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Heli Simola

CO2 emissions embodied in EU-China trade and carbon border tax

Bank of Finland, BOFIT
Institute for Economies in Transition

Contents

Heli Simola

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Abstract

In this note, we provide a brief description of the CO$_2$ emissions embodied in global trade flows with an emphasis on the EU's external trade with China. Our analysis suggests that imported emissions account for an increasing share of CO$_2$ emissions associated with consumption within the EU. The CO$_2$ emissions embodied in EU imports mainly originate from emerging economies, particularly China. We also discuss possible effects from the introduction an EU border adjustment mechanism that would impose tariffs on CO$_2$ embodied in imports to the EU. Our results suggest that a potential border adjustment mechanism would likely affect EU trade with China, the largest source of CO$_2$ imports to the EU. The effects would probably be felt more in imports of inputs for production chains located in the EU than in final products consumed in the EU.

Keywords: CO$_2$ emissions, international trade, border adjustment, EU, China, input-output

1. Introduction

Policy discussions on emission reduction strategies have ramped up in recent years as climate change has topped political agendas and governments seek to lower greenhouse gas emissions. National emissions can be measured from the perspective of production or consumption.[1] International trade flows affect these national measures as a country can be net exporter or importer of "virtual" CO_2 emissions, i.e. the CO_2 embodied in the goods and services it imports and exports. International trade can also create the risk of "carbon leakage," i.e. tight environmental policies geared to reducing emissions in one country are circumvented by producers who shift emission-intensive production to countries with looser environmental standards or enforcement.[2] Such behavior undermines global emission reduction efforts and may damage the competitiveness of countries with stringent regulations.

To address these issues, we provide a general description of the virtual CO_2 emissions embodied in cross-country trade flows in 2000–2014, focusing specifically on the external trade flows of the 28 members of the European Union (EU-28) and China. Noting that the introduction of a border adjustment mechanism for reducing the risk of carbon leakage was suggested in the EU's recently released climate policy strategy, we also provide a hypothetical exercise to illustrate the aggregate level magnitude of possible cost effects from a border adjustment mechanism that employs a simple import tariff on embodied CO_2[3]. This analysis applies recent data to approaches presented in the previous literature.[4]

Our main data source is the World Input-Output Database (WIOD) and the compatible environmental accounts.[5] The WIOD includes international input-output tables that depict the global production network. The tables are compiled from official national statistics and complemented with estimated inputs. The data are annual and cover an observation period from 2000 to 2014. The WIOD includes 43 individual countries and an aggregate bloc for rest of the world. It is further divided to 53 economic sectors according to the ISIC Rev. 4 classification. The data are expressed in current US dollars. The associated environmental accounts contain data on CO_2 emissions compatible with the WIOD input-output tables. We describe general global and EU-level trends related to CO_2 emissions embodied in trade flows, and then in more detail emissions associated with EU imports from China. The discussion finishes with an illustration of the possible aggregate level cost effects of a border adjustment mechanism for the EU.

2. Brief description of global carbon emission trends

Global CO_2 emissions increased from about 22 Gt in 2000 to 32 Gt in 2014[6]. In the same period, the emissions of developed countries declined slightly, while emissions from emerging economies soared. The largest individual contributor to the global growth of CO_2 emissions during this period was China (Figure 1), which accounted for over half of emissions growth. China today is the globally

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[1] Peters (2008).

[2] Fischer (2015).

[3] This approach is purely illustrative and not likely to be adopted in practice. For more plausible alternatives, see recent discussion e.g. by Mehling et al. (2019).

[4] Atkinson et al. (2011), Zhang et al. (2017).

[5] For a detailed description of the WIOD, see Timmer et al. (2015). For a discussion of the environmental accounts compatible with WIOD, see Corsatea et al. (2019).

[6] There is variation between the exact emission figures in different statistical sources due to e.g. methodological differences, but in qualitative terms various statistical sources tend to give a similar picture on trends in emissions.

largest source of CO_2 emissions by far. In per capita terms, China does not come close to top-emitter countries in our sample like Australia or the US, however.

