ESRI Working Paper No. 803

June 2025

Production- and Consumption-Based Emissions: An International Comparison

Kelly de Bruin[a,b] Çağaçan Değer[a,b] and Aykut Mert Yakut[a,b]

a: The Economic and Social Research Institute, Dublin, Ireland
b: Trinity College Dublin, Dublin, Ireland

* Corresponding Author:
Dr Çağaçan Değer
Economic and Social Research Institute, Whitaker Square, Sir John Rogerson's Quay, Dublin, Ireland
Email: cagacan.deger@esri.ie

Acknowledgements:
This research was carried out as part of a programme of research on environmental socio-economics, funded by the Environmental Protection Agency (EPA) under the EPA Research Programme 2021-2030. The EPA Research Programme is a Government of Ireland initiative funded by the Department of the Environment, Climate and Communications.

Abstract

Production-based accounting (PBA) and consumption-based accounting (CBA) of emissions differ in how they consider the emissions resulting from the production of internationally traded commodities. This paper applies both approaches to calculate and compare emissions for Ireland and selected countries. We investigate the sources of variations in PBA and CBA emissions across countries. Ireland is observed to have lower PBA and CBA emissions in levels and per gross national income (GNI) terms. Sectoral patterns of PBA and CBA emissions vary across the countries; none of the selected countries have similar PBA and CBA emissions across all sectors compared to Ireland. Ireland's emissions are clustered in the fuels, transport sector and animal agriculture. This is not the standard pattern for all countries, and a lack of similarity is observed across countries. Ireland diverges from the rest of Europe in terms of the origins of fuel-embedded emissions as well, with the United Kingdom as a major source. Ireland's export of agricultural emissions is more similar to that of New Zealand than that of other European countries.

JEL codes: Q51; Q56; Q57

Keywords: Consumption-based accounting; Production-based accounting; Trade embedded emissions

1 INTRODUCTION

The Intergovernmental Panel on Climate Change's (IPCC) Synthesis Report, part of the Sixth Assessment Report, explains that human activities are responsible for climate change (IPCC, 2023). Policies aimed at addressing this by reducing greenhouse gas (GHG) emissions depend on reliable measurements of the GHG emissions. As such, it is essential to consider the methods applied to measure GHG emissions.

Due to the globalised nature of economies, identifying which emissions each country should take into account is a key issue. There are three frameworks for accounting GHG emissions: the territorial approach, the production-based accounting (PBA) approach and the consumption-based accounting (CBA) approach (European Environment Agency, 2013).

Territorial emissions refer to the emissions that occur within a country's borders. PBA assigns emissions to the country where the good is produced. Technically, the PBA perspective takes into consideration the emissions by the residents of a country. Emissions from production relate to the production by the resident firms of a country. Another key difference in practice between territorial and PBA emissions is the inclusion of household emissions in to the PBA emissions. And the CBA approach assigns emissions to the country where the good is consumed irrespective of the place of production (Benini et al., 2014; Chen et al., 2018).

When countries face strict environmental regulations, the firms operating in these countries may choose to relocate their production facilities to countries with more lenient environmental policies. These countries are known as pollution havens, and the resulting increase in GHG emissions outside the policy area is referred to as carbon leakage (Ben-David et al., 2021; Chung, 2014; European Commission, 2024; Levinson, 2018; Singhania & Saini, 2021). When carbon leakage occurs, the firms that pollute more tend to be the ones that relocate as they would pay more under the environmental regulation in the original country than they would in the new country. The reallocation of firms will reduce the GHG emission levels in the original country according to the PBA approach. However, if the goods produced by the firm that moved country are still imported into and consumed by the original country, then the pollution emitted whilst producing these goods would still be counted in the original country's CBA. This example shows that understanding how national GHG emissions are measured is important when determining policies. Additionally, since the relocated firm pays less for the emissions they pollute in the new country, their products can be sold for lower prices than they would have in the original country.

A policy response to this is the Carbon Border Adjustment Mechanism (CBAM), which necessitates the importer of a commodity to pay for certificates that reflect the carbon price that would have been paid if the commodity had been produced in the EU (European Commission, 2023). The mechanism is expected to address carbon leakage, i.e., the increase in emissions in non-EU regions due to the movement of production activities out of the EU caused by environmental regulation. The added cost to imports would shift demand away from the commodities covered by the CBAM and contribute to emission reduction on a global scale. A key indicator to understand the effectiveness of such a mechanism would be the emissions embedded in traded commodities, which requires the calculation of PBA versus CBA emissions in an international context.

The aim of this study is to compare Ireland's PBA and CBA emissions with those of a selected group of countries whose economies are akin to Ireland's in various respects. This comparison is done by analysing the sectoral composition of PBA and CBA emissions across countries and comparing emissions embedded in international trade. The next section reviews the literature, followed by the method and data sections. After this, we present Ireland's PBA and CBA emissions compared to our selected countries. Finally, the last section concludes.

2 LITERATURE

Over time, policy debates regarding the reduction of GHG emissions have become more complex. To provide more insights, emission measurements have been refined, and there has been an increase in academic interest in how emissions are measured. As such, PBA and CBA emissions and the emissions embedded in international trade have been a focus of this literature.

Earlier studies of PBA and CBA emissions and emissions embedded in international trade were restricted by data availability. Due to the lack of harmonised international databases on commodity trade and emissions, earlier studies had to assume that all the countries had the same emission content in the commodities they produce. In an analysis of the Japanese economy, Kondo et al. (1998) use the same emission coefficients for imports and exports, assuming that all the countries generate the same level of emissions per unit of produced goods. This was an extremely restrictive assumption that could be overcome by considerable data gathering, as shown by Wyckoff & Roop (1994). The increased availability of international databases has allowed this restrictive assumption to be discarded and led to an increase in the number of empirical studies on emissions embedded in international trade. These studies no longer needed to rely on only domestic emission intensities for both import and export flows.

The empirical investigations benefited significantly from the development of Multi-Regional Input Output (MRIO) tables. A single country input-output table can represent the flows of commodities across sectors due to input use in a given country. MRIOs can do this for multiple countries and multiple sectors. There are several such databases. The EORA database, for example, represents 190 countries and almost 16,000 sectors for the 1990 to 2022 period (Lenzen et al., 2012, 2013). Another MRIO is EXIOBASE version 3, representing 163 sectors for 44 countries (Stadler et al., 2018; Merciai & Schmidt, 2018). The OECD has the Inter-Country Input-Output Table (ICIO) database covering 76 countries with 45 sectors (OECD, 2024). The World Input-Output Database (WIOD) covers 43 countries and 56 sectors (Timmer et al., 2015).

Augmented with emission data, MRIOs contributed to expanding the global analysis of PBA and CBA emissions. A leading example of such data enhancement is the case of the Global Trade Analysis Project (GTAP) database (Aguiar et al., 2023). GTAP was developed in the 1990s as a multi-region general equilibrium model focusing on international trade analysis. Currently, it covers 141 countries and 65 sectors with related data on emissions. Although GTAP 11 is not an MRIO, it is an established data source on multiple countries and sectors. This makes it a good resource for the analysis of environmental issues.

Inspired by different research objectives, a large portion of the recent literature has estimated the emissions embedded in trade to compare PBA and CBA emissions using such databases. Simas et al. (2017) using the EXIOBASE database report that production-based emissions vary considerably across countries, whereas consumption-based results have much less variability. They argue that consumption patterns are relatively globalised due to similar needs across countries, whereas production is constrained by specialisation dynamics.

There is concern that emissions-related policies may cause firms to relocate to countries with less strict environmental policies, i.e., there may be carbon leakage. The effects of such relocation have been investigated in the literature. Taking the high growth of the Asia-Pacific region from 1995 to 2015 as given, Yang et al. (2020, p. 5) proceed to examine the global impact of the region using the EXIOBASE database version 3.6 and show that the region is a net exporter of GHG emissions. Meng et al. (2023) are concerned that the shift of production from the global north to the global south may have increased global emissions. As production moves to the global south, emissions in the global south would increase, creating an emission gap between the north and the south. They use the GTAP version 11 database and discover that this emission gap is closing over time. They also report results for aggregated sectors and regions, pointing to emission-intensive sectors such as ferrous metals, mineral products and chemical products for mitigation actions to reduce the North-South emission intensity gap. Davis & Caldeira (2010) present a consumption-based inventory of global emissions for the year 2004. Based on GTAP 7 and supplemented by other data sources, the analysis reveals the centrality of China as a net exporter and the United States of America (US) as a net importer of emissions. Homma et al. (2012) show how PBA and CBA emissions for aggregated regions change from 1990 to 2005. They point out that *".. the trends observed over time show an increase in [large economies'] consumption-based, rather than production-based, emissions."* (Homma et al., 2012, p. 826).

Nakano et al. (2009) assess the claim that if production activities are relocated to countries without carbon restriction polices, efforts to reduce GHGs may fail. They calculate PBA and CBA emissions for 41 countries and 17 industries for 1995 and 2000 and find evidence of emission-intensive activities relocating to non-OECD countries. As more goods are traded, investigating emissions embedded in traded goods would become essential in understanding global emissions.

Empirical studies have been undertaken concerning emissions embedded in trade across different countries and regions. Investigating this is complex and requires consistent data across countries concerning both trade and emissions. The empirical findings are, unfortunately, not uniform. Convergence of the emission intensities of the global south and the global north, measured as carbon emissions per unit of GDP, is observed through the GTAP datasets; this implies a reduction in emissions embedded in trade (Meng et al., 2023). On the other hand, Karakaya et al. (2019) find a lack of convergence in per capita consumption-based emissions. Franzen & Mader (2018) use the ratio of CBA to PBA emissions to look for, and fail to find, empirical evidence of carbon leakage.

Two literature reviews (Du et al., 2024; Zheng et al., 2022) examine the direction taken by carbon accounting research in the 2000s and 2010s. They show that the related research output picked up around 2009. International trade is identified as a keyword hotspot. This is consistent with the importance of trade-embedded emissions for CBA emission calculation. In terms of methodology, MRIO is often referred to.

The advancements in data availability have led to studies focusing on specific regions and countries with increasing sectoral detail. China and the Southeast Asia region is of interest due to the perceived status of the region as a manufacturing centre. Through an analysis of the Asia-Pacific region, (Yang et al., 2020, p. 6) show that the region "... made remarkable achievements in the transition to cleaner and greener consumption and trade, but this region still lags behind the global averages in terms of improvement in energy and GHG footprint intensity, as well as the PM2.5 intensity of trade." Rahman et al. (2022) report the sectoral details of CBA emissions for Southeast Asia region using the 2015 OECD Input-Output tables. An analysis of New Zealand's PBA and CBA emissions for year 2012 was done using a MRIO based on the Eora database (Chandrakumar et al., 2020). A report on Turkey's PBA and CBA emissions via the Eora database and a global MRIO analysis states for 2015 that 10% of Turkey's emissions originate from abroad (Mangır & Şahin, 2022).

