PAPER

Title: Positioning multinationals enterprises in global carbon chains. Measuring the impact on the mitigation targets of the Paris Agreement

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Abstract:

In this paper we evaluate, as a first objective, how the position of a country in global value chains (Antràs et al. (2012); Antràs and Chor (2018)) and carbon chains (Shapiro, 2020) is conditioned by the presence of foreign multinational affiliates. To do this, we use a multiregional input-output model with firm heterogeneity and calculate the economic and environmental footprint for domestic companies and multinational affiliates. We employ the recent update of the OECD ICIO database, the AMNE database (OECD, 2020), and combine it with information on emissions provided by the International Energy Agency database (IEA, 2019).

The second objective is to evaluate the relationship between position in global value chains, the carbon intensity of a country and the Nationally Determined Contributions

(INDCs) to reduce greenhouse gas emissions under the Paris Agreement. Most OECD countries, which have a lower carbon intensity than the world average, are positioned in the final stages of production chain and the higher their per capita income, the higher their emission reduction targets. This leads us to conclude that there is a mismatch between the countries' emissions reduction targets and their pollution intensity, since OECD countries have committed strongly to reducing their total emissions while many non-OECD countries, which are positioned in the initial stages of production, maintain a higher carbon intensity than the world average, but nevertheless have less ambitious mitigation targets as they have lower per capita income.

Keywords: *carbon emissions, upstreamness, global value chains, multiregional input-output model.*
JEL codes: F18 - Trade and Environment; F6 - Economic Impacts of Globalization; Q56 - Environment and Development; Environment and Trade; Sustainability; Environmental Accounts and Accounting; C67 - Input–Output Models.

1. Introduction

To be consistent with global emission pathways with no or limited overshoot of the 2°C goal global CO_2 emissions[1] need to decrease by about 25 per cent from the 2010 level by 2030 and reach net zero around 2070 (IPCC, 2018)[2]. However, the report made in February of 2021 by UNFFCC (2021) in relation the updated nationally determined contributions communicated by 75 Parties, account for about 40 per cent of the Parties to the Paris Agreement and about 30 per cent of the global GHG emissions, foresees a decrease in emissions by 2030 of only 0.5 per cent lower than in 2010 and 2.1 per cent lower than in 2017.

The climate emergency requires urgent measures to reduce carbon emissions and the need to exert political pressure on governments to become aware of the existing environmental crisis. The positive and negative effects of Climate Change mitigation measures are spread along all the economic system through the presence that the institutions involved in these policies have in the global production chains. Multinational enterprises (MNE) are called to be a key part of this emissions mitigation process. As producers, through their downstream linkages, shift both the changes in their costs and the technological improvements to the companies that buy their products and to the final consumers. As consumers, through their upstream linkages influence their suppliers and can select those that are directly and indirectly more environmentally friendly. In addition, MNE have enough power to influence in investors and consumers to make more sustainable choices.

In this paper, the first objective is to evaluate how the position of a country in global value chains (Antràs et al. (2012) and Antràs and Chor (2018)) and global carbon chains (Shapiro, 2020) is conditioned by the presence of foreign multinational affiliate. To do this, we develop a multiregional input-output model, introducing firm heterogeneity by

[1] According to the SR1.5, 7 to be consistent with global emission pathways with no or limited overshoot of the 1.5 °C goal, global net anthropogenic CO2 emissions need to decline by about 45 per cent from the 2010 level by 2030, reaching net zero around 2050. For limiting global warming to below 2 °C, CO2 emissions need to decrease by about 25 per cent from the 2010 level by 2030 and reach net zero around 2070. Deep reductions are required for nonCO2 emissions as well. Thus, the estimated reductions referred to in paragraphs 10–11 above fall far short of what is required, demonstrating the need for Parties to further strengthen their mitigation commitments under the Paris Agreement.

[2] 7 IPCC. 2018. IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. V Masson-Delmotte, P Zhai, H-O Pörtner, et al. (eds.). Geneva: World Meteorological Organization. Available at https://www.ipcc.ch/sr15/

sectors that allow us to calculate the economic and environmental footprint for domestic companies and MNE. The second objective is to evaluate the relationship between the position in global (production and carbon) chains, their carbon intensity, and their Nationally Determined Contributions (INDCs) to reduce greenhouse gas emissions under the Paris Agreement.

We use the recent update of the OECD – ICIO database, the AMNE database (OECD, 2020), combining with information on emissions provided by the International Energy Agency database (IEA, 2019). For measuring the position of a country in the global value chains we use the upstreamness measure proposed by (Antràs et al., 2012) and (Antràs and Chor, 2018), which is useful to computing the average (weighted) position of an industry's output in the value chain, to identify the position of countries and sector in global value chains (Miller and Temurshoev, 2017).

Additionally, when we add carbon in the positioning measure (Shapiro, 2020), the carbon upstreamness would inform us about the influence capacity of the countries or sectors on the rest of the productive system. In this sense, the higher the carbon upstreamness measure, the further back the country or sector will be positioned, and the greater the ability to influence to the rest of the production system and the greater the ability to spread contamination with each production decision.