Figure 1. CO_2 emissions by production and consumption in the largest emitter countries
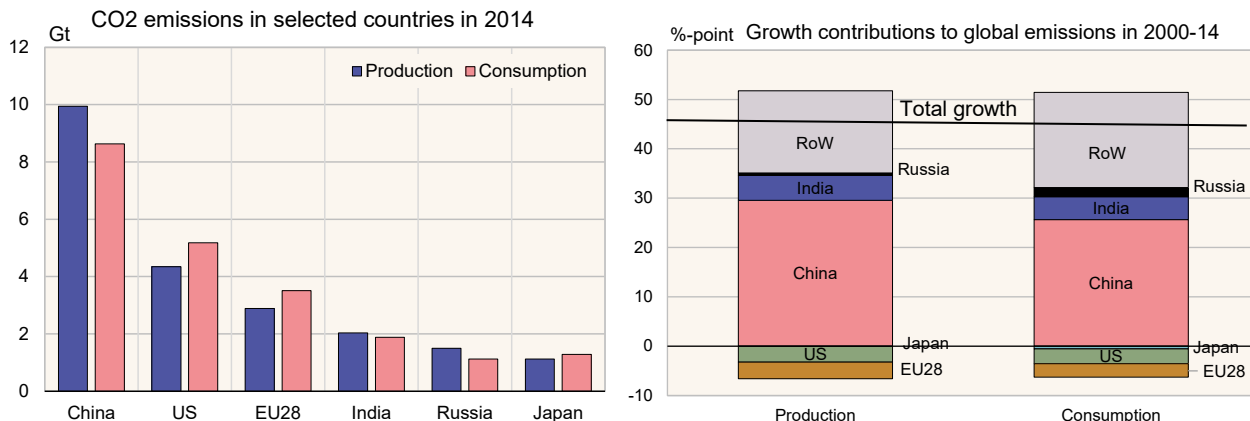
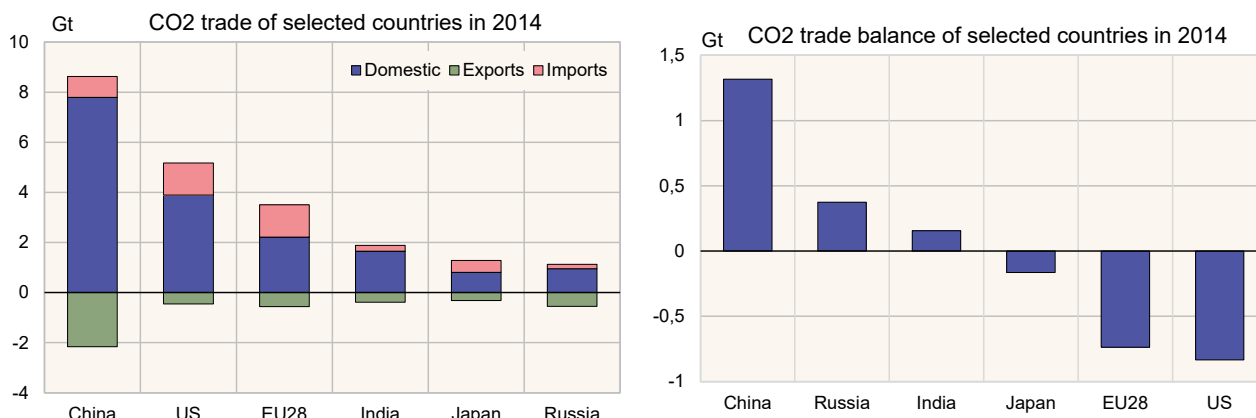Source: Author's calculations based on WIOD data.

As China is one of the world's major exporters, a large part of Chinese emissions involve export production. International trade causes some differences in the emission volumes depending on whether we consider production or consumption-related emissions. Here, we evaluate the virtual CO_2 embodied in the imports and exports of countries to distinguish between emissions associated with production and consumption. First, we calculate value-added production, exports, and imports by country and by sector. Next, we assign the corresponding emissions for each country and sector in order to calculate the international trade flows and trade balance in virtual CO_2 for individual countries and regions.[7] For the sake of brevity, we refer to these flows simply as CO_2 exports and imports.

In line with previous literature,[8] we find that developed economies tend to be net importers of CO_2, whereas most emerging economies are net exporters of CO_2. China is the largest net exporter of CO_2 emissions by far (Figure 2). Even when taking into account the CO_2 emissions embodied in international trade flows, China still accounts for the largest share of global emissions. Indeed, China's CO_2 emissions nearly tripled between 2000 and 2014, regardless of whether we consider the emissions as associated with production or consumption.

