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Linking NAMEA and Input output for 'consumption vs. production perspective' analyses

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Linking NAMEA and Input output for 'consumption vs. production perspective' analyses.

Evidence on emission efficiency and aggregation biases using the Italian and Spanish environmental accounts

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Abstract

We integrate input output and NAMEA tables for Spain and Italy in 1995, 2000 and 2005, in order to address the hot policy issue of sustainable consumption and production. A comparison of a production and consumption perspective may have relevant policy implications. We deal with the domestic technology assumption and primarily the aggregation bias that may result when calculating indirect emission using different sector aggregation in the analyses (e.g. 16, 32, 50). Extended Input output analysis provides analyses of the emissions embodied in domestic consumption and domestic production by considering the structure of intermediate inputs and environmental efficiency in each production sector. Our empirical findings show that different sectoral aggregation significantly biases the amount of emissions both for the consumption and the production perspective, though differently in the two countries. Italy surprisingly show consumption/production ratios around or lower than one, but in line with some major work at EU level. Our results thus suggest that special attention must be paid when interpreting the EE-IOA of country estimated amounts of embodied emissions, both in domestic final demand and those directly associated with the production sectors when the sectoral aggregation level has a low definition as considered in some recent similar studies.

Keywords: NAMEA, extended input output, sustainable consumption and production, aggregation bias, final demand

JEL: Q53, Q56, D57, F18

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1. Introduction: NAMEA, extended input ouput and sustainable consumption and production issues

1.1 The background and the rationale within an economic-policy perspective

The integration of the National Accounting Matrix including Environmental Accounts (NAMEA) and input output (I-O) tables (usually referred to as Environmental Extended-Input Output Analysis - EE-IOA based on National Accounting Matrices including Environmental Accounts – NAMEA - data) is a challenging but promising way to analyse the factors behind income-environment relationships in international settings, with sound overlapping with research fields such as Environmental Kuznets curves (EKC), IPAT (Impact Population Affluence technology) based analysis, trade-related and globalization-dependant environmental impacts and 'sustainable growth and resource productivity' analysis (Marin and Mazzanti, 2011; Cole, 2004; Copeland and Taylor, 2004; Frankel and Rose, 2005; Bleischwitz et al., 2009). More specifically, it can be used to disentangle production and consumption perspectives on sustainability through the detailed sector-based information provided by the two frameworks. The sector based perspectives is crucial in the current analyses of economic-environmental dynamics since it may shed light on structural phenomena that neither macro nor microeconomic settings can provide due to opposite limitations (too large, too narrow focus). The meso level is capable of unveiling what the changing composition (e.g. industry mix, increasing share of services in advanced economies) and new specializations of our economies mean in economic and environmental terms. New sources of competitiveness and their environmental impacts are possibly analysed in a way that also provides relevant food for thought to environmental and industrial policies, that are in this perspective necessarily integrated.

National and international sources of environmental effects can be ascertained in strict connection with streams of literature such as the 'ecological footprint' kind of analysis and decomposition analyses, that are probably the closer fields. The production and exploitation of EE-IOA and NAMEA is also heavily embedded in the wide research and policy realm that deals with 'sustainable consumption and production (SCP)' issues (Harris, 2001), a key pillar of current and future EU policy efforts. The analysis of sector specificities, direct and indirect emissions, the role of international trade are ways to make concrete and operational the discussion on the Green economy. EE-IOA links in this discussion to another quite concrete issue: economic and resource productivity dynamics (OECD, 2011; ETC/SCP, 2011a, which among other findings highlights the increasing role of trade and that resource productivity has improved less than labour productivity, a signal of potential un-sustainability; Mazzanti and

Zoboli, 2009)[2], insofar the changing industry mix (will a service based economy be associated with higher resource efficiency? The persistence of manufacturing in some countries as Germany, are key issues[3]) and the environmental impacts embodied in trade contribute to the overall resource productivity performance of our economies, which is a first signal of sustainability (complementary to capital based view of sustainability such as the Genuine saving approach). Resource productivity and its sub-themes are manageable from both analytical and political points of view. A 'Resource Efficiency Roadmap' is currently under development by the European Commission. SCP is the main operational framework, where EE-IOA plays its role.

