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The Global Emissions Impact of Irish Consumption

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Abstract

This paper calculates and compares the level of Greenhouse gas (GHG) emissions using a production-based accounting (PBA) method and a consumption-based accounting (CBA) method. The PBA attributes GHG emissions resulting from production processes to the country in which the production takes place. CBA attributes these emissions instead to the country which consumes the goods produced. Our results show that emissions, as calculated by the CBA method, are 74% higher than when calculated using a PBA method. This reflects that the global carbon footprint of Irish consumption is higher than what is reflected in our current PBA calculations. The main cause of higher CBA emissions is the import of goods for household consumption. Climate policies in Ireland focus on reducing PBA emissions and would need to include measures to address CBA emissions to ensure Ireland's global carbon footprint is limited.

Keywords: consumption, input-output analysis, consumption-based accounting, production-based accounting, climate policies, CGE

1 Introduction

Anthropogenic climate change poses an increasing global threat resulting in the urgent need to decrease greenhouse gas (GHG) emissions. Ireland has shown its commitment to reducing emissions, where the Government Plan of 2020 included an annual emission reduction target of 7%, resulting in a 51% reduction of emissions by 2030. This target was made legally binding by the recent Climate Action and Low Carbon Development (Amendment) Act of 2021 and further commits to net-zero emissions by 2050. The first step in emission reduction policy setting has been measuring and accounting for GHG emissions. One of the first actions of the IPCC was to publish guidelines for national greenhouse gas inventories in 1996 describing the appropriate method of estimating anthropogenic emissions (Mosier et al., 1999). Nations were required to submit their national greenhouse gas inventories as signatories to UNFCCC agreements such as the Kyoto Protocol and the Paris Agreement.

Accounting for GHG emissions is generally based on the location of emission, applying the production-based accounting (PBA) method, where the producing economic agent is considered responsible for the emissions directly resulting from the production of goods and services (see, e.g., Benini et al., 2014). Hence, a country's total emissions are calculated based on how much is emitted in all production activities. It is the approach taken when estimating the IPCC national greenhouse gas inventories. However, the rapidly expanding volume of global trade means that many emissions embodied in trade are not captured correctly in traditional PBA frameworks.

Recent studies have found that 20–25% of global CO_2 emissions result from the production of internationally traded products (Hertwich & Peters, 2009a; Peters & Hertwich, 2008; Davis & Caldeira, 2009). These emissions are growing by, on average, 3.4% per year (1990–2008), increasing from around 20% (4.3 Gt CO_2) in 1990 to 26% (7.8 Gt CO_2) in 2008 (Peters et al., 2011a). The concern is that under a PBA framework, developed countries can simply outsource their production activities to less developed countries and then import the produced goods while maintaining the same high levels of consumption, thereby sidestepping international emissions reduction obligations (Tukker et al., 2020). Indeed, Peters et al. (2011b) find that the change in net emissions transfers from developing to developed countries offsets PBA reductions achieved by the Annex B countries of the Kyoto Protocol by a factor of five. In this case, the largest polluters would continue to contribute the most to pollution but would be able to avoid any emissions-based penalties as their pollution would not show up in their national accounts. Ultimately, this system of emissions accounting penalises those countries – typically poorer – that are involved in the more carbon-heavy stage of the global supply chain (Grasso, 2015). As such, this process elicits a question of responsibility: who is responsible for the emissions produced in a country when they relate to goods not used in that country? Is it the producing country? Or the country for whom the goods are being produced, i.e. the end user? (Steininger et al., 2018).

In light of this, an alternative framework exists for emissions accounting – consumption-based accounting (CBA). This framework takes a consumer perspective, where the emissions generated by the final use of goods and services and along these goods and services' supply-chain are accounted to the consuming country (Munksgaard & Pedersen, 2001). CBA differs from standard emissions accounting because it considers the emissions embedded in the international trade of goods and places the "ownership" of the emissions from traded goods in the hands of the country responsible for final consumption. Essentially, this procedure incorporates a good's life-cycle emissions. Most CBA frameworks allocate total emissions to different countries on the basis of their final demand as a measurement of each country's emissions from a consumption point of view (Chen et al., 2018). In essence, consumption-based emissions are calculated by subtracting emissions embedded in export and adding emissions embedded in imports to the level of production-based emissions.