As more data sources became available, the research focus shifted to improving the consistency of CBA measures across databases. This led to research comparing the performances of such databases, even journal special issues covering this (Inomata & Owen, 2014). According to Owen et al. (2014), differences across the MRIOs and GTAP are attributed to Leontief inverses, emissions data and differences in final demand. Arto et al. (2014) compare the World Input-Output Database (WIOD) and the GTAP database to official sources and attribute the deviations from the official data to the adopted data harmonisation procedures with different priorities, i.e., trade for GTAP and the structure of supply and use tables for WIOD. Despite data harmonisation attempts, Moran & Wood (2014) find divergences across the EORA, WIOD, EXIOBASE, and the OpenEU MRIO databases regarding CBA calculations. The study calculates emissions under different assumptions on harmonising environmental stressor accounts and inter-industry flow variations. The analysis reveals that for most economies, the deviations are less than 10%. Of the databases, for Ireland EXIOBASE seems to have the highest deviations. Referring to Schoer et al. (2013), Moran & Wood (2014) point out that results from MRIO models may quantitatively differ but are qualitatively similar.

The IO method is frequently used in CBA emission calculations (Du et al., 2024; Zheng et al., 2022). Unfortunately, these datasets come with their own set of problems. At a time when MRIO-related studies were on the rise, Droege (2011) concluded that the lack of a reliable international measurement system is one of the obstacles to the adoption of a CBA system of emissions. Data uncertainties regarding MRIOs, trade data and emissions data may be caused by data management procedures and data gaps(Sato, 2014, p. 843-844). IO models are subject to parametric and structural uncertainty (Kokoni & Skea, 2014, p. 379). Parametric uncertainty regards the coefficients in the IO tables. Structural uncertainty is related to the choice of sector and country aggregations. The large amount of data harmonisation required to construct these datasets also requires caution (Afionis et al., 2017, p. 8). A review of the available MRIO databases indicates a need for more detailed and accessible databases (Malik et al., 2019). Such concerns led to studies comparing both CBA results obtained from different datasets (Inomata & Owen, 2014; Rodrigues et al., 2018) and the input-output method to other methods such as the life cycle assessment (Castellani et al., 2019). It would be safe to assume that the search for a consistent data handling procedure regarding CBA emission calculations continues.

The literature tends to focus on aggregate emissions regardless of their research questions. As such, there is an increasing interest in country and sector-level details. Such detail is needed for policy purposes, especially if policy actions aimed at the emission content of international trade are debated. The Carbon Border Adjustment Mechanism (CBAM) is a prime example of such policy actions. Hence, an empirical investigation into PBA and CBA emissions with country and sector results is needed. This study contributes to the literature by providing international comparisons for a number of countries, with Ireland as the basis of comparison. This builds on the work by de Bruin & Yakut (2022) and de Bruin et al. (2024), which focus on the isolated case of Ireland. This paper adopts the method developed by de Bruin et al. (2024) to calculate PBA and CBA emissions and implements it for multiple countries to make comparisons. The next section presents the method and outlines the data that is used. After this, we compare the PBA and CBA emissions of different countries and the associated net imported emissions.

3 METHOD AND DATA

A consistent approach and international data on economic variables are needed to compare Ireland's PBA and CBA emissions with those of other countries. The most recent version of the GTAP 11 database for 2017, including 65 sectors and 141 countries, is employed. The database represents 99% of the world's Gross Domestic Product (GDP) and 96.4% of the global population (Aguiar et al., 2023). Although GTAP is not an MRIO, it is an extensive database used for environmental impact analysis. Its several versions were used to calculate the global consumption-based emissions for 2004 (Davis & Caldeira, 2010) and from 1990 to 2004 for very aggregated regions and sectors (Homma et al., 2012), and to compare various MRIO databases' implications for emissions (e.g., Rodrigues et al., 2018; Owen et al., 2014; Inomata & Owen, 2014).

The calculation of the PBA and CBA emissions is done by following the method outlined by de Bruin et al. (2024). We consider carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions. The calculations generate the following emission items:

- PBA emissions include production-related emissions and the emissions due to the final consumption of fuels, i.e., GHGs emitted in Ireland.
- Imported emissions are the emissions embedded in commodities that are imported from other countries. To a certain extent, we can account for indirectly imported emissions, i.e., emissions embodied in the imported inputs the partner country uses to produce its exports to the final country.
- Exported emissions are the emissions embedded in exported commodities. To a certain extent, we are able to account for re-exported emissions, i.e., emissions embedded in the imported inputs used to produce exports.
- CBA emissions are PBA emissions corrected for emissions embedded in internationally traded commodities. To calculate CBA emissions, we start with PBA emissions and then add directly and indirectly imported emissions. Next, we subtract exported and re-exported emissions.

The calculations presented by de Bruin et al. (2024) imply three cases. The first case uses the GTAP 11 data without any data modifications. The second case recognises that trade, especially services trade, does not fully represent the emissions embedded in electricity. Thus, electricity-related emissions are redistributed across sectors. Thirdly, the cattle sector generates considerable methane emissions. However, meat and dairy products are not traded by the cattle sector but by the food manufacturing sector. Hence, the third case builds on the second by reallocating cattle-related emissions to meat manufacturing sectors to better account for the methane embedded in the meat trade. This paper focuses on the third case where both electricity and cattle sectors' emissions are reallocated.[1]

Once PBA and CBA emissions are calculated, we need to develop an approach that enables us to compare the emissions across countries. We initially

[1] In the GTAP database, the cattle (CTL) sector includes bovine animals, other ruminants, horses and other equines and bovine semen.

considered comparing total PBA and CBA emissions. However, there are large differences across countries in terms of size. To account for this, we compare PBA emissions per national income and CBA emissions per capita. To this end, population and national income data have been obtained from the World Bank's World Development Indicators database (World Bank, 2024a,b).

Due to the special circumstances of the Irish national income accounts, a comparison based on national income requires caution. Ireland's GDP is considerably high due to the presence of multinational firms. The globalisation process and the implied internationalisation of the production process (CSO, 2024a) has necessitated the introduction of a modified Gross National Income (CSO, 2024b). Since modified GNI is not universally available, emissions per dollar GNI has been used for comparison purposes. The GNI values in current USD have been obtained from the World Development Indicators (World Bank, 2024a).

The GTAP 11 database contains 141 countries and 65 sectors representing year 2017. A two-step approach has been used to make the data manageable and accessible for comparison. Firstly, we aggregate sectors. The aggregation key is in Table A.1. Secondly, we need to select a number of countries which will serve as a useful comparison to Ireland. To do this, we apply the Krugman similarity index as introduced by Krugman (1991).

The Krugman similarity index is a measure of trade structure and specialisation. We adopt a conceptual variation to measure the similarity of economic structure. Let $Q_{i,r}$ be the output level of sector i in country r, thus $\overline{Q}_r = \sum_i Q_{i,r}$ is the aggregate output level of country r so that $\sigma_{i,r} = \frac{Q_{i,r}}{\overline{Q}_r}$ is the share of sector i in the aggregate output of region r. We define this ratio for Ireland as $\sigma_{i,irl}$ where $r = irl$ has been adopted. The difference between the share of sector i in the aggregate output of region r ($\sigma_{i,r}$) compared to the share of sector i in Ireland relative to the aggregate output of Ireland ($\sigma_{i,irl}$) is $\sigma_{i,r} - \sigma_{i,irl}$. As such, an index of similarity to Ireland can be calculated as follows:

$$S_{r,irl} = \sum_i |\sigma_{i,r} - \sigma_{i,irl}| \tag{1}$$

The index sums the output share differences per sector between countries. If the shares and, therefore, the structures of the two economies are similar for most of the sectors, the differences in the absolute value will be small, and the index will converge to zero. Thus, countries similar to Ireland will have a small index value. The index has been calculated for both production and consumption data. Hence, we have a technical tool to identify countries with production and consumption patterns similar to those in Ireland. However, there is one issue with the index. It considers similarity in terms of ratios. The index may point to two countries being similar, but they may be very different sizes. To account for this, we check the per capita GDP and GNI of index-wide similar countries.

4 RESULTS

For consistency, we first compare our calculated PBA emissions per NACE rev 2 sector with those of the CSO's Environmental Accounts Air Emissions Archive (CSO, 2024) for 2017. We examined whether these two data sources were consistent. This comparison is based on Table 1, which shows the sectoral distribution of production emissions from CSO's Environmental Accounts Air Emissions and the GTAP database. The table necessitated considerable sectoral aggregation for comparability. We observe that the calculations based on GTAP point to an emission distribution consistent with the data presented by the CSO. Production emissions of Ireland are clustered in agriculture, transport, electricity and metal and mineral products sectors.

Table 1: CSO Environmental Accounts Air Emissions and GTAP production emissions comparison (% of total for each column)

	CSO	GTAP
Fuels and extraction	0.7	4.2
Agriculture	31.6	32.1
Chemical products	0.3	0.3
Basic pharmaceuticals	0.3	0.3
Metal and mineral products	6.7	5.3
Other Manufacturing	2.3	1.7
Electricity	15.7	15.5
Water and waste management	2.1	1.2
Construction	0.5	0.4
Other transport	13.3	14.3
Air transport	22.1	22.1
Other services	4.4	2.7

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023) and CSO (2024).

One point noticed in Table 1 is that the share of fuels and extraction is higher in the GTAP data, whereas the share of services is higher in the CSO data. This is partly due to the content of fuel and extraction sectors in the GTAP database. In GTAP, the data on fuel-related sectors include services related to the extraction of fuels. Therefore, the share of services is lower in the GTAP database. There are further deviations in the details of the services sub-sectors. These are individually very small, but add up to relatively large deviations with the services sector aggregated.

In levels, the GTAP database has higher emission values. It is the impression of the authors that the deviations are due to the differences in how the two datasets are processed. For example, in the case of air transport, the GTAP database allocates bunkers to countries with respect to shares in exports of air transport services. Whereas in the CSO database the levels are calculated based on the emissions in Irish airspace. Furthermore, CSO database adjusts the data for the residency principle. It is not possible to make such a rearrangement using the data available within the GTAP11 database.

Our main objective is to compare Irish emissions with those of other countries. First, we will discuss the process that we used to select the countries that we compare to the Irish case. We focus on the European Union members, the United Kingdom and New Zealand. We then present the international comparison of PBA and CBA emissions.

4.1 Country selection

We selected a sample of countries to compare with Ireland based on the similarity index and other considerations. Firstly, the index values in Table 2 point to the Netherlands as having the most similar production structure compared to Ireland. They also rank fifth in consumption similarity. Thus, this seems to be a good country for comparison. As an alternative, consider Luxembourg, which ranks sixth in production similarity and first in consumption similarity. Although Luxembourg seems to be a good match to the Irish case, the per capita GNI of Luxembourg is 41% more than Ireland's per capita GNI. This large deviation casts doubt on the suitability of Luxembourg as an appropriate country to compare with Ireland.

In terms of structural similarity and per capita GNI, Sweden, Denmark, and the Netherlands are EU members that seem to be good countries to compare. During the European debt crisis, Ireland was regarded as one of the weaker economies of the Eurozone along with Portugal, Italy, Greece and Spain (Liberto, 2024). Hence, these countries have been included for comparison purposes. Due to its economic ties to Ireland, the United Kingdom is also included. Outside of the EU, New Zealand is similar to Ireland, given its position as a small open economy with a relatively large animal agriculture sector.

