THE IMPACT OF A CARBON TAX ON SECTORS COMPETITIVENESS

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Abstract Asymmetric climate policies are expected to distort the level-playing field regarding international trade, singularly to the detriment of small open economies. The paper develops a flexible method that provides essential input regarding the design of offsetting measures at the sectoral level. It builds on input-output analysis and standard input-output data to provide proxies for both the carbon-intensity and the trade-intensity of production. These are used to reckon the impact that such policies as carbon taxation have on the price-competitiveness of sectors. The method is then applied to the case of Belgium.

Keywords Asymmetric climate policies - Carbon taxes - Input-output analysis - Sectors price-competitiveness

JEL classification C67 - D57 - H23 - Q56 - Q58

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1 Introduction

Mitigating global warming and moving towards a low-carbon economy is now widely recognized as a crucial challenge. Since the early nineties, international negotiations regarding greenhouse gases (GHG) emissions reduction took place under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) and the various agreements that ensued, mainly the Kyoto Protocol. They rest on a number of principles, amongst which the idea that countries share common but differentiated responsibilities as for causing climate change. It implies that those countries which benefited the most from carbon-intensive development must be the first to take measures aimed at cutting down emissions, whereas less advanced countries are allowed to delay such actions until they reach a certain level of development.

However fair it is, this principle brings up several cost and competitiveness-related issues. Adapting productions structures in order to decrease emissions brings along costs that would otherwise not be supported. It obviously distorts the level-playing field regarding international trade, as those countries facing emissions constraints undergo cost increases while the others do not. In other words, asymmetric climate policies raise the issue of the international price-competitiveness of the economies that implement domestic environmental instruments to curb emissions ('carbon-constrained economies' hereafter). Their transition towards a low-carbon economy is potentially costly in the short run in terms of market share. This in turn weakens the support for a global agreement, as countries are reluctant to penalize their domestic economy if others do not participate in global agreements or free-ride –a phenomenon known as the 'regulatory chill'. The fear is that sectors of which the cost structure is affected engage in global arbitrage and relocate production in non-constrained areas, which might lead to carbon leakage and jeopardizes the environmental efficiency of global agreements. The Intergovernmental Panel on Climate Change (IPCC) surveyed the related literature extensively in its fourth assessment report (Barker et al., 2007).

Obviously, not all countries and sectors will be affected in the same way by emissions constraints. Two dimensions should be considered. First, the impact depends on the extend to which producers are (not) able to pass cost increases into production prices. Second, the cost increase experienced by a productive sector depends on the total emissions that were caused by the production of its output, not only directly, but also indirectly by the production of intermediate inputs. That is, the impact of relatively stringent domestic climate policies on competitiveness depends on both the trade-intensity and the carbon-intensity of production. The rest of the section goes through these two dimensions in more detail.

The first one regards the ability of producers to shift forward to consumers the costs caused by the climate policy. Price-taking firms that evolve in a competitive, trade-exposed environment are unlikely to be able to do that. More generally, the competitiveness concern is particularly striking for small open economies (SOEs), as they are typically price-taker and very much exposed to international trade. The existing contrast between large economies and SOEs is emphasized in Table 1; for instance, while 8.3 per cent of total American CO_2 discharge is actually used for producing exports, this figure amounts to 45.5 per cent in the Belgian case (Peters and Hertwich, 2008).

Table 1: CO_2 emissions embodied in trade for selected countries[a].

Country	**Imports** %	**Exports** %
Russian Federation	5.9	27.5
China	6.6	24.4
United States	15.6	8.3
Slovenia	44.8	40.1
The Netherlands	58.1	39.1
Ireland	66.6	49.1
Belgium	89.4	45.5

[a] Percentage of total emissions, year 2001.

Source: Peters and Hertwich (2008).

The issue of international competitiveness loss due to asymmetric climate policies is problematic from both an environmental and an economic standpoint, the latter being singularly true in SOEs. Therefore, the design of measures aimed at offsetting the competitiveness impact of such policies like carbon taxes or cap-and-trade received considerable attention in the literature. Two main options are considered.

The first one regards the method used for the allocation of tradable emission allowances, which can be designed so as to alleviate carbon costs; Grubb and Neuhoff (2006) provide an overview. The second is related to the vast literature on border tax adjustment. Recent theoretical contributions include Ismer and Neuhoff (2007) and McCorriston and Sheldon (2005), while practical implementation is examined, amongst others, by Monjon and Quirion (2010) and Brewer and van Asselt (2010).

Offsetting measures implementation typically requires the quantitative appraisal of competitiveness impact. The IPCC fourth assessment report surveyed the literature on the impact of CO_2 emissions constraints on competitiveness. It concludes that competitiveness losses are not significant but also that the evidence is limited and there is no full agreement on the conclusion (Barker et al., 2007). However, there exists a major shortcoming in the literature: this overall limited impact hides important heterogeneity across sectors that is not satisfactorily reckoned in. As stressed in a meta-analysis focused on the European Union Emission Trading Scheme (EU ETS) by Oberndorfer and Rennings (2007), general equilibrium models do not allow for high sectoral disaggregation, while sector-level analyses (e.g. Smale et al., 2006) are limited by their partial equilibrium nature. More recently, empirical research on the impact of climate policies on competitiveness has been conducted as data become available. It typically uses gravity models and finds no significant evidence of negative impact, as in the recent contribution by Kee et al. (2010). Again, the heterogeneity issue is not addressed. There is actually a surprising lack of research at the sectoral level. Moreover, current research rests on existing climate policy measures, that are not enough to reach UNFCCC objectives in terms of global warming stabilization. It should be noted that most policy-oriented projections on competitiveness impact do not build on sufficiently restrictive measures either (Zhang and Baranzini, 2004).

