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Improving the UKMRIO's Trade Data

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Abstract

The UK's Multi-Regional Input-Output database (UKMRIO) is used to calculate the UK's consumption-based greenhouse gas (GHG) emissions as well as a number of other environmental and economic indicators. The UKMRIO is constructed from National Accounts from the UK's Office for National Statistics, as well as from international trade data from a global Multi-Regional Input-Output (GMRIO) databases. As various GMRIOs exist, this research tests the potential use of four current GMRIO databases in the UKMRIO model: EXIOBASE, GLORIA, the ICIO, and FIGARO.

We find that the UK's estimated domestic emissions are highly similar across the four GMRIOs. However, imported emissions show more variance, with ICIO estimating the highest imported emissions for the UK. Differences in findings further appear to be impacted by the COVID-19 pandemic, with EXIOBASE reporting higher emission increases for 2020 and 2021 than GLORIA and FIGARO. This is likely due to methodological differences in database construction and source data.

As each GMRIO has its own set of strengths and limitation, we evaluate their suitability for the UKMRIO using the GMRIO's source data, annual coverage, regional coverage, industry coverage, extension variables, and ease of use. We conclude that using a combination of EXIOBASE (for the years 2001-2014) and FIGARO (2015-2021) provides the best trade date for the UKMRIO model, based on these criteria.

Keywords: Multi-regional input-output analysis, environmental accounting, international trade, carbon footprint

JEL classification: Q56, Q57

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Summary

The UK's Multi-Regional Input-Output database (UKMRIO) is used to calculate the UK's consumption-based greenhouse gas (GHG) emissions as well as a number of other environmental and economic indicators. The UKMRIO is constructed from National Accounts from the UK's Office for National Statistics, as well as from international trade data from a global Multi-Regional Input-Output (GMRIO) databases. As various GMRIOs exist, this research tests the potential use of four current GMRIO databases in the UKMRIO model: EXIOBASE, GLORIA, the ICIO, and FIGARO.

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As each GMRIO has its own set of strengths and limitation, we evaluate their suitability for the UKMRIO using the GMRIO's source data, annual coverage, regional coverage, industry coverage, extension variables, and ease of use. We conclude that using a combination of EXIOBASE (for the years 2001-2014) and FIGARO (2015-2021) provides the best trade date for the UKMRIO model, based on these criteria.

Introduction

The University of Leeds (UoL) has developed the UK's Multi-Regional Input-Output database (UKMRIO) that is used to calculate the Consumption-based greenhouse gas (GHG) emissions and a number of other environmental and economic indicators for the UK (see Owen et al., 2023). The model considers the emissions embodied in global trade, to estimate the impact of UK consumption irrespective of where production occurred. This is in contrast to other measures, including territorial and production-based emissions, which estimate emissions by where they occur and who owns the production, respectively (see ONS, 2024). The model can also trace UK production emissions and calculate the amount that is embodied in final goods and services for both domestic consumption and exports.

The UKMRIO model is constructed using National Accounts data from the Office for National Statistics and global trade data from EXIOBASE, a global Multi-Regional Input-Output (GMRIO) database. However, various GMRIO databases exist, each with their its own strengths and limitations. The availability and reliability of such databases can impact, for instance, trade policies, carbon agreements, and national demand side mitigation strategies. As accounting from a consumption perspective moves up the political agenda in the effort to reduce emissions (IPCC, 2022), understanding the impact of these GMRIOs on the UKMRIO is crucial.

In this research, we investigate the potential use of four current GMRIO databases in the UKMRIO model. These include EXIOBASE (Stadler et al., 2018), GLORIA (Lenzen et al., 2023), the OECD's ICIO (OECD, no date), and Eurostat's FIGARO (Eurostat, no date). These four GMRIO databases are currently maintained and updated, as well as widely used by researchers and governments. We explore the differences of these databases to improve the robustness of the UKMRIO model.

GMRIO Databases

The current UKMRIO uses GMRIO data came from EXIOBASE, a GMRIO model constructed by the Norwegian University of Science and Technology (NTNU) and partners (Stadler et al., 2018). However, EXIOBASE[1] only uses actual SUT and IOT data until 2011, whereafter a nowcasting method is used to model future years. Meanwhile, other GMRIO (see Table 1) are being developed and becoming more robust. Exploring which GMRIO provides the most robust trade data for the UKMRIO is therefore timely and necessary.