Table 2: Similarity index values and rankings (2017)

	Index values		Ranks	
	Production	Consumption	Production	Consumption
Netherlands	0.4852	0.4784	1	5
France	0.5552	0.4431	2	4
United Kingdom	0.5576	0.5071	3	9
Belgium	0.5747	0.5912	4	20
Malta	0.5978	0.6353	5	23
Luxembourg	0.6011	0.3795	6	1
Sweden	0.6033	0.5048	7	8
Germany	0.6135	0.5191	8	13
Austria	0.6139	0.4905	9	7
Portugal	0.6196	0.4306	10	2
Finland	0.6509	0.4344	11	3
Denmark	0.6574	0.6140	12	21
Italy	0.6872	0.5468	13	15
Estonia	0.6985	0.5550	14	17
New Zealand	0.6998	0.5305	15	14
Poland	0.7011	0.5529	16	16
Cyprus	0.7013	0.7029	17	27
Latvia	0.7031	0.6991	18	26
Czechia	0.7043	0.5157	19	12
Spain	0.7141	0.5092	20	10
Slovenia	0.7169	0.6413	21	24
Hungary	0.7520	0.5865	22	18
Croatia	0.7689	0.5893	23	19
Bulgaria	0.7758	0.6571	24	25
Greece	0.7914	0.4845	25	6
Romania	0.7947	0.7030	26	28
Slovakia	0.8106	0.5137	27	11
Lithuania	0.8172	0.6196	28	22

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

4.2 An international comparison

The analysis reveals a PBA value of 69.39 $MtCO_2eq$ and a CBA value of 74.89 $MtCO_2eq$ for Ireland for the year 2017, as can be seen in Table 3. The CBA emissions are 8% larger than the PBA emissions, and thus, Ireland is a net importer of emissions. In this regard, Ireland is similar to the OECD case. Table 3 shows the OECD averages as 397.88 $MtCO_2eq$ PBA emissions and 429.89 $MtCO_2eq$ CBA emissions. Like Ireland, an excess of about 8% over PBA is observed. The EU average PBA value is 145.66 $MtCO_2eq$, and their CBA value is 164.65 $MtCO_2eq$. For the EU average, CBA is 13% higher than PBA. As such, EU members are, on average, larger net importers of emissions compared to Ireland.

Table 3: PB and CB: Ireland vs averages for selected regions ($MtCO_2eq$, 2017)

	PBA	CBA	PBA/CBA, %
Ireland	69.39	74.89	107.93
EU average	145.66	164.65	113.04
OECD average	397.88	429.89	108.05

Source: Authors' calculations based on GTAP11 data (Aaguiar et al, 2022).

Table 4 presents the PBA and CBA values in per capita and per USD GNI terms. In per capita terms, Ireland's PBA is 14.43 tCO_2eq (tonnes of CO_2 equivalent), and the CBA value is 15.58 tCO_2eq. The values for the average of the OECD countries are 10.34 tCO_2eq for PBA and 11.25 tCO_2eq for CBA. The EU per capita PBA average is 9.54 tCO_2eq, and CBA is 10.89 tCO_2eq.

Table 4: Per capita and per GNI PBA and CBA, selected countries (2017)

	Per cap, tCO_2eq		Per USD GNI, $kgCO_2eq$	
	PBA	CBA	PBA	CBA
Ireland	14.43	15.58	0.26	0.28
Ireland*			0.33	0.36
New Zealand	18.12	16.81	0.44	0.41
United Kingdom	7.36	8.89	0.18	0.22
Greece	8.21	9.15	0.44	0.49
Italy	7.38	9.44	0.23	0.29
Spain	7.37	8.66	0.26	0.31
Portugal	6.85	9.19	0.33	0.44
Denmark	9.06	10.18	0.15	0.17
Netherlands	13.27	14.38	0.28	0.30
EU	9.54	10.89	0.39	0.44
OECD	10.34	11.25	0.36	0.39

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023) is the source for PBA and CBA values. Population and GNI data are obtained from World Development Indicators, the World Bank. The row Ireland* is based on GNI* (modified Gross National income) for year 2017, converted to USD taking 1 Euro = 1.129681 USD, due European Central Bank foreign exchange time series. Ireland's GNI* for 2017 is from CSO (Central Statistics Office) of Ireland.

An alternative comparison would be in terms of $kgCO_2eq$ (kilograms of CO_2 equivalent) emissions per USD value of GNI. For Ireland, PBA emissions per USD of GNI are 0.26 $kgCO_2eq$, and the CBA equivalent is 0.28 $kgCO_2eq$. For the OECD, PBA per USD GNI is 0.36 $kgCO_2eq$, with a value of 0.39 $kgCO_2eq$ for CBA. Finally, for the EU, the figures are 0.39 $kgCO_2eq$ and 0.44 $kgCO_2eq$ per USD GNI for PBA and CBA emissions, respectively. The relatively low per USD GNI emissions of Ireland are due to the relatively high GNI of Ireland, ranking 11th in the EU and 23rd in the OECD in 2017 according to GNI data from the World Development Indicators (World Bank, 2024a). An alternative comparison would be based on GNI* (the modified GNI) of Ireland. This is also presented in the table, in the row for Ireland*. With GNI*, the per USD values for Ireland increase to 0.33 for PBA and 0.36 for CBA. But this metric needs to be approached with caution. Even though the metric is designed to better reflect Ireland's domestic activity, it is simply not the same as GNI. Without detailed knowledge of how GNI and GNI* may differ for the sample countries, using GNI* for Ireland but GNI for other countries may not be a reasonable comparison.

4.3 Sectoral deviations relative to Ireland

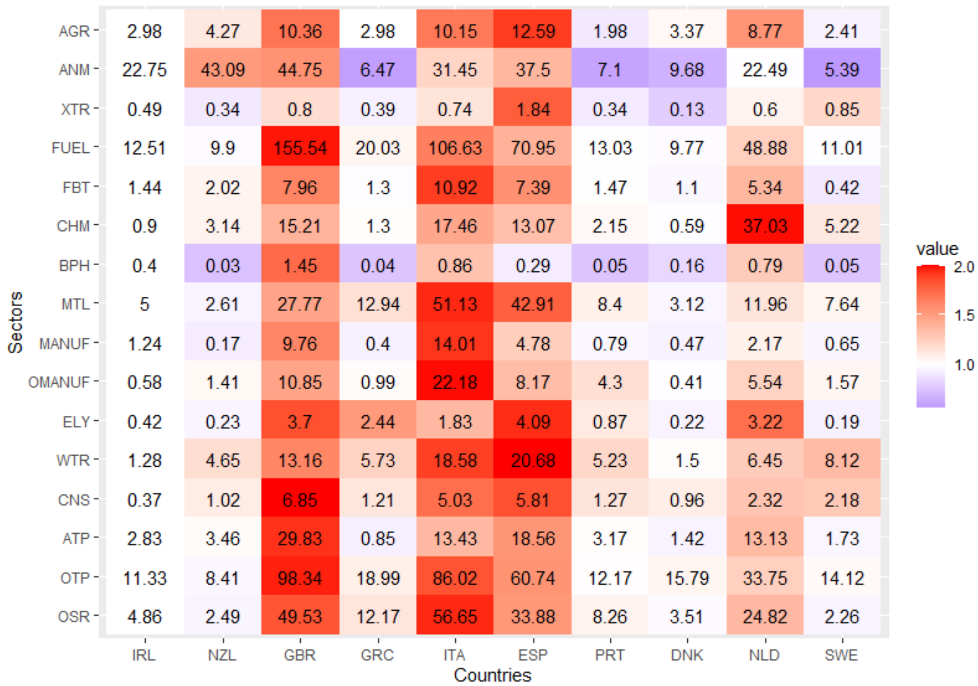
Our calculations yield emission results for each sector for Ireland and other countries. A per-region comparison with Ireland is available in Tables A.2, A.3 and A.4. In order to visually present the information embedded in these Tables, heat maps are adopted.

The heat maps look at PBA and CBA emissions separately and colour-code the differences across countries. The colour coding is based on whether the deviation from the Irish emission value is positive (red) or negative (blue). Hence, the cells are red where the country's emissions are larger than Ireland's and blue when the country's emissions are smaller than Ireland's. Additionally, the cells with larger deviations have more saturated colours.

Figure 1 shows the PBA emissions of the countries in this study. The first column refers to Ireland. For each row, the colouring is based on deviations from the Irish value, standardised using the difference between the maximum and the minimum value across countries for a given sector. The figure shows the high emissions of the United Kingdom (GBR), Italy (ITA) and Spain (ESP) compared to Ireland by the proportion of red-coloured cells in the columns for these countries. Portugal and Denmark appear to have emissions similar to Ireland across all the sectors. These impressions are replicated for CBA emissions presented in Figure 2.

However, one should approach these representations carefully, as they do not account for size differences across countries. Simply put, the economic activities in the United Kingdom, Italy, and Spain are larger than those in Ireland. According to Gross National Income data from the World Development Indicators, the GNI of the United Kingdom was almost 10 times the Irish GNI. This

Figure 1: PBA emissions ($MtCO_2eq$, 2017)



Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

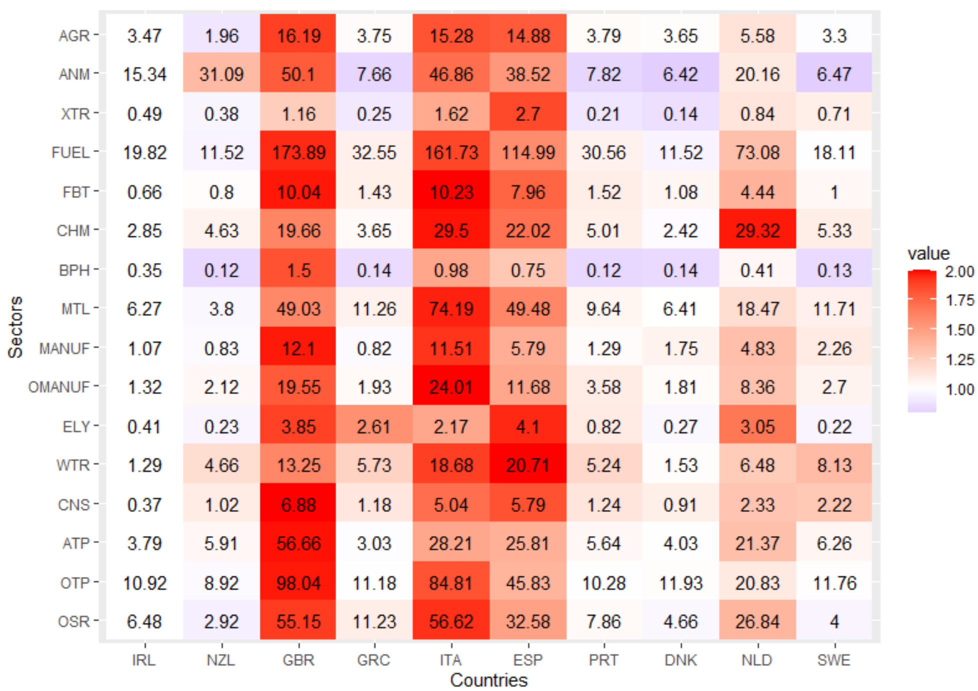
ratio was seven for Italy and almost five for Spain. Hence, it would be beneficial to account for size differences across countries.

To account for size differences across countries, PBA per output values (Figure 3) and CBA per capita values (Figure 4) have been used. PBA per output has been calculated using the sectoral output data from the GTAP 11 database[2]. CBA per capita values have been calculated using the population values for countries obtained from World Bank (2024b).

