Input-Output analysis and the richness of applications for environmental analysis: A researcher's perspective

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Introduction

The development of global, coherent input output tables has led to the availability of a rich policy tool ideally suited for a globalized world. Yet, we argue that there is still ample scope for further application of input output tables as a complementary environmental policy support tool. We discuss several examples and their results to demonstrate how IO analysis can be applied to feed environmental policy decisions with quantified measurements and potential impact assessments of (hypothetical) policies.

The increase in the potential of IO for environmental policy is closely related to the emergence of interregional tables which have the explicit advantage of integrating the entire global economic system without a need to make cutoffs in terms of the boundaries of the system which one is exploring. This is specifically of interest for environmental analyses where a global perspective is at times required in analyzing problems that go beyond the territorial boundaries of a country (e.g. climate change, resource depletion,…). Yet, the application of these IO models for environmental policy purposes can still be hindered if environmental policy is set at a subnational rather than the national level. This is the case for the Belgian region of Flanders, which also differs substantially in terms of industrial structure from other Belgian regions, thereby making the interregional IO models insufficiently detailed to apply in Flemish environmental policy analysis.

To this end, we integrated the regional Flemish IO model for the year 2010 constructed by the Belgian Federal Planning Bureau with the EXIOBASE interregional model (Wood et al., 2015; Stadler et al., 2018). While the Flemish model has less industry detail (124 industries) than the EXIOBASE model (163 industries per country), both apply the same type of industry classifications which improves the integration process. Additionally, specific Flemish emission and material intensity extensions and economic extensions are added to the integrated IO model to accommodate the needs of local environmental policy analysis. The final extended IO table can be applied in multiple ways to support environmental policy. In this paper we discuss two different application groups and show several practical applications of how IO tables can be applied by researchers to analyze environmental policy.

Applications of IO tables for environmental policy analysis

Measuring the environmental footprint of a region's consumption

One general application of the interregional input output tables concerns the measurement of the material or the carbon footprint of consumption at a regional level. To this end, we used our enhanced IO table to analyze the carbon footprint of the Flemish consumption. Our analysis showed that food, transport and housing make up over half of the total carbon footprint of consumption. Our findings also indicate how the carbon footprint of consumption in small open regions can differ substantially from that of its production structure. This is highlighted in Figure 1 and Figure 2. Figure 1 shows that the evolution of the carbon footprint of Flemish consumption in 2003, 2007 and 2010 is opposite to the evolution of the territorial greenhouse gas emissions in Flanders: While the overall carbon footprint increases, territorial emissions are decreasing. Given its small and open character, a considerable fraction of the carbon footprint (and other types of footprints associated with Flemish consumption) of Flemish consumption results from activities abroad. Figure 2 shows that around half of the Flemish carbon footprint can be retraced to other European countries, while less than 20 percent is situated in Flanders itself. It was shown that the fraction of consumption's carbon footprint that originates from outside the borders of the region itself is also increasing over time. The evolution and decomposition of this carbon footprint offers important lessons for policy makers in terms of combatting climate change while highlighting the need to think trans-territorially.