Whether direct or indirect, the level of global GHGs emissions is determined by our consumption patterns. Governments introduce taxes and incentives to deter emissions contributing to climate change; however, these policies take a restrictive national approach and focus on reducing the national (PBA) emissions and not the global level of emissions. Given that national targets have been formulated based on GHGs emitted within the borders of a nation, i.e. based on a PBA approach, these policies make sense. This would also make sense from a global perspective if similar targets and carbon prices were set across nations limiting carbon leakage. However, due mainly to the large differences in wealth across nations, this is not the case and to effectively reduce global GHG emissions, we would need to look beyond our borders and consider the emissions our consumption patterns create in other nations. Applying CBA to calculate a reference scale for emissions reduction has potential advantages of fairness, effectiveness, and cost (Grasso, 2017). Overall, while there is a growing momentum towards incorporating consumption emissions into the mainstream emissions accounting framework, as well as incorporating them into national policy on emissions targets, the scientific literature on consumption-based emissions remains comparatively smaller (Grasso, 2017; Blanco et al., 2014). Further research is needed on the methods and equity impacts of using a CBE accounting method, as well as on the institutional capacity required to facilitate a reliable CBE inventory. As things stand, international emissions obligations such as those set by the EU continue to be framed in terms of territorial emissions.

Inevitably, this debate has important political consequences. The decision to use either a PBA or CBA approach can have an impact on how polluting a country is deemed to be. In turn, this can impact the growing number of financial penalties countries face in light of increasing GHG pollution. The feasibility of a transition towards a primarily CBA system is discussed in Grasso (2015). He outlines three "foundations" which should serve as checkpoints of the feasibility, namely the overall fairness of the use of CBA as a concept, an equal distribution of the costs of such a transition, and the institutional capacity to adequately facilitate the implementation of CBA accounting.

This paper aims to create a better understanding of the global emissions embedded in Irish consumption and how this compares to emissions associated with Irish production processes. We apply a national computable general equilibrium (CGE) model (called Ireland Environment, Energy and Economy, I3E) and a global input-output table (EXIOBASE 3) to estimate the consumption-based emissions of Ireland and the embedded emissions in various consumption goods and to compare this to the traditional PBA estimates. This paper is structured as follows. In section 2, a brief overview of the literature will be given. Section 3 describes the methods applied in this study. The results are presented in section 4, and conclusions are drawn in section 5.

2 Literature Review

To estimate consumption-based emissions, the emissions created throughout the production process of all final goods will need to be estimated. Hence, a quantitative representation of the supply chain of a final good is crucial. In this sense, input-output models provide an extremely useful tool as these models represent the sectoral linkages in the economy, outlining detailed transactions between producers and consumers. Over the last ten years, input-output models have become the standard method to calculate consumption-based emissions in the literature. As global production has expanded, Multi-Region Input-Output (MRIO) models have become prevalent as a means of calculating and tracking a good's lifetime emissions cycle, particularly with respect to its trade on the global market (Peters, 2008; Davis & Caldeira, 2010; OECD, 2016).

Environmentally extended MRIO (EE-MRIO) databases have also been developed, which track not only the movement of goods across sectors and countries but also environmental indicators such as emissions and natural resources. Examples of these databases include EXIOBASE versions 2 and 3 (Wood et al., 2015; Stadler et al., 2018; Merciai & Schmidt, 2018), WIOD (Dietzenbacher et al., 2013; Timmer et al., 2015) and EORA (Lenzen et al., 2012; Lenzen et al., 2013a). Applying these databases, a number of studies estimate the carbon footprint of nations (Moran & Wood, 2014; Schmidt & Muños, 2014; Ivanova et al., 2016); the material footprint (Pothen & Schymura, 2015); land or water footprints (Lenzen et al., 2013b); with some studies considering the four of them (Tukker et al., 2016; Wood et al., 2018).