We observe through Figure 3 that Ireland does not have very high PBA emissions per output in most sectors compared to other countries. Relatively high PBA emissions per output are observed for animal agriculture and fuel commodities. A systematic similarity to Ireland would be visualised by a column of pale cells in Figure 3. The lack of such a column leads to the conclusion that we do not observe a single country that has an emission profile similar to Ireland. Furthermore, none of the rows in the figure are completely pale in colour. Thus, we do not observe similarity across countries for each aggregated sector.

[2] Within the GTAP 11 database, production is based on input purchases and primary factor purchases of firms. The social accounting matrix for the GTAP database (Corong et al., 2017, p. 115) is very helpful in relating economic concepts to the GTAP database. Since GTAP11 is a monetary database, the output values are also in monetary units and are not physical quantities.

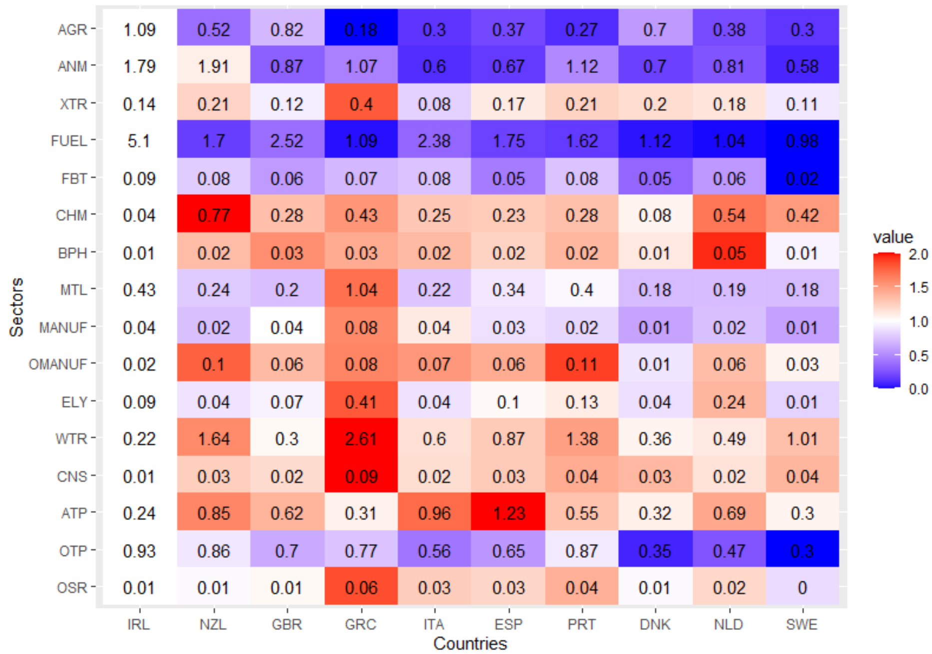
Figure 2: CBA emissions ($MtCO_2eq$, 2017)



Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

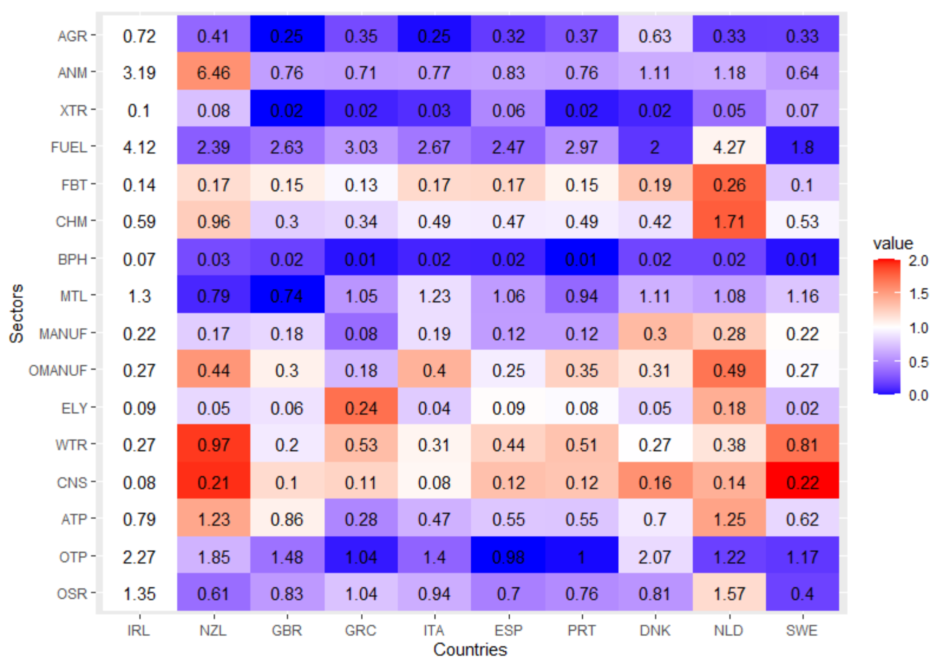
Per capita CBA values have been presented in Figure 4. The figure is dominated by blue cells, implying that, in general, Ireland has higher per capita emissions than other countries in the sample. For no country do we observe a column of white cells; these observations could lead to the notion that no country is similar to Ireland in terms of PBA and CBA emissions.

Figure 3: PBA per output emissions (MtCO$_2$eq per billion USD of output, 2017)



Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

Figure 4: CBA per capita emissions (tCO$_2$eq per person, 2017)



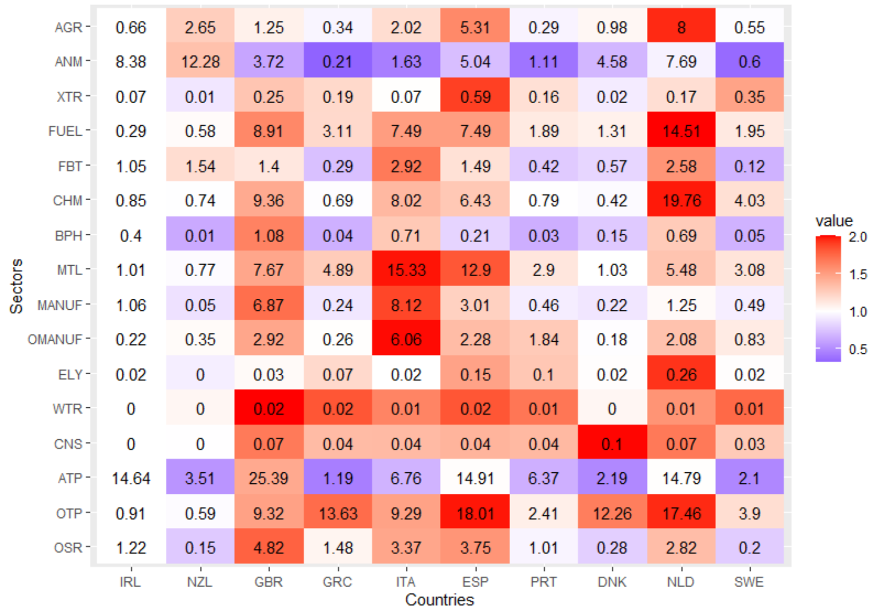
Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

Such a claim needs to be made with caution. The adopted metric in Figure 4 is in per capita terms. All the PBA and CBA values are divided by each country's population. Although this may account for differences in country size to a certain extent, population is constant across the sectors of a country. Hence, a per capita metric may not be able to account for sectoral variations within a country. Therefore, we have also calculated PBA per output for sectors, which may account for sectoral variation to a certain extent. It should be noted that the calculated output values are based on the GTAP 11 database, where variables are stated in US dollars. The calculated output values are in monetary terms and not in physical quantities. Thus the per-output comparisons are not based on physical quantities.

Consider next the emissions embedded in international trade. Figure 5 shows the emissions embedded in exported commodities. Ireland's exported emissions are clustered in the air transport (14.64 $MtCO_2eq$) and animal agriculture (8.38 $MtCO_2eq$) commodities. Ireland generally has lower emissions in other commodities compared to other countries. Regarding imported emissions, see Figure 6. Ireland's imported emissions are concentrated in fuels and services (OSR). The table shows that Ireland generally has lower imported emissions than other countries.

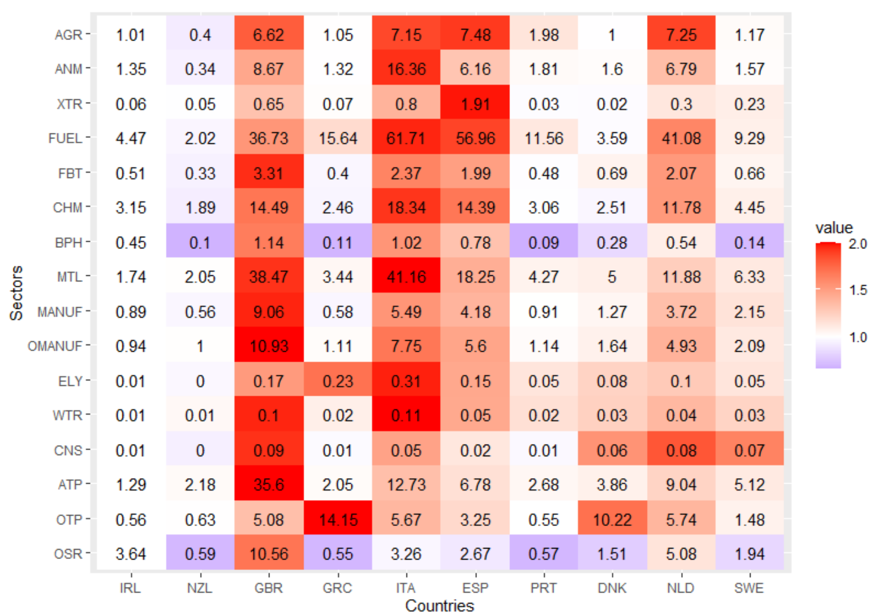
Figure 7 presents net imported emissions, i.e., directly and indirectly, imported emissions less exported and re-exported emissions. Positive values imply that a country is a net emission importer of the commodity, whereas negative values imply that a country is a net emission exporter of the commodity. The figure shows that Ireland is a net exporter of emissions in animal agriculture and air transport. In the sample, the only other country with relatively high net exports in animal agriculture is New Zealand. Other countries have lower net imported emissions in animal-related agriculture. Italy, as an outlier, has large net imported emissions.