Therefore, it would be appropriate that countries or sectors positioned further back in global carbon chains try harder to maintain more ambitious emission reduction commitments, to be able to transfer their adoption to the rest of the countries or sectors that purchase these goods and services as inputs. Our study confirms that countries with the highest carbon upstreamness set the lower emission reduction targets. These are mainly developing countries (non-OECD) with a lower per capita income. Considering firm heterogeneity, we observe how MNE are positioned further back in global production and global carbon chains than domestic companies, which exacerbates the problem of non-OECD countries, by making countries hosting MNE affiliates position even further back in global carbon chains.

Measuring the position of a country in the global carbon chains can be an opportunity as well as it would indicate the possibilities that the companies of a country have to transfer their successful mitigation strategies throughout the entire production system of the rest of the countries of the world economy. However, the emission reduction targets committed by the countries respond to their domestic conditions, regardless of how these countries can influence the targets proposed by the rest of the world. This work raises the need for the mitigation objectives of the firms and, especially MNE, to be aligned with the Paris Agreement, which leads us to consider the debate of whether these objectives should be aligned with the countries of origin of MNE or with the destination countries of the MNE affiliates.

2. Materials & Methods

2.1 The MRIO model.

The standard MRIO model (Miller and Blair, 2009) includes regions and countries with their own technology, and trade is split into intermediate trade with a specific industry destination and final trade. The basic input-output equation can be expressed as follows:

$$\mathbf{x}^r = \mathbf{A}^{rr}\mathbf{x}^r + \mathbf{y}^{rr} + \sum_{s\neq r}\mathbf{A}^{rs}\mathbf{x}^s + \sum_{s\neq r}\mathbf{y}^{rs} \quad [1]$$

Where $\mathbf{x}$ is the output of the region indicated in the superscript, $\mathbf{A}^{rr}$ is the domestic matrix of coefficients of production (intraregional matrix), $\mathbf{A}^{rs}$ is the trade between industries from region *r* to region *s* (intermediate exports of region *r* or intermediate imports of region *s*), both calculated as $\mathbf{A}^{ij} = \mathbf{Z}^{ij}\left(\hat{\mathbf{x}}^j\right)^{-1}$ and $\mathbf{y}^r = \mathbf{y}^{rr} + \mathbf{y}^{rs}$ is the final demand of region *r*, which can be divided into domestic final demand $(\mathbf{y}^{rr})$ and exported final demand $(\mathbf{y}^{rs})$ or trade between industries in region *r* to final consumers in region *s* (final exports of region *r* o final imports of region *s*).

The Model can be expressed in compact form by eq. [2] and solved through the Leontief Inverse $\boldsymbol{L} = (I - A)^{-1}$ as in eq. [3]:

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{x} + \hat{\mathbf{y}} \quad [2]$$

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\hat{\mathbf{y}} \quad [3]$$

Where $\mathbf{A}$ is the matrix of technical coefficients and the term $\hat{\mathbf{y}}$ is the diagonalized vector of final demand.

An advantage of the Leontief model is the ability to observe how final demand incites production processes and traces chains of intermediate consumption through layers or tiers. We can approximate each one of the layers decomposing the Leontief inverse in different production phases, using the Taylor series approximation (Jing et al., 2015; Owen et al., 2018; Skelton et al., 2011; Zhang et al., 2017) as shown in:

$$L = (I - A)^{-1} = I + A + A^2 + A^3 + \cdots + A^t \text{ where } t \to \infty \qquad [4]$$

Each element of the expansion in equation [4] denotes a different production layer and represents the production of intermediate goods used as input into the preceding layer.

Equation [5] allows us to calculate the outputs of the sectors in any tier or layer generated by the final demand:

$$\boldsymbol{x}_i^r = \boldsymbol{y}_i^r + \sum_{j=1}^{N} \boldsymbol{a}_{ij}\, \boldsymbol{y}_i^r + \sum_{j=1}^{N} \sum_{k=1}^{N} \boldsymbol{a}_{ik} \boldsymbol{a}_{kj}\, \boldsymbol{y}_i^r + \sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{t=1}^{N} \boldsymbol{a}_{it} \boldsymbol{a}_{ik} \boldsymbol{a}_{kj}\, \boldsymbol{y}_i^r + \cdots \qquad [5]$$

Therefore, equation [5] shows industry's output in country *r* as an infinite sequence of terms which reflect the use of this country-industry's output at different positions in global value chains, starting with its use as a final good/service, as a direct input in the production of final goods/services in all countries and industries, as a direct input of a direct input in the production of final goods/services in all countries and industries, and so on (Antràs and Chor, 2018).

2.2 Calculating the upstreamness measure

The application of the Structural Path Analysis (SPA) and the identification of the different layers or tiers will allow us to subsequently apply the upstreamness measure proposed by (Antràs et al., 2012) and (Antràs and Chor, 2018) calculate the average (weighted) position of an industry's output in the value chain, by multiplying each of the layers by its respective production-staging distance from final use plus one, and dividing by total output as follows:

$$U_i^r = 1 * \frac{y_i^r}{x_i^r} + 2 * \frac{\sum_{j=1}^{N} a_{ij} y_i^r}{x_i^r} + 3 * \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} a_{ik} a_{kj} y_i^r}{x_i^r} + 4 * \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{t=1}^{N} a_{it} a_{ik} a_{kj} y_i^r}{x_i^r} + \cdots \quad [6]$$

where $U_i^r \geq 1$.