It is worth noting in the discussion of the various EU strategies, that EUROSTAT is aimed at releasing a full 2000-2006 NAMEA for EU27 that will support EU SCP policy efforts, and for the first released in April 2011 an indirect emission dataset that should take into account the 'consumption perspective', as a complement to the production view offered by original NAMEA. The ongoing status of the project, which is a key pillar of EU data production, is summarised in EUROSTAT (2011).

A comparison of the production vs. consumption perspective can have important policy implications. Substantially, the *production perspective* takes the view of a country *producer responsibility* considering direct emissions in a country due to domestic production processes that generate pressures and impacts *within* the country. On the other hand, the *consumption perspective* (or country *final user responsibility* as appropriately suggested by Serrano and Dietzenbacher, 2010) investigates the impacts due to domestic consumption (*all* domestic final demand and not exclusively from household consumption) regardless where they have been produced. So the two perspectives take into different consideration the direct effects of the needs of society when producing the products needed in a particular domestic territory (regardless if domestic consumers or consumers abroad – exports - caused the emissions) and the country's responsibility for emissions generated globally (including the embodied emissions in imports) in order to satisfy its domestic final demand.

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[2] We also refer the reader to the web site of the EU topic centre on Sustainable Consumption and production, http://scp.eionet.europa.eu/.

[3] Another key issue that gives value to EE-IOA analyses is the observed increasing interdependency in production: the intensity of intermediate inputs in the production of total ouput has increased following service-manufacturing stricter inter relationships. I-O based analyses and sector specific investigations are motivated by those facts (EC, 2009). Recent evidence seems to suggest that resource efficiency trends are driven more by technology than composition effects. This is in part dependant on the gloomier performance of services when indirect emissions are accounted for, that this paper also discusses, and in part relates to the fact that increasing inter-industry linkages are part of the technological dynamic (e.g. outsourcing of production, vertical disintegration, etc..).

Traditionally, environmental policy focused mainly on production activities as sources of impacts and the actor to be targeted by legislation and regulation (examples are carbon taxes, emission trading). Looking at the role of final consumption for vertically integrated domestic and international impacts can push policy attention towards the possible role of the consumer as an actor of environmental policies, together with the international responsibility for spillover of impacts abroad. In that direction, policies on the supply side may be find complements in environmental policies that target consumption (labelling, but also green consumption taxes, taxes that correlate with the embodied emissions or materials in the production of the good). The revenue accruing from ecological taxes can also find a possible use in the funding of 'product innovation' aimed at resource efficiency.

A key issue is the modelling of the technology associated with imported goods (produced abroad by the stimulus of domestic consumption), which is tricky in practice given the scarcity of data at that level of detail and at sector level. Given the technology, (net, accounting for export and import, see Levinson, 2010) trade-embodied pollution arises as a structural phenomenon of the globalised economy, depending on the systematic difference between the composition of domestic and foreign production. These increasing differences may be responsible of a 'burden shifting' in terms of environmental impacts relocated abroad (then imported, thus appearing in a consumption view of sustainability). A burden that can depend upon differences in policy stringency (the pollution haven hypothesis), but also on structural facts of changing specialization and industry mix. Structural imbalances may appear in globalised – difficult to regulate – markets, than risk of being not sustainable if we take a worldwide perspective. Advanced countries environmental performances in the production side (e.g. EKC) may appear better than what are in reality. Systematic differences can fast change given that the production specialization of a country is usually more marked and in the development if compared to the 'consumption specialization' of a country (a relative long run phenomenon in terms of development). ETC/SCP (2011b) discusses production and consumption long term indicators with reference to SCP[4], and presents some answers to these 35 policy questions through assessing trends in 39 relevant European indicators.