Figure 5: Export emissions (MtCO$_2$eq, 2017)



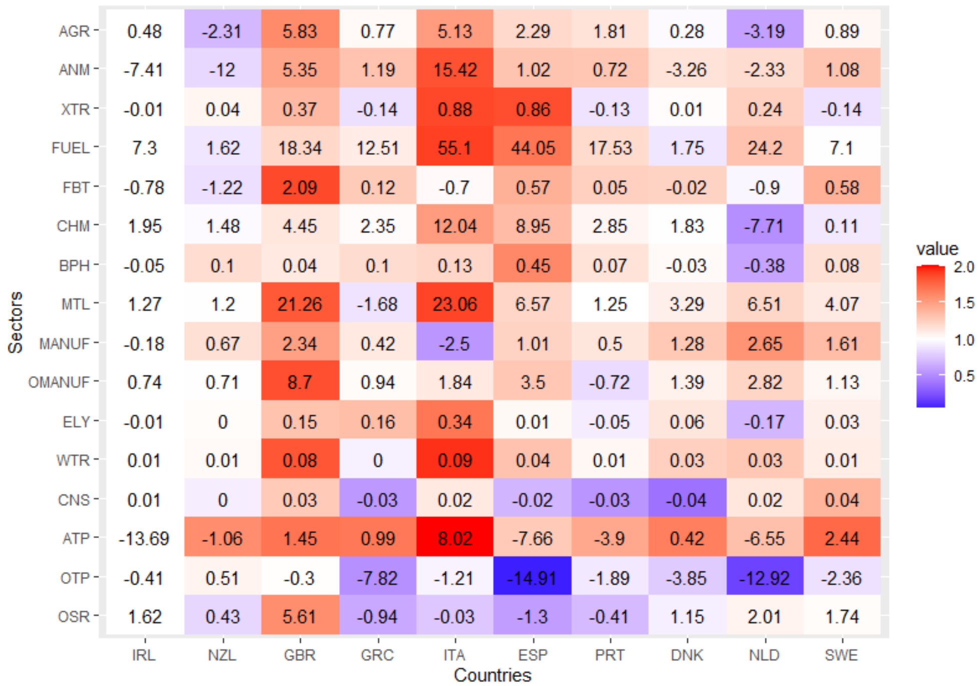
Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

Figure 6: Import emissions (MtCO$_2$eq, 2017)



Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

Figure 7: Net imported emissions (MtCO$_2$eq, 2017)



Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

4.4 Ireland's animal-related emissions

One of the key agricultural activities in Ireland is raising cattle. As such, activities related to the production of meat products are also important. The analysis so far has considered an aggregate animal agriculture sector (ANM). The results show that the aggregated ANM sector has a PBA emission value of 22.75 MtCO$_2$eq. The PBA emission per output value for this aggregated sector is 1.79 MtCO$_2$eq per billion USD of output. We now delve into the details of this sector. However, this analysis is limited by the sectoral granularity of the GTAP 11 database and is restricted to year 2017.

Within the classification of the GTAP 11 database, the ANM sector includes:

- CTL: Bovine cattle, sheep, goats and horses
- OAP: Animal products not elsewhere classified
- RMK: Raw milk
- WOL: Wool, silk-worm cocoons
- FSH: Fishing

- CMT: Bovine meat products
- OMT: Meat products not elsewhere classified

The first five sub-sectors are part of the agricultural sector, whereas the last two (CMT and OMT) relate to the manufacturing of meat products. Hence, they are technically part of the manufacturing sector. We will consider the details of these sub-sectors. To introduce a European perspective in this comparison, we have extended the sample of countries to account for most of Europe. [3]

Table 5 presents key details regarding the animal agriculture sub-sectors focusing on Ireland. [4] The output rank shows Ireland's ranking relative to the 28 European countries; the higher the rank, the higher the output produced by this sector. Ireland has a high rank in each of these sub-sectors; i.e., Ireland has a higher output value in each of these sub-sectors than most other European countries. In CTL, Ireland ranks 24th out of the 28 European countries. However, despite the above-average ranks, these sectors do not represent a very high percentage of European output. For example, Ireland accounts for 8% of CTL production. But the United Kingdom (18%), France (19%), Germany (12%) and Italy (11%) account for much larger shares. Similar observations are made for other sectors in Table 5. Hence, the high ranks in production should not be taken to mean exceedingly high production shares or levels.

Another issue is the ratio of exports to output. In Ireland, 17% of CTL output and 22% of OAP output are exported. In the case of CMT and OMT, the ratio of exports to output increases to 86% and 88%, respectively. We have observed the distinction between the manufacturing and purely agricultural sectors. The CTL, OAP, RMK, WOL, and FSH sub-sectors have relatively low export ratios compared to the manufactured meat sub-sectors, i.e., CMT and OMT.

In terms of PBA emissions, these sub-sectors have relatively high rankings. CTL ranks 26th out of 28 countries, implying very high PBA emissions. However, the shares of these PBA emissions in the total PBA emissions of each sub-sector in Europe are not high. Consider the case of CTL. This sector has a ranking of 26 in PBA emissions. However, Ireland's CTL sub-sector generates

[3] This extended sample is a total of 28 countries. These are EU members (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden) and the United Kingdom.

[4] The table includes ranks for some of the data. It should be noted that these ranks are arranged such that a higher rank implies a higher value. For example, Ireland ranks 24th in cattle (CTL) output. This means that out of the 28 countries accounted for in this table, Ireland has one of the highest output values. This is the opposite of the established convention where a higher ranking implies a better situation, i.e., ranking first in output means the country has the highest output. This inversion is done to provide a better intuition for emission-related rankings. A country with a higher ranking generates more emissions. For example, Ireland ranks 10th in CH_4 per output. This is good, meaning that Ireland has lower CH_4 emissions compared to most of the 28 countries analysed in this subsection.

only 10% of PBA emissions of the CTL sub-sector in Europe, whereas France generates 18%. For the CMT sub-sector, Ireland accounts for 6% of PBA emissions while France generates 21% and Germany generates 13%.

For generated emissions per output, Ireland's rank decreases for four of the sub-sectors relative to the output rank. In the CTL sub-sector, Ireland ranks 14th in terms of PBA per output. In the OAP, Ireland now ranks first, implying the lowest emissions per unit of output. In FSH, Ireland ranks 10th. In the meat manufacturing sectors of CMT and OMT, however, the rankings increase. The CMT sub-sector ranks 27th, and the OMT sub-sector ranks 26th.

Table 5: Animal agriculture sector details (2017)

	CTL	OAP	RMK	WOL	FSH	CMT	OMT
Output rank	24	16	20	27	18	20	15
Output share of IRL in sector (%)	7.98	1.68	3.69	13.98	2.81	2.98	1.11
Ratio of exports in output (%)	17.28	21.46	0.02	5.79	45.37	86.14	87.91
PBA value (MtCO2eq)	10.73	0.63	3.91	0.01	0.12	6.75	0.60
PBA rank	26	15	22	26	18	22	20
PBA shares (%)	10.11	1.00	5.36	10.91	1.18	6.11	2.61
PBA per output rank	14	1	22	13	10	27	26
CH4 (CO2eq) rank	13	8	11	14	10	10	8
CH4(CO2eq) per output rank	10	5	23	22	24	21	21
CH4 shares (%)	8.04	1.04	5.48	23.26	4.16	3.87	1.34

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).
Note: Higher rank implies a higher value. *CTL* is Bovine cattle, sheep, goats, and horses; *OAP* is Animal products nec.; *RMK* is Raw milk; *WOL* is Wool, silk, and worm cocoons; *FSH* is Fishing; *CMT* is Bovine meat products; and, finally, *OMT* is Meat products nec.

The majority of animal agriculture-related emissions are due to the CH_4 emitted by the raising of animals. Specifically, the CTL sector is key here. In the case of Ireland, almost 65% of the production-related emissions of the animal agriculture sector are due to the CH_4 in CTL. In an international comparison, the CH_4 emissions are not very high. In CTL, Ireland ranks 13th. The ranking in CH_4 per output is 10th in CTL. Although IRL appears to have relatively high PBA emission values in the animal agriculture sub-sectors, Ireland's emissions ranking fares much better in terms of CH_4 emission per unit of output values, a key source of agricultural emissions.

4.5 Imported emissions embedded in fuels

An international comparison of imported emissions embedded in fuels is provided. This is important because fuel combustion is a major and universal source of emissions. It is universal in the sense that fuel emissions account for a high share of emissions for all countries, as countries often import fuels. Given the importance of emissions from fuel combustion, it is important to know where fuels come from. Thus, we are interested in identifying the countries that are the sources of imported fuels.

To this aim, we have created Table 6, which lists the five major fuel emission source countries for each of the countries that we have studied. The table names the major source country and then states the percentage of aggregate imported fuel emissions originating from that country. For example, the first cell of the table shows that 40% of Ireland's imported fuel emissions originate from the United Kingdom.

Table 6: Emissions embedded in fuel imports by source country (percentage of total imported fuel emissions, 2017)

Ireland	**New Zealand**	**UK**	**Greece**	**Italy**
UK (40)	Untd. Arab Emirates (22)	Norway (20)	Iraq (39)	Algeria (21)
USA (14)	Korea (15)	Russia (18)	Russia (16)	Russia (16)
Russia (9)	Australia(14)	Qatar (13)	Algeria (10)	Iraq (9)
Nigeria (7)	Malaysia (11)	USA (8)	Iran (10)	Qatar (8)
Norway (7)	Singapore (7)	Nigeria (7)	Kazakhstan (8)	Iran (6)
Spain	**Portugal**	**Denmark**	**Netherlands**	**Sweden**
Nigeria (22)	Nigeria (17)	Russia (44)	Russia (33)	Nigeria(29)
Algeria (16)	Algeria (12)	Norway (12)	Iraq (9)	Russia (29)
Russia (8)	Russia (12)	USA (7)	Norway (9)	Norway (10)
USA (5)	USA (10)	Qatar (8)	Kazakhstan (7)	Denmark (5)
Iraq(4)	Eq. Guinea (8)	South Africa (4)	Nigeria (7)	Iraq (4)

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).
Note: The table shows the imported fuel emission source countries for each selected country, stated as the percentage of aggregate imported fuel emissions by the country. For example, the first cell of the table shows that 40% of Ireland's imported fuel emissions originate from the United Kingdom.

It should be noted that the data in Table 6 refers to 2017. Given the Russia-Ukraine War, the sourcing of fuels in Europe has changed. European Parliamentary Research Service (2023) points out the reaction to Russia through restrictions on energy imports. The European energy imports have diverged from Russia (Eurostat, 2024; Rokicki et al., 2023) and the USA appears to be rising as a supplier (Eurostat, 2024). Hence, the statements made here regarding the source of fuel imports should be approached with caution.

Ireland imports fuel-related emissions from the United Kingdom, the US, and Russia. New Zealand's fuel-embedded emission imports originate from locations closer to New Zealand, such as Korea and Australia. Russia, Iraq, Algeria, and Nigeria are the leading sources of fuel-related emission imports for the Mediterranean countries. The other European countries receive fuel-embedded emissions from Russia, Norway, and Nigeria.

The underlying database, GTAP 11, classifies five commodities as fuels. These are coal (COA), gas (GAS), gas manufacture and distribution (GDT), oil (OIL) and petroleum and coal products (P_C). Table A.5 shows the imported emissions for each selected country by each major supplier measured in $MtCO_2eq$. The first table shows the imported fuel-embedded emissions originating from Russia. The first line shows that Ireland imports a total of 0.423 $MtCO_2eq$ fuel emissions from Russia. Of this total, 0.003 $MtCO_2eq$ is embedded in coal (COA), 0.001 $MtCO_2eq$ is embedded in gas manufacture and distribution (GDT), and 0.418 $MtCO_2eq$ is embedded in the manufacture of coke and refined petroleum products (P_C).

Russia is the country that supplies the largest amount of imported emissions as it is the source of 43 $MtCO_2eq$ of imported emissions to the selected countries. These imported emissions are not concentrated in a single fuel commodity and are primarily in petroleum and coal products, oil and coal. The second largest source of imported emissions for the selected countries is Algeria, and the emissions are concentrated in the Italian and Spanish gas imports. Nigeria is the third largest supplier of imported fuel emissions; these are mainly in oil imports into Spain. The fourth source is Iraq's oil emissions. These are spread between Spain, Greece, Italy, and the Netherlands. The fifth-largest source of fuel-embedded emissions is Norway, with emissions embedded in gas and oil imports.