The result of U_i^r represents the average distance from final use and larger values of this measure are associated with relatively higher levels of upstreamness of the output.

2.3 The environmental extension of the upstreamness measure

For calculating the carbon upstreamness measure (CU) we use the general equation for estimating CO_2 emissions, both under the production-based accounting (PBA) or producer footprint (PF) (López et al., 2019; Ortiz et al., 2020) approaches using the AMNE tables:

$$E = \hat{f}\,(I - A)^{-1}\hat{y} = \hat{f}L\hat{y} \quad [7]$$

where $\hat{f}$ refers to the direct emissions coefficients or the diagonalized vector of emissions per unit of output. A is the integrated matrix of technical coefficients. The term L is the Leontief inverse that represents the total requirements matrix that, multiplied by the intensity factor (in our case $\hat{f}$), indicates the amount of emissions per unit of output destined to satisfy a unit of final demand, designated as emission multiplier or total emissions intensity. Finally, $\hat{y}$ is the matrix diagonalized of final demand. In this approach, we do not distinguish between domestic and foreign final demand, therefore, all off diagonal elements of the matrix are zeros.

Adding matrix **E's** elements along columns results in the PF emissions by producer country of firm type. PF considers the emissions emitted in country *r* that are incorporated in the finished goods produced within the boundaries of country *s* and allocates those emissions to country *s*, regardless of whether those goods are subsequently exported or domestically consumed. Adding matrix **E's** elements along rows results in the PBA, direct emissions or producer responsibility, where emissions are allocated to the country where they occur, and it is the measure traditionally adopted by international agreements such as Kyoto Protocol and Paris Agreement for commitments of emissions reduction.

The application of the Structural Path Analysis allows us to identify the contribution of each part of the value chain and the key carbon flows and industries in final demand. Total carbon emissions flows between sector *i* of the country *r* and sector *j* of country *s* in the path (*p*) would be given by the following expression [8], where each component indicates emissions incorporated in each stage of production.

$$E_i^r = e_i^r y_i^r + \sum_{j=1}^{N} e_i^r a_{ij} y_i^r + \sum_{j=1}^{N} \sum_{k=1}^{N} e_i^r a_{ik} a_{kj} y_i^r + \sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{t=1}^{N} e_i^r a_{it} a_{ik} a_{kj} y_i^r + \cdots \quad [8]$$

As in the case of the output, once the different layers have been calculated, we calculate the carbon upstreamness measure (CU), following Antràs et al. (2012) and Antràs and Chor (2018) combined with carbon emissions as stressor, similar to Shapiro (2020):

$$CU_i^r = 1 * \frac{e_i^r y_i^r}{E_i^r} + 2 * \frac{\sum_{j=1}^{N} e_i^r a_{ij} y_i^r}{E_i^r} + 3 * \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} e_i^r a_{ik} a_{kj} y_i^r}{E_i^r} + 4 * \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{t=1}^{N} e_i^r a_{it} a_{ik} a_{kj} y_i^r}{E_i^r} + \cdots \quad [9]$$

where $CU_i^r \geq 1$.

The measure of CU by country informs about the position of a country *r* in the global carbon chains. A value close to 1 indicates that an important part of the country's production is destined for final demand and, therefore, the emissions are incorporated in the last stages of production. On the contrary, the higher the value of the CU, the further back the country is in the global carbon chains and, therefore, its emissions are more importantly incorporated in inputs sold to other companies that use it to produce final goods.

2.4 Data sources

The empirical application of this paper combines information from two main sources. Regarding the input-output framework, we employed the last update of ICIO tables, distinguishing firm ownership, released by the AMNE database of OECD (Cadestin C, 2018; OECD, 2020). This database provides symmetric MRIO tables in basic prices for the period 2005-2016 in millions of USD, 60 regions (36 OECD countries, 23 non-OECD countries, and an aggregate for the rest of the world), 34 industries, and 2 types of company ownership.

Regarding global CO_2 emissions, we use statistics on CO_2 emissions provided by the International Energy Agency database (IEA, 2019), which offers data on CO_2 emissions released in the combustion of fuel for 1960-2018, for 144 individual countries (and several aggregates), 32 emitter activities and 43 fuel types, in kilotonnes of CO_2 ($ktCO_2$). To reconcile this information into the industry and region classification of OECD-ICIO tables, we have created a a CO_2 emissions vector as in Wiebe and Yamano (2016) but considering additionally the 2 types of ownership following Duan and Jiang (2021).

