(0.329)	0.457	1.360
25 Hungary	0.716	(0.321)	0.426	1.334	25 Hungary	0.765	(0.311)	0.464	1.336	25 Czech Republic	0.751	(0.386)	0.383	1.428
26 Mexico	0.704	(0.053)	0.628	0.819	26 Czech Republic	0.717	(0.353)	0.352	1.351	26 United States	0.735	(0.095)	0.593	0.898
27 Canada	0.679	(0.093)	0.568	0.870	27 Mexico	0.650	(0.138)	0.369	0.823	27 Canada	0.697	(0.109)	0.557	0.901
28 United States	0.635	(0.061)	0.552	0.760	28 Canada	0.649	(0.119)	0.506	0.855	28 Mexico	0.687	(0.117)	0.472	0.827

**Table E.1 (cont., 10/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

**Other community, social and personal services**

	AVG	(SD)	MIN	MAX
1 Denmark	2.434	(0.356)	2.029	2.888
2 Sweden	1.648	(0.207)	1.303	1.999
3 Japan	1.584	(0.098)	1.416	1.781
4 Austria	1.533	(0.350)	1.153	2.179
5 Italy	1.518	(0.313)	1.190	2.076
6 Portugal	1.464	(0.186)	1.184	1.705
7 Germany	1.450	(0.264)	1.123	1.887
8 Ireland	1.293	(0.312)	0.938	1.832
9 Belgium	1.252	(0.174)	1.036	1.595
10 Netherlands	1.238	(0.191)	1.009	1.582
11 Korea	1.235	(0.122)	1.032	1.437
12 Greece	1.164	(0.187)	0.891	1.515
13 Luxembourg	1.134	(0.208)	0.832	1.426
14 Turkey	1.108	(0.197)	0.795	1.476
15 Spain	1.079	(0.221)	0.811	1.472
16 Finland	1.060	(0.105)	0.875	1.243
17 Slovenia	1.045	(0.239)	0.776	1.405
18 France	1.007	(0.107)	0.824	1.200
19 Australia	0.954	(0.226)	0.676	1.344
20 Estonia	0.950	(0.229)	0.688	1.328
21 Great Britain	0.913	(0.106)	0.745	1.084
22 Slovak Republic	0.872	(0.511)	0.323	1.698
23 Poland	0.854	(0.190)	0.653	1.241
24 United States	0.743	(0.080)	0.624	0.906
25 Hungary	0.698	(0.302)	0.395	1.274
26 Mexico	0.683	(0.108)	0.458	0.820
27 Canada	0.660	(0.137)	0.505	0.924
28 Czech Republic	0.659	(0.295)	0.269	1.194