None of these countries is a major fuel emission source for Ireland. However, the United Kingdom is a major source of imported fuel emissions for Ireland. The emissions from the petroleum and coal products imported from the United Kingdom account for 37% of the total imported emissions. This is followed by the petroleum and coal product emissions from the US, accounting for 14%. Russia is another source of petroleum and coal emissions, representing 7% of the imported fuel emissions. Oil-embedded imports are also a considerable share of total imported emissions from Norway (7%) and Nigeria (8%).

5 CONCLUSION

This study presents an international comparison of Ireland's PBA and CBA emissions relative to a group of selected countries in the year 2017. The initial observation is that Ireland's CBA emissions are approximately 8% more than its PBA emissions. This is similar to the OECD average but is lower than the EU average. Hence, Ireland appears to be less of a net importer than the EU average. However, the picture is different in per capita terms, where Ireland has PBA and CBA values greater than the EU and the OECD averages. In terms of PBA and CBA emissions per USD GNI, Ireland has values lower than the EU and OECD averages.

The presented data shows considerable variations across countries due to country-specific characteristics. Ireland is an exporter of emissions embedded in animal agriculture. Greece, on the other hand, exports emissions embedded in the water transport sector. Italy demands more land transport services, thus generating more emissions in this sector, and is an importer of animal agriculture emissions. Ireland and Portugal appear to have similar PBA and CBA aggregate values, but their sectoral distributions vary as Portugal has higher manufacturing-related emissions. Ireland and the Netherlands have a similar CBA to PBA ratio but are quite different in terms of the sectoral distribution of imported emissions. The Netherlands is a net exporter of transport emissions, whilst Ireland is a net exporter of animal agriculture emissions. Sweden and Ireland have similar PBA emissions values, but Sweden has a much higher CBA value and does not have a sector in which exported emissions are concentrated. Ireland diverges in terms of fuel emission sources as well, with the United Kingdom and the US dominating the Irish case. Hence, there is no systematic similarity between Ireland and any of the selected countries.

Shifting production to countries where environmental policies are less stringent, labour market policies are more flexible and welfare policies are limited will have important repercussions for emissions accounting. Given the international mobility of production processes, the PBA approach to emissions accounting is not in line with the polluter pays principle. Therefore, accounting for emissions embedded in imported commodities should be considered in environmental policy setting—such as in the case of the CBAM policy proposed within the EU's Fit for 55 package. As the CBAM will introduce an environmental import tariff on certain commodities, potential retaliatory measures from its trade partners should also be considered. Given the variation of emission sources across countries, such reciprocal actions may have different implications for different EU Members.

The EU ETS2 represents another important policy that may have differing impacts across countries. Expected to come into effect by 2027, the EU ETS2 scheme aims to impose a minimum carbon tax across EU members on the GHG emissions of the residential and road transport sectors. This policy will affect the Member states to differing degrees depending on their share of these emissions in total emissions, the composition of their housing stock (the share of new vs old buildings), the availability of alternative transportation options, and the existence and current level of a national carbon tax. The EU Commission proposes to set the initial permit price in the new scheme at €45 in 2020 prices (European Commission, 2025). This policy change will have no direct repercussions for Ireland, as the Irish carbon tax is expected to be higher at €77.5 in 2027. However, it will have important implications for other countries such as Italy, Greece and Eastern European countries where currently, no national carbon taxes are in place.

References

Afionis, S., Sakai, M., Scott, K., Barrett, J., & Gouldson, A. (2017). Consumption-based carbon accounting: does it have a future? *WIREs Climate Change*, *8*(1), e438. doi: https://doi.org/10.1002/wcc.438

Aguiar, A., Chepeliev, M., Corong, E., & van der Mensbrugghe, D. (2023). The Global Trade Analysis Project (GTAP) Data Base: Version 11. *Journal of Global Economic Analysis*, *7*(2), 1-37. doi: 10.21642/JGEA.070201AF

Arto, P., Rueda-Cantuche, J. M., & Peters, G. P. (2014). Comparing the GTAP-MRIO and WIOD databases for carbon footprint analysis. *Economic Systems Research*, *26*(3), 327–353. Retrieved from https://doi.org/10.1080/09535314.2014.939949 doi: 10.1080/09535314.2014.939949

Ben-David, I., Jang, Y., Kleimeier, S., & Viehs, M. (2021, 02). Exporting pollution: where do multinational firms emit CO2? *Economic Policy*, *36*(107), 377-437. Retrieved from https://doi.org/10.1093/epolic/eiab009 doi: 10.1093/epolic/eiab009

Benini, L., Mancini, L., Sala, S., Manfredi, S., Schau, E. M., & Pant, R. (2014). *Normalisation method and data for environmental footprints* (Tech. Rep.). Luxembourg: Publications Office of the European Union.

Castellani, V., Beylot, A., & Sala, S. (2019). Environmental impacts of household consumption in Europe: Comparing process-based LCA and environmentally extended input-output analysis. *Journal of Cleaner Production*, *240*, 117966. Retrieved from https://www.sciencedirect.com/science/article/pii/S0959652619328367 doi: 10.1016/j.jclepro.2019.117966

Chandrakumar, C., McLaren, S., Malik, A., Rmilan, T., & Lenzen, M. (2020). Understanding New Zealand's consumption-based greenhouse gas emissions: An application of multi-regional input-output analysis. *International Journal Life Cycle Assess*, *25*, 1323–1332. doi: 10.1007/s11367-019-01673-z

Chen, Z.-M., Oshita, S., Lenzen, M., Wiedmann, T., Jiborn, M., Chen, B., … Liu, Z. (2018). Consumption-based greenhouse gas emissions accounting with capital stock change highlights dynamics of fast-developing countries. *Nature Communications*, *9*(3581). doi: https://doi.org/10.1038/s41467-018-05905-y

Chung, S. (2014). Environmental regulation and foreign direct investment: Evidence from South Korea. *Journal of Development Economics*, *108*, 222-236. Retrieved from https://www.sciencedirect.com/science/article/pii/S0304387814000054 doi: https://doi.org/10.1016/j.jdeveco.2014.01.003

Corong, E. L., Hertel, T. W., McDougall, R., Tsigas, M. E., & van der Mensbrugghe, D. (2017). The Standard GTAP Model, Version 7. *Journal of Global Economic Analysis*, *2*(1), 1–119. Retrieved from https://jgea.org/ojs/index.php/jgea/article/view/47 doi: 10.21642/JGEA.020101AF

CSO. (2024). *Environmental accounts air emissions.* Retrieved from https://www.cso.ie/en/statistics/environmentaccounts/environmentalaccountsairemissions/ (Central Statistics Office)

CSO. (2024a). *Globalisation.* https://www.cso.ie/en/interactivezone/statisticsexplained/nationalaccountsexplained/globalisation/, Accessed 2024-08-30.

CSO. (2024b). *Modified GNI.* https://www.cso.ie/en/interactivezone/statisticsexplained/nationalaccountsexplained/modifiedgni/, Accessed 2024-08-30.

Davis, S., & Caldeira, K. (2010). Consumption-based accounting of CO2 emissions. *PNAS*, *107*(12), 5687-5692. Retrieved from https://doi.org/10.1073/pnas.0906974107

de Bruin, K. C., Deger, C., & Yakut, A. M. (2024). Production and consumption-based accounts of Ireland's emissions. *ESRI Working Paper 791*. Retrieved from https://www.esri.ie/publications/production-and-consumption-based-accounts-of-irelands-emissions

de Bruin, K. C., & Yakut, A. M. (2022). The global emissions impact of Irish consumption. *ESRI Working Paper 740*. Retrieved from https://www.esri.ie/publications/the-global-emissions-impact-of-irish-consumption

Droege, S. (2011). Using border measures to address carbon flows. *Climate Policy*, *11*(5), 1191–1201. doi: 10.1080/14693062.2011.592671

Du, Y., Liu, H., & Huang, H. (2024). Bibliometric analysis of research progress and trends on carbon emission responsibility accounting. *Sustainability*, *16*(9). doi: 10.3390/su16093721

European Commission. (2023). *Carbon border adjustment mechanism.* Retrieved from https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en (Accessed: 2024-09-25)

European Commission. (2024). *Carbon leakage.* Retrieved from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/free-allocation/carbon-leakage_en (Accessed: 2024-09-25)

European Commission. (2025). *ETS2: Buildings, Road Transport and Additional Sectors.* Retrieved from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets2-buildings-road-transport-and-additional-sectors_en (Accessed: 2025-05-19)

European Environment Agency. (2013). *European Union CO2 emissions: Different accounting perspectives* (Tech. Rep. No. 20/2013). European Environment Agency. Retrieved from https://www.eea.europa.eu/en/analysis/publications/european-union-co2-emissions-accounting (Accessed: 2025-02-10)

European Parliamentary Research Service. (2023). *EU energy security and the war in Ukraine: From sprint to marathon.* Retrieved from https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2023)739362

Eurostat. (2024). *Main suppliers of petroleum oils, natural gas and coal to the eu.* https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=564016#Main_suppliers_of_petroleum_oils.2C_natural_gas_and_coal_to_the_EU. (Accessed: 2024-10-07)

Franzen, A., & Mader, S. (2018). Consumption-based versus production-based accounting of CO2 emissions: Is there evidence for carbon leakage? *Environmental Science & Policy*, *84*, 34-40. doi: https://doi.org/10.1016/j.envsci.2018.02.009

Homma, T., Akimoto, K., & Tomoda, T. (2012). Quantitative evaluation of time-series GHG emissions by sector and region using consumption-based accounting. *Energy Policy*, *51*, 816-827. Retrieved from https://www.sciencedirect.com/science/article/pii/S0301421512008063 doi: https://doi.org/10.1016/j.enpol.2012.09.031

Inomata, S., & Owen, A. (2014). Comparative evaluation of MRIO databases. *Economic Systems Research*, *26*(3), 239–244. Retrieved from https://doi.org/10.1080/09535314.2014.940856 doi: 10.1080/09535314.2014.940856

IPCC. (2023). *Climate Change 2023: Synthesis Report*. Geneva, Switzerland: IPCC. doi: 10.59327/IPCC/AR6-9789291691647

Karakaya, E., Yılmaz, B., & Alataş, S. (2019). How production-based and consumption-based emissions accounting systems change climate policy analysis: The case of CO2 convergence. *Environmental Science and Pollution Research*, *26*(16), 16682-16694. Retrieved from https://doi.org/10.1007/s11356-019-05007-2 doi: 10.1007/s11356-019-05007-2

Kokoni, S., & Skea, J. (2014). Input–output and life-cycle emissions accounting: Applications in the real world. *Climate Policy*, *14*(3), 372–396. doi: 10.1080/14693062.2014.864190

Kondo, Y., Moriguchi, Y., & Shimizu, H. (1998). CO2 emissions in Japan: Influences of imports and exports. *Applied Energy*, *59*(2), 163-174. Retrieved from https://www.sciencedirect.com/science/article/pii/S0306261998000117 doi: https://doi.org/10.1016/S0306-2619(98)00011-7

Krugman, P. (1991). *Geography and Trade*. MIT Press.