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[7] A similar methodology has been applied in several earlier studies, see e.g. Atkinson et al. (2011), Peters (2008), Su & Ang (2011), Zhang et al. (2017). Emissions related to transporting goods are taken into account through value-added and related emissions created by the transport sector in each country.

[8] Atkinson et al. (2011), Sakai & Barrett (2016), Zhang et al. (2017).

5

Figure 2. CO_2 emissions embodied in the foreign trade flows of the largest emitter countries
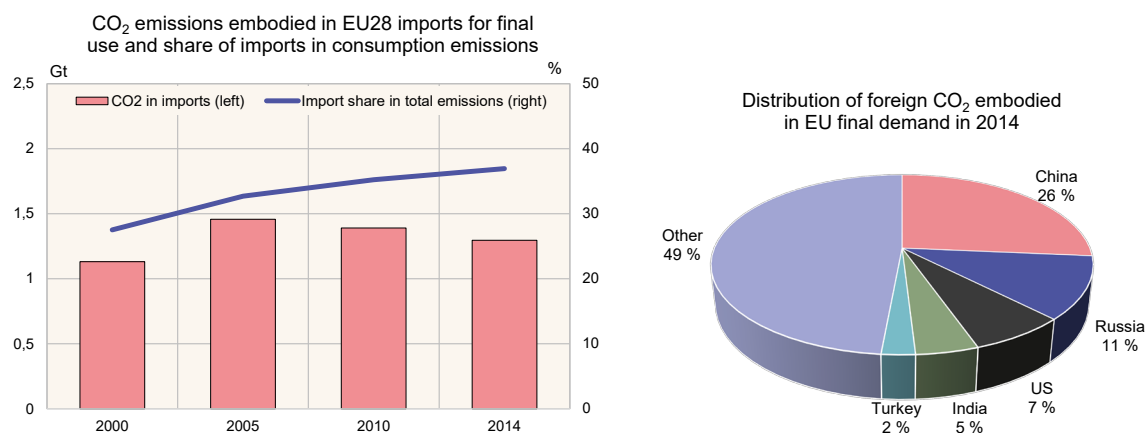

Source: Author's calculations based on WIOD data.

At the sector level, manufacturing is the most relevant sector from the point of view of international trade. Within global manufacturing, nearly 90 % of total CO_2 emissions in 2014 were created by the five sectors with the highest CO_2 intensity (CO_2 emissions per unit of value added). These sectors include manufacturing of other non-metallic minerals (materials such as cement and glass) and manufacturing of basic metals. These are also among the sectors, where the growth of CO_2 emissions has been fastest in 2000–2014. This appears to reflect both volume and technology effects. The production of these sectors has increased substantially, which has also increased emissions in these sectors. In line with general trends, the CO_2 intensity of the sectors has declined, but less than in most sectors. This probably largely reflects the contribution of China and its huge investment demand. Overall, development varies widely across sectors, with global emissions actually declining in certain sectors. For example, the CO_2 emissions associated with printing sector halved globally during 2000–2014. Emissions also declined by 22 % in the manufacturing of computers and electronics, and by 15 % in textile manufacturing.

3. CO_2 emissions and CO_2 embodied in EU imports

CO_2 emissions in the EU declined during 2000–2014. On the production side, the reduction was 20 %, while emissions dropped by only 15 % on the consumption side. Correspondingly, the share of emissions covered by imports from outside the EU increased from 27 % in 2000 to 37 % in 2014 (Figure 3). The increase in imported CO_2 mainly originated from China. While EU imports from most other emerging markets also grew, imports from developed markets declined. China was the single largest source of the CO_2 embodied in the EU imports with a share of about 26 % in 2014. The other important countries originating embedded CO_2 were Russia, the US and India.

Figure 3. CO_2 emissions embodied in EU imports

Source: Author's calculations based on WIOD data.

The variation between individual EU countries was high. While EU CO_2 imports increased by 15 % in aggregate during 2000–2014, the change in external imports of member countries varied from an increase of 97 % for Romania to a reduction of 35 % for Greece. In line with global trends, import shares tended to be higher for EU countries with high per capita income levels. In 2014, the import share varied from slightly over 20 % in Poland, Estonia and Bulgaria to 55 % in Luxembourg and Belgium. In terms of geographical distribution of imports, individual EU countries were relatively similar. For most countries, China was the main source of CO_2 imports. The exceptions were Latvia, Lithuania and Cyprus, all of which had Russia as their largest carbon source country.