**Table E.1 (cont., 11/11):** Country ranking based on the average shadow price<sup>a</sup>

<sup>a</sup> In thousands of 2005 U.S. dollars per ton of oil equivalent

## Appendix F: Correlation coefficients

	AUS	JAP	KOR	TUR	CAN	MEX	USA	CZE	EST	HUN	POL	SVR	SLO	AUT
Australia	1.00													
Japan	0.95	1.00												
Korea	0.98	0.88	1.00											
Turkey	-0.84	-0.64	-0.93	1.00										
Canada	0.52	0.33	0.67	-0.83	1.00									
Mexico	-0.46	-0.62	-0.28	-0.04	0.52	1.00								
United States	0.94	0.87	0.96	-0.88	0.75	-0.17	1.00							
Czech Republic	-0.33	-0.04	-0.49	0.75	-0.63	-0.36	-0.35	1.00						
Estonia	-0.89	-0.71	-0.95	0.98	-0.70	0.14	-0.86	0.73	1.00					
Hungary	-1.00	-0.97	-0.97	0.81	-0.51	0.47	-0.94	0.27	0.86	1.00				
Poland	0.11	-0.03	0.27	-0.46	0.88	0.79	0.44	-0.36	-0.28	-0.11	1.00			
Slovak Republic	-0.97	-0.89	-0.99	0.91	-0.71	0.24	-0.99	0.41	0.91	0.97	-0.35	1.00		
Slovenia	-0.99	-0.99	-0.94	0.76	-0.46	0.52	-0.93	0.19	0.81	1.00	-0.08	0.95	1.00	
Austria	-0.91	-0.81	-0.96	0.93	-0.82	0.06	-0.99	0.46	0.89	0.91	-0.51	0.98	0.88	1.00
Belgium	-0.99	-0.94	-0.99	0.87	-0.61	0.36	-0.97	0.35	0.89	0.99	-0.23	0.99	0.98	0.95
Denmark	-0.99	-0.92	-0.99	0.88	-0.65	0.32	-0.98	0.37	0.90	0.99	-0.27	1.00	0.97	0.97
Finland	-0.99	-0.91	-0.99	0.90	-0.58	0.38	-0.94	0.45	0.94	0.98	-0.16	0.98	0.96	0.93
France	-0.55	-0.77	-0.40	0.05	0.09	0.68	-0.50	-0.60	0.11	0.60	0.19	0.47	0.67	0.38
Germany	-0.87	-0.78	-0.93	0.89	-0.84	0.00	-0.99	0.41	0.84	0.88	-0.58	0.96	0.85	0.99
Great Britain	-0.86	-0.86	-0.86	0.73	-0.69	0.16	-0.96	0.11	0.69	0.88	-0.47	0.92	0.89	0.93
Greece	-0.51	-0.23	-0.66	0.87	-0.70	-0.25	-0.52	0.98	0.85	0.46	-0.37	0.58	0.38	0.61
Ireland	-0.60	-0.35	-0.71	0.87	-0.59	-0.04	-0.54	0.94	0.89	0.55	-0.19	0.62	0.48	0.62
Italy	-0.99	-0.97	-0.97	0.81	-0.55	0.42	-0.96	0.25	0.85	1.00	-0.18	0.98	0.99	0.93
Luxembourg	-1.00	-0.95	-0.98	0.84	-0.53	0.45	-0.94	0.34	0.89	1.00	-0.12	0.97	0.99	0.92
Netherlands	-0.87	-0.70	-0.95	0.99	-0.86	-0.03	-0.94	0.66	0.96	0.85	-0.51	0.95	0.81	0.97
Portugal	-0.69	-0.73	-0.69	0.56	-0.67	0.02	-0.86	-0.06	0.49	0.72	-0.58	0.79	0.74	0.83
Spain	-0.64	-0.39	-0.74	0.88	-0.58	0.00	-0.57	0.92	0.91	0.59	-0.17	0.65	0.52	0.64
Sweden	-0.98	-0.98	-0.95	0.77	-0.51	0.46	-0.95	0.19	0.81	0.99	-0.15	0.96	1.00	0.91

	BEL	DEN	FIN	FRA	GER	GB	GRE	IRE	ITA	LUX	NET	POR	SPA	SWE
Belgium	1.00													
Denmark	1.00	1.00												
Finland	0.99	0.99	1.00											
France	0.54	0.52	0.44	1.00										
Germany	0.93	0.94	0.88	0.40	1.00									
Great Britain	0.91	0.92	0.83	0.65	0.95	1.00								
Greece	0.53	0.55	0.62	-0.43	0.56	0.29	1.00							
Ireland	0.59	0.60	0.70	-0.33	0.55	0.30	0.98	1.00						
Italy	0.99	0.99	0.97	0.62	0.91	0.92	0.44	0.52	1.00					
Luxembourg	0.99	0.99	0.99	0.55	0.88	0.87	0.51	0.60	0.99	1.00				
Netherlands	0.91	0.92	0.91	0.17	0.95	0.82	0.79	0.78	0.86	0.87	1.00			
Portugal	0.76	0.77	0.65	0.66	0.88	0.96	0.10	0.07	0.78	0.70	0.68	1.00		
Spain	0.63	0.64	0.73	-0.28	0.57	0.33	0.97	1.00	0.55	0.64	0.80	0.10	1.00	
Sweden	0.99	0.98	0.96	0.67	0.89	0.92	0.38	0.46	1.00	0.98	0.83	0.79	0.50	1.00

**Table F.1:** Correlation coefficients between the different country-specific wedges of the chemicals sector with the countries grouped by world regions