Several studies compare CBA and PBA estimates. Mózner (2013) estimate CBA and PBA for the UK, the Netherlands, Germany and Hungary, applying industry-by-industry input-output tables from the OECD's STAN Database for Structural Analysis. They find that for all four countries, consumption-based emissions are higher than production-based. The highest levels are found in the UK, where CBA emissions are 66% higher than PBA. It is followed by Hungary, the Netherlands, and Germany, where CBA emissions are 52%, 24%, and 7% higher than PBA, respectively. Wood et al. (2019) also find higher levels of CBA emissions for EU countries with on average 16% higher level of CBA emissions than PBA. They also find significant differences across countries. Barrett et al. (2013) focus on the UK and finds that CBA emissions are around 60% higher than PBA and that most of these imported emissions result from the imports of electronic equipment and machinery, vehicles, textiles, metals and chemicals.

Other studies estimate the environmental footprint of European consumption but do not compare this with a PBA approach. Beylot et al. (2019) combines an EE-MRIO (EXIOBASE 3) with up-to-date impact assessment models to quantify the environmental impacts induced by final consumption in the EU Member States in 2011. Castellani et al. (2019) estimate the environmental impacts using both a Life Cycle Analysis and an input-output method. Ivanova et al. (2017) calculates the household carbon footprints for the EU nations and finds that Ireland has one of the highest within the EU.

Our method relies not only on an EE-MRIO but supplements this with national data in the form of a national CGE model, current trade data and national emissions data. This allows us to make a more current and accurate estimation of CBE emissions for Ireland.

3 Method

The methodology we use combines a national computable general equilibrium (CGE) model, the Ireland Environment, Energy and Economy (I3E model), and a global multi-regional input-output database, EXIOBASE 3. We will introduce each in turn and then discuss how they are linked and applied.

3.1 The I3E model

The I3E model is an intertemporal CGE model which reproduces the structure of the economy in its entirety. It includes productive sectors, households, and the government, among others. In the model, the nature of all existing economic transactions among diverse economic agents is quantified. According to microeconomic behaviour, producers/consumers maximise their profits/utility given their budget constraints. In other words, a CGE model examines how inputs and outputs flow between production sectors of the economy and ultimately result in final goods consumed by households.

For this analysis, we apply the production emission estimates from the I3E model and their flows to the various final consumers (production activities, households, government or other countries). The production sector comprises 39 representative activities/firms. The central data source applied to replicate inter-sectoral linkages in the Irish economy is the Supply and Use Tables (SUTs) provided by the Central Statistics Office (CSO). The I3E model includes energy flows and emissions in addition to the standard monetary flows. Each production sector produces an economic commodity using labour, capital, material inputs, and energy inputs. The I3E model explicitly comprises a set of carbon commodities, including peat, coal, natural gas, crude oil, fuel oil, LPG, gasoline, diesel, kerosene, and other petroleum products. GHG emissions are directly linked to the use of carbon commodities by firms, households and the government. The estimation of carbon usage throughout the economy is based on the Energy Balances of the Sustainable Energy Authority of Ireland (SEAI), the Business Energy Use Survey (BEUS) published by the CSO and other data sources as described in de Bruin & Yakut (2021).

3.2 EXIOBASE

An input-output model is based on the economic identity between the total output of a production sector and the sum of intermediate demand (demand for that sector's output from other sectors) plus final demand. This is referred to as the Leontief inverse equation and given as:

$$x = (1 - A)^{-1} f$$

where x is the vector of output productions, A is the technological requirement matrix and f is the final demand. The inventory of emissions, g, as a response to a given final demand can then be calculated as:

$$g = Bx = B(1-A)^{-1} f$$

where B is the matrix of sectoral emission intensities, i.e. the sectoral coefficients of emissions per unit of output in the sector. MRIO models extend this standard IO matrix, where each industry and region has a separate row and column (Hertwich & Peters, 2009b).

EXIOBASE is a global, detailed EE-MRIO database developed by harmonizing and detailing supply-use tables for a large number of countries, estimating emissions and resource extractions by industry. Subsequently, the country supply-use tables (SUTs) were linked via trade, creating a Multi-Region SUT (MR-SUT) and producing Multi-Region Input-Output Tables (MR-IOTs) from this. The MR-IOT can be used to analyse the environmental impacts associated with the final consumption of product groups. EXIOBASE maps imports to each production sector, households, and the government in Ireland to an exporting production sector from a specific country. We calculate each country's emission intensity per production sector and multiply this by the goods imported by each Irish production sector, households, and the government. We take into account CO_2, N_2O, and CH_4 emissions.