In sector terms, over 40 % of the CO_2 embodied in imports for the EU final demand can be attributed to the electricity sectors of the import markets. Energy use accounts for a large part of CO_2 emissions created in the production of certain goods. Moreover, electricity generation tends to be more CO_2 intensive in emerging markets than the EU. This demonstrates the importance of taking into account the entire production chain when assessing the emissions associated with a particular product. It also makes determination and implementation of any border adjustment mechanism more challenging.[9]

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[9] For more discussion, see e.g. Fischer (2015) and Sakai & Barrett (2016).

4. Embodied CO$_2$ emissions in EU imports from China

This section provides more detailed analysis of the embodied CO$_2$ in EU imports from China. For analytical purposes, we divide CO$_2$ emissions embodied in Chinese production that was imported to the EU into four groups. First, we have the imports of Chinese final products used in the EU (group A in Figure 4). Next, we have the Chinese inputs embodied in the production of final goods in third countries imported to the EU (group B). Finally, we have Chinese inputs used in production chains located in the EU. Such inputs to EU production chains can be intended for final use within the EU (group C) or serve as inputs for EU export production (group D). The emissions associated with the imports of the first three groups involve EU consumption, while the emissions embodied in the imports of the fourth group are effectively exported elsewhere. We focus only on the direct imports (groups A, C and D) as they represented for the majority of embodied CO$_2$ emissions in total EU imports from China in 2014.

Figure 4. Distribution of total CO$_2$ emissions embodied in direct and indirect EU imports from China in 2014
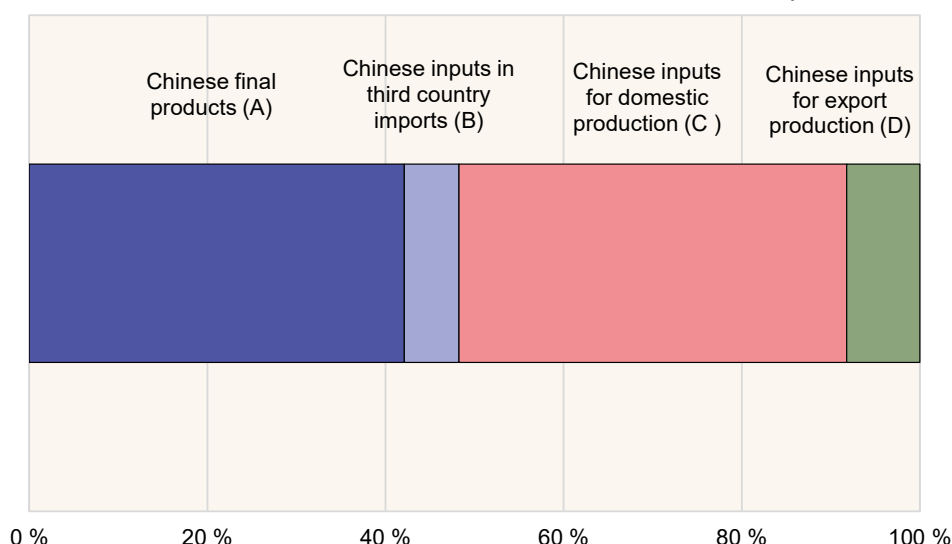
Source: Author's calculations based on WIOD data.