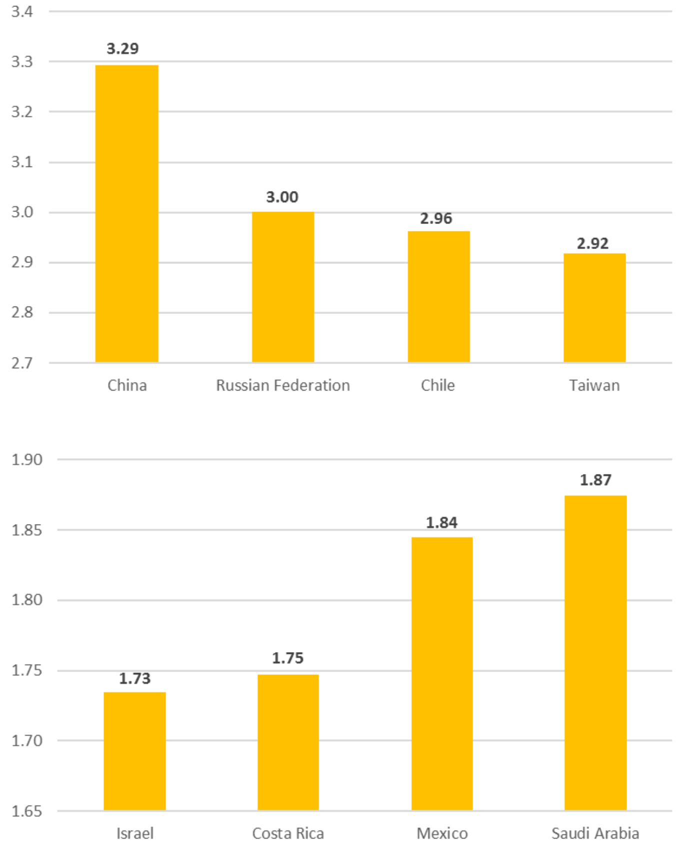
Regarding the emission reduction target data, we have collected the information from the INDCs submitted by country within the framework of the Paris Agreement. Per capita income as well as other indicators of interest have been obtained from World Bank statistics.

3. Results

3.1 Posicionamiento de los países en las cadenas globales de los sectores y emisiones de carbono

As can be seen in Figure 1, there is a significant discrepancy in the value of the carbon upstreamness measure. Values range from 1.7 in Israel to 3.29 in China. Countries with higher carbon upstreamness measure are China (3.29), Russia (3.00) and Chile (2.96). We observe how the countries that are more present in the last stages of carbon chains (lower CU) present different criteria in relation to their per capita income, size of the economy or sectoral specialization or direct carbon intensity. However, most of the countries with the highest CU do share several characteristics: they are carbon-intensive countries, with many natural resources and with a low average per capita income (except for Norway and Switzerland).

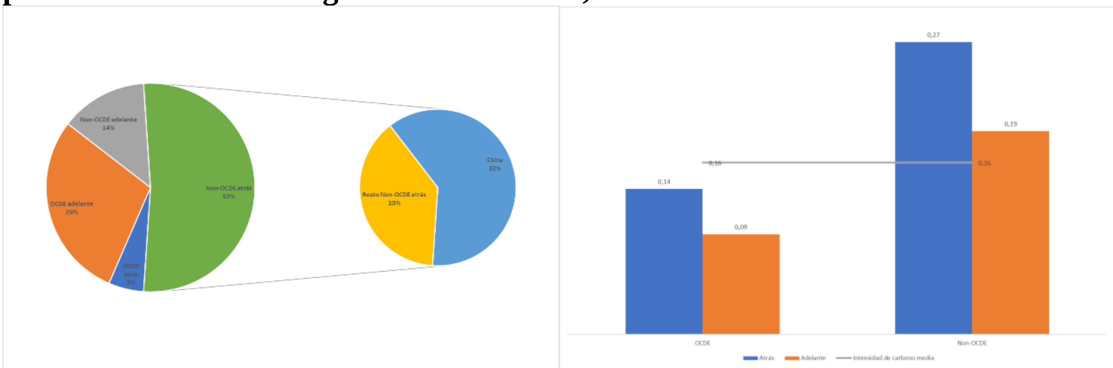
Figure 1. Position of countries in global carbon chains, 2016



The distribution of carbon emissions between countries in relation to their position in global value chain is different for OECD and non-OECD countries (Figure 2A). In the OECD, most of the emissions are generated by countries that are located in the final stages of production (29% of the world total) compared to those that are located in the initial stages (5% of the world total). However, in non-OECD countries, 52% of global carbon emissions are produced by countries and regions that are in the early stages of global value chain (where China stands out with 20% of the total) and only 14% are in the final stages.

At the same time, OECD countries have a lower carbon intensity than non-OECD countries, but for both groups of countries the pollution intensity of countries positioned in the initial production chain is 140% higher than those located in the final chains (Figure 2B). Specifically, the average carbon intensity of the OECD countries located in the initial chains is 0.27 kCO2/$ and for the world average is 0.16 kCO2/$ (170% higher).