[4] Thus, this means that in a dynamic setting, consumer behaviour is changing slowly in terms of embodied environmental efficiency, compared with domestic production, thus possibly creating a net demand of pollution abroad, through import from emerging countries. Although consumption structure and behaviour can be less sensitive to environmental policies than production, there can be room for addressing consumers and their behaviour to contribute to higher efficiency in terms of vertically integrated environmental impacts. The EU strategies on Sustainable Consumption and Production paves the way to this policy direction, and analyses based on environmental extended – Input Output Analysis, addressing the differences between the two perspective, can clarify the needs and implications of these policies.

1.2 The evolution of EE-IOA studies and new research targets

We can affirm that sector-based input-output datasets existing for EU countries offer the possibility of highlighting how emissions are indirectly associated with production. NAMEA-type tables are datasets with coefficients on emission per output that can thus be matched with I-O tables for useful integration. Integration aims at calculating economic-environmental performances by sector by including the role of trade. In other words, it aims to test the hypothesis that given different relative emission efficiency, the structure of imports and exports matters.

From a general and methodological point of view, the integration of NAMEA accounting and input output (I-O) tables touches upon ecological/environmental economics and industrial ecology frameworks. Due to the striking increase of related works in such realms, the brief survey we provide in the next paragraph aims to give insights into recent developments and offer stimulus for future analyses rather than offering full coverage. It is worth noting that, very recently, there has been increasing interest in these environmental issues in the 'Input Ouput world'. A boom of papers on environmental extended I-O was reached in 2009 that witnessed a peak (Hoekstra, 2010), with a total amount of 360 papers, from 1969 to 2010. A related field of analyses which has witnessed great relevance in the I-O arena is structural decomposition analysis (SDA), one of the most effective and widely applied tools for investigating the mechanisms influencing energy consumption and emissions and their environmental side-effects (Mazzanti and Montini, 2010). Many studies address industry. Nevertheless, services are also relevant: they are less energy intensive but present lower technological contents and can indirectly contribute to strong environmental impacts (we note the NAMEA-based disentangled analyses in Marin and Mazzanti (2011), who present industry vs. services assessments for Italy). Alcantara and Padilla (2009) analyse CO_2 emissions for Spain using I-O (year 2000).

Trade is the key factor in recent extended I-O and NAMEA works that aim to deal with SCP contents[5]. We recall that the main aim is to assess direct and indirect environmental effects by attributing their relative weights to national consumption and to exports in the explanation of a country environmental performance. Currently, main efforts aim to move away from the Domestic Technology Assumption (DTA) that says that imported goods use the same

[5] Some main streams of research can be outlined: I-O models accounting for trade and embodied emissions (through energy accounts); global multi-region input–output (MRIO) model; extension for eco-footprint analysis; comparing physical trade balance (PTB) and pollution trade balance (UTB) associated with fossil use; analysing pollution terms of trade, pollution haven tests; analysing I-O tables linked with satellite accounts. For brevity, we refer the reader to the mounting, extensive literature that is also touched by many contributions in this book.

technology (in terms of structure of intermediate inputs and environmental efficiency) as goods produced domestically.

A very recent example is Arto et al. (2010). They show that Spain is a net emission exporter and consequently, its consumer responsibility in emissions is higher than its producer responsibility. The difference between both types of responsibility increases by applying the physical DTA. This is substantially due to the fact that the monetary DTA estimates less embodied emissions in imports from non-Annex I countries than the physical DTA[6].

A study that brings together various frameworks highlighting flexibility of methods and usefulness of integrated use is certainly Moll et al. (2007). The work shows that, according to different sectors and countries, the domestic production patterns and associated direct domestic environmental pressures are rather different. Electricity, gas and hot water production, agriculture and transport and communication services cause the majority of environmental pressures. Direct pressures from private households (mainly for heating and private transport) constitute another important source. With regard to international factors, it can be seen that a second determinant for cross-country differences in domestic direct pressures is the role of exports. When it comes to consumption and investment patterns, Moll et al. (2007) show that cross-country differences are far less pronounced than production patterns. Analyses focusing on environmental impacts of consumption (by categories) are also found in Huppes et al. (2005): food, heating and transport emerge as core impacting aggregation[7]. We also note the extensive IPTS ‘EIPRO’ report (2006). In general, it is the satisfaction and organization of basic needs, i.e. eating, housing and mobility, that is responsible for the majority of production-cycle-wide environmental pressures.