The PBA considers the emissions stemming from the use of energy commodities, and these emissions are calculated as follows in the I3E model.

$$EMIS\_I3E_{em,a} = \sum_c carcon_{em,c}\, INT_{c,a} \tag{1}$$

where $carcon_c$ is the carbon content of commodity c and $INT_{c,a}$ is the intermediate input demand of activity a for commodity c.

Using the EXIOBASE 3 database, the emission intensity of activity a in region r for each type of emissions em, $EMFF_{em,r,a}$, is calculated as follows:

$$EMFF_{em,r,a} = \frac{EA_{em,r,a}}{PXQX_{r,a}} \tag{2}$$

where $EA_{em,r,a}$ is the activity emissions and $PXQX_{r,a}$ is the value of sectoral output.

CSO data was used to scale imports up to the current level per product category, resulting in estimates based on the year 2019. The composition of Irish imports with respect to activities and regions calculated from the EXIOBASE is used to disaggregate the total Irish imports retrieved from CSO's trade statistics for each commodity c.

$$IM_{r,c,IRL,a} = IM\_CSO_c\, shr\_im_{r,c,IRL,a} \tag{3}$$

If the multiplication of the emission intensity of activities and the imports by commodities is summed over regions and commodities, we end up with the emissions embedded in imports of each activity in

Ireland by type of emissions, $EMIM_{em,r,a}$;

$$EMIM_{em,IRL,a} = \sum_{r,c} IM_{r,c,IRL,a}\, EMFF_{em,r,a} \tag{4}$$

In both the EXIOBASE and CSO trade statistics, the data for energy commodities are available only for one product; petroleum and petroleum products. However, as the I3E model has a detailed representation of carbon commodities, each of which has different emission intensities, the Irish firms' imports of this commodity are replaced by the activity emissions of the I3E model. Therefore, the emissions of Irish producers are calculated as

$$EMIS_{em,IRL,a} = EMIM_{em,IRL,a} + EMIS\_I3E_{em,a} \tag{5}$$

where $EMIS\_I3E_{em,a}$ covers only CO_2 emissions, as these are the combustion-related emissions.

After this, we distinguish how much of the activity emissions are produced for domestic consumption in Ireland and how much is exported. In order to do so, we first calculate the embedded emission in each commodity produced in Ireland, QXC_c. As the I3E model allows firms to provide multiple outputs, a commodity can be produced by multiple activities. We use the calibrated parameter of the model, $shr\_qxac_{c,a}$, which shows the composition of sectoral output across different commodities.

$$EMIS\_QXC_{em,c,IRL} = \sum_{a} shr\_qxac_{c,a}\, EMIS_{em,IRL,a} \tag{6}$$

where $EMIS\_QXC_{em,c,IRL,a}$ is the emissions embedded in the commodity c produced by activities in Ireland by type of emissions. The commodity c produced in Ireland is either sold in the domestic market, QD_c, or exported, QE_c. The I3E model also provides data on the levels of both variables.

$$EMIS\_Dom_{em,c,IRL} = EMIS\_QXC_{em,c,IRL}\, \frac{QD_c}{QXC_c} \tag{7}$$

where $EMIS\_Dom_{em,c,IRL}$ is the level of emissions embedded in domestically consumed commodity c. The difference between $EMIS\_QXC_{em,c,IRL}$ and $EMIS\_Dom_{em,c,IRL}$ is the emissions embedded in Irish exports in commodity c by type of emissions.

We can disaggregate the emissions consumed in Ireland by using the composition of total demand across agents defined in the I3E model. For instance, the emissions of households embedded in commodities produced in Ireland are calculated as follows.

$$EMIS\_DomHH_{em,c,IRL} = EMIS\_Dom_{em,c,IRL}\, \frac{TOTPRCON_c}{QD_c} \tag{8}$$

Calculating the total consumption-based emissions of Ireland requires the emissions embedded in the imported commodities for final demand purposes. To do so, we convert the activity-level emissions provided by EXIOBASE to commodity-level emissions by mapping activities to commodities.

$$EMIS_{em,r,c} = \sum_{a \ if \ map\_a\_c} EA_{em,r,a} \tag{9}$$

where map_a_c is a parameter mapping each activity to a commodity.