Table 1. GMRIO metadata differences.

	EXIOBASE	ICIO	FIGARO	GLORIA
Data maker	NTNU, TNO, SERI, Uni. Leiden, WU, 2.-0 LCA Consultants	OECD	Eurostat	Uni. of Sydney, CSIRO, Uni. Wien, UNSW Sydney
Year range	1995 - 2022	1995 - 2021	2010 – 2022	1990 - 2027[2]
Countries/regions	49	77	46	164
Industries	163	45	64	120
Extension variables[3]	1115 including CO_2e	CO_2e only[4]	CO_2 and CO_2e	5677 including CO_2e
Final demand	7	6	9	6

*** Note: These metadata are from October 2024.*

While previous GMRIO databases were mainly constructed by academic institutions, multilateral institutions are now involved in the construction of GMRIO tables. GMRIO include Eurostat's FIGARO and OECD's ICIO databases which are based on published and unpublished official data giving them a clear quality advantage. In addition, we test the impact on the UKMRIO of the novel GLORIA database, which is constructed by the University of Sydney and partners, and offers a more detailed level of country and sector disaggregation than other GMRIO databases. A comparison of these databases is shown in Table 1.

Method

We test the trade data improvements in the UKMRIO by analysing consumption-based greenhouse gas emissions (GHG) estimated from each GMRIO. For this, we assess the GHG estimate when GMRIO data is integrated into the UKMRIO. Thus, we make four UKMRIO models, each using trade data from one of the four GMRIOs. A detailed method for the construction of the UKMRIO published via the Department for Environment Food & Rural Affairs (Owen et al., 2023; Owen and Kilian, 2024).

The GHGs reported include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride. All GHGs are converted into their carbon equivalents. Emissions data is taken from each GMRIO data respectively, as this analysis studies the impact from using each GMRIO in the UKMRIO, rather than assessing the differences between individual components of these GMRIO databases.

Consumption-based emissions are calculated using input-output analysis. The Leontief input-output model reports the economic interrelationships between industries throughout the global supply chain (Wood et al., 2019; Miller and Blair, 2022). The fundamental Leontief equation, $\mathbf{d} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$,

[1] EXIOBASE version 3.8.2
[2] GLORIA includes forecasted data for future years.
[3] This shows all extension variables available, not only environmental variables.
[4] In 2023 version

indicates the inter-industry requirements of each sector to deliver a unit of output ($\mathbf{x}$) to final demand ($\mathbf{y}$), where $\mathbf{A} = \mathbf{Zx}^{-1}$, and **I** is the identity matrix with the same dimensions as the input-output matrix (**Z**). To calculate embedded consumption-based emissions (***p***), direct industry emissions (**s**) are added into the equation (Equation 1).

Equation 1.

$$\boldsymbol{p} = \boldsymbol{s}(\boldsymbol{I} - \boldsymbol{A})^{-1}\hat{\boldsymbol{y}}$$

Results

Consumption-based emissions are comparable across the four UKMRIO models (see Figure 1). As the UKMRIO uses ONS data for the domestic portion of the model, the estimates for domestic emissions[5] show high levels of similarity in both absolute emissions estimated and in the emission pattern. Imported emissions are also comparable, although these show more differences than the domestic ones. ICIO and FIGARO estimate higher imported emissions than EXIOBASE and GLORIA. On average, ICIO, estimates imported emissions to be around 40% higher than GLORIA (see Figure 1). However, when comparing this to the percentage change over time, emission patterns show high levels of similarity across all four GMRIO models (see Figure 2). This shows that even when absolute estimates show differences, the longitudinal trends are the same across all four UKMRIO models for most years.

Despite this similarity, 2021 imports data indicates that EXIOBASE data may be less reliable for the UK's footprint in COVID-19 pandemic years, likely because of its nowcasting methodology. While GLORIA, FIGARO, and EXIOBASE all estimate an increase in the 2021 footprint compared to 2020, GLORIA and FIGARO find this increase to be approximately 10%, while EXIOBASE finds it to be 19%. This might indicate that EXIOBASE's nowcasting method is less accurate to measure the impact of the COVID19 pandemic and its bounce-back. As FIGARO uses actual National Accounts for all years, FIGARO data is more reliable to measure this impact. However, FIGARO shows an inconsistency in 2011 in imported emissions, where it shows a notable spike not detected in other GMRIOs. This spike is analysed further below.

