Nowcasting OECD indicators of carbon emissions embodied in international trade

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Abstract
The OECD has established a small working group on better quality and more timely indicators of CO2 embodied in international trade in early 2015 following the call of the OECD Secretary General to make "the organisation more useful and relevant to its Members and Partner countries, by providing them with timely and targeted policy advice, supporting them during the implementation of reforms and quantifying their impact, delivering a whole-of-government narrative and explaining to the public the benefits of difficult decisions." (Letter Mandate 20 January 2015). The objective of this working group is to determine best practices for producing better quality and more timely indicators of CO_2 (and other GHG) emissions embodied in international trade. Particular attention will be given to: a) nowcasting techniques and b) methods for producing improved estimates of emissions by industry – particularly for developing countries and for emissions associated with the energy sector. The methods used here will be compared with ongoing research on nowcasting the EXIOBASE/CREEA data.

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1 Overview and objectives

Overview

1. One of the priorities of the OECD Secretary General is to make "the organisation more useful and relevant to its Members and Partner countries, by providing them with timely and targeted policy advice, supporting them during the implementation of reforms and quantifying their impact, delivering a whole-of-government narrative and explaining to the public the benefits of difficult decisions." (Letter Mandate 20 January 2015)

2. The OECD-WTO joint Trade in Value Added (TiVA) initiative is one of the flagship projects of the OECD. The data system underlying the TiVA indicators is the OECD's inter-country input-output (ICIO) system, a statistical infrastructure, which can not only be applied to issues related to trade in value added, but also used to identify environmental and socio-economic impacts along global production chains and embodied in international trade.

3. Given the substantial data requirements, one of the issues in constructing ICIOs (or MRIOs) is timeliness. Typically, national Supply and Use tables (SUTs) or Input-Output tables (IOTs) are available 3-5 years after the year being measured. This means that, for example, by end-2014 an ICIO based on maximum official statistics can only reasonably be expected to have estimates to 2011. Policy analysts thus question the relevance of many derived indicators.

4. The objective of this informal working group is to determine best practices for producing better quality and more timely indicators of CO2 (and other GHG) emissions embodied in international trade. Particular attention will be given to: a) nowcasting techniques and b) methods for producing improved estimates of emissions by industry – particularly for developing countries and for emissions associated with the energy sector.

5. The working group will provide information for the further development of the OECD ICIO so as to ensure a more timely production of policy-relevant indicators. It brings together experts from countries and academia to take stock of the state-of-the art methodologies and identify best practice methods to be followed by the OECD when producing timely indicators of CO2 embodied in international trade and other indicators based on the OECD ICIO that can be used for policy analysis and policy advice.

Objectives

5. Review of state-of-the-art methodologies for nowcasting in general and methods currently used for nowcasting of multi-regional input-output (MRIO) databases. The review should identify current challenges and provide suggestions for improvements. The review will include minimum requirements on data availability for nowcasting as well as suggestions for sensitivity analyses and quality control. This will then result in a recommendation of methodologies that can be applied to the OECD ICIO. (Deliverable D.1). The most promising methods could further be tested and their results be used for a comparison of the methodologies. (Deliverable D.2).

6. Review and further development of methods for the timely production of CO2 (and other GHG) emission and energy use estimates: The review will include taking stock of existing methodologies (emission inventories and emission accounting systems) and identifying differences in the results of the different methods. (Deliverable D.3) Particular attention needs to be paid to possibilities of improving estimates at the industry level as well as a more timely production of these estimates. (Deliverable D.4)

7. Based on the review of general nowcasting methodologies the WG will assess the possibility of nowcasting CO2 embodied in international trade directly without necessarily nowcasting the individual components of the ICIO system and the production-based emission estimates. (Deliverable D.5)

8. The last step is a comparison of the combination of the methodologies for nowcasting of the OECD ICIO and of the emissions estimates (production-based) to produce better quality and more timely indicators of CO2 (and other GHG) embodied in international trade with methodologies that directly nowcast CO2 embodied in international trade. (Deliverable D.6)

2 Data-sources for carbon emissions at the national and industry level[1]

There are a variety of different databanks on carbon emissions ranging from emissions reported at a country level for all countries in the world to emissions reported in high level of detail for individual countries. The emission data used as an extension to an ICIO system should be comparable across countries and structured similarly to allow for similar processing for inclusion in an ICIO. The UNFCCC website provides an overview on existing international databases on greenhouse gas (GHG) emissions[2].. The main (primary) data sources for GHG emissions are