Lenzen, M., Kanemoto, K., Moran, D., & Geschke, A. (2012). Mapping the structure of the world economy. *Environmental Science & Technology*, *46*(15), 8374-8381. Retrieved from https://doi.org/10.1021/es300171x doi: 10.1021/es300171x

Lenzen, M., Moran, D., Kanemoto, K., & Geschke, A. (2013). Building eora: A global multi-region input–output database at high country and sector resolution. *Economic Systems Research*, *25*(1), 20–49. Retrieved from https://doi.org/10.1080/09535314.2013.769938 doi: 10.1080/09535314.2013.769938

Levinson, A. (2018). Pollution haven hypothesis. In *The New Palgrave Dictionary of Economics* (pp. 10449–10454). London: Palgrave Macmillan UK. Retrieved from https://doi.org/10.1057/978-1-349-95189-5_2693 doi: 10.1057/978-1-349-95189-5_2693

Liberto, D. (2024). *European sovereign debt crisis: Eurozone crisis causes, impacts.* https://www.investopedia.com/terms/e/european-sovereign-debt-crisis.asp, Accessed 2024-10-18.

Malik, A., McBain, D., Wiedmann, T. O., Lenzen, M., & Murray, J. (2019). Advancements in input-output models and indicators for consumption-based accounting. *Journal of Industrial Ecology*, *23*(2), 300-312. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12771 doi: 10.1111/jiec.12771

Mangır, N., & Şahin, U. (2022). An environmentally extended global multi-regional input–output analysis of consumption-based and embodied import-based carbon emissions of Turkey. *Environmental Science and Pollution Research*, *29*, 54813–54826. doi: 10.1007/s11356-022-19290-z

Meng, J., Huo, J., Zhang, Z., Liu, Y., Mi, Z., Guan, D., & Feng, K. (2023). The narrowing gap in developed and developing country emission intensities reduces global trade's carbon leakage. *Nature Communications*, *14*(1), 3775. Retrieved from https://doi.org/10.1038/s41467-023-39449-7 doi: 10.1038/s41467-023-39449-7

Merciai, S., & Schmidt, J. (2018). Methodology for the construction of global multi-regional hybrid supply and use tables for the EXIOBASE v3 Database. *Journal of Industrial Ecology*, *22*(3), 516-531. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12713 doi: 10.1111/jiec.12713

Moran, D., & Wood, R. (2014). Convergence betweeen the EORA, WIOD, EXIOBASE, and OPENEU's consumption-based carbon accounts. *Economic Systems Research*, *26*(3), 245–261. Retrieved from https://doi.org/10.1080/09535314.2014.935298 doi: 10.1080/09535314.2014.935298

Nakano, S., Okamura, A., Sakurai, N., Suzuki, M., Tojo, Y., & Yamano, N. (2009). The measurement of CO2 embodiments in international trade. *OECD Science, Technology and Industry Working Papers*. Retrieved from https://www.oecd-ilibrary.org/content/paper/227026518048 doi: 10.1787/227026518048

OECD. (2024). *OECD Inter-Country Input-Output (ICIO) Database.* Author. Retrieved from https://www.oecd.org/icio

Owen, A., Steen-Olsen, K., Barrett, J., Wiedmann, T., & Lenzen, M. (2014). A structural decomposition approach to comparing MRIO databases. *Economic Systems Research*, *26*(3), 262–283. Retrieved from https://doi.org/10.1080/09535314.2014.935299 doi: 10.1080/09535314.2014.935299

Rahman, M., Anan, N., Mashud, A., et al. (2022). Consumption-based CO2 emissions accounting and scenario simulation in Asia and the Pacific region. *Environmental Science and Pollution Research*, *29*, 34607–34623. doi: 10.1007/s11356-021-18265-w

Rodrigues, J. F. D., Moran, D., Wood, R., & Behrens, P. (2018). Uncertainty of consumption-based carbon accounts. *Environmental Science & Technology*, *52*(13), 7577-7586. Retrieved from https://doi.org/10.1021/acs.est.8b00632 doi: 10.1021/acs.est.8b00632

Rokicki, T., Bórawski, P., & Szeberényi, A. (2023). The impact of the 2020–2022 crises on EU countries' independence from energy imports, particularly from Russia. *Energies*, *16*(18). Retrieved from https://www.mdpi.com/1996-1073/16/18/6629 doi: 10.3390/en16186629

Sato, M. (2014). Embodied carbon in trade: A survey of the empirical literature. *Journal of Economic Surveys*, *28*(5), 831-861. doi: https://doi.org/10.1111/joes.12027

Schoer, K., Wood, R., Arto, I., & Weinzettel, J. (2013). Estimating raw material equivalents on a macro-level: Comparison of multi-regional input–output analysis and hybrid lci-io. *Environmental Science & Technology*, *47*(24), 14282-14289. Retrieved from https://doi.org/10.1021/es404166f doi: 10.1021/es404166f

Simas, M., Pauliuk, S., Wood, R., Hertwich, E. G., & Stadler, K. (2017). Correlation between production and consumption-based environmental indicators: The link to affluence and the effect on ranking environmental performance of countries. *Ecological Indicators*, *76*, 317-323. Retrieved from https://www.sciencedirect.com/science/article/pii/S1470160X17300328 doi: https://doi.org/10.1016/j.ecolind.2017.01.026

Singhania, M., & Saini, N. (2021). Demystifying pollution haven hypothesis: Role of fdi. *Journal of Business Research*, *123*, 516-528. Retrieved from https://www.sciencedirect.com/science/article/pii/S0148296320306573 doi: https://doi.org/10.1016/j.jbusres.2020.10.007

Stadler, K., Wood, R., Bulavskaya, T., Södersten, C.-J., Simas, M., Schmidt, S., … Tukker, A. (2018). EXIOBASE 3: Developing a time series of detailed environmentally extended multi-regional input-output tables. *Journal of Industrial Ecology*, *22*(3), 502-515. doi: https://doi.org/10.1111/jiec.12715

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., & de Vries, G. J. (2015). An illustrated user guide to the World Input–Output Database: The case of global automotive production. *Review of International Economics*, *23*(3), 575–605. doi: 10.1111/roie.12178

World Bank. (2024a). *GNI (current US$).* https://data.worldbank.org/indicator/NY.GNP.MKTP.CD, accessed 2024-05-30.

World Bank. (2024b). *Population, total.* https://data.worldbank.org/indicator/SP.POP.TOTL, accessed 2024-05-30.

Wyckoff, A. W., & Roop, J. M. (1994). The embodiment of carbon in imports of manufactured products: Implications for international agreements on greenhouse gas emissions. *Energy Policy*, *22*(3), 187-194. Retrieved from https://www.sciencedirect.com/science/article/pii/0301421594901589 doi: https://doi.org/10.1016/0301-4215(94)90158-9

Yang, L., Wang, Y., Wang, R., Klemeš, J. J., Almeida, C. M. V. B. d., Jin, M., … Qiao, Y. (2020, Sep 08). Environmental-social-economic footprints of consumption and trade in the Asia-Pacific region. *Nature Communications*, *11*(1), 4490. Retrieved from https://doi.org/10.1038/s41467-020-18338-3 doi: 10.1038/s41467-020-18338-3

Zheng, Y., Yu, H., & Zhang, Y. (2022). A bibliometric review on carbon accounting in social science during 1997–2020. *Environmental Science and Pollution Research*, *29*, 9393–9407. doi: 10.1007/s11356-021-17600-5

Appendix A I

Table A.1: Sector list

Sector abbreviation	Name	GTAP11 abbreviation	Name
FUEL	Fuels	COA	Coal
		OIL	Oil
		GAS	Gas
		P_C	Petroleum, coal products
		GDT	Gas manufacture, distribution
AGR	Agriculture, plant	PDR	Paddy rice
		WHT	Wheat
		GRO	Cereal grains nec
		V_F	Vegetables, fruit, nuts
		OSD	Oil seeds
		C_B	Sugar cane, sugar beet
		PFB	Plant-based fibers
		OCR	Crops nec
		FRS	Forestry
ANM	Agriculture, animal	CTL	Bovine cattle, sheep and goats, horses
		OAP	Animal products nec
		RMK	Raw milk
		WOL	Wool, silk-worm cocoons
		FSH	Fishing
		CMT	Bovine meat products
		OMT	Meat products nec
XTR	Other extraction	OXT	Other Extraction (formerly omn Minerals nec)
FBT	Food, beverage, tobacco	VOL	Vegetable oils and fats
		MIL	Dairy products
		PCR	Processed rice
		SGR	Sugar
		OFD	Food products nec
		B_T	Beverages and tobacco products
CHM	Chemical products	CHM	Chemical products
BPH	Basic pharmaceuticals	BPH	Basic pharmaceutical products
MTL	Metal and mineral products	NMM	Mineral products nec
		I_S	Ferrous metals
		NFM	Metals nec
		FMP	Metal products
OMANUF	Other manufacturing	TEX	Textiles

		WAP	Wearing apparel
		LEA	Leather products
		LUM	Wood products
		PPP	Paper products, publishing
		RPP	Rubber and plastic products
		OMF	Manufactures nec
MANUF	Machinery manufacturing	ELE	Computer, electronic and optical products
		EEQ	Electrical equipment
		OME	Machinery and equipment nec
		MVH	Motor vehicles and parts
		OTN	Transport equipment nec
ELY	Electricity	ELY	Electricity
WTR	Water and waste management	WTR	Water
CNS	Construction	CNS	Construction
OTP	Other transport	OTP	Transport nec
		WTP	Water transport
ATP	Air transport	ATP	Air transport
OSR	Other services	TRD	Trade
		AFS	Accommodation, Food and service activities
		WHS	Warehousing and support activities
		CMN	Communication
		OFI	Financial services nec
		INS	Insurance (formerly isr)
		RSA	Real estate activities
		OBS	Business services nec
		ROS	Recreational and other services
		OSG	Public Administration and defense
		EDU	Education
		HHT	Human health and social work activities
		DWE	Dwellings

Table A.2: PBA and CBA by sectors, Ireland vs New Zealand and Great Britain ($MtCO_2eq$, 2017)

	Ireland			New Zealand			United Kingdom		
	PBA	CBA	Diff.	PBA	CBA	Diff.	PBA	CBA	Diff.
Agriculture, plant	2.98	3.47	0.48	4.27	1.96	-2.31	10.36	16.19	5.83
Agriculture, animal	22.75	15.34	-7.41	43.09	31.09	-12.00	44.75	50.10	5.35
Other extraction	0.49	0.49	-0.01	0.34	0.38	0.04	0.80	1.16	0.37
Fuels	12.51	19.82	7.30	9.90	11.52	1.62	155.55	173.89	18.34
Food, beverage, tobacco	1.44	0.66	-0.78	2.02	0.80	-1.22	7.96	10.04	2.09
Chemical products	0.90	2.85	1.95	3.14	4.63	1.48	15.21	19.66	4.45
Basic pharmaceuticals	0.40	0.35	-0.05	0.03	0.12	0.10	1.45	1.50	0.04
Metal and mineral products	5.00	6.27	1.27	2.61	3.80	1.20	27.77	49.03	21.26
Machinery manufacturing	1.24	1.07	-0.18	0.17	0.83	0.67	9.76	12.10	2.34
Other manufacturing	0.58	1.32	0.74	1.41	2.12	0.71	10.85	19.55	8.70
Electricity	0.42	0.41	-0.01	0.23	0.23	0.00	3.70	3.85	0.15
Water and waste management	1.28	1.29	0.01	4.65	4.66	0.01	13.16	13.25	0.08
Construction	0.37	0.37	0.01	1.02	1.02	0.00	6.85	6.88	0.03
Air transport	2.83	3.79	0.95	3.46	5.91	2.45	29.83	56.66	26.83
Other transport	11.33	10.92	-0.41	8.41	8.92	0.51	98.34	98.04	-0.30
Other services	4.86	6.48	1.62	2.49	2.92	0.43	49.53	55.15	5.61
SUM	69.39	74.89	5.50	87.23	80.92	-6.32	485.86	587.05	101.18
CBA/PBA		107.92			92.76			120.83	