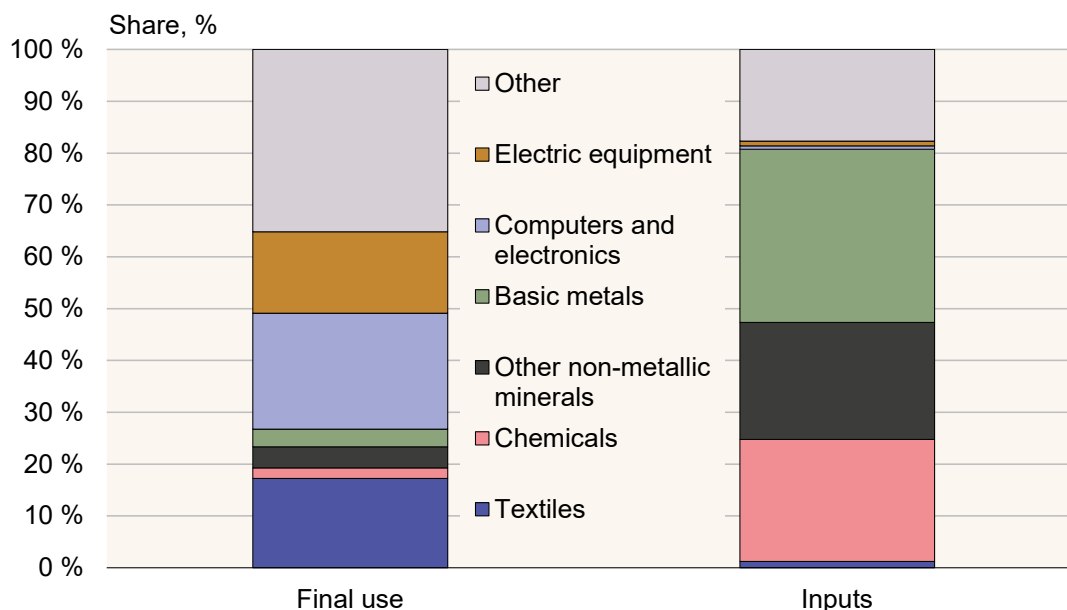## 4.1 Imports of final products from China

We focus first on the Chinese products that are imported for final use in the EU. We decompose Chinese production chains by value added created in different sectors and countries. Then we evaluate the CO$_2$ emissions associated with Chinese production chains and calculate the emissions imported to the EU[10]. Three sectors covered 55 % of the CO$_2$ emissions embodied in these EU imports from China in 2014 (Figure 5): computers and electronics (23 %), textiles (16 %) and electrical equipment (15 %). These sectors are not in general the most CO$_2$ intensive sectors as noted above, but they account for the majority of value added imports of the EU from China. This suggests that the EU imports from China for final use are not particularly geared towards highly emission intensive sectors.

Chinese production in these sectors, as in all manufacturing sectors, is much more CO$_2$ intensive than similar production in the EU. Comparing Chinese and EU production chains shows that the

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[10] The methodology follows Timmer et al. (2015) and is previously applied on WIOD tables with a focus on Chinese production chains in Simola (2018).

Chinese production chains are in general 2–5 times more CO_2 intensive than the corresponding EU production chains. This probably reflects differences in production technology (especially electricity generation, but also other factors), since both Chinese and EU production chains mainly rely on domestic, instead of imported, inputs. The difference can also be partly attributed to the kinds of products manufactured within each sector in China and the EU. Unfortunately, we cannot address this due to the level of aggregation of the data.

Figure 5. Manufacturing sector distribution of CO_2 emissions embodied in EU imports of inputs and final products from China in 2014

Source: Author's calculations based on WIOD data.

4.2 Imports of inputs from China

In this section, we focus on emissions imported from China to the EU that are embodied in inputs for production chains within the EU. Similar to the previous section, we now calculate the share of Chinese inputs in EU production chains and evaluate their associated emissions.[11] Chinese inputs accounted for about half of the total emissions produced in China and imported to the EU in 2014 (groups C and D). As shown in Figure 3, the inputs for production within the EU (group C) covered the majority of emissions embodied in imported inputs, while the share of inputs for export production (group D) was much smaller[12].

For EU production chains, imported inputs from China were the most important for manufacturing of computers and electronics, electrical equipment and textiles. Chinese inputs accounted for 3–6 % of total value added created in these production chains in 2014 (Figure 6). In terms of CO_2, however, Chinese inputs accounted for much larger shares, up to 24 % in the manufacturing of computers and electronics. This apparently reflects technological differences and to some extent the orientation of input imports towards sectors with greater emission intensity.

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[11] The results are not perfectly accurate as we have not calculated the results country by country and then aggregated them to the level of EU, but used the EU aggregate.

[12] This mainly reflects the relatively small share of external exports in EU production.

Indeed, EU imports of inputs from China differ in sector terms quite substantially from the imports for final use (Figure 5). The manufacturing sectors that accounted for the largest shares in CO_2 emissions embodied in imported inputs were unsurprisingly chemicals, other non-metallic minerals and basic metals.