This paper develops a method that allows to fill those gaps. It focuses on carbon taxation. This is a Pigovian tax, that is, a tax aimed at adjusting for the carbon dioxide externality by distorting relative prices to encourage firms and consumers to substitute away from carbon-intensive products, and therefore cut down emissions.

CO_2 discharge is estimated at the sectoral level. The flat carbon tax is levied on emissions. The tax level is set so that climate policy targets are met, that is, it is set at the equilibrium marginal cost of abating emissions that is required to fulfill the reduction objective. The tax burden raises sectors production costs. Depending on the sectors ability to shift it forward to consumers, this will cause either an increase in final prices or a drop in operating margins. Sectors aptitude to pass on the cost increase is approximated by the trade-intensity of their production, as reflected by their imports from and exports towards non-constrained economies. Although imperfect, this proxy is convenient as it only requires standard System of National Accounts (SNA) data.

The purpose is to provide a competitiveness assessment that enables to quantitatively distinguish between sectors. Indeed, as stressed above, not all of them would experience the same increase in production costs, nor would they undergo the same loss of competitiveness for a given increase. This distinction between sectors is crucial, because negotiations regarding emissions reduction policies and the design of offsetting measures are notably lobbied by industrial federations that are expected to bear a disproportionate burden that potentially harms their operating margins. This calls for rigorous impact analysis at the sectoral level in order to prevent some industries from making windfall gains because of too favorable offsetting measures. This paper is a modest contribution towards the accurate and unbiased estimation of the relative impact of climate policies on the competitiveness of the different economic sectors.

It should be clear that the competitiveness concern arises in the short term, due to limited substitution possibilities in the production structure. In the longer run however, technological progress, the evolution of industrial structure and other structural changes cause adjustment. Concerns underlying the short-run impact of carbon taxation regard the potential repercussions on the immediate economic and social situation in the domestic economy, namely troubles with firms survival and their unemployment consequences with potential hysteresis.

The second dimension to be considered is carbon-intensity, which is closely related to energy-intensity. The short-run price-effects are determined by the use of inputs that lead to GHG emissions at any time during the production process. Estimating total CO_2 emissions all along the production chain ('embodied emissions' hereafter) is key in the competitiveness appraisal. Indeed, an educated guess might be sufficient to designate heavy industries of which the production costs are likely to be affected, e.g. steel industries or the electric power generation sector. However, in a world where all carbon emissions are priced, any final product that caused CO_2 discharge somewhere in the production chain becomes costlier. Take for instance aluminum window frames. The production of the aluminum they contain requires important quantities of electric power, of which the cost is expected to increase because the marginal production of electricity uses natural gas, which is a source of CO_2 emissions. Window frames production costs would then increase in such situation, which is potentially problematic if domestic frame producers face international competition from non-constrained economies. Taking the whole production structure into account is thus critical.

Input-output (IO) analysis is the prominent tool in the literature to investigate questions related to the production structure at the sectoral level. Initiated by Leontief (1936), IO techniques typically model production in a general equilibrium framework at a relatively high level of sectoral disaggregation by relating total, direct and indirect sectoral output to final demand through interindustry relationships. Its analytical power has been used for numerous economic research, and notably taxation impact and energy or environment-related questions; for seminal contributions, see Aaron (1968) and Ayres and Kneese (1969), respectively. Recently, global warming concern and the perspective of emissions constraints led to a revival of IO modelling to investigate emissions-related issues. Minx et al. (2009) provide an overview of the growing literature on the topic. They emphasize the methodological pre-eminence of IO analysis for the purpose of estimating embodied emissions.

The very large majority of research regards the environmental consequences of international trade. Specifically, it computes indicators such as carbon footprint of nations (e.g. Hertwich and Peters, 2009) or environmental balance of trade and related carbon leakage (e.g. Wilting and Vringer, 2009). It rests on generalized IO models, that is, IO models extended with data on production-related flows ('social accounting matrix'), in this case GHG emissions. This approach requires important data on energy use and emissions for both the industry and households that may be difficult to treat, if available. This is a drawback, as it makes such research less easy. Therefore, the method developed here goes beyond this drawback by only calling for standard SNA IO tables in monetary value, making it more flexible. Physical quantities are derived with a price vector and embodied CO_2 is inferred with emissions coefficients. From a methodological standpoint, the approach by Creedy and Sleeman (2006) is the closest to what is done here. Their purpose is however essentially different since they use their estimates of carbon embodiment to examine the distributive impact of a carbon tax on household welfare.

Finally, it should be mentioned that two different types of IO models are used in the literature: the single-region model, which assumes the same production structure for domestic products and imports (e.g. Peters and Hertwich, 2008), and the multi-region model, which overcomes the single-region assumption, as in Wilting and Vringer (2009). The method developed here builds on the single-region assumption. Although restrictive[1], it has the advantage of easiness and flexibility regarding data collection and treatment.