EXIOBASE provides data for imports for final demand purposes, including households, government, and investment demand, which are represented by the subscript fd. We first calculate the share of each commodity imported by Ireland for each final demand purpose.

$$shr\_fd_{r,c,IRL,fd} = \frac{FD_{r,c,IRL,fd}}{\sum_{r,c} FD_{r,c,IRL,fd}} \tag{10}$$

By multiplying these share parameters with the emissions embedded in commodities, we end up with the emissions embedded in commodities for final demand purposes as follows.

$$EMIS\_FD_{em,c,IRL,fd} = shr\_fd_{r,c,IRL,fd} \ EMIS_{em,r,c} \tag{11}$$

By using the energy-related emissions retrieved from the I3E model, as the EXIOBASE and CSO data for energy commodities is very limited, the total emissions embedded in commodity c consumed for final consumption purposes by type of emissions is

$$EMIS\_FDT_{em,c,IRL,fd} = EMIS\_FD_{em,c,IRL,fd} + EMIS\_I3E_{em,c,fd} \tag{12}$$

where $EMIS\_I3E_{em,c,fd}$ covers only CO_2 emissions, as these are the combustion-related emissions.

By summing up $EMIS\_Dom_{em,c,IRL}$, which is the level of emissions embedded in domestically consumed commodity c, and $EMIS\_FDT_{em,c,IRL,fd}$, which is the level of emissions embedded in imported emissions for final demand purposes, we can calculate the total consumption-based emissions of Ireland;

$$TEMIS_{em,c,IRL} = \sum_{fd} EMIS\_FDT_{em,c,IRL,fd} + EMIS\_Dom_{em,c,IRL} \tag{13}$$

4 Results

4.1 Activity Emissions

Emissions associated with the Irish production sectors are given in Table 1 in Kt of CO_2 equivalent for 2019. Domestic emissions refer to the emissions emitted during the production process in Ireland (from I3E). These domestic production emissions represent a core part of PBA emissions, however, not the total. PBA emissions include emissions emitted in Ireland resulting from both production and consumption and hence include emissions related to, e.g. private care transportation and home heating.

Table 1: Activity emissions in Kt CO_2-eq.

Activity	NACE Codes	Imported	Domestic
Primary Agriculture		4,350	603
Forestry		0	60
Fishing		19	92
Peat		0	139
Other Mining Products		0	10
Food, Beverage and Tobacco	10-12	51	780
Textile	13-15	40	3
Wood and Wood Products	16	1,130	26
Other Industrial Products	17,18,33	225	45
Petroleum		0	771
Other Manufacturing	31-32	0	845
Chemical Products	20	599	137
Basic Pharmaceutical Products	21	0	147
Rubber and Plastic Products	22	565	193
Other Non-metallic Products	23	922	2,774
Basic Metal Manufacturing	24-25	1,895	699
High-Tech Products	26-28	142	78
Transportation Equipment	29-30	12	4
Electricity - Conventional		14	8,512
Wind		0	4
Other Renewables		3	21
Natural Gas Supply		0	1,626
Water and Sewerage	36,37-39	0	63
Construction	41-43	0	303
Trade	45-47	266	751
Land Transportation	49	202	824
Water Transportation	50	2,822	139
Air Transportation	51	6	7,672
Other Transport (Storage and Postal)	52-53	0	104
Accommodation and Hotel Services	55-56	1	221
Telecommunication Services	61	282	120
Financial Services	64-66,77	483	103
Real Estate Services	68	0	38
Professional Services	69-75	4,210	186
Admin and Support Services	77-82	0	165
Public Sector	84	0	335
Education Sector	85	0	265
Health Sector	86-88	0	279
Other Services	remaining*	635	220
Total		18,874	29,357

*: It excludes NACE codes 5-9 (Mining, Quarrying and Extraction), 19 (Petroleum Products), and 35 (Electricity and Gas Supply).

Note: The activities without NACE codes are further disaggregated sectors.