Figure 6. Chinese share of the total value added and CO_2 emissions embodied in select sector value chains located in the EU (2014)
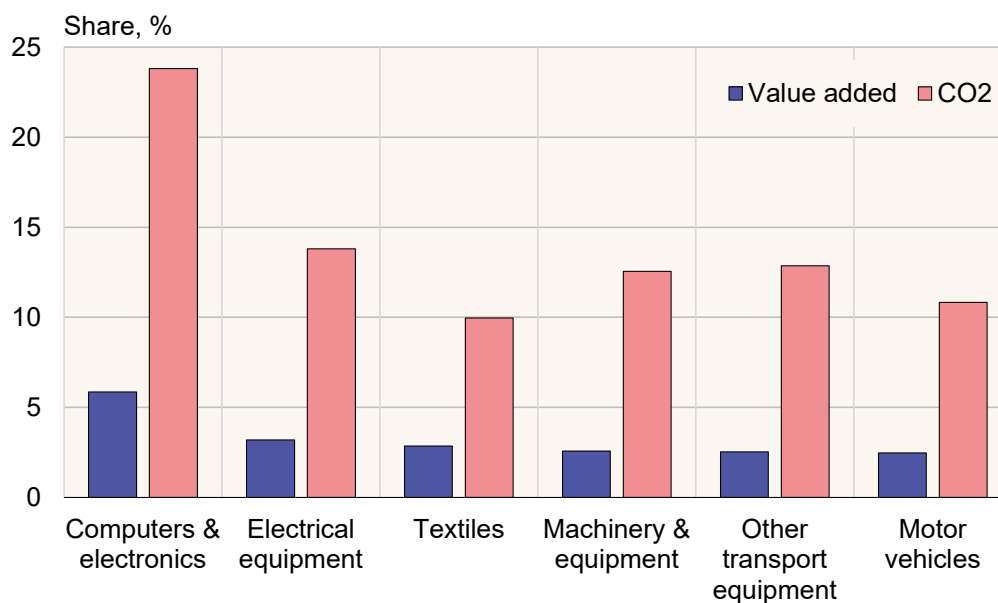
Source: Author's calculations based on WIOD data.

5. Illustrating the potential effects of an EU border adjustment mechanism

The EU's recently released climate policy strategy, the European Green Deal,[13] argues for more ambitious goals on EU emission reductions than earlier. Its key target is to cut EU greenhouse gas emissions by 2030 to half of 1990 levels. A core mechanism for reducing EU emissions is the Emission Trading System (ETS), which has been in place since 2005 and developed gradually. The ETS places a limit on total emissions from participating production facilities. The system has the widest coverage with respect to CO_2 emissions, although it also addresses other emissions. Participation in the ETS with regards to CO_2 is mandatory for companies involved in power and heat generation, energy-intensive industrial sectors (e.g. metals, cement and pulp) and commercial aviation. Under the ETS, the participating companies receive or buy emission allowances to cover the emissions created in their production.[14]

5.1 Carbon leakage and border adjustment mechanism

The Green Deal Strategy mentions the risk of carbon leakage, pointing out that it undermines the impact of EU emission reduction efforts at the global level. To deal with this problem, the strategy brings up the possibility of introducing a carbon border adjustment mechanism in selected sectors to

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[13] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf
[14] More information on the ETS is provided in https://ec.europa.eu/clima/policies/ets_en

10

reduce the risk of carbon leakage. The proposed mechanism would replace the current mechanism of allocating free allowances for production of certain goods to avoid leakage. At this point, however, the EU has yet to provide details of the proposed scheme.

Carbon leakage generally refers to an increase in foreign emissions resulting from domestic actions to reduce emissions. The literature has identified two main channels for carbon leakage, an *energy market channel* and a *competitiveness channel*. The energy market channel arises when environmental regulation in certain countries leads to a decline in fossil fuel demand and consequently in the prices of fossil fuels. When fossil fuels become cheaper, countries with looser environmental regulation are tempted to increase their consumption of fossil fuels and thus increase their carbon intensity. The competitiveness channel is more closely associated with the border adjustment measures. It refers to policies increasing the costs of emission intensive production in trade-exposed industries that can hamper their competitiveness in relation to foreign producers located in countries with less stringent environmental policies.[15]

While the evidence on carbon leakage provided in the literature is not conclusive, estimates typically range between 5–30 %.[16] The effects arising through the energy market channel are found to be larger, but they are difficult to address without global policies. Unilateral policies have more potential in addressing the leakage associated with the competitiveness channel. The competitiveness channel mainly concerns a limited range of sectors and products. For example, the latest EU carbon leakage list that is used for determining free allowances in the ETS identifies 63 product categories subject to high carbon leakage risk.[17]