Figure 2. Distribution of carbon emissions and carbon intensity according to the position of countries in global value chains, 2016



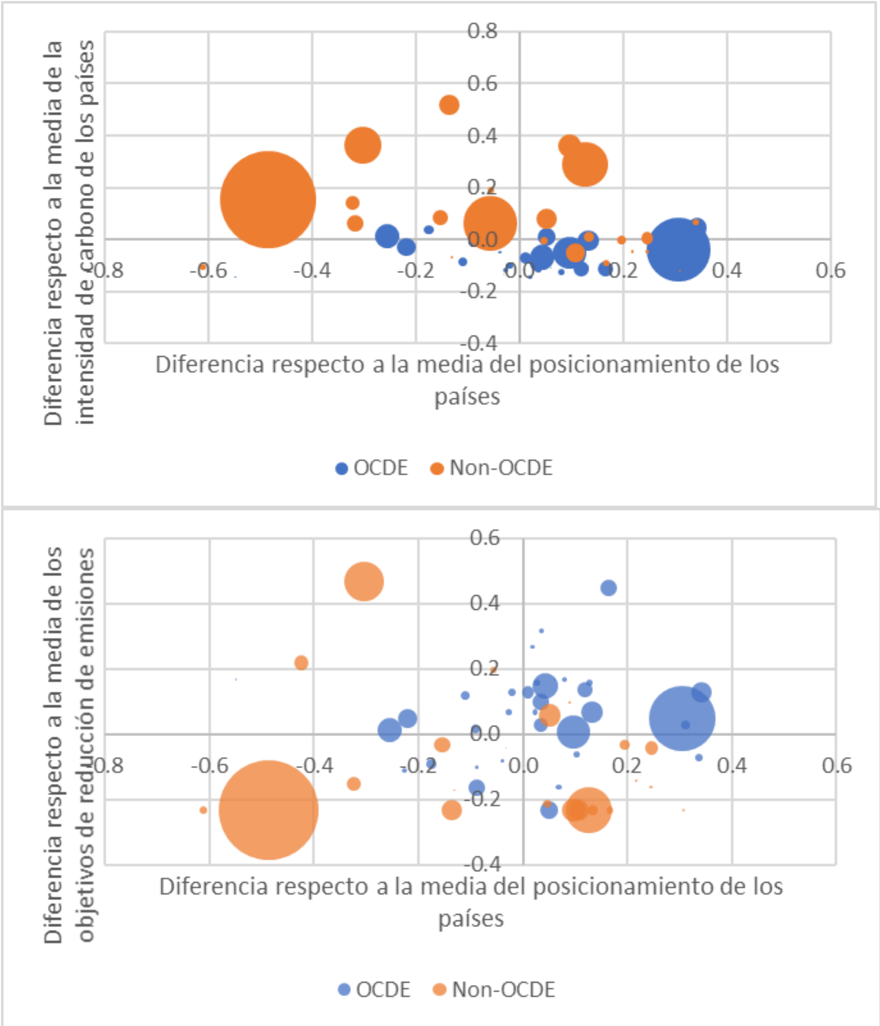
Note: The distribution of the countries has been made in relation to their position in the mean of the global production chains of all the countries. The countries located in in the final stages are those that supply their production to final demand more intensively than the average for the economy as a whole and those located backwards sell more to intermediate demand than the average.

There is a different pattern between OECD and non-OECD countries when comparing differences from the world average (Figure 3A). Thus, most OECD countries have lower carbon intensity than the world average and are positioned in the final stages of production, which means that a high proportion of OECD emissions are located in the quadrant I. On the other hand, most of the countries and the emissions of the non-OECD countries are located in quadrant II, as they maintain a higher carbon intensity than average and are positioned in the initial stages of production chains.

Figure 3B shows how the different countries are positioned with respect to the position in GVC and, at the same time, in relation to the emission mitigation objectives committed by the world economy on average. Most OECD countries are located above the horizontal axis, therefore, maintain mitigation targets above the average. OECD countries with higher emissions are in the quadrant I, indicating that are positioned in the final stages of the production chains. In contrast, most of non-OECD countries maintain emission mitigation targets lower than the average, regardless of whether they are further forward or further back in global production chains.

Paradoxically, although the richest OECD countries are those that adopt the most ambitious mitigation commitments, they are the ones that can least influence the production of low-carbon goods as they are specialized in the production of goods and services that are mainly destined to final demand and, therefore, they have less capacity to contribute to decarbonize the rest of the world economy. However, the poorest non-OECD countries have the greatest capacity to influence the rest of the economy as they are positioned in production phases further back and with higher carbon intensity.

Figure 3. Position in global production chains and carbon intensity of OECD and non-OECD countries, 2016