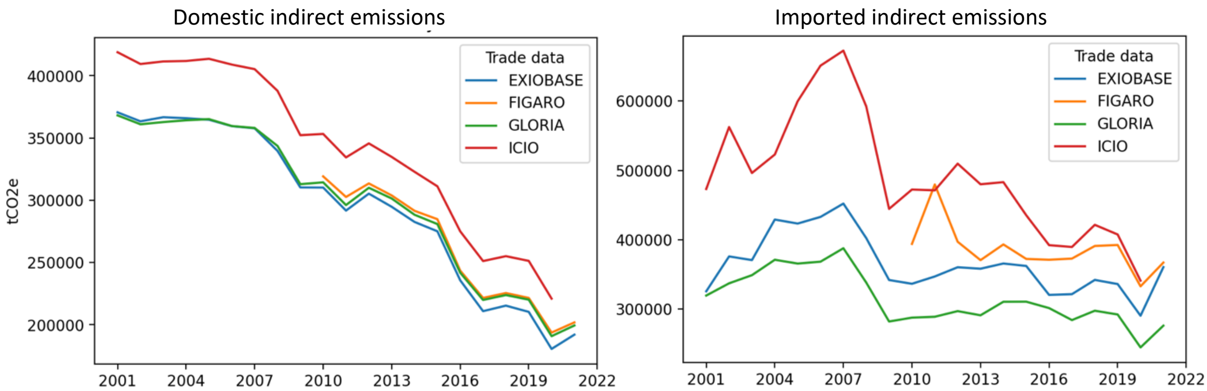

Figure 1. Longitudinal domestic (left) and imported (right) emissions by GMRIO trade data.

Domestic indirect emissions (2010=100)

Imported indirect emissions (2010=100)

[5] Domestic emissions are produced and consumed in the UK, imported emissions are produced outside of the UK and consumed in the UK.

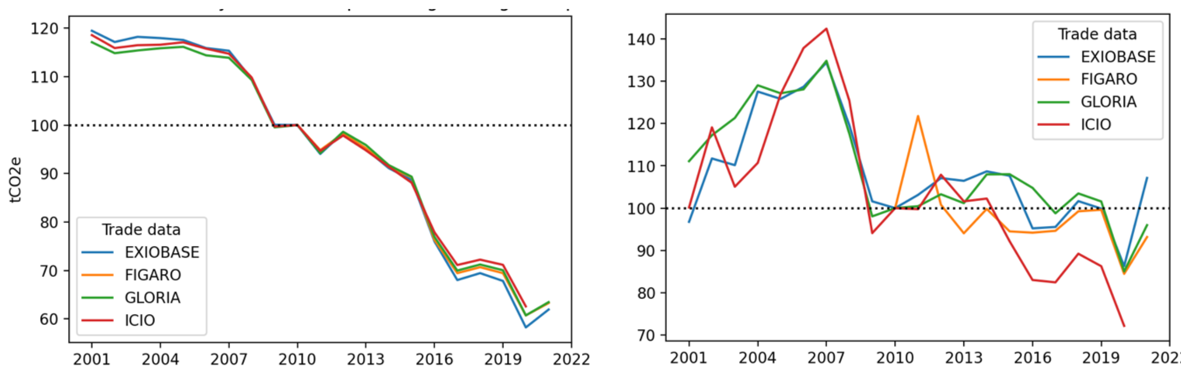

Figure 2. Longitudinal domestic (left) and imported (right) emissions change compared to 2010 (2010=100) by GMRIO trade data.

Next, we investigate emissions by final uses or users and by region of origin. As not all GMRIO databases cover the same years, we use only years present in all GMRIO databases for this analysis. Thus, we investigate mean emissions from 2010-2020. Mean emissions by final demand are comparable across the four versions of the UKMRIO mode (see Figure 3). However, emissions by region of origin show higher levels of difference. For instance, GLORIA's rest of the world emissions are noticeably lower than the rest of the world emissions from the other GMRIO databases. In addition, ICIO estimates more than double the emissions from Russia as all other databases. EXIOBASE and FIGARO, on the other hand, indicate a similar distribution of region of origin, with the exception of FIGARO estimating higher emissions from China. However, this difference is smaller than differences to ICIO and GLORIA. Additionally, the increased emissions from China in the FIGARO data are largely from 2011 and explain the 2011 emissions spike in FIGARO.