- UNFCCC (primary) https://unfccc.int/ghg_data/ghg_data_unfccc/time_series_annex_i/items/3814.php
- OECD/IEA (2012, 2013) (primary) http://www.iea.org/publications/freepublications/publication/name,43840,en.html
- EDGAR (not primary) (http://edgar.jrc.ec.europa.eu/index.php#)
- CDIAC (primary) http://cdiac.ornl.gov/CO2_Emission/

The differences between the compilation procedures are the use of emission inventory or the use of data on energy use combined with emission factors. While the UNFCCC data is based on emission inventories that are reported by individual countries and created using the IPCC guidelines (IPCC, 2006), the OECD/IEA data is based on detailed energy balances that differentiate between the uses of various energy carriers by different activities from which emissions can be calculated using emission factors given in the 1996 IPCC guidelines. This latter method is based on the IPCC Tier 1 sectoral approach.

EDGAR is in itself not a primary data source for emission data, rather it is an important supplementary source, which builds on OECD/IEA and IPCC data. EDGAR adjusts the OECD/IEA data "for incomplete or inconsistent time trends"[3]; in addition it uses emission factors provided by the IPCC.

There are a variety of other statistical databanks providing information in carbon emissions; however most only report territorial emission at the country level, which is not sufficient here; see for example the data provided by the United Nations Statistical division for the Millennium Development Goal indicators[2] or the environmental indicators[3]. For the European countries the European Environment Agency (EEA) provides National Accounting Matrices with Environmental Accounts (NAMEA). Similar datasets are also available for some of the other OECD countries and the large emerging economies. Still, this data is, in most cases, based on the data provided by the primary sources mentioned above and then adapted to meet the sector classification of the National Accounting Matrices. Given the difference in the sector classification of the OECD-ICIO and the existing NAMEAs, it is therefore suggested to directly use one of the primary data sources.

Table 1 lists the source of the territorial carbon emission data used in different existing global ICIO/MRIO systems to estimate consumption-based emissions.

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[1] This section is based on Section 4 of the final report of INTELLECTUAL SERVICES 2013/STI/EAS RELATIVE TO CONTRIBUTING TO FURTHER DEVELOPMENT OF OECD'S INTER-COUNTRY INPUT-OUTPUT (ICIO) SYSTEM by Kirsten Wiebe, July 2014.

[2] https://unfccc.int/ghg_data/ghg_data_non_unfccc/items/3170.php

[3] http://edgar.jrc.ec.europa.eu/methodology.php

Table 1 CO2 data used in existing ICIO/MRIO databases[4]

Database	Emission data	Source
EORA	EDGAR	Lenzen et al. (2012, 2013)
EXIOBASE / CREEA	Own calculations based on IPCC emission factors*	Tukker et al. (2009), CREEA Deliverable 6.1
GRAM	OECD/IEA emissions from fuel combustion combined with IEA energy balances	Bruckner et al. (2012), Lutz & Wiebe (2012), Wiebe et al. (2012a,b)
GTAP	CDIAC and NAMEAs	Davis and Caldeira (2010), Peters et al (2008, 2009, 2011, 2012), Peters and Solli (2010)
OECD	OECD/IEA emissions from fuel combustion	Ahmad and Wyckoff (2003), Nakano et al. (2009)
WIOD	Own construction of NAMEA data based on EEA/EURSTAT or national NAMEAs, EDGAR, EXIOPOL (for international bunkers) and, in case no emission inventories were available, IEA energy balances combined with IPCC emission factors.*	Timmer et al. (2012), Genty et al. (2012)

According to Peters and Solli (2010, p. 108) "the officially reported emissions data to UNFCCC is not suitable for economic modelling as it is not consistent with the principles used in the System of National Accounts." In addition to this, the ease of using emission data within the OECD-ICIO system is an equally important factor. The ease of use is primarily given by the availability of emission data at the sectoral classification of the ICIO system. Given the sectoral detail available in the OECD/IEA emission data in addition to this data being "in-house", the OECD/IEA CO_2 emissions from fuel combustion data is used to complement the OECD ICIO system with an emission extension. However, OECD/IEA database only covers emissions of IPCC emission category 1A. The emissions from the remaining categories are neatly collected in the EDGAR database, which can also be used to fill the gaps in the 1A emission data.
Important: Both OECD/IEA and EDGAR indicate that the emissions provided in their databases may not amount to the exact same total as reported by countries to the UNFCCC. The OECD/IEA report deviations of up to 5% for the Annex I countries and larger deviations for some of the other countries (IEA 2009, p.I.4 and I.5). PBL and JRC (2013, Table A1.1, p.48) report the deviations for selected countries to be between -2% and +13% as an average across years of the EDGAR data from the UNFCCC data.