5.2 Cost effects of tariffs on CO_2 embodied in EU imports

To illustrate the potential cost effects of an EU border adjustment mechanism, we assume a tariff on CO_2 emissions on all external value added imports of 28 USD per ton.[18] This very rough approximation is sufficient to give an impression on the order of magnitude of the effects. We do not consider the actual design of the border adjustment mechanism. The Green Deal strategy only notes that the potential mechanism must comply with WTO rules and other international obligations of the EU. These issues are beyond the scope of this note, but there exists plenty of literature discussing trade policy concerns,[19] as well as other matters related to the design and implementation of border adjustment mechanisms.[20]

Imposing a 28 USD per ton import tariff on CO_2 embodied in external imports of the EU implies an average tariff corresponding to about 2 % of the total value added imports of the EU in 2014. Concerning individual EU countries, there is relatively little variation in the CO_2 intensity of imports, and hence in the implied average tariffs. The applied tariffs would vary from a low of just over 1 % for Ireland up to nearly 3 % for Cyprus and Latvia. From the perspective of country of origin of imports, the highest tariffs would be applied to EU imports from India (4 %), Russia (4 %) and China (3 %). These tariffs are of similar magnitude to those calculated in previous studies[21].

As China accounts for the largest share of imported CO_2 to the EU, these potential tariffs have the greatest implications for China. If a carbon tax of 28 USD per ton is levied on the value added imports of Chinese final products to the EU, it implies a 2–10 % additional cost on imports depending

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[15] Fischer (2015).

[16] Branger and Quirion (2014), Fischer (2015).

[17] The list is presented in the Appendix.

[18] Average of EU ETS carbon price in 2019 converted to USD.

[19] See e.g. Kaufmann & Weber (2011), Mavroidis & de Melo (2015), Monjon & Quirion (2011).

[20] See e.g. Fischer (2015), Monjon & Quirion (2010), Sakai & Barrett (2016), van Asselt & Brewer (2010).

[21] Atkinson et al. (2011), Sakai & Barrett (2016).

on the sector. In relative terms, the highest tariffs would apply to manufacturing of other non-metal minerals, basic metals and chemicals, i.e. China's most CO_2 intensive goods. These goods account, however, for only a small fraction of EU value-added imports of Chinese final products. In absolute terms, the largest cost effects would concern the sectors that account for the largest shares in imports of final products from China, i.e. computers and electronics, textiles and electrical equipment. The total tariff would thus correspond to about 3 % of the EU's total value-added imports of final products from China in 2014.

From the perspective of EU production chains, imposing CO_2 tariffs of 28 USD a ton on the value added imported in the form of inputs from China implies about 3 % additional costs on average for imported inputs from China. The effect varies between 2–5 % across manufacturing sector production chains. The highest effects concern the EU production chains of non-metallic minerals and basic metals, since these production chains import the most emission-intensive inputs from China.

6. Discussion

Our analysis suggests that imported emissions account for an increasing share of CO_2 emissions associated with consumption within the EU. The CO_2 emissions embodied in EU imports mainly originate in emerging economies, and China in particular. In 2014, nearly 10 % of CO_2 emissions associated with EU consumption originated in China and were embodied in EU imports from China. While addressing the carbon leakage itself is beyond the scope of this note, our analysis suggests that carbon leakage is not the main factor behind increased imports of CO_2 emissions. EU imports of final goods from China, for example, in value terms mainly consist of goods from sectors that are not highly CO_2 intensive. China has risen among the largest producers of goods like textiles or electronics primarily for other reasons than environmental regulations. Imports of inputs, however, are more oriented towards CO_2 intensive sectors, which could point to carbon leakage.

The risk of carbon leakage is raised in the EU's new climate policy strategy, which brings up the possibility of introducing a border adjustment mechanism for reducing the risk of leakage. To get some idea of the magnitude of potential cost effects, we considered a simple border adjustment mechanism for all EU external imports that assumes a uniform tariff corresponding to the recently prevailing ETS price of about 28 USD a ton of CO_2. Our illustration suggests that introduction of such a tariff would lead to moderate increases in EU import prices. In practice, the effect could be even more moderate as the border adjustment mechanism would likely only be applied to select sectors. On the other hand, the required adjustments could be much higher, implying stronger price effects. For example, the IMF (2019) has recently evaluated that limiting global warming to 2°C or less requires an immediate goal of raising the global carbon tax to USD 75 a ton of CO_2 by 2030.