The paper is organized as follows. Section 2 exposes the basic method. An application to the case of Belgium is presented in Section 3. Section 4 eventually concludes.

2 The basic method

2.1 Production

The method builds on the standard IO quantity model as exposed in Miller and Blair (2009, chap. 2). Consider an economy with n productive sectors. The gross output of each sector is allocated between the intermediate demand by sectors that use it as inputs and the final demand, which consists in private and public consumption,

[1]The single-region assumption and its implications are discussed in Section 4.

investments and exports. Let x_{ij}^d be the the value of domestic output flowing from sector i to sector j and y_i the value of the final demand of output from domestic sector i. The value of the gross output of each domestic sector can be written as the sum of final and intermediate demands:

$$x_i^d = \sum_{j=1}^{n} x_{ij}^d + y_i \tag{1}$$

Assume that intermediate inputs are not substitutable, as admissible in the short term. That is, there exist short-run fixed linear interdependencies between sectors, implying that sectors use intermediate inputs x_{ij}^d in fixed proportion[2]. Therefore, the domestic production structure is fully described by a set of $n \times n$ technical coefficients $a_{ij}^d = x_{ij}^d / x_j^d$. Each technical coefficient a_{ij}^d represents the value of output of sector i that is directly required to produce one unit worth of output of sector j. The output of each sector can then be expressed in terms of its interindustry relationships:

$$x_i^d = \sum_{j=1}^{n} a_{ij}^d x_j^d + y_i \tag{2}$$

The economy therefore consists in n production structures described by Eq. 2. With x^d and y denoting the n-vector of x_i^d and y_i, respectively, and A^d being the n-square matrix of technical coefficients a_{ij}^d, the system of n equations can be rewritten in matrix form:

$$x^d = A^d x^d + y \tag{3}$$

Solving Eq. 3 for x^d yields the basic IO model

$$x^d = \left(I - A^d\right)^{-1} y \tag{4}$$

where I denotes the unit matrix and $\left(I - A^d\right)^{-1}$ is the well-known Leontief inverse, of which each element $l_{i,j}$ indicates the total, direct and indirect value of domestic production of sector i that is required in the economy as a whole to satisfy one unit worth of final demand for output of sector j. The inverse thus captures linkages between sectors[3].

[2] The associated production function –the so-called Leontief technology– is nothing else than a particular case of the CES production function where factors are perfect complements. This assumption is discussed in Section 4.

[3] The successive linkages clearly appear if one recalls that, since the matrix norm of A^d is smaller than unity by construction, the Leontief inverse is equal to the matrix expansion $I + A^d + A^{d^2} + A^{d^3} + ...$ where the successive terms are the multiplier effects of final demand on production.

Imports are taken into account just as intermediate production. In an exact analogy with A^d, let A^m denote the n-square matrix of imports coefficients. Total requirements in both domestic production and imports can be expressed as

$$x = x^d + x^m = (I + A^m)\left(I - A^d\right)^{-1} y \tag{5}$$

Note eventually that, for each sector as a consumer, it is possible to break down total requirements over each sector as a producer. It only takes the slight rearrangement of Eq. 5 with final demand expressed as diagonal matrix (indicated by a hat) rather than as a vector:

$$X = (I + A^m)\left(I - A^d\right)^{-1} \widehat{Y} \tag{6}$$

2.2 Carbon-intensity and price-effects

Under the somewhat restrictive assumption that all sectors face homogenous intermediate and imports prices (Weisz and Duchin, 2006), physical quantities can readily be derived from monetary IO data by dividing the monetary value of output by its price. Let p^d and p^m be the domestic and imports price vector, respectively. Then total required quantities for each consuming sector broken down by producing sectors is obtained by dividing the value of domestic intermediates and the value of imports in Eq. 6 by the corresponding price vector:

$$Q = \left(\widehat{P^{d-1}} + \widehat{P^{m-1}} A^m\right)\left(I - A^d\right)^{-1} \widehat{Y} \tag{7}$$

The total CO_2 emissions embodied in sectors output all along the production chain can now be inferred thanks to carbon dioxide emissions coefficients. Let ϵ be a n-vector that takes the suitable emission coefficient value for primary fossil energy sectors and zero otherwise. Pre-multiplying Eq. 7 by the transpose of the emissions coefficients vector gives the vector of embodied emissions by sectors:

$$e' = \epsilon' Q = \epsilon' \left(\widehat{P^{d-1}} + \widehat{P^{m-1}} A^m\right)\left(I - A^d\right)^{-1} \widehat{Y} \tag{8}$$

A carbon tax τ is levied on every emission of carbon dioxide. Suppose that the tax is fully passed on in the output price[4]. This is a common assumption for cost-

[4]This usual, although very questionable assumption is discussed in Section 4.