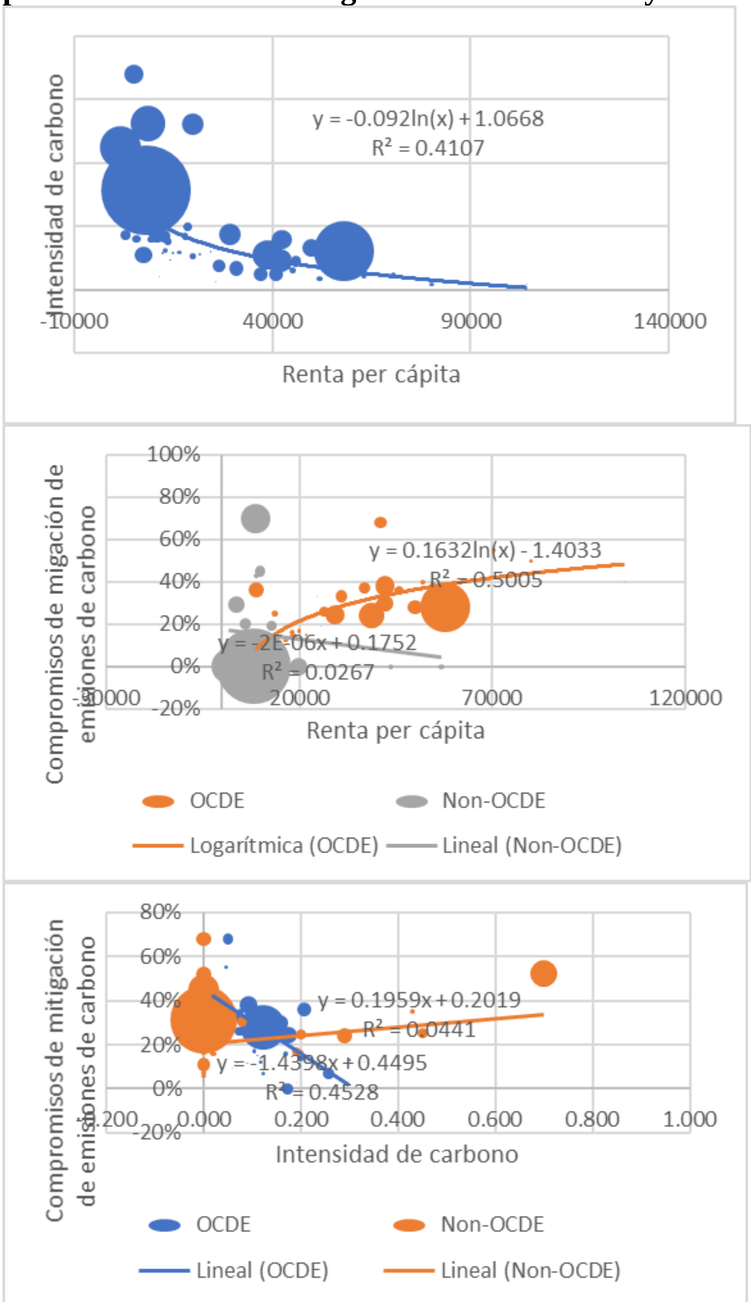
3.2 Emission mitigation commitments and the positioning of countries in global production chains

There is an inverse relationship between the level of income per capita and the carbon intensity of the countries, the higher the income per capita, the lower the intensity of pollution in the country for all the countries considered (either due to their productive structure, their regulatory policies, citizen preferences, etc.) (Figure 4A). We also find an inverse relationship between the level of per capita income and the emission reduction targets committed under the Paris Agreement, although this relationship is only found with the countries belonging to the OECD (Figure 4B). However, for non-OECD countries their emission reduction targets are not related to their per capita income level.

The combination of these two facts leads us to conclude that there is a mismatch between emission reduction targets and pollution intensity in the OECD countries

(Figure 4C), since it is the most carbon-intensive countries that are the least committed, which makes difficult to reduce global emissions since it should be the most carbon-intensive countries that should carry out more ambitious mitigation policies. However, for non-OECD countries, no relationship is found between emission reduction targets and committed mitigation targets. These countries are emerging emitters, including many low-income, whose annual emissions grew faster than the global nations' average 2010-2018 (Guan et al., 2021), prioritizing the development and growth of their economies and not reducing emissions.

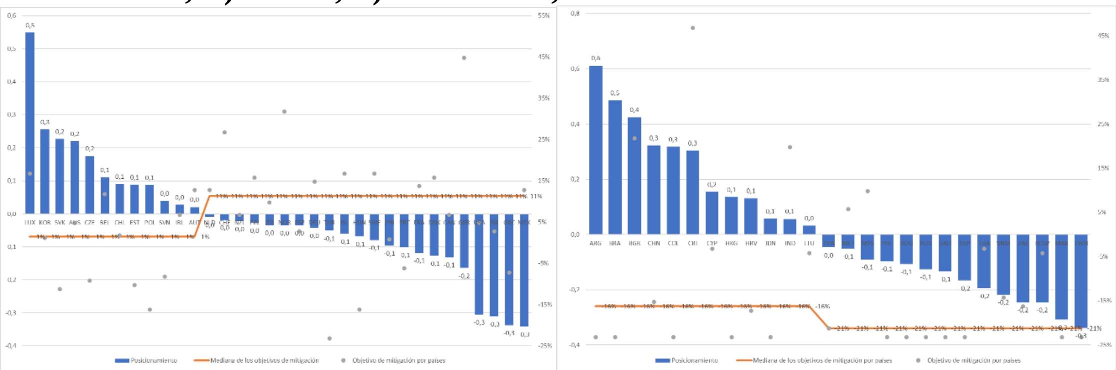
Figure 4. Relationship between carbon intensity, per capita income, the country's position in 2016 and mitigation commitments by 2030



Note: The size of the bubble shows the total emissions of the economy.