[4] Table from final report of INTELLECTUAL SERVICES 2013/STI/EAS RELATIVE TO CONTRIBUTING TO FURTHER DEVELOPMENT OF OECD'S INTER-COUNTRY INPUT-OUTPUT (ICIO) SYSTEM

3 Estimation of CO2 emissions factor using fuel combustion emissions and IO/SUT data sources

< TBC >

C1,…, C34 = Emission by industry / Output by industry
C*h* = Emissions from fuel combustion by domestic household / household consumption of Petroleum products

EF*f,j* = Emissions by economy activity *j* from fuel product *f*.

The industry dimension of IEA CO2 emisions data from fuel combustion does not fully comparable with industry activity in Input-Output/ Supply-Use tables. For example, *transport* includes emissions of transport activities in various sectors including household consumption. The total reported transport emission for each fuel type is split using the intermediate consumption by using industries and households.

Transport emissions factor by individual industry and household for each fuel product respectively are estimated as
Cfj = (EF [f,T) * Zfj / sum_j (Zfj+HCf)) / Xj
and
Cfh = (EF [f,T] * HCf / sum_j (Zfj+HCf)) / HCf

where EF [f, T] is emissions from fuel f combustion in transport activity, Xj is output of industry j, Zfj is intermediate consumption of fuel f by industry j reported in I-O / SUT (total table ie. domestic +imports).
HCf is household consumption (ideally, consumptions fuels for operation of personal transport equipment, COICOP 07.2.2).

<<< Note that fuel consumption by international marine bunker and international aviation can be also allocated using exports by fuel product >>>

Then, the emissions factor vector feeds into the global CO2 multiplier is aggregating the emissions from all fuel products

cB = diag [sum_f C f1 … sum_f C fN] $(I-A)^{-1}$

where N is number of industry, A is global Leontief inverse

The total CO2 emissions by transport activity for each country in this framework is defined as

Consumption based CO2 emissions = cB * FD + sum_f (Cfh * HCf),
F = final demand of all countries
Production based CO2 emissions = sum_f (Cf1 * X1) + … + sum_f (C fN*XN) + sum_f (Cfh * HCf),

We have three separate categories of emissions sources: electricity, transport, other industrial activity

4 Calculating emissions embodied in international trade and final consumption

4.1 Trade related indicators

4.2 Final demand related indicators

5 Nowcasting

Banbura et al. (2010) define nowcasting as "**the prediction of the present, the very near future and the very recent past**". Nowcasting is usually necessary because the data politicians, economists and other scientists need for their analyses are only available with a time lag. Most of the nowcasting literature in the broad field of economics deals with the nowcasting of key macroeconomic data such as GDP or its components. The frequency of publishing this data is substantially higher than the frequency at which IOTs or SUTs are published, but the underlying approach of nowcasting is the same: GDP is constructed from various components, one being industrial production. This indicator is available on a monthly and thus more frequent basis, than the quarterly GDP estimates. Having data on this more frequent indicator enables statisticians to estimate GDP at a higher frequency as well. In more general term: every indicator available at a low frequency can be "nowcasted" using data available at a higher frequency, that are major components or drivers of the development of the indicator in question.

However, to apply the advanced econometric techniques such as bridge equations (Trehan, 1989; Parigi and Schlitzer, 1995; Parigi and Golinelli, 2007; Rünstler and Sédillot, 2003; Diron, 2008), MIDAS (mixed data sampling) regressions (Clements and Galvão, 2008; and Marcellino and Schumacher, 2008) or the combination of a factor model with quasi maximum likelihood estimation (Forni, Hallin, Lippi and Reichlin, 2000; Stock and Watson, 2002; Doz, Giannone, and Reichlin, 2006), the number of available observations for the problem at hand is too small or, in case of the bridge equation, the underlying econometric problem is slightly different, as the ICIO data is not available in regular frequencies for which lower regular frequencies need to be estimated.

IOTs and SUTs are not available on a yearly basis, thus the nowcasting of the ICO system underlying the embodied carbon calculations is a complex task. Demand-based emissions data only exist for the years for which the ICIO is available, thus a direct approach to nowcasting demand-based carbon emissions using econometric techniques is difficult as well, again due to the limited number of observations available. Nowcasting of territorial carbon emissions, however, can be done using simple econometric techniques, as data on the industry level is available for the years since 1970 for many countries, if estimates or real data points of the influencing factors exist.