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

Table A.3: PBA and CBA by sectors, Ireland vs EU Mediterranean countries ($MtCO_2eq$, 2017)

	Ireland			Greece			Italy			Spain			Portugal		
	PBA	CBA	Diff.	PBA	CBA	Diff.	PBA	CBA	Diff.	PBA	CBA	Diff.	PBA	CBA	Diff.
Agriculture, plant	2.98	3.47	0.48	2.98	3.75	0.77	10.15	15.28	5.13	12.59	14.88	2.29	1.98	3.79	1.81
Agriculture, animal	22.75	15.34	-7.41	6.47	7.66	1.19	31.45	46.86	15.42	37.50	38.52	1.02	7.10	7.82	0.72
Other extraction	0.49	0.49	-0.01	0.39	0.25	-0.14	0.74	1.62	0.88	1.84	2.70	0.86	0.34	0.21	-0.13
Fuels	12.51	19.82	7.30	20.03	32.54	12.51	106.63	161.73	55.10	70.95	114.99	44.05	13.03	30.56	17.53
Food, beverage, tobacco	1.44	0.66	-0.78	1.30	1.43	0.12	10.92	10.23	-0.70	7.39	7.96	0.57	1.47	1.52	0.05
Chemical products	0.90	2.85	1.95	1.30	3.65	2.35	17.46	29.50	12.04	13.07	22.02	8.95	2.15	5.01	2.85
Basic pharmaceuticals	0.40	0.35	-0.05	0.04	0.14	0.10	0.86	0.98	0.13	0.29	0.75	0.45	0.05	0.12	0.07
Metal and mineral products	5.00	6.27	1.27	12.94	11.26	-1.68	51.13	74.19	23.06	42.91	49.48	6.57	8.40	9.64	1.25
Machinery manufacturing	1.24	1.07	-0.18	0.40	0.82	0.42	14.01	11.51	-2.50	4.78	5.79	1.01	0.79	1.29	0.50
Other manufacturing	0.58	1.32	0.74	0.99	1.93	0.94	22.18	24.01	1.84	8.17	11.67	3.50	4.30	3.58	-0.72
Electricity	0.42	0.41	-0.01	2.44	2.61	0.16	1.83	2.17	0.34	4.09	4.10	0.01	0.87	0.82	-0.05
Water and waste management	1.28	1.29	0.01	5.73	5.73	0.00	18.58	18.68	0.09	20.68	20.71	0.04	5.23	5.24	0.01
Construction	0.37	0.37	0.01	1.21	1.18	-0.03	5.03	5.04	0.02	5.81	5.79	-0.02	1.27	1.24	-0.03
Air transport	2.83	3.79	0.95	0.85	3.03	2.18	13.43	28.21	14.78	18.56	25.81	7.25	3.17	5.64	2.47
Other transport	11.33	10.92	-0.41	18.99	11.18	-7.82	86.02	84.81	-1.21	60.74	45.83	-14.91	12.17	10.28	-1.89
Other services	4.86	6.48	1.62	12.17	11.23	-0.94	56.65	56.62	-0.03	33.88	32.58	-1.30	8.26	7.86	-0.41
SUM	69.39	74.89	5.50	88.25	98.39	10.14	447.06	571.44	124.39	343.26	403.59	60.34	70.60	94.64	24.04
CBA/PBA		107.92			111.49			127.82			117.58			134.05	

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

Table A.4: PBA and CBA by sectors, Ireland vs Other EU countries ($MtCO_2eq$, 2017)

	Ireland			Denmark			Netherlands			Sweden		
	PBA	CBA	Diff.	PBA	CBA	Diff.	PBA	CBA	Diff.	PBA	CBA	Diff.
Agriculture, plant	2.98	3.47	0.48	3.37	3.65	0.28	8.77	5.58	-3.19	2.41	3.30	0.89
Agriculture, animal	22.75	15.34	-7.41	9.68	6.42	-3.26	22.49	20.16	-2.33	5.39	6.47	1.08
Other extraction	0.49	0.49	-0.01	0.13	0.14	0.01	0.60	0.84	0.24	0.85	0.71	-0.14
Fuels	12.51	19.82	7.30	9.77	11.52	1.75	48.88	73.08	24.20	11.01	18.11	7.10
Food, beverage, tobacco	1.44	0.66	-0.78	1.10	1.08	-0.02	5.34	4.44	-0.90	0.42	1.00	0.58
Chemical products	0.90	2.85	1.95	0.59	2.42	1.83	37.03	29.32	-7.71	5.22	5.33	0.11
Basic pharmaceuticals	0.40	0.35	-0.05	0.16	0.14	-0.03	0.79	0.41	-0.38	0.05	0.13	0.08
Metal and mineral products	5.00	6.27	1.27	3.12	6.41	3.29	11.96	18.47	6.51	7.64	11.71	4.07
Machinery manufacturing	1.24	1.07	-0.18	0.47	1.75	1.28	2.17	4.83	2.65	0.65	2.26	1.61
Other manufacturing	0.58	1.32	0.74	0.41	1.81	1.39	5.54	8.36	2.82	1.57	2.70	1.13
Electricity	0.42	0.41	-0.01	0.22	0.27	0.06	3.22	3.05	-0.17	0.19	0.22	0.03
Water and waste management	1.28	1.29	0.01	1.50	1.53	0.03	6.45	6.48	0.03	8.12	8.13	0.01
Construction	0.37	0.37	0.01	0.96	0.91	-0.04	2.32	2.33	0.02	2.18	2.22	0.04
Air transport	2.83	3.79	0.95	1.42	4.03	2.61	13.13	21.37	8.24	1.73	6.27	4.54
Other transport	11.33	10.92	-0.41	15.79	11.93	-3.85	33.75	20.83	-12.92	14.12	11.76	-2.36
Other services	4.86	6.48	1.62	3.51	4.66	1.15	24.82	26.84	2.01	2.26	4.00	1.74
SUM	69.39	74.89	5.50	52.20	58.68	6.48	227.26	246.38	19.12	63.80	84.34	20.53
CBA/PBA		107.92			112.41			108.41			132.19	

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).

Table A.5: Origins of imported fuel emissions ($MtCO_2eq$, 2017)

Source country: Russia	COA	GAS	GDT	OIL	P_C	Sum
IRL	0.003	0.000	0.001	0.000	0.418	0.423
NZL	0.000	0.000	0.000	0.119	0.001	0.121
GBR	2.283	0.032	0.001	0.442	3.940	6.697
ESP	2.357	0.000	0.003	0.609	1.414	4.383
GRC	0.155	0.395	0.000	0.522	1.390	2.462
ITA	2.378	4.741	0.001	1.760	1.245	10.125
PRT	0.118	0.000	0.001	0.927	0.309	1.356
DNK	0.720	0.000	0.000	0.094	0.757	1.570
NLD	2.744	1.059	0.000	4.960	4.606	13.369
SWE	0.315	0.000	0.000	1.834	0.539	2.688
Sum	11.073	6.227	0.007	11.267	14.620	43.194

Source country: Iraq	COA	GAS	GDT	OIL	P_C	Sum
IRL	0.000	0.000	0.000	0.001	0.000	0.001
NZL	0.000	0.000	0.000	0.001	0.000	0.001
GBR	0.000	0.000	0.000	0.004	0.001	0.004
ESP	0.000	0.000	0.000	2.533	0.000	2.533
GRC	0.000	0.000	0.000	6.169	0.000	6.169
ITA	0.000	0.000	0.000	5.380	0.032	5.412
PRT	0.000	0.000	0.000	0.546	0.000	0.546
DNK	0.000	0.000	0.000	0.000	0.000	0.000
NLD	0.000	0.000	0.000	3.689	0.000	3.689
SWE	0.000	0.000	0.000	0.377	0.000	0.377
Sum	0.000	0.000	0.000	18.699	0.033	18.732

Source country: Algeria	COA	GAS	GDT	OIL	P_C	Sum
IRL	0.000	0.000	0.000	0.066	0.001	0.067
NZL	0.000	0.000	0.000	0.000	0.000	0.000
GBR	0.000	0.251	0.000	0.952	0.012	1.215
ESP	0.000	7.949	0.000	0.374	0.862	9.185
GRC	0.000	1.531	0.000	0.029	0.002	1.562
ITA	0.000	11.600	0.000	0.423	0.879	12.902
PRT	0.000	1.056	0.000	0.297	0.037	1.390
DNK	0.000	0.000	0.000	0.008	0.000	0.008
NLD	0.000	0.082	0.000	0.634	0.570	1.286
SWE	0.000	0.000	0.000	0.000	0.000	0.001
Sum	0.000	22.469	0.000	2.784	2.363	27.616

Source country: Nigeria	COA	GAS	GDT	OIL	P_C	Sum
IRL	0.000	0.000	0.001	0.324	0.000	0.324
NZL	0.000	0.000	0.000	0.001	0.000	0.001
GBR	0.000	0.094	0.000	2.383	0.001	2.479
ESP	0.000	3.482	0.000	9.183	0.000	12.665
GRC	0.000	0.000	0.001	0.004	0.000	0.005
ITA	0.000	0.180	0.000	1.619	0.006	1.805
PRT	0.000	1.811	0.000	0.133	0.000	1.944
DNK	0.000	0.000	0.000	0.070	0.000	0.070
NLD	0.000	0.098	0.000	2.646	0.018	2.761
SWE	0.000	0.000	0.000	2.732	0.001	2.733
Sum	0.000	5.665	0.002	19.094	0.026	24.788

Source country: Norway	COA	GAS	GDT	OIL	P_C	Sum
IRL	0.000	0.000	0.000	0.295	0.015	0.310
NZL	0.000	0.000	0.000	0.000	0.000	0.000
GBR	0.000	4.811	0.000	1.750	0.787	7.349
ESP	0.000	0.450	0.000	0.395	0.021	0.867
GRC	0.000	0.016	0.000	0.000	0.000	0.017
ITA	0.000	0.388	0.000	0.196	0.019	0.603
PRT	0.000	0.007	0.000	0.012	0.021	0.040
DNK	0.000	0.048	0.000	0.291	0.089	0.428
NLD	0.000	2.679	0.000	0.787	0.192	3.657
SWE	0.000	0.055	0.001	0.742	0.173	0.971
Sum	0.000	8.453	0.002	4.469	1.318	14.242

Source: Authors' calculations based on GTAP11 data (Aguiar et al., 2023).