Countries located to the right of Figure 5 are positioned in the final production chains and those located to the left in the initial production chains. In the OECD, countries located in the bottom chains maintain, on average, mitigation targets above the average for the world economy as a whole and, specifically, the median of the differences between the objectives committed by these countries and those committed by the global economy is 11% higher. While the OECD countries that are in the initial phases maintain less ambitious mitigation objectives (as they are more carbon intensive) and their median is only 1% higher. However, the median of the non-OECD countries that are in the initial phases of production maintain mitigation objectives 16% lower than the average of the world economy and those in the final chains of 26% lower than average.

Figure 5. Positioning in global production chains and emission mitigation commitments, A) OECD, B) Non-OECD, 2016



Note: The horizontal axis shows the average position in the global production chains of the world economy and, therefore, the column data shows the difference with respect to the average. The further to the right a country is, the more the country is positioned in the final chains and the further to the left it is positioned further back in the global chains.

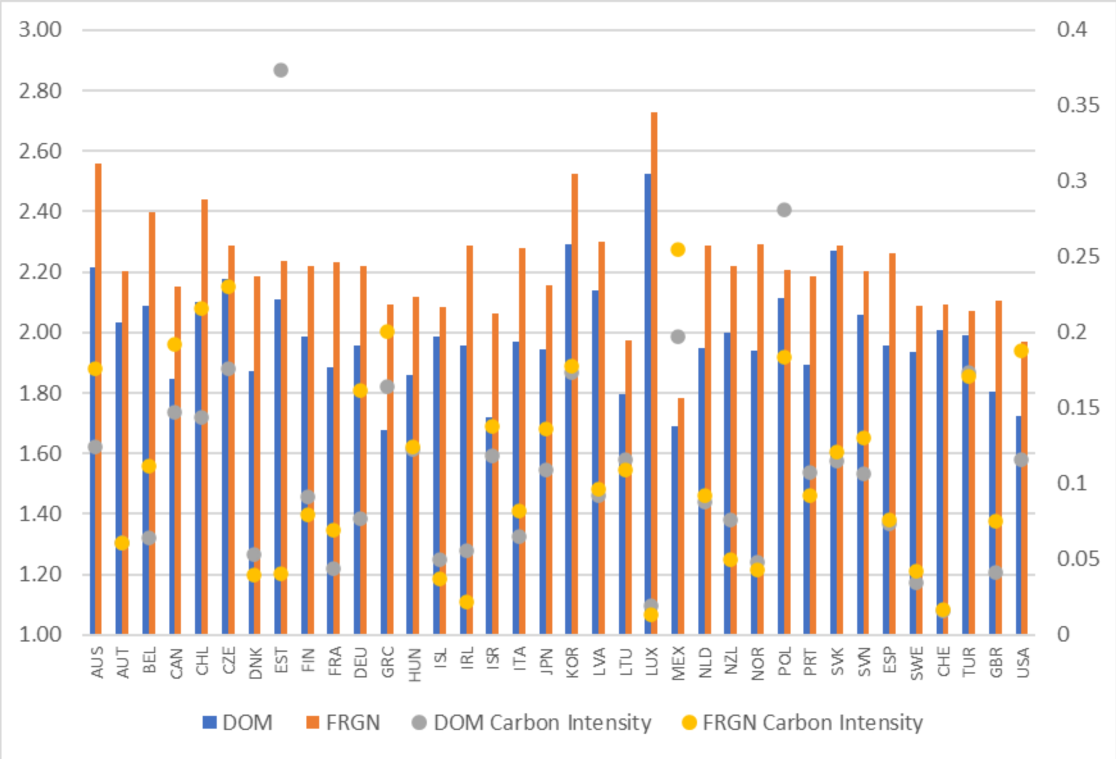
3.3 Positioning MNE and domestic firms in the global value chains

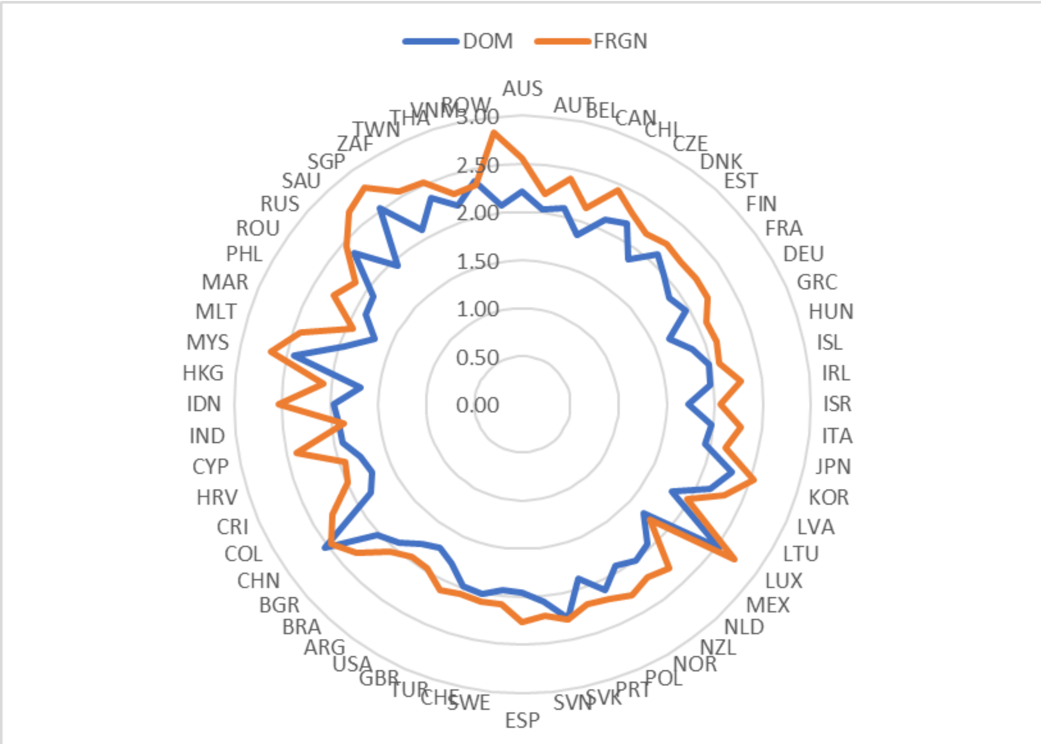
Differentiating between domestic companies and MNE affiliates, we obtain how MNE are located further back in the global production chains and, at the same time, have a higher carbon intensity than the rest of the domestic companies in economies (Figure 6A). When differentiating between OECD and non-OECD countries, we find that the existing differences are more significant in both variables among non-OECD countries (2.33 on average for MNE compared to 2.03 for domestic companies, that is, 28% higher[3]), indicating that the MNE in these countries make the country go even further