	AUS	JAP	KOR	TUR	CAN	MEX	USA	CZE	EST	HUN	POL	SVR	SLO	AUT
Australia	1.00													
Japan	0.96	1.00												
Korea	-0.86	-0.97	1.00											
Turkey	-0.94	-0.95	0.86	1.00										
Canada	0.96	0.97	-0.89	-1.00	1.00									
Mexico	0.94	0.94	-0.84	-1.00	0.99	1.00								
United States	0.96	0.95	-0.86	-1.00	1.00	1.00	1.00							
Czech Republic	-0.99	-0.96	0.87	0.98	-0.99	-0.98	-0.99	1.00						
Estonia	-0.72	-0.54	0.32	0.73	-0.71	-0.76	-0.75	0.74	1.00					
Hungary	-0.71	-0.86	0.95	0.66	-0.71	-0.63	-0.66	0.70	0.04	1.00				
Poland	-0.97	-0.99	0.94	0.97	-0.99	-0.97	-0.98	0.99	0.62	0.80	1.00			
Slovak Republic	-0.69	-0.60	0.42	0.82	-0.78	-0.84	-0.82	0.75	0.92	0.12	0.68	1.00		
Slovenia	-0.97	-0.99	0.95	0.92	-0.95	-0.91	-0.93	0.96	0.55	0.85	0.98	0.56	1.00	
Austria	-0.44	-0.40	0.24	0.66	-0.60	-0.69	-0.64	0.54	0.79	-0.07	0.48	0.95	0.32	1.00
Belgium	-0.76	-0.88	0.88	0.91	-0.90	-0.90	-0.89	0.83	0.45	0.72	0.88	0.68	0.81	0.62
Denmark	-0.96	-0.86	0.71	0.94	-0.94	-0.95	-0.96	0.97	0.89	0.49	0.91	0.86	0.87	0.65
Finland	-0.56	-0.42	0.21	0.68	-0.63	-0.71	-0.68	0.62	0.95	-0.10	0.51	0.97	0.39	0.94
France	-0.87	-0.92	0.85	0.98	-0.97	-0.98	-0.97	0.93	0.67	0.65	0.94	0.82	0.87	0.71
Germany	-0.92	-0.90	0.79	0.99	-0.98	-1.00	-0.99	0.96	0.80	0.56	0.94	0.89	0.87	0.74
Great Britain	0.86	0.68	-0.49	-0.76	0.77	0.78	0.80	-0.84	-0.92	-0.28	-0.74	-0.76	-0.73	-0.52
Greece	-0.99	-0.96	0.86	0.98	-0.99	-0.98	-0.99	1.00	0.75	0.68	0.98	0.77	0.96	0.56
Ireland	-0.77	-0.93	0.98	0.83	-0.84	-0.80	-0.81	0.80	0.22	0.94	0.89	0.39	0.88	0.27
Italy	-0.92	-0.96	0.91	0.99	-0.99	-0.98	-0.98	0.96	0.63	0.74	0.98	0.76	0.92	0.62
Luxembourg	0.73	0.88	-0.96	-0.69	0.73	0.66	0.69	-0.72	-0.07	-1.00	-0.82	-0.16	-0.87	0.02
Netherlands	-0.31	-0.32	0.20	0.58	-0.51	-0.60	-0.55	0.42	0.63	-0.08	0.39	0.86	0.22	0.98
Portugal	-0.95	-0.90	0.77	0.98	-0.98	-0.99	-0.99	0.98	0.84	0.55	0.94	0.88	0.89	0.70
Spain	-0.91	-0.98	0.98	0.86	-0.89	-0.84	-0.86	0.90	0.37	0.94	0.95	0.41	0.98	0.19
Sweden	0.85	0.81	-0.78	-0.64	0.70	0.63	0.68	-0.78	-0.37	-0.79	-0.79	-0.22	-0.88	0.09

	BEL	DEN	FIN	FRA	GER	GB	GRE	IRE	ITA	LUX	NET	POR	SPA	SWE
Belgium	1.00													
Denmark	0.72	1.00												
Finland	0.49	0.78	1.00											
France	0.96	0.88	0.67	1.00										
Germany	0.88	0.96	0.77	0.98	1.00									
Great Britain	-0.43	-0.94	-0.75	-0.66	-0.80	1.00								
Greece	0.83	0.97	0.64	0.93	0.97	-0.85	1.00							
Ireland	0.92	0.62	0.17	0.85	0.75	-0.35	0.79	1.00						
Italy	0.96	0.89	0.59	0.99	0.97	-0.67	0.96	0.89	1.00					
Luxembourg	-0.75	-0.52	0.06	-0.68	-0.59	0.30	-0.70	-0.95	-0.76	1.00				
Netherlands	0.63	0.51	0.84	0.67	0.65	-0.33	0.44	0.26	0.56	0.04	1.00			
Portugal	0.83	0.99	0.77	0.95	0.99	-0.86	0.98	0.71	0.95	-0.58	0.59	1.00		
Spain	0.81	0.76	0.22	0.82	0.79	-0.59	0.89	0.94	0.89	-0.95	0.11	0.79	1.00	
Sweden	-0.44	-0.69	-0.10	-0.53	-0.58	0.68	-0.77	-0.66	-0.63	0.79	0.24	-0.64	-0.88	1.00