In this paper we attempt to provide complementary evidence with respect to the mentioned works. The main purpose of the current analysis is to aggregate our original Italian and Spanish data according to relevant aggregations used in other studies and to compare our benchmark estimates (i.e. the estimates arising from the most disaggregated model) with the estimates arising from less detailed aggregations. More specifically, our benchmark consists of a

[6] The physical DTA refers to the use of imports in physical quantities and using, for imports, the same physical environmental coefficient (emissions per kg of import) as domestic physical environmental coefficients (emissions per kg of domestic output). This assumes that, although of different quality (value per physical unit), the emissions content of goods is closely correlated to its weight and less correlated to its value.

[7] Automobile driving and related maintenance activities are by far the largest contributing products to total environmental impacts by consumption in the EU25. However, by summing several animal-based foods (meat, meat products, poultry, dairy products), animal food products would become dominant. At the aggregate level of 12 consumption domains, food already comes up as the largest contributor to environmental problems.

disaggregation of 50 commodities[8]. This benchmark will be compared with the sub-section NACE rev. 1.1 level (accounting for 30 sectors) and with an aggregation of 16 sectors roughly corresponding to previous studies based on OECD/IEA data.

We provide new evidence through an application that focus and compare Italy and Spain, two countries with an historical experience of NAMEA and I-O table's generation, which is witnessed in the many papers published by Ecological Economics and collected in dedicated books (Costantini et al., 2011) in recent years. The choice of using Italy and Spain is nevertheless motivated by various specific facts.

From a data quality and availability point of view, we selected two of the top experiences in the EU. We observe that our projected began well before the publication and release of the first result of EUROSTAT project (summarised in the publication by EUROSTAT (2011), "Creating consolidated and aggregated EU27 Supply, Use and Input-Output Tables, adding environmental extensions (air emissions), and conducting Leontief-type modelling to approximate carbon and other 'footprints' of EU27 consumption for 2000 to 2006", which attempts to improve the data availability situation in the EU towards a more institutionalised and homogeneous generation of data on I-O supply and use tables and air emissions, and their integration to account for embodied emissions in final demand. NAMEA data generation had been more scattered before 2011. Even after recent improvements, in the cited report itself the data quality assessment signals that a few countries present excellent status over 2000-2006. Italy and Spain are among those few, and have historically allowed many analyses, including panel econometric studies (Mazzanti and Zoboli, 2009). Germany is another country with excellent quality in all years. As example, France and the UK are countries that had not presented and which still present not excellent situations (see EUROSTAT, 2006, Detailed tables on air emissions 2006). Germany posed problems in terms of commensurability of sector aggregation, which lead us to end up with a Italy-Spain comparisons in this exercise (more details on this fact are available upon request). Extensions to other countries are suggested for future research on the shoulders of the fast improving conditions of data availability (as a reference the I-O tables and NAMEA availability, including pilot projects for various countries, is summarised and available at the EUROSTAT web site http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/publications/physical_and_hybrid_environmental_accounts). The assessment of the aggregation bias in extended input output analysis is crucial to achieve robust analysis of embodied emissions in final demand (and import-export), which is a key pillar of the EU strategy on sustainable

[8] This level of disaggregation corresponds roughly to the 2-digit NACE rev. 1.1 classification (see Table B.1 for a description of each sector). For more details, refer to Section 3.2.

consumption and production. The methodological clarification of the bias is important to reduce the overall bias of such analyses, which is on the other hand depending on sector data commensurability and on (the relaxation of) the Domestic Technology assumption.

From an economic point of view, those are two Southern EU countries which, notwithstanding differences in their industrial composition, share on the other hand similar features in terms of level of economic development and GDP per capita (Mazzanti and Musolesi, 2010, present the case of strong differences between northern and southern EU countries regarding income-Green house gases structural relationships in a EKC framework). Italy is relatively more industrial and export oriented. This main significant difference can be useful to compare in the end the results and provide explanation of eventual non homogeneity.