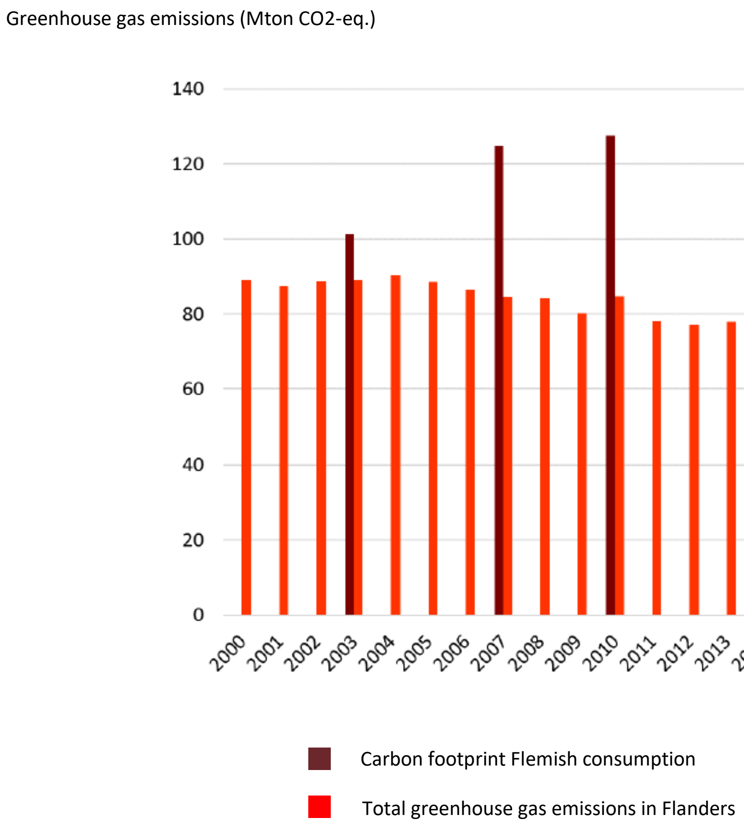

Figure 1: Evolution of Flemish carbon footprint and territorial emissions from 2000 to 2014 (source: Vercalsteren et al., 2017)

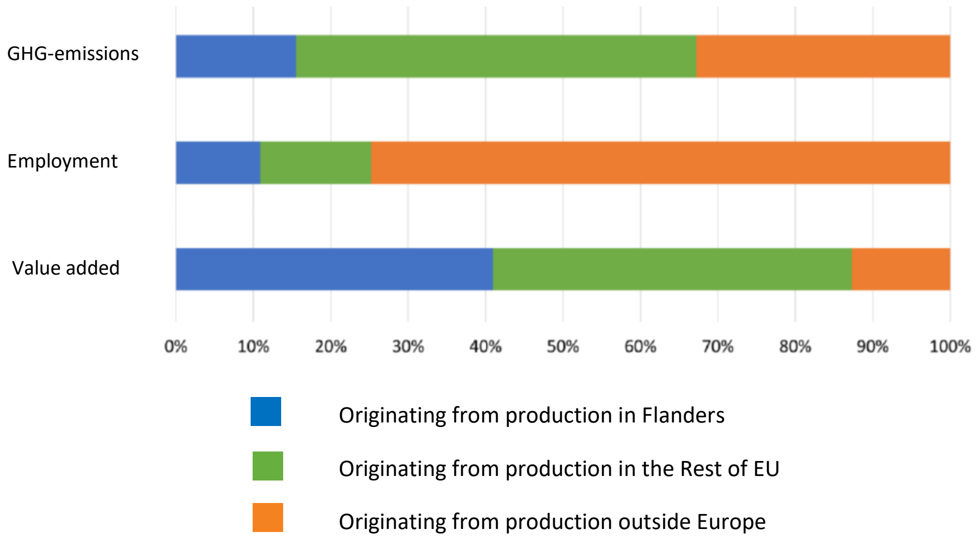

Figure 2: geographical distribution of carbon, value added and employment footprint of Flemish consumption in 2010 (source: Vercalsteren et al., 2017)

The large interregional tables also allow for consistently comparing measurements across different countries or within a group of countries (e.g. Europe). Therefore, the tables can offer strong underpinnings to not only local (regional or national) policy, but also European policies, to monitor whether earlier policy objectives are being met. In our work, we analyzed the food system from a European perspective and decomposed the greenhouse warming potential of the food system in a food mix effect (effect of changing composition of the consumed foods), the food consumption volume effect (effect of consuming more food) and an intensity effect (effect of changes in the greenhouse warming potential per unit of food consumed) using the decomposition methods developed by Dietzenbacher and Los (1998). We found that the carbon footprint of the European food consumption system remained more or less stable over the period from 1995 to 2011. However, this was despite an increase in the volume of food that was consumed which was largely offset by the decreasing global warming potential of the food production system and, to a much lesser extent, a change in the consumption mix. Figure 3 presents the results of this decomposition exercise.