push analysis in the IO literature (ten Raa, 2005, chap. 3). Therefore, the total cost increase is τe and the short-run price effect for every sector i is

$$\frac{dp_i^d}{p_i^d} = \frac{\tau e_i}{x_i^d} \tag{9}$$

2.3 Trade-intensity and competitiveness

Consider a number of foreign economies indexed by z. Some are carbon-constrained (C) while others are not (NC). Two proxies are used for reckoning the trade-intensity of sectors. The first is the proportion of the total output of a sector that is exported towards non-constrained economies, that is, a proxy of exports competitiveness. The second is a proxy of the vulnerability to imports and is defined as the amount of imports of a product coming from non-constrained economies relative to the total domestic production of that product. Let x_{iz} denote the exports flow from domestic sector i to zone z. Let also m_{ijz} be the imports flow of type i from zone z towards sector j. Then the two proxies are expressed by Eqs. 10 and 11, respectively:

$$\xi_i = \frac{\sum_{z \in NC} x_{iz}}{x_i^d} \tag{10}$$

$$\mu_i = \frac{\sum_{z \in NC} \sum_j m_{ijz}}{\sum_j \left(\sum_z m_{ijz} + x_{ij}^d \right)} \tag{11}$$

Finally, competitiveness is assessed by examining trade exposure together with price effects. Formally, it consists in arbitrarily determining critical values for exports and imports exposure, $\bar{\xi}$ and $\bar{\mu}$, as well as for the price effects, $\overline{dp^d/p^d}$, that define a set $\mathcal{S}$ the inclusion in which indicates a competitiveness issue:

$$\mathcal{S} = \left\{ i : \frac{dp_i^d}{p_i^d} \geq \overline{\frac{dp^d}{p^d}} \;\cap\; \xi_i \geq \bar{\xi} \;\cap\; \mu_i \geq \bar{\mu} \right\} \tag{12}$$

3 Application: the case of Belgium

3.1 Data

The SNA quinquennial I-O table used for this application was compiled by the Belgian Federal Planning Bureau (FPB). It describes the Belgian economy in 2000 and has the 143 × 143 format[5,6]. Interindustry flows are expressed in monetary value. Sectors are identified with FPB codes, which roughly correspond to NACE-Bel rev.1.1.

Note Belgium's position regarding primary fossil energy is particular as it has no fossil fuel resources and all the primary fossil energy is imported. The products considered for fossil energy imports are coal and lignite, coke, crude petrol, natural gas and refined petroleum products. The energy price vector and the emissions coefficients are reported in Table 2.

Table 2: Energy price and emissions coefficient vectors.

Energy source	**Price** EUR/GJ	**Emissions coefficient** $kgCO_2/GJ$
Coal	1.60	97.0
Coke	3.60	107.0
Crude petrol	5.23	73.3
Natural gas	4.31	56.1
Refined petroleum products	5.95	74.5

Sources: IEA and IPCC.

The carbon tax level is such that the objectives set by the European Union (EU) in its energy and climate package are met. This climate policy consists in an independent commitment by the EU to a twenty per cent cut of its emissions by 2020 compared to 1990 levels, as well as to a twenty per cent share of renewable energy in gross final energy demand and a twenty per cent improvement of energy efficiency. The corresponding tax level has been computed by the PRIMES energy model and amounts to EUR 33.5/tCO_2 (Bossier et al., 2008).

Finally, the method has been improved to better fit the Belgian context. Belgium is a net electric power-importing country. As imported electricity comes from France and Germany, the constraint on emissions puts up its price[7]. This increase has been estimated by FPB. It is taken into account in the estimation of the cost increase

[5]This table is used by courtesy of the Federal Planning Bureau. It is not published owing to data confidentiality. The official release by the Institute for National Accounts (2004) has the 60 × 60 format.

[6]However, data treatment led to some re-aggregation. The final results have a disaggregation level of 121 sectors.

[7]Indeed imported electric power is by definition the marginal production of the exporting country. For technical reasons, marginal production comes from plants using the combined gas-and-steam technology and therefore causes CO_2 discharge.

faced by sectors that directly or indirectly use imported electric power as an input.

3.2 Results

First, it is worth mentioning that the total carbon emissions estimate, around 125 $MtCO_2$, has the same order of magnitude as the corresponding year inventory by the Belgian National Climate Commission (2007).

Full gross results are presented in Table 5 in the Appendix. The percentage cost increases –or price effects– computed from Eq. 9 are displayed in the first column of figures. The second and third columns contain the proxies of trade-exposure, as calculated from Eqs. 10 and 11. Sectoral employment appears in the fourth one. Total, direct and indirect (or 'cumulative') sectoral employment is computed thanks to the Leontief inverse and reported in column five. Employment statistics are recorded in full-time job equivalents. The last column contains data on sectoral production as a share of gross national product.

As expected, manufacture's production costs are the most affected, with a two and a half per cent increase on average. Transportation industries are logically also strongly affected. Construction and trade come next. Services, in general, suffer less. Note that the impact on agriculture is relatively low, but it does not take into account other GHG gases of which the emission is constrained too. Table 3 brings together the sectors of which the production costs are the most affected. Many of these sectors take part in the EU-ETS, namely refinery[8], chemical, iron, steel and mineral industries, as well as electric power generation. Other affected industries include the different sectors of food-processing, transports, fishing and building, as well as the rubber and plastic industries.