Due to this similarity between FIGARO and EXIOBASE, we explore using a combined approach for the UKMRIO. We explore this joint approach due to FIGARO's coverage only beginning in 2010 and the data inconsistency in FIGARO in 2011. The UK's footprint is reported from 2001 every year, leaving a 9-year gap without FIGARO data as well as an additional year with inconsistent data for emissions imported from China. As a result, we investigate using EXIOBASE data from 2001-2014 and FIGARO data from 2015-2021. Choosing 2014/15 as a cut-off year also ensures that the impacts of the 2007/08 financial crisis can be measured, as switching datasets during this time would add uncertainty to the timeline. In 2013 the UK's economy returns to its pre-downturn size (ONS, 2018).

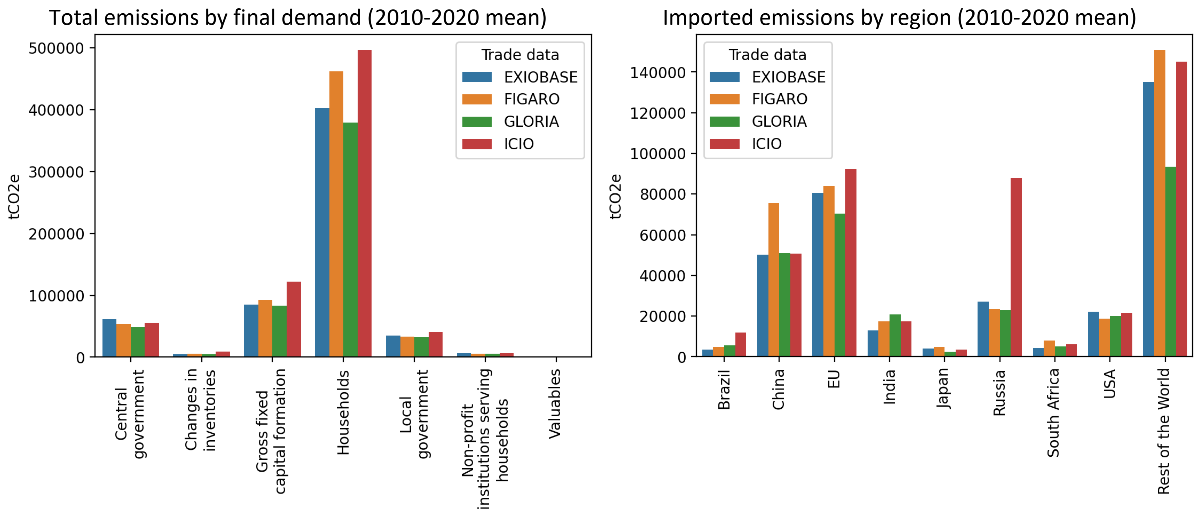

Figure 3. Mean emissions by finale demand (left) and region of origin (right) by GMRIO trade data.

As shown in Figure 4, longitudinal emissions from the FIGARO and EXIOBASE versions of the UKMRIO model align well. Despite some small jumps in emissions from 2014 EXIOBASE to 2015 FIGARO, the order of highest to lowest final demand categories and regions of origin matches well. Moving forward with this combination may therefore provide a feasible and reliable method of calculating the UK's consumption-based footprint for future years. It is possible that this is a data issue, which will be corrected in future releases of the FIGARO GMRIO database.