The imported emissions refer to the emissions embedded in the imported inputs used in the production processes (estimated through EXIOBASE). These imported emissions by production sectors are calculated to later determine the embedded emissions in Irish consumption of Irish goods. Overall the total domestic production sector emissions in Ireland were approximately 29 Mt of CO_2, and the imported emissions were 19 Mt of CO_2. A large share (40%) of these imported emissions in intermediate inputs are exported again in final goods.

Primary agriculture shows high levels of imported emissions; however, imported emissions are out shadowed by domestic emissions. In manufacturing, wood and wood products and basic metal manufacturing show high levels of imported emissions. Water transportation also has high levels resulting from imported machinery.

Most services sectors, such as education, health, and admin and support, have negligible amounts of imported emissions. This is due to the nature of the service industry, which relies on skilled labour as opposed to material inputs. Some services, however, have considerably higher imported emissions than domestic emissions. These are the professional, financial and telecommunication services which rely on high technological imports.

4.2 Emissions Profile of Irish Consumption

Here we discuss the emissions embedded in consumption goods, distinguishing between 38 different commodities in line with the commodities in the I3E model. We calculate the level of domestically emitted GHG emissions for Irish consumption purposes (*Domestic*). These emissions include emissions from Irish production that is domestically consumed and emissions from the domestic consumption of carbon commodities, such as diesel and gas., the level of embedded GHG emissions in imports (*Imported*) and the level of GHG emissions embedded in exports (*Exported*). The level of embedded emissions imported for the final consumption of goods includes the embedded emissions in imports of final demand as well as the embedded emissions in the necessary imported intermediate inputs to the production of domestically produced final consumption goods. Table 2 shows the domestic, imported and exported emissions for the different commodities in Kt equivalent of CO_2. We also calculate emissions per consumption good by applying both the CBA and PBA approaches. In the case of CBA, total emissions equal the sum of imported and domestic emissions. In the case of PBA, total emissions equal the sum of domestic and exported emissions minus exported emissions that were originally imported, i.e. emissions embedded in input imports for the production of exports.

From the table, it is clear that most consumption goods have higher imported emissions than domestic emissions. The highest absolute levels of imported emissions are found for other mining products, chemicals, high technological products, public services, crops, trade and transportation equipment. Though their absolute levels of imported emissions are not as high, for many commodity types, the level of domestic emissions is negligible compared to imported emissions, e.g. textiles, construction and other manufacturing. In other words, there are virtually no production-based emissions associated with the consumption of these goods; however, the consumption-based emissions are significant. All national

Table 2: Commodity Emissions in Kt CO_2-eq. in 2019

Commodity	Exported	Imported	Domestic	PBA	CBA
Crops	2,775	4,210	889	3,565	5,099
Diary products	2,122	114	1,186	3,095	1,300
Cattle	9,503	184	1,090	10,345	1,274
Sheep	519	926	95	525	1,021
Poultry	122	87	214	312	302
Pig	264	101	253	457	354
Forestry	14	0	40	54	40
Fishing	33	1	78	105	79
Peat	0	136	1,696	1,696	1,832
Coal	0	2	2,076	2,076	2,078
Other mining	314	7,255	96	332	7,351
Food, beverage, and tobacco	647	496	91	692	588
Textile	48	213	1	9	214
Wood and wood products	561	547	14	28	561
Other industrial products	94	273	36	53	309
Gasoline	89	26	2,963	3,052	2,989
Kerosene	1	14	1,858	1,859	1,872
Fuel-oil	146	10	75	221	85
Liquid petroleum gas	4	5	230	234	235
Diesel	4	128	4,608	4,613	4,737
Other petroleum products	1	17	154	155	171
Other manufacturing	613	163	21	626	184
Chemical products	536	5,961	16	213	5,977
Basic pharmaceuticals	408	16	9	195	25
Rubber and plastic	482	3,642	75	204	3,718
Other non-metallic minerals	782	1,681	1,638	2,224	3,319
Basic fabricated metals	1,914	1,042	128	652	1,170
High-tech products	292	5,366	0	98	5,367
Transportation equipment	22	5,353	6	12	5,359
Electricity	24	4,302	7,653	7,677	11,956
Natural gas	0	1,095	3,733	3,733	4,828
Water and sewerage	0	191	63	63	254
Construction	0	264	303	303	567
Trade	843	4,940	990	1,687	5,931
Land transportation	38	1,385	841	873	2,226
Water transportation	1,080	1,879	88	139	1,967
Air transportation	4,382	1,533	1,848	6,227	3,381
Other transportation	17	38	77	94	115
Accom. and hotel serv.	23	3,007	204	227	3,210
Telecommunication services	327	202	49	175	251
Financial services	359	326	45	102	371
Real estate services	0	20	40	40	60
Professional services	1,567	3,016	529	789	3,545
Admin and support services	434	160	113	358	273
Public services	1	5,253	334	335	5,587
Education	0	127	252	252	379
Health	4	138	276	279	414
Other services	44	3,445	210	221	3,655
Total	31,410	69,289	37,077	61,275	106,576