As explained above, the costs increases should be examined together with proxies for trade-intensity in order to appraise competitiveness (see Eq. 12). In this application, all non-EU economies are considered as non-constrained, because only

[8] The manufacture of refined petroleum products is a special case. Indeed the method is based on total fossil energy embodiment, but a significant proportion of the carbon embodied in refined petroleum products is not burnt yet, hence has not generated emissions. Therefore, the enormous figure for that industry's output price increase has no relevance, as the tax would most likely be borne by the final consumer. Nevertheless, the sector is likely to actually be affected since refineries usually burn five to ten percent of refined petroleum products as auto-consumption.

Table 3: Sectors with the highest cost increase.

FPB code	Sector	dp^d/p^d %
23A1B	Manufacture of refined petroleum products	22.59
23A1A	Manufacture of coke products	6.16
27A1	Manuf. of basic iron and steel and ECSC ferro-alloys	4.69
62A1	Air transport	4.14
24A1	Manufacture of basic chemicals	3.83
5A1	Fishing and fish farms	3.48
40A1A	Electric power generation	2.99
63A1	Travel agencies and tour operators	2.27
26C1	Manufacture of cement, lime and plaster	1.90
61A1	Sea and coastal water transport	1.86
13A1	Mining of metal ores	1.76
61B1	Inland water transport	1.68
14A1	Other mining and quarrying	1.58
60C1	Road freight transp.; removal op.; transp. via pipeline	1.57
50B1	Retail sale of automotive fuel	1.50
26B1	Manufacture of ceramic products	1.48
15B1	Processing and preserving of fish	1.37
24F1	Manufacture of other chemical products	1.37
26A1	Manufacture of glass and glass products	1.30

the EU committed to post-2012 emissions reduction in precise figures so far. The sectors that combine both high trade- and carbon-intensity are displayed in Table 4. The chosen bound values for the proxies are one per cent for the cost increase (Eq. 9) and five per cent for both the exports and imports exposure (Eqs. 10 and 11). It is beyond the scope of this paper to discuss the bound values, but it should be kept in mind that the result for each sector is first and foremost to be interpreted in relation to the results for the other sectors. Also note that the cost increase could alternatively be reported to other available SNA sectoral data, as value added or earnings before interest and taxes.

Table 4 shows that the price-competitiveness of steel, refinery, chemical and some other heavy non-mineral industries is badly hit, as expected and compatible with most other studies. But this analysis also produces new and less expected results. Food-processing and textiles are two major Belgian sectors which would be affected if the country actually implements climate policies that enable it to reach its reductions objectives under the EU energy and climate package. Moreover, the anal-

Table 4: Sectors of which the competitiveness is affected[a].

FPB code	Sector	Direct empl. *jobs*	Cumul. empl. *jobs*
13A1	Mining of metal ores	145	232
14A1	Other mining and quarrying	5 140	4 492
15A1	Production, processing and preserving of meat	18 099	67 997
15B1	Processing and preserving of fish	1 319	2 608
15C1	Processing and preserving of fruit & vegetables	6 159	13 572
17A1	Prep., spinning, weaving & finishing of textiles	19 267	19 842
23A1A	Manufacture of coke products	54	80
23A1B	Manufacture of refined petroleum products	3 048	14 276
24A1	Manufacture of basic chemicals	22 719	53 182
24F1	Manufacture of other chemical products	12 652	15 493
24G1	Manufacture of man-made fibres	2 027	2 579
25A1	Manufacture of rubber products	3 392	4 639
26A1	Manufacture of glass and glass products	11 222	14 047
26B1	Manufacture of ceramic products	4 766	2 534
27A1	Manuf. of basic iron, steel & ECSC ferro-alloys	21 162	38 022
29D1	Manufacture of domestic appliances	2 556	4 242
36C1	Man. mus. instr., sport goods, games, toys; misc.	3 563	2 316
45C1B	Construction of water projects	4 282	4 444
60C1	Road freight transport	62 820	36 350
61A1	Sea and coastal water transport	2 124	9 008
62A1	Air transport	10 317	14 562

[a] Set of sectors defined by $\overline{dp^d/p^d} = 1.00$, $\bar{\xi} = 5.00$ and $\bar{\mu} = 5.00$.

ysis emphasizes the contrasted situations faced by these sectors that take part to the EU-ETS. Some of them, like cement production or power generation, are much less affected than others because they are less exposed to competition from non-constrained economies. Eventually, cumulative employment for each sector gives an idea of how many jobs are directly and indirectly affected by the impact that emissions constraints have on competitiveness. It turns out that the affected sectors[9] account for about three hundred thousand jobs, making up more than five percent of Belgian GDP.

[9]Note that, although satisfying the exposure criterion, transportation sectors are a special case as competitors whose headquarters are located in a non-constrained area would also face emission taxes when operating in constrained areas. However, increased transport prices further penalize exports, which is not accounted for here.

4 Conclusion

The purpose of this paper has been to deal with the international price-competitiveness issue that arises because of asymmetric climate policies. In particular, it was intended to account for sectors heterogeneity regarding the impact of carbon taxation by estimating the competitiveness losses at the sectoral level. This is a crucial research topic indeed, because the design of offsetting measures aimed at leveling the international trade playing field typically requires to be able to distinguish between sectors. In order to do so, a flexible method has been developed. It rests on standard IO analysis of SNA data and basically consists in deriving relevant proxies of carbon- and trade-intensity of production in order to appraise the consequences of climate policies on competitiveness.