The impacts could, however, vary widely across individual products. For example, while manufacturing of other non-metallic minerals on the aggregate level one of the most CO_2-intensive sectors, it includes a very heterogeneous range of goods. On country terms, a potential border adjustment mechanism would likely affect EU trade with China, which is the largest source of imported CO_2 for the EU. Although CO_2 embodied in EU imports from China is quite evenly distributed between inputs and final goods, the effects would probably emphasize imports of inputs over final products. The imports of inputs are more focused on sectors that are CO_2 intensive (e.g. non-metallic minerals and basic metals) and therefore more likely to fall under the potential border adjustment mechanism.

The goal of introducing a border adjustment mechanism is to prevent carbon leakage – policy-induced emission reductions within the EU leading to increasing CO_2 intensive production in locations with less stringent environmental regulation. The leakage would undermine the emission

reduction efforts of the EU and could hamper the competitiveness of cleaner production. The evidence on the effectiveness of border adjustment mechanisms in preventing leakage is mixed, however.[22] This underscores the fact that global measures are preferable to local ones. Unfortunately, global measures are unlikely to be feasible. Thus, as our results highlight, any unilateral measures must be designed and implemented carefully in order to achieve the desired goals.

[22] See e.g. Branger & Quirion (2014), Böhringer et al. (2012), Kuik & Hofkes (2010), Sakai & Barrett (2016).

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Appendix. List of sectors and subsectors deemed at risk for carbon leakage in the EU for 2021–30

Crop and animal production
1. Extraction of salt

Mining and quarrying
2. Mining of hard coal
3. Extraction of crude petroleum
4. Mining of iron ores
5. Mining of other non-ferrous metal ores
6. Mining of chemical and fertilizer minerals
7. Other mining and quarrying n.e.c.

Manufacture of food products
8. Manufacture of oils and fats
9. Manufacture of starches and starch products
10. Manufacture of sugar
11. Manufacture of malt
12. Kaolin and other kaolinic clays
13. Frozen potatoes
14. Dried potatoes
15. Concentrated tomato puree and paste
16. Skimmed milk powder
17. Whole milk powder
18. Casein
19. Lactose and lactose syrup
20. Whey and modified whey
21. Bakers' yeast
22. Vitrifiable enamels and glazes, englobes and similar preparations
23. Liquid lustres and similar preparations

Manufacture of textiles, wearing apparel and leather products
24. Preparation and spinning of textile fibres
25. Manufacture of non-wovens and articles made from non-wovens, except apparel
26. Manufacture of leather clothes
27. Finishing of textiles

Manufacture of wood and paper
28. Manufacture of veneer sheets and wood-based panels
29. Manufacture of pulp
30. Manufacture of paper and paperboard

Manufacture of coke and refined petroleum products
31. Manufacture of coke oven products
32. Manufacture of refined petroleum products

Manufacture of chemical and pharmaceutical products
33. Manufacture of industrial gases
34. Manufacture of dyes and pigments
35. Manufacture of other inorganic basic chemicals
36. Manufacture of other organic basic chemicals
37. Manufacture of fertilizers and nitrogen compounds
38. Manufacture of plastics in primary forms
39. Manufacture of synthetic rubber in primary forms
40. Manufacture of man-made fibres
41. Manufacture of basic pharmaceutical products

Manufacture of other non-metallic mineral products
42. Manufacture of flat glass
43. Manufacture of hollow glass
44. Manufacture of glass fibres
45. Manufacture and processing of other glass, including technical glassware
46. Manufacture of refractory products
47. Manufacture of ceramic tiles and flags
48. Manufacture of bricks, tiles and construction products, in baked clay
49. Manufacture of ceramic household and ornamental articles
50. Manufacture of ceramic sanitary fixtures
51. Manufacture of cement
52. Manufacture of lime and plaster
53. Manufacture of other non-metallic mineral products n.e.c.

Manufacture of base metals and metal products
54. Manufacture of basic iron and steel and ferro-alloys
55. Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
56. Cold drawing of bars
57. Aluminium production
58. Lead, zinc and tin production
59. Copper production
60. Other non-ferrous metal production
61. Processing of nuclear fuel
62. Casting of iron
63. Open die forged ferrous parts for transmission shafts, etc.

Source: https://ec.europa.eu/clima/news/adoption-delegated-decision-carbon-leakage-list-2021-2030_en

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