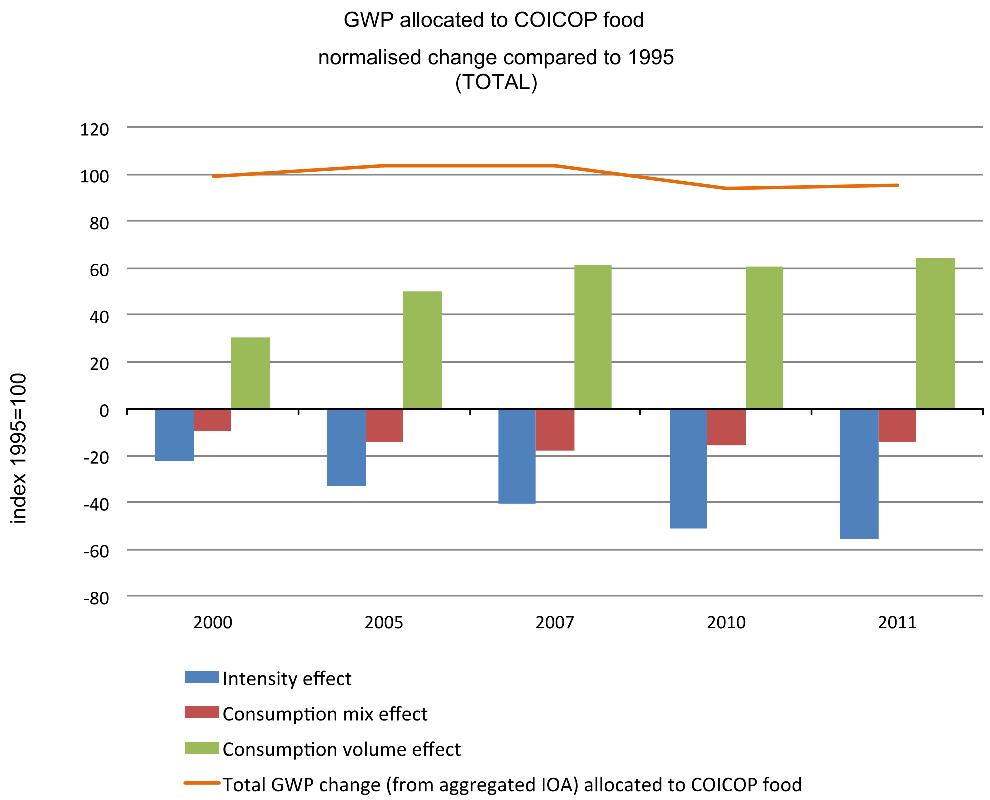

Figure 3: Decomposition of the carbon footprint of European food consumption (source: EEA, 2018)

The above examples indicate that there is ample scope for the application of interregional IO tables in measuring and monitoring the current economy. Yet, the combination of these tables with other rich data is also possible. For instance, detailed household budget surveys (HBS) can provide further insights that are relevant to policy makers that need to consider multiple topics such as climate change but also social inequalities in introducing apt policies that address environmental problems. To this end, we combined the Flemish HBS, which contains a greater level of detail with respect to the consumption of products, with our IO table that integrated the Flemish region. This was done based on an official table that indicates how the products included in the HBS (these are reported by COICOP category) are linked to the consumption of industry products (in the case of an industry-by-industry table) or the products used in the IO tables (in the case of a product-by-product table). The Flemish HBS also report data based on the social background of the households (by income decile, by composition of the household, etc.).

As one would come to expect, we found that the carbon footprint of households rises with the income level of the household. However, for determining environmental policy while considering social aspects, the most interesting findings are obtained by deconstructing the carbon footprint. For instance, the carbon footprint of low income households is mostly due to housing while food and transport increasingly matter as households start earning a higher income. Admittedly, caution remains warranted while interpreting these results as differences in expenditure patterns could equally indicate quality differences that translate into higher expenditure. Hence, patterns do not immediately reflect a greater volume consumed but an interaction of price and volume which requires further exploration. This is not possible with the macro-level IO tables where a single intensity (CO_2 eq. per euro expenditure) is applied for each industry or product in the IO tables. Nevertheless, the results form a fertile starting base from which to further explore the discrepancies in environmental impact between the different income deciles. The tables are thus a helpful tool in constructing socially just environmental policies which are more likely to be broadly accepted within society.