Of course, the method is limited by a number of conceptual shortcomings. Not the least, IO modeling is static by nature and singularly does not allow for quantities response to price shocks. In particular, the tax is fully passed on into output prices without affecting demand, which is economically counterfactual. Still, this hypothesis of constant inputs coefficients might be closer to reality in this very case of fossil energy because demand is inelastic in the short run due to the relative absence of substitution possibilities. Another limit lies in the single-region assumption, because it does not allow to take into account the production structure of the rest of the world and thus assumes it is similar to the domestic one. In particular, imports from non-constrained areas are expected to be more carbon-intensive. However, what we are ultimately interested in are price effects. But the very definition of non-constrained economies implies that the prices of imports from those areas do not increase. This makes the single-region assumption less problematic in this case. All the same, further research is definitely needed, in particular regarding the use of multi-regional IO models. Eventually, it should be understood that the way the carbon tax is set, although convenient, probably overstates the sectoral cost increase for economies where energy-efficiency is low. Indeed, it assumes that all emissions are paid for and none are abated in the short term. Yet this is likely to be the case in developed economies where industries are energy-efficient and where energy demand is inelastic.

Despite these limitations, it is hoped this paper has demonstrated the usefulness of the method developed here when it comes to discriminating sectors in order to design measures aimed at offsetting the price-competitiveness impact of asymmetric climate policies in SOEs.

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Appendix

Table 5 provides the full gross results of the application to the case of Belgium.

Table 5: Full results for Belgium.

FPB code	Sector	Cost increase %	Exports outside EU *% output*	Imports from outside EU *% output*	Direct empl. *jobs*	Cumul. empl. *jobs*	Gross prod. *% GDP*
01A1	Agriculture and hunting	0.48	1.68	9.57	98 018	39 057	1.41
02A1	Forestry and logging	0.38	5.46	12.41	2 456	880	0.07
05A1	Fishing and fish farms	3.48	1.12	17.44	1 057	696	0.03
10A1	Mining of coal and lignite	0.24	0.27	58.01	60	44	0.00
11A1	Extraction of crude petroleum and natural gas	–	–	–	0	0	0.00
12A1	Mining of uranium ores	–	–	–	0	0	0.00
13A1	Mining of metal ores	1.76	16.76	23.77	145	232	0.00
14A1	Other mining and quarrying	1.58	28.21	21.74	5 140	4 492	0.22
15A1	Production, processing and preserving of meat	0.95	6.45	4.78	18 099	67 997	0.40
15B1	Processing and preserving of fish	1.37	4.98	17.2	1 319	2 608	0.03
15C1	Processing and preserving of fruit and vegetables	0.91	10.54	9.14	6 159	13 572	0.17
15D1	Manufacture of oils and fats	0.45	8.56	8.70	636	5 446	0.03
15E1	Manufacture of dairy products	0.81	7.88	11.34	6 363	24 703	0.15
15F1	Manufacture of grain mill and starch products	0.81	9.42	8.13	1 686	8 225	0.05
15G1	Manufacture of animal feeds	0.22	2.67	5.58	2 828	4 032	0.09
15H1	Manufacture of bread, pastry, biscuits and cakes	0.52	3.78	4.62	33 047	41 325	0.46
15I1	Manuf. of sugar, cocoa and chocolate; sugar confect.	0.67	9.92	6.03	6 003	12 774	0.28
15J1	Manuf. of pasta and farinaceous products; tea and coffee	0.46	4.46	8.96	6 843	9 629	0.21
15K1	Manufacture of beverages, except water and softs	0.56	6.36	12.21	6 075	8 263	0.30

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Table 5 – continued from previous page

FPB code	Sector	Cost increase %	Exports outside EU *% output*	Imports from outside EU *% output*	Direct empl. *jobs*	Cumul. empl. *jobs*	Gross prod. *% GDP*
15L1	Production of water and softs	0.66	10.97	6.48	3 742	7 380	0.14
16A1	Manufacture of tobacco products	0.29	1.18	8.04	1 185	3 005	0.14
17A1	Preparation, spinning, weaving and finishing of textiles	0.91	18.63	13.15	19 267	19 842	0.40
17B1	Manufacture of textiles, except apparel	0.67	22.25	12.35	21 639	32 956	0.41
18A1	Manufacture of wearing apparel and fur	0.51	8.57	25.22	9 344	14 576	0.13
19A1	Manufacture of leather, luggage and footwear	0.43	12.55	29.03	2 650	2 795	0.04
20A1	Manufacture of wood and wooden products	0.40	5.14	13.33	15 135	11 056	0.31
21A1	Manufacture of pulp, paper and paper products	0.62	7.25	18.16	16 296	17 428	0.57
22A1	Publishing of recorded media	0.35	1.99	9.97	9 727	15 797	0.38
22B1	Printing and reproducing of recorded media	0.14	1.20	2.32	26 606	7 270	0.62
23A1A	Manufacture of coke products	6.16	16.36	44.56	54	80	0.00
23A1B	Manufacture of refined petroleum products	22.59	13.86	18.49	3 048	14 276	0.31
23A1C	Processing of nuclear fuel	0.10	17.39	20.13	780	1 291	0.07
24A1	Manufacture of basic chemicals	3.83	21.80	8.32	22 719	53 182	1.90
24B1	Manufacture of pesticides and agrochemical products	0.57	17.94	4.11	1 039	3 515	0.05
24C1	Manuf. of paints, varnishes, printing ink and mastics	0.22	19.88	7.05	3 782	4 174	0.14
24D1	Manufacture of pharmaceuticals	0.32	21.08	9.47	13 296	23 400	0.79
24E1	Manufacture of soap and detergents; cosmetics	0.69	16.11	7.23	5 454	9 523	0.18
24F1	Manufacture of other chemical products	1.37	19.98	7.34	12 652	15 493	0.68
24G1	Manufacture of man-made fibres	0.96	20.14	10.16	2 027	2 579	0.06