emissions policies relying on a PBA approach would not directly impact the consumption of these goods and their associated emissions.

The bulk of embedded emissions in Irish exports arise from the export of dairy and beef products, as well as some manufacturing sectors such as basic fabricated metals, other non-metallic minerals, chemicals, plastic, wood and wood products and food, beverage and tobacco. Concerning services, high levels of embedded emissions in exports are found in air and water transportation, trade, telecommunications, financial services and professional services. For several sectors, we see a pass-through of emissions, where emissions embedded in imported intermediate inputs for production sectors are exported again as final goods (e.g. basic fabricated metals, other non-metallic minerals, telecommunications, financial services and professional services). In fact, 23% of exported emissions through final goods were originally imported as inputs to Irish production.

The total level of production-based emissions is the sum of domestic and exported emissions for all commodities, whereas the total level of consumption-based emissions is the sum of domestic and imported emissions for all commodities. Comparing these totals, we find that the level of Irish emissions applying a PBA approach is approximately 61 Mt of CO_2, whereas applying a CBA approach, the level is 107 Mt of CO_2. Imported emissions in Ireland account for 69 Mt of CO_2, almost equivalent to our production-based emissions total. This is concerning given that Irish emission reduction policies focus on the production-based approach and neglect an equal amount of imported emissions.

4.3 For Whom and From Where

Here we examine the consumption-based emissions of different final consumers and where in the world Irish consumption-based emissions are emitted. Figure 1 shows the share of total imported emissions by the final user. Households consume the largest share of total imported emissions. Production sectors use the second largest share as inputs to production. The third share is used for investment, and the government is responsible for the smallest share.

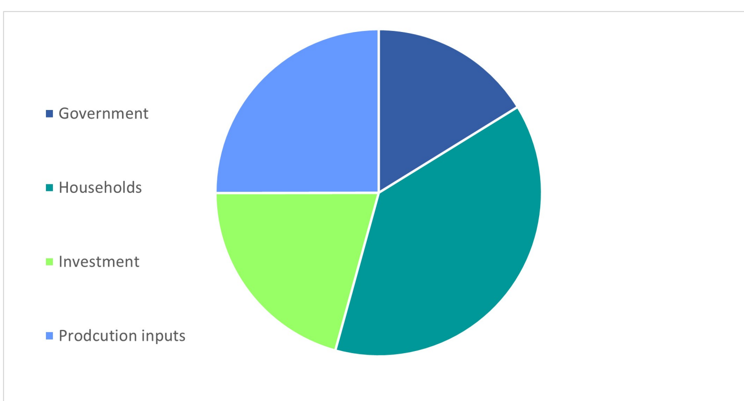

Figure 1: Emissions embedded in final demand by purpose

Figure 2 gives a regional overview of the origin of Irish imported emissions, where for each region, the share of total Irish imported emissions is given. Note that this relies on the EXIOBASE regions, where, e.g. the US, Japan, China and each EU country constitutes a region, whereas other countries are aggregated into regions such as Africa, the Middle East and Asia. Examining the figure, we find that the imported emissions from the EU, UK and US are high. Given that these represent Ireland's largest trade partners, this would be expected. We also see a high level of imported emissions from the Middle East, which is intuitive. Supplementing this analysis with national trade data, which has a higher level of detail, would help create a better understanding of the most emissions-intensive trade patterns.