**Table F.2:** Correlation coefficients between the different country-specific wedges of the inland transport sector with the countries grouped by world regions

	$\lambda_E$	$Z_E$	$\frac{x_{E^{Total}}}{y}$	$\frac{CO_2}{y}$	$\frac{CH_4}{y}$	$\frac{N_2O}{y}$	$\frac{NO_x}{y}$	$\frac{SO_x}{y}$	$\frac{CO}{y}$	$\frac{NMVOC}{y}$
$\lambda_E$	1.00									
$Z_E$	0.86	1.00								
$x_{E^{Total}} / y$	-0.34	-0.34	1.00							
$CO_2 / y$	-0.32	-0.34	0.64	1.00						
$CH_4 / y$	0.00	-0.03	0.42	0.16	1.00					
$N_2O / y$	-0.21	-0.28	0.35	0.73	-0.06	1.00				
$NO_x / y$	-0.50	-0.52	0.38	0.70	0.06	0.48	1.00			
$SO_x / y$	-0.29	-0.32	0.22	0.70	0.21	0.49	0.77	1.00		
$CO / y$	-0.25	-0.24	0.04	0.20	0.16	0.14	0.49	0.54	1.00	
$NMVOC / y$	-0.20	-0.26	0.29	0.41	0.13	0.52	0.57	0.49	0.57	1.00
$NH_3 / y$	0.06	-0.01	0.26	0.36	0.38	0.26	0.25	0.46	0.34	0.37
$\Delta x_{E^{Total}} / y$	0.09	0.12	-0.36	-0.21	-0.19	-0.05	-0.10	0.00	0.00	-0.08
$\Delta CO_2 / y$	-0.07	-0.06	0.31	0.24	0.06	0.22	0.08	0.12	-0.01	0.06
$\Delta CH_4 / y$	-0.01	0.02	0.05	-0.08	-0.10	0.00	-0.04	-0.02	-0.02	-0.06
$\Delta N_2O / y$	0.04	0.04	-0.02	-0.01	-0.04	-0.12	-0.01	0.03	-0.06	0.01
$\Delta NO_x / y$	-0.07	-0.06	0.27	0.23	0.08	0.17	-0.01	0.04	-0.11	0.01
$\Delta SO_x / y$	-0.12	-0.15	0.21	0.43	-0.01	0.39	0.32	0.26	-0.06	0.07
$\Delta CO / y$	0.02	0.06	0.02	0.01	-0.03	0.04	-0.14	-0.10	-0.36	-0.17
$\Delta NMVOC / y$	0.00	0.05	0.06	0.06	0.03	0.01	-0.11	-0.03	-0.17	-0.21
$\Delta NH_3 / y$	-0.10	-0.11	0.25	0.14	0.05	0.07	0.04	-0.07	-0.09	0.03

	$\frac{NH_3}{y}$	$\frac{\Delta x_{E^{Total}}}{y}$	$\frac{\Delta CO_2}{y}$	$\frac{\Delta CH_4}{y}$	$\frac{\Delta N_2O}{y}$	$\frac{\Delta NO_x}{y}$	$\frac{\Delta SO_x}{y}$	$\frac{\Delta CO}{y}$	$\frac{\Delta NMVOC}{y}$	$\frac{\Delta NH_3}{y}$
$NH_3 / y$	1.00									
$\Delta x_{E^{Total}} / y$	-0.05	1.00								
$\Delta CO_2 / y$	0.11	0.30	1.00							
$\Delta CH_4 / y$	0.04	0.33	0.58	1.00						
$\Delta N_2O / y$	-0.03	0.13	0.10	0.04	1.00					
$\Delta NO_x / y$	0.07	-0.09	0.53	0.19	-0.03	1.00				
$\Delta SO_x / y$	0.08	-0.18	0.27	0.03	-0.16	0.34	1.00			
$\Delta CO / y$	-0.03	0.06	0.10	0.05	-0.03	0.28	0.18	1.00		
$\Delta NMVOC / y$	-0.02	0.05	0.10	0.01	-0.01	0.30	0.13	0.45	1.00	
$\Delta NH_3 / y$	-0.17	-0.26	0.23	-0.10	-0.01	0.33	0.12	-0.02	0.15	1.00