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Table 5 – continued from previous page

FPB code	Sector	Cost increase %	Exports outside EU % output	Imports from outside EU % output	Direct empl. jobs	Cumul. empl. jobs	Gross prod. % GDP
25A1	Manufacture of rubber products	0.94	13.76	26.51	3 392	4 639	0.10
25B1	Manufacture of plastic products	0.69	11.46	7.04	26 730	27 960	0.73
26A1	Manufacture of glass and glass products	1.30	9.44	12.16	11 222	14 047	0.34
26B1	Manufacture of ceramic products	1.48	5.13	19.24	4 766	2 534	0.10
26C1	Manufacture of cement, lime and plaster	1.90	3.87	3.23	2 516	1 867	0.20
26D1	Manuf. of concrete, plaster, cement and stone products	0.43	3.29	5.21	16 125	7 650	0.38
27A1	Manuf. of basic iron and steel and ECSC ferro-alloys	4.69	12.29	13.38	21 162	38 022	0.84
27B1A	Other first processing of iron	0.84	9.68	12.53	3 981	4 691	0.17
27B1B	Manufacture of non-ferrous metals	0.65	12.16	16.65	8 325	17 512	0.33
27B1C	Casting of metal	0.00	0.00	0.00	1 237	0	0.07
28A1	Man. of struct. met.; forg., press., stamp. & roll form.	0.27	3.81	5.31	32 571	22 204	0.69
28B1	Treatment and coating of metal	0.00	0.00	0.03	15 552	13	0.27
28C1	Man. of cutlery, tools, gen. hardware and other	0.64	9.25	20.02	17 071	17 759	0.40
29A1	Man. of machinery for the prod. & use of mechan. power	0.32	29.28	14.44	6 805	14 073	0.38
29B1	Manufacture of other general purpose machinery	0.43	19.87	14.27	15 907	22 922	0.41
29C1	Manufacture of agricultural and forestry machinery	0.67	19.55	12.55	26 430	49 930	0.68
29D1	Manufacture of domestic appliances	1.07	14.63	18.53	2 556	4 242	0.06
30A1	Manufacture of office machinery and computers	0.42	14.28	30.58	4 746	10 892	0.23
31A1	M. elec. motors, gen. & transf., distr. & contr. app., wire	0.29	10.66	11.40	13 040	12 381	0.39
31B1	Man. of accus, prim. cells & batt., light. equip., lamps	0.44	16.26	11.42	18 234	19 229	0.50

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Table 5 – continued from previous page

FPB code	Sector	Cost increase %	Exports outside EU % output	Imports from outside EU % output	Direct empl. jobs	Cumul. empl. jobs	Gross prod. % GDP
32A1	Man. of radio, television and communic. equip. & app.	0.31	27.09	14.34	11 975	26 003	0.50
33A1	Man. of medic., precis. & optic. instr.; watches & clocks	0.36	12.62	18.20	9 790	11 699	0.21
34A1	Manufacture of motor vehicle	0.33	15.66	11.70	32 822	79 309	0.96
34B1	Manufacture of parts and accessories for motor vehicles	0.26	13.47	16.80	15 543	20 426	0.43
35A1A	Building and repairing of ships and boats	0.27	8.56	5.08	1 007	942	0.06
35A1B	Man. of railway & tramway locomotives & rolling stock	0.75	4.49	8.87	1 889	3 812	0.00
35A1C	Manufacture of aircraft and spacecraft	0.30	26.96	13.38	7 135	9 431	0.22
35B1	Manufacture of motorcycles and bicycles	0.82	15.10	21.46	547	775	0.01
36A1	Manufacture of furniture	0.62	18.12	9.34	22 336	27 349	0.40
36B1	Manufacture of jewelery	0.10	42.79	18.69	3 072	4 293	0.06
36C1	Man. of musical instr., sport goods, games, toys; misc.	1.18	15.44	19.10	3 563	2 316	0.08
37A1	Recycling	–	–	–	0	0	0.00
40A1A	Electric power generation	2.99	0.05	0.00	16 264	12 151	1.95
40A1B	Manufacture of gas	0.29	0.22	31.74	1 799	2 299	0.41
41A1	Collection, purification and distribution of water	0.29	0.00	0.00	6 337	3 566	0.28
45A1	Site preparation	0.27	0.49	0.20	5 383	960	0.16
45B1A	Building of constructions; civil engineering	1.00	0.52	0.32	88 987	172 398	1.80
45B1B	Erection of roof covering and frames	0.23	0.02	0.00	8 790	4 665	0.27
45C1A	Construct. of highways, roads, airfields & sport facilities	0.81	0.16	0.74	20 459	20 296	0.51
45C1B	Construction of water projects	1.18	6.94	5.78	4 282	4 444	0.14