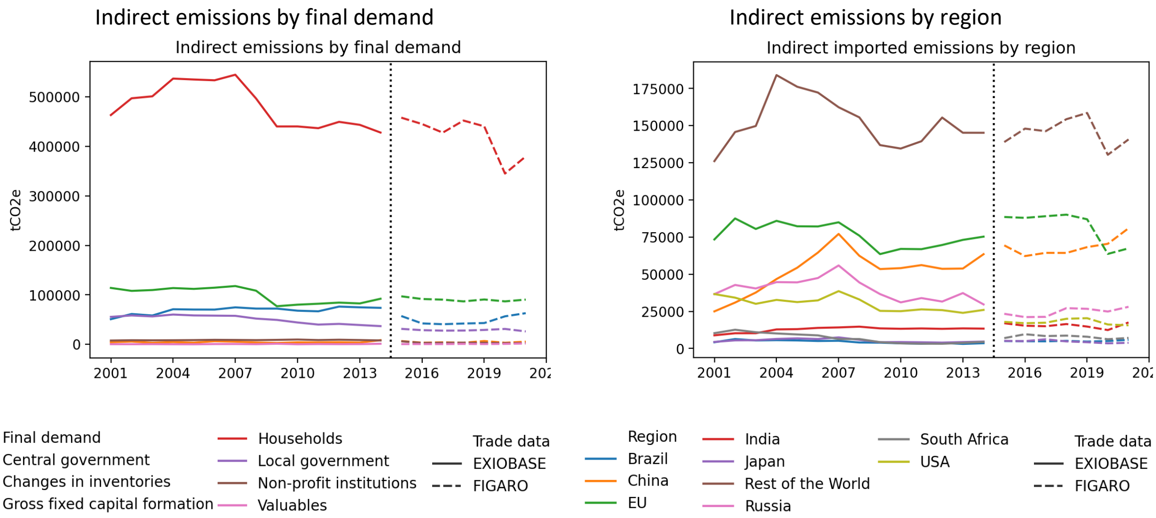

Figure 4. Testing the new UKMRIO model emissions by final demand (left) and region of origin (right).

Discussion and Conclusion

This short report investigates differences in the UK's consumption-based GHG footprint when connecting the UKMRIO model to four different GMRIO databases. The current model uses the EXIOBASE database. EXIOBASE is commonly used by governments and academics to estimate emissions and provides similar emission estimate as other MRIO databases for most years. However, when used in the UKMRIO model after 2019, its nowcasting method adds uncertainties. However, other databases also come with their strengths and weaknesses when aiming to use them in the UKMRIO model (Table 2). For the UKMRIO, FIGARO provides the best balance of strengths and limitations as well as being based on official data. It is updated at the same frequency as the UKMRIO model, provides a similar geographic coverage as the current UKMRIO, and contains extension variables which match the UKMRIO. The ICIO model, on the other hand, is missing the most recent year of the UKMRIO and only has GHG, and not CO_2 alone in the most recent release. Finally, the GLORIA database shares some of the uncertainty from modelling the data as the EXIOBASE dataset, although its 2021 results are similar to FIGARO findings. In addition, while it provides a lot more sectoral and country level detail than ICIO and FIGARO, this also makes loading the data much more computationally heavy. As this level of detail is not needed in the UKMRIO model, FIGARO provides a better balance of detail and ease of use.

Table 2. Strengths and weaknesses of UKMRIO models generated from different GRMIOs.

	EXIOBASE	ICIO	FIGARO	GLORIA
Input data	Data mostly modelled; last National Accounts from 2015	National Accounts used regularly	National Accounts used annually	Data mostly modelled
Annual coverage	Matches current UKMRIO	Misses 2021	Misses 2001-2009	Matches current UKMRIO

Regional coverage in final UKMRIO	UK, Brazil, China, India, Japan, Russia, South Africa, USA, EU, Rest of Europe, Rest of the OECD, Rest of Africa, Rest of America, Rest of Asia, Rest of Middle East	UK, Brazil, Russia, India, China, South Africa, USA, Japan, EU, Rest of the OECD, Rest of the World	UK, Brazil, Russia, India, China, South Africa, USA, Japan, EU, Rest of the OECD, Rest of the World	UK, Brazil, China, India, Japan, Russia, South Africa, USA, EU, Rest of Europe, Rest of the OECD, Rest of Africa, Rest of America, Rest of Asia, Rest of Middle East
Industries	From 163 to 112 in UKMRIO	From 45 to 112 in UKMRIO	From 64 to 112 in UKMRIO	From 120 to 112 in UKMRIO
Extension variables	Matches current UKMRIO	CO_2 only until 2018, CO_2e after	Matches current UKMRIO	Matches current UKMRIO
Ease of use	Easy to implement	Easy to implement	Easy to implement	Heavy computing power needed, large dataset

In conclusion, therefore, we find that FIGARO provides the most reliable input data for international trade for the UKMRIO. Gaps in the annual coverage before 2015 can be filled with EXIOBASE data, as these data are more regularly taken from National Accounts. Moreover, extension variables needed are available. This version of the UKMRIO will be tested going forward, to ensure that the UK's footprint is robust. Further sectoral disaggregation will be assessed in future work.

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