**Table F.3:** Correlation coefficients between the wedges, the shadow prices, and the other measures of climate policy stringency for the chemicals sector

	$\lambda_E$	$Z_E$	$\frac{x_{E^{Total}}}{y}$	$\frac{CO_2}{y}$	$\frac{CH_4}{y}$	$\frac{N_2O}{y}$	$\frac{NO_x}{y}$	$\frac{SO_x}{y}$	$\frac{CO}{y}$	$\frac{NMVOC}{y}$
$\lambda_E$	1.00									
$Z_E$	0.79	1.00								
$x_{E^{Total}} / y$	-0.44	-0.44	1.00							
$CO_2 / y$	-0.26	-0.26	0.67	1.00						
$CH_4 / y$	-0.53	-0.44	0.34	0.19	1.00					
$N_2O / y$	-0.44	-0.38	0.45	0.39	0.63	1.00				
$NO_x / y$	-0.36	-0.42	0.63	0.69	0.14	0.24	1.00			
$SO_x / y$	-0.38	-0.50	0.50	0.45	0.09	0.21	0.77	1.00		
$CO / y$	-0.43	-0.45	0.33	0.32	0.01	0.12	0.66	0.47	1.00	
$NMVOC / y$	-0.22	-0.29	0.43	0.62	-0.05	0.15	0.77	0.64	0.60	1.00
$NH_3 / y$	-0.12	-0.12	0.17	0.07	-0.10	0.01	0.14	0.00	0.49	0.17
$\Delta x_{E^{Total}} / y$	0.04	0.07	-0.15	-0.06	0.06	0.03	-0.04	-0.04	-0.11	-0.03
$\Delta CO_2 / y$	0.02	0.06	-0.17	-0.34	0.04	-0.04	-0.14	-0.12	-0.07	-0.15
$\Delta CH_4 / y$	0.04	0.03	-0.03	-0.04	-0.11	-0.08	-0.02	-0.02	0.00	0.00
$\Delta N_2O / y$	0.07	0.13	-0.17	-0.21	-0.10	-0.29	-0.15	-0.14	-0.10	-0.16
$\Delta NO_x / y$	-0.07	-0.06	0.04	-0.04	0.02	-0.02	0.10	0.13	0.02	0.13
$\Delta SO_x / y$	-0.08	-0.13	0.15	0.07	0.01	0.05	0.18	0.11	0.12	0.15
$\Delta CO / y$	-0.08	-0.09	0.03	-0.03	0.02	0.01	0.06	-0.02	-0.02	-0.08
$\Delta NMVOC / y$	-0.01	0.01	-0.05	0.01	-0.01	0.02	-0.04	-0.23	-0.03	-0.15
$\Delta NH_3 / y$	0.06	0.02	-0.11	0.00	0.01	0.00	-0.06	0.00	-0.12	0.00

	$\frac{NH_3}{y}$	$\frac{\Delta x_{E^{Total}}}{y}$	$\frac{\Delta CO_2}{y}$	$\frac{\Delta CH_4}{y}$	$\frac{\Delta N_2O}{y}$	$\frac{\Delta NO_x}{y}$	$\frac{\Delta SO_x}{y}$	$\frac{\Delta CO}{y}$	$\frac{\Delta NMVOC}{y}$	$\frac{\Delta NH_3}{y}$
$NH_3 / y$	1.00									
$\Delta x_{E^{Total}} / y$	-0.11	1.00								
$\Delta CO_2 / y$	-0.03	0.54	1.00							
$\Delta CH_4 / y$	0.01	0.03	0.03	1.00						
$\Delta N_2O / y$	-0.01	0.23	0.40	0.06	1.00					
$\Delta NO_x / y$	0.03	0.50	0.66	-0.02	0.33	1.00				
$\Delta SO_x / y$	0.03	0.27	0.43	0.03	0.07	0.62	1.00			
$\Delta CO / y$	0.13	0.22	0.25	0.02	0.12	0.43	0.38	1.00		
$\Delta NMVOC / y$	0.03	0.14	0.16	0.02	0.06	0.24	0.43	0.59	1.00	
$\Delta NH_3 / y$	-0.19	0.19	0.14	0.00	0.06	0.11	0.05	0.05	0.03	1.00

**Table F.4:** Correlation coefficients between the wedges, the shadow prices, and the other measures of climate policy stringency for the inland transport sector