Three basic approaches for nowcasting demand-based carbon emissions can be distinguished:

1. directly nowcasting the demand-based carbon indicators using advanced econometric techniques;
2. estimating the indicators based on constant demand-based carbon to final demand ratios, and,
3. nowcasting both the underlying ICIO system and territorial carbon emissions to then obtain demand-based carbon emissions using the ICIO approach.

5.1 Directly nowcasting the demand-based carbon indicators

As mentioned above, directly nowcasting demand-based emissions using advanced econometric techniques is impossible due to the limited number of observations.

5.2 Estimating demand-based carbon indicators using constant ratios

The second approach, estimating the indicators based on constant demand-based carbon to final demand ratios, is based on the idea that the carbon intensity of demand does not quickly change in the short run, so that it is possible to approximate the total amount of demand-based emissions based on most recent final demand data by industry, i.e.

- CO2inFD [2012] = CO2inFD [2011] / FD [2011]* FD [2012]
- CO2inFD [2013] = CO2inFD [2011] / FD [2011]* FD [2013]
- CO2inFD [2014] = CO2inFD [2011] / FD [2011]* FD [2014]

The problem however is that this does not consider quickly changing trade relations. Bearing in mind the changes in trade relations, however, is inevitable since the carbon intensity of production varies greatly across countries (include figure on this) and thus significantly influences the total level of carbon embedded in final demand.

< Idea >

Use most recent trade data and apply this approach to approximate emissions in trade (BTDIxE available until 2014, i.e. t-1) and then translate this into emissions embedded in FD

- imported final demand goods are covered
- total carbon trade balances are covered
- absolute level of demand-based emissions are not covered, because of unknown final demand at industry level (for domestically produced final goods)
  - most important industries: electricity production data by fuel
  - emissions from transport

→ Q1: would this be sufficient information for policy makers?

5.3 Nowcasting the underlying system

This approach uses the exact same approach to approximating demand-based carbon emissions from territorial carbon emissions as the calculation of historical demand-based carbon emissions; each part of the system, final demand, intermediate input structure, output and production-based carbon intensities or absolute emission levels. This in turn can be split into two problems: nowcasting the underlying ICIO system and nowcasting related production-based carbon emissions.

5.3.1 Nowcasting the ICIO system

- BTDIxE data available until 2014
- use OECD/UN SNA aggregates for final demand components (households, government, GFCF) available until 2013/2014
- use OECD/UN SNA by activity data until 2013/2014 (t-1 to t-2) for output and value added, adapt VA/output ratios accordingly and rescale coefficient matrix.

Update the ICIO system

Option I (this is what is done at OECD/STD so far):
Use FD aggregates and constant industry shares, update intermediate flow matrix using RAS to align with new FD and VA and output data

Option II:
Calculate FD by industry from output and input coefficients: $FD = (I - A)x$

→ Q2: which of these two is intuitively more appealing?

5.3.2 Nowcasting production-based carbon emissions

Before presenting some options on how to nowcast territorial (production-based) carbon emissions, please note the following:

> *"To estimate emissions, the countries that are Parties to the Climate Change Convention (UNFCCC) use complex, state-of-the-art methodologies recommended by the Intergovernmental Panel on Climate Change (IPCC)."*[5]

Due to the complexity of the estimation process, detailed as well as aggregate CO2 data from IEA is only available with a lag of two to three years; the time lags from other data sources are even larger. The challenge therefore is to estimate emissions levels for the most recent two to three years. Two different approaches can be followed:

1. Estimating emissions data using constant emission factors based on their origin, i.e. fuel use and calculating emission intensities from ICIO output data
2. Directly estimating the development of emission intensities, i.e. emissions per unit of output.

Nowcasting emission intensities

Option I:
Data on total fuel use by the main fuels is usually available a little faster than emissions. Using constant emission factors, corresponding to each fuel, emissions can be estimated on the aggregate level. However, this underlying data is also not available for the most recent year and would need to be estimated as well.

Option II:
Use simple econometric techniques (time series/panel data) to extrapolate the trend of emissions per output (aggregate, or if possible on the industry level). IEA emissions data on the industry level is available from 1970/1980 for most countries in the ICIO, output data on the industry level, see ICIO system.

→ Q3: which underlying data set is better?

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[5] http://mdgs.un.org/unsd/mdg/Metadata.aspx?IndicatorId=0&SeriesId=750

6 Results

- Selected methods (the only two that are feasible, details to be discussed – see questions Q1, Q2, Q3 above)
    - “constant ratios”
    - “underlying system”
- Results of applying methods to historical data points, thus having the actual ICIO as a comparison
    - Comparison at industry level
- Compare historical and nowcasted demand-based emissions to results of other ICIO databases

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