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FPB code	Sector	Cost increase *%*	Exports outside EU *% output*	Imports from outside EU *% output*	Direct empl. *jobs*	Cumul. empl. *jobs*	Gross prod. *% GDP*
45C1C	Other construction	0.25	0.89	1.09	16 585	4 212	0.20
45D1	Building installation	0.14	0.11	0.05	49 919	20 540	1.17
45E1	Other building completion	0.28	0.13	0.04	48 587	28 318	1.06
50A1	Sale, mainten. & repair of motor vehicles & motorcycles	0.86	2.71	0.01	83 051	88 856	1.66
50B1	Retail sale of automotive fuel	1.50	0.00	0.00	7 714	11 762	0.11
51A1A	Wholesale of fuel	0.71	14.00	7.29	16 118	29 656	0.74
51A1B	Other wholesale	0.38	8.47	0.00	209 161	180 887	6.78
52A1	Retail trade; repair of personal and household goods	0.79	0.00	0.00	274 547	328 152	2.74
55A1	Hotels	0.52	7.13	11.64	21 159	23 473	0.47
55B1	Restaurants, bars, canteen and catering	0.58	0.78	2.75	129 352	126 297	1.37
60A1	Rail transport	0.36	1.51	1.06	33 438	25 133	0.68
60B1	Passenger land transport, taxi operation and others	1.18	0.16	0.26	27 805	19 715	0.52
60C1	Road freight transp.; removal op.; transp. via pipeline	1.57	6.83	6.94	62 820	36 350	1.46
61A1	Sea and coastal water transport	1.86	40.86	8.27	2 124	9 008	0.04
61B1	Inland water transport	1.68	12.10	1.08	2 783	977	0.04
62A1	Air transport	4.14	21.74	7.88	10 317	14 562	0.06
63A1	Travel agencies and tour operators	2.27	0.02	0.36	8 478	25 669	0.14
63B1	Cargo handling, storage, support. & aux. transp. act.	0.90	12.74	7.87	33 743	48 847	1.19
64A1	Post	0.12	5.42	1.88	53 322	12 540	0.87
64B1	Telecommunications	0.34	4.50	3.61	29 132	25 886	1.73

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FPB code	Sector	Cost increase %	Exports outside EU *% output*	Imports from outside EU *% output*	Direct empl. *jobs*	Cumul. empl. *jobs*	Gross prod. *% GDP*
65	Financial intermediation	0.17	0.67	2.15	56 532	77 718	–
66	Insurance and pension funding	0.21	1.70	2.76	27 263	46 623	1.24
67	Activities auxiliary to financial intermediation	0.11	5.38	2.60	58 624	33 063	2.09
70	Real estate activities	0.13	0.15	0.07	14 044	35 891	10.62
71A1	Location of transport equipment	0.12	1.04	6.04	2 304	1 285	0.69
71B1	Location of machinery equipment and other	0.15	0.86	0.85	7 146	821	0.65
72A1A	Hardware consult.; software supply & consult.; data act.	0.47	8.60	5.56	47 572	47 930	1.25
72A1B	Maintenance and repair of computing machinery	0.10	3.47	3.07	6 367	2 459	0.32
73	Research and development	0.83	15.79	10.01	10 680	15 322	0.30
74A1	Legal, account.& audit. act.; market research & op. poll.	0.13	3.66	2.56	84 088	21 069	1.73
74B1	Business & management consult.; holdings	0.15	12.53	7.26	32 607	28 877	4.11
74C1	Architect. & engineering act. and related techn. consult.	0.18	8.64	6.42	67 707	43 333	0.80
74D1	Advertising	0.03	1.80	1.20	27 357	4 331	0.35
74E1	Labour recruitment and provision of personnel	0.00	0.59	0.74	118 061	2 085	1.52
74F1	Investigation & security act.; industr. cleaning; misc.	0.12	2.08	1.14	150 285	19 050	1.31
75	Public administration	0.51	0.00	0.00	396 090	439 604	7.79
80	Education	0.22	0.00	0.00	337 667	343 423	6.49
85	Health and social work	0.46	0.65	0.00	379 357	426 576	6.80
90	Sewage and refuse disposal, sanitation and similar act.	0.64	0.22	0.72	9 433	5 435	0.34
91	Activities of membership org. n.e.c.	0.63	0.00	0.00	35 419	27 608	0.62

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FPB code	Sector	Cost increase *%*	Exports outside EU *% output*	Imports from outside EU *% output*	Direct empl. *jobs*	Cumul. empl. *jobs*	Gross prod. *% GDP*
92	Recreational, cultural and sporting activities	0.52	1.16	3.29	55 583	67 974	1.34
93	Other service activities	1.23	0.00	0.00	59 815	50 542	0.42
95	Private households with employed persons	0.00	0.00	0.00	82 982	82 982	0.54