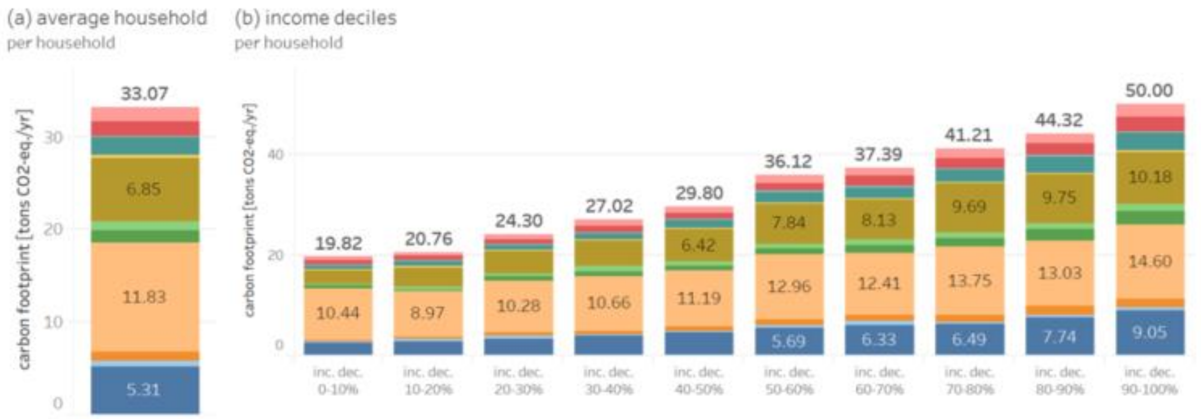

Figure 4: Carbon footprint of households by income decile (Source: Christis et al., 2019a)

Analysis of environmental policy scenarios

As argued, the holistic nature of the IO tables allows for measurements and all-encompassing indicators. However, they also offer an interesting tool for scenario-building. Here, we discuss three

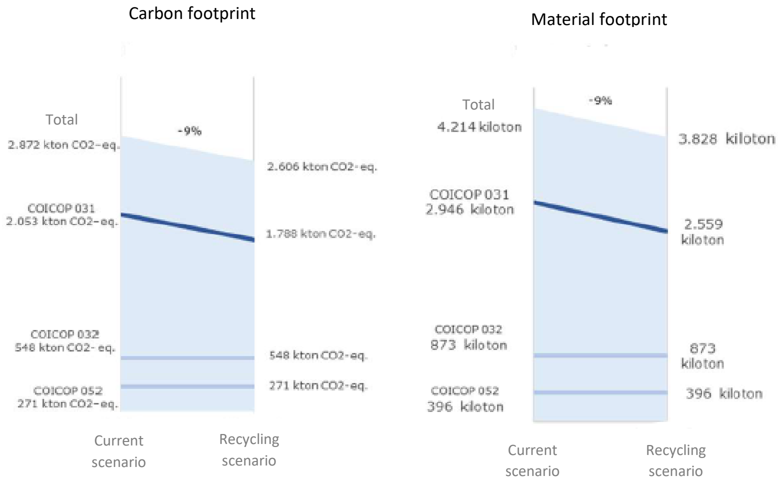

Figure 5: Carbon footprint and material footprint outcome of scenario of applying recycled textile fibers in clothing to replace half of virgin fibers (source: Christis et al., 2018). COICOP 031 is clothing, COICOP 032 is footwear and COICOP 052 is household textiles; Recycling only applies to clothing items and is upscaled for all Flemish clothing consumption.

such analyses that we have performed. In the analyses we focused exclusively on a certain product class (textiles, food, glass) and then modelled an alternative to the current system by adjusting the demand structure and/or the production structure inside the IO tables according to the specified scenarios.

In a first analysis, we examined how the implementation of certain circular economy strategies would help in reducing the carbon footprint/material footprint of the consumption of textile products. We built one scenario where production was altered so that a substantial fraction of recycled textiles were used and another scenario where items of baby clothing were leased and clothing items were expected to be reused for up to six times. In both cases we based the scenarios on real-life examples to ensure scenarios were built under realistic conditions. We show the results of the recycling scenario in Figure 5. Specifically, the scenario was based on a case where jeans fibers were recycled and just over half of the textile fibers in the new jeans pants consisted of these recycled fibers. All other fibers were virgin and sourced from within Europe. This scenario was then extrapolated to the rest of Flemish clothing consumption. The results show substantial reductions in carbon and material footprints as a result of the reduced demand of virgin fibers.

In a different analysis we upscaled several scenarios associated with a more sustainable food and textile consumption. However, this time we looked at generic policy measures that had no direct foundation based on existing real-life micro-economic cases. One such policy was the implementation of a WHO-based diet that amongst others shifts food consumption away from meat consumption. In an attempt to balance the overall nutritional value of the diet, a larger part of food consumption was shifted to the consumption of other nutritious food items (e.g. legumes). However, such diets also entail changes in expenditure patterns and thus the environmental impact of the adjusted consumption pattern needs to be accounted for. Based on the income decile data from the HBS, we constructed simplified income elasticities for each consumption category included in our analysis to approximate to which consumption items the additional disposable income would be assigned. Next, we analyzed what the rebound effect associated to this shift in the consumption pattern would induce in terms of carbon footprint. This is presented in Figure 6. While overall the analysis is highly simplified, accounting for the rebound effect directly indicates to policy makers that each policy actions brings about a complex reaction from the consumer that needs to be accounted for in constructing effective environmental policy measures.