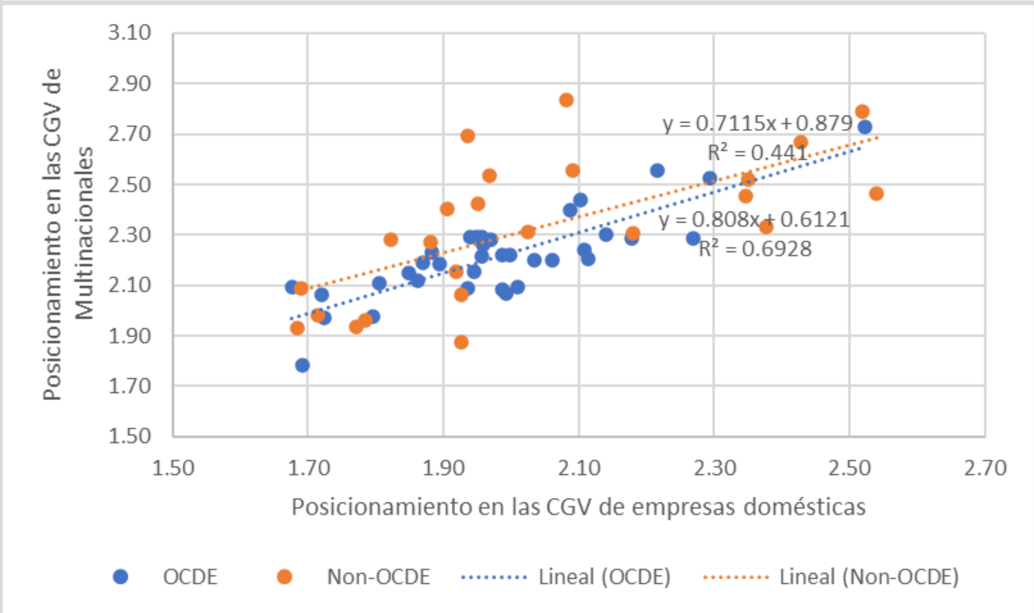
[3] In relative terms, as the minimum value is 1 when all production demand is destined for final demand, the greater positioning of MNs compared to domestic ones implies a 28% higher positioning than domestic companies and 23% for companies of the OECD.

back in the GVC (on average, the MNE take back the position of a country around 4%, for both OECD and non-OECD countries). And, at the same time, MNE also increase the carbon intensity of the countries where they are established (0.27 kCO2 / $ for MNE versus 0.23 kCO2 / $ for domestic firms), this is explained because MNE operate in more intensive sectors and they have higher carbon intensity by sector (Ortiz et al., 2021).

Figure 6. Position in the global value chain and carbon intensity of the countries of the world economy, domestic companies and MNEs, 2016







4. Conclusions

The distribution of carbon emissions between countries in relation to their position in global value chain is different for OECD and non-OECD countries. In the OECD, most of the emissions are generated by countries that are located in the final stages of production compared to those that are located in the initial stages. At the same time, OECD countries have a lower carbon intensity than non-OECD countries, but for both groups of countries the pollution intensity of countries positioned in the initial production chain is 140% higher than those located in the final chains.

This paper confirms that countries with the highest carbon upstreamness set the lower emission reduction targets. These are mainly developing countries (non-OECD) with a lower per capita income. Considering firm heterogeneity, we observe how MNE are positioned further back in global production and global carbon chains than domestic companies, which exacerbates the problem of non-OECD countries, by making countries hosting MNE affiliates position even further back in global carbon chains.

As the further back the country is positioned, the greater the ability to influence to the rest of the production system and the greater the ability to spread contamination with each production decision, it will be important to involve both emerging countries and MNE in the adoption of mitigation objectives in line with the Paris Agreement.

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