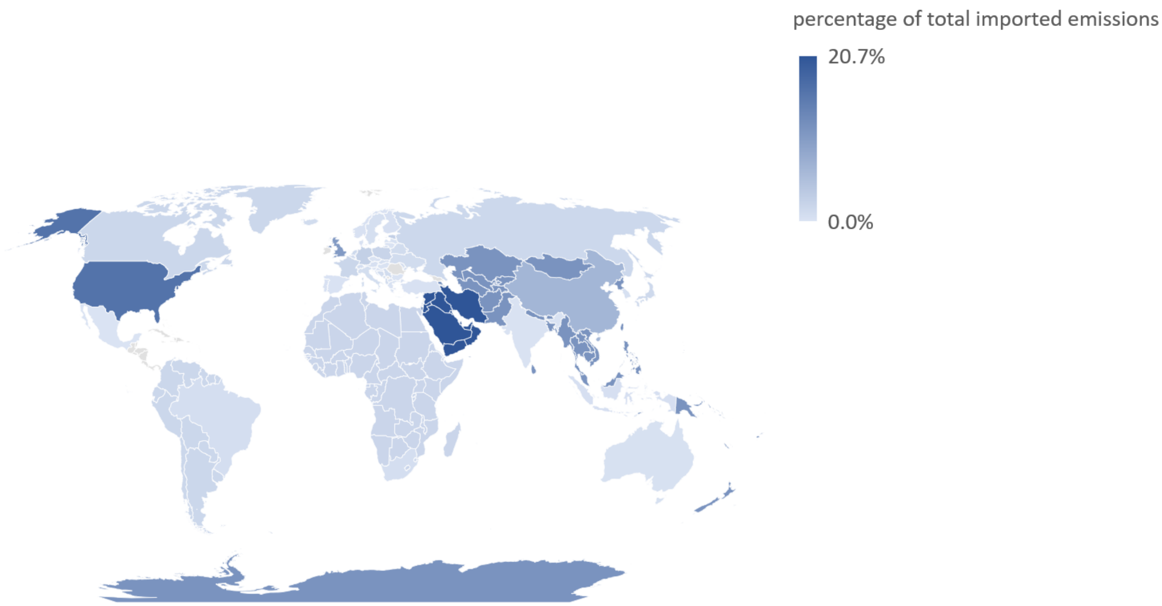

Figure 2: Percentage of Irish imported emissions by origin country

5 Conclusions

This paper applies a national Irish CGE model (I3E) and a multi-regional input-output database (EXIOBASE 3) to estimate emissions by applying both a consumption-based approach (CBA) and a production-based approach (PBA). Traditionally PBAs are applied to calculate national levels of GHG emissions and to determine climate policies and targets. A PBA approach attributes emissions to the country where they are emitted, hence to the producer. Conversely, CBA attributes the production emissions of a good to the consuming country of the final good. A CBA estimate can give insights into the global carbon footprint of Irish consumption.

Our results show that despite the high level of emissions embedded in Irish agricultural products, Ireland imports considerably more emissions than it exports. Consumption-based emissions are estimated to be 107 Mt CO_2 eq., which is 74% higher than the estimated production-based emissions. Production sectors import intermediate inputs for production processes, and the embedded emissions in these imports are highest for professional services, water transportation and basic metal manufacturing. Approximately 40% of these imported emissions are exported again through final goods.

Emissions embedded in imports for household consumption constitute the largest share of imported emissions. The most emission-intensive imported goods are chemicals, rubber, other mining products, trade, transportation equipment, high technological products, food, beverage and tobacco, and textiles. Production-based emissions are low and even negligible for many of these products, meaning that climate policies focused on reducing production-based emissions will not reduce the consumption of these products or their associated emissions. Approximately 66 Mt of CO_2 eq. is emitted in other countries for Irish consumption. If Ireland is committed to reducing its global carbon footprint, it would need to implement policies that tackle these emissions outside our borders.

This work constitutes the first assessment of consumption-based emissions for Ireland and includes several limitations. Firstly, this work relies heavily on the EXIOBASE database and includes the same caveats as this global database. A more robust analysis would include various global databases and supplement this with more detailed trade data where possible. A further limitation is the aggregation level of the results, which is determined by the available data. More detailed data could improve our understanding of the most emission-intensive trade patterns. For example, our results find that high technological products from the middle east have high levels of embedded emissions. However, we need to find out what type of product and from which country it is imported.

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