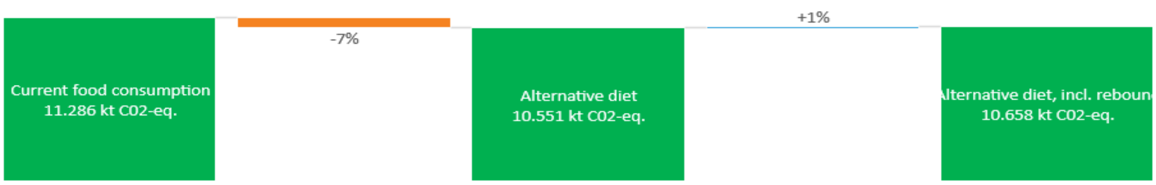

Figure 6: Change in carbon footprint from switching to an alternative diet and accounting for the rebound effect that occurs subsequently (source: Christis et al., 2019b).

It is however important to note that another sustainable food consumption scenario also revealed some of the limitations of applying IO work for shifting consumption patterns between detailed products with widely varying carbon footprints. There, we analyzed a shift in the consumption pattern away from imported fruit and vegetables produced in distant countries to consumption of local fruit and vegetables. However, as a considerable fraction of Flemish fruit and vegetables are produced in greenhouses, the analysis showed such a transition was deleterious with respect to the reduction of greenhouse gas emissions. The limitations of the IO table thus need to be carefully considered in defining the scenarios that the researcher wishes to analyze in order to avoid confusion in communicating the final results.

By implementing the scenarios at a macroeconomic scale, one is able to assess what the overall impact is of the relevant strategy in a world where all else remains unaltered. In most of the analyses for the food and textile system, global greenhouse gas emissions decreased, but as activities shifted more towards Europe and Flanders, the local greenhouse gas emissions increased. Aside from changes in the geographic situation of environmental impacts, it was also possible to observe shifts between industries and to show a decomposed picture of how the supply chain was affected. Such scenarios also give an indication of economic consequences, as alterations in the production chain shift jobs and value added from outside of the EU to inside the EU. However, it does so exclusively from a partial equilibrium perspective, thus assuming perfect adjustment and flexible supply in the other factor markets.

Of course, identifying individual (incongruous) scenarios does not suffice when a number of new consumption and production strategies need to be implemented simultaneously to achieve strict goals. In the case of our analysis of the food and textile system, we also adjusted the IO model so that one combined strategy is implemented. Hence, rather than exclusively creating separate models for each strategy, we also created an integrated model that combined the different policies for each consumption system (textiles or food) and explored how the combined outcome differs from the outcome one obtains by accumulating the results of each individual strategy.

Alternatively, a wide array of impact assessments could also be constructed. For instance, in our analysis of the glass industry we embedded a fully linear industry, i.e. using only primary materials, and an industry using recycled glass exclusively in the same model. By adjusting the shares of both industries, it is possible to explore what the material footprint, carbon footprint and economic consequences could be from switching from a fully linear production system to a system that re-uses glass accounting for current technical feasibility or (hypothetically) only uses recycled glass. In said way, a range of estimates are obtained that vary depending on the exact definition of the scenario. This serves policy by indicating how certain efforts will translate into environmental savings.

Conclusion

As we have shown, there are various applications for IO models to guide policy. Moreover, when regional trade and input-output tables are available, these can be integrated into existing interregional tables to account for region-specific consumption and production patterns. However, it remains important that upon choosing the ideal tool for environmental analysis, one remains aware of the strengths and the limitations of IO-based analysis. It can largely be considered as a tool that is complementary to existing environmental policy tools. For the purposes of measurement and monitoring policies, it is more holistic in nature than relying on bottom-up analysis exclusively, but the latter type of analysis can show important shifts that offer further clarification to the macro-economic trend. Additionally, the lag in the availability of IO tables make it necessary to keep a close eye on non-IO based measures as well.

When it comes to building hypothetical scenarios, IO models offer a flexible tool that integrates the entire world-economy into one model. However, it differs from general computable general equilibrium (CGE) models in that the changes that are applied to the model only lead to a new partial equilibrium in the production industry. By associating the relevant extensions we can gather an idea of what occurs on the labor market, but the labor market itself is not balanced. Nevertheless, CGE models with the same global depth as the interregional IO tables are difficult to construct and more computationally intensive. IO thus deserves its place among these tools to support environmental policy and its further applications and use to policy makers needs to be further considered among researchers.

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