The paper is organized as follows. In paragraph 2, we review the specific empirical literature on the estimation of environmental pressures induced by domestic consumption and domestic production activities, with a specific focus on environmentally extended input-output methodologies and related potential biases. In paragraph 3, we describe our methodological approach, with a particular focus on the role of aggregation bias in environmentally extended input-output analyses, and our data source, stressing the value added of merging NAMEA emissions with the input-output framework. In paragraph 4, we report and comment on our main results. Paragraph 5 concludes.

2. Methodological issues in the relevant literature

Empirical analysis with an extension of the use of the statistical information derived from environmental accounts and the input-output tables requires several considerations to be made. The main aim of this paper is linked to the investigation of the so-called *aggregation bias*. As suggested by Lenzen (2011), environmental I-O analyses of environmental issues are often plagued by the fact that environmental and I-O data exist in different classifications.

A recurring problem in EE-IOA is that input–output accounts and environmental statistics used as environmental extensions are often not compiled by the same statistical agency and therefore often differ with respect to the classification of economic sectors and other definitions. In these cases, analysts have to carry out data collection and harmonization procedures in order to integrate both accounts. What can happen is that: (i) environmentally sensitive sectors are sometimes more aggregated in the economic I-O database than the environmental dataset because monetary I-O tables are compiled with no environmental implications in mind; (ii) I-O data are disaggregated into more sectors than environmental satellite data, especially for services sectors (Lenzen, 2011).

There are two basic alternatives for dealing with such a misalignment: either environmental data have to be aggregated into the I-O classification (but some environmental sensitive data will lose their peculiarities) or I-O data have to be disaggregated based on fragmentary information (with several assumptions).

By keeping this in mind, the aggregation bias is likely to severely affect the construction of environmentally extended Multi-Region Input-Output (EE-MRIO) analysis, as recently suggested by Su et al. (2010) and Lenzen (2011), as well as environmentally extended Single Region Input-Output accounts with specific assumption regarding the technology used (embodied in international trade, specifically those in the import data).

As will be explained below the DTA (Domestic Technology Assumption) relies on the consideration that all imported commodities are produced with the same mix of intermediate inputs (in monetary terms and as indicated by the intermediate flows in the input-output table) and with the same environmental efficiency (in terms of emissions per monetary unit of output) as domestic commodities.

Some authors (including Turner et al., 2007; Peters, 2007; Serrano and Dietzenbacher, 2010; Arto et al., 2010) suggest moving away from the DTA because they consider it too simplistic but they recognize that, generally, the DTA produces better estimates than ignoring imports altogether. Ideally, full information on bilateral trade plus corresponding NAMEA data by country is equivalent to analysing trade of impacts at country-by-country differentiated coefficients. However, it requires a wide and often unavailable range of data. A possibility for dealing with the latter is to include only the most important trade partners in terms of emissions embodied in imports and this, as suggested by Andrew et al. (2009). For the emissions embodied in imports, Andrew et al. (2009) find that the unidirectional trade model gives a good approximation to the full MRIO model when the number of regions in the model is small. Moreover, the assumption that imports are produced with DTA in an MRIO model can introduce significant errors and requires careful validation before results are used.

If we re-examine the issue of aggregation bias, the studies that have analysed the CO2 emissions embodied in international trade have also been carried out by using an input-output framework at a specific level of sector aggregation. Generally, the choice has been made to a large extent according to economic and energy data availability or, similarly, economic and environmental data availability. A finding for Su et al. (2010) is that levels of around 40 sectors appear to be sufficient to capture the overall share of emissions embodied in a country’s exports.

The issues related to aggregation bias and a possible DTA obviously affect the consumption[9] and production perspective when looking at the corresponding emissions. As suggested in the introduction, the focus of the EU policy area on Sustainable Consumption and Production forces researchers to consider new tools of analysis and one of them is the EE-IOA based on NAMEA data. The notion of 'responsibility' (either for the consumer or the producer) allows some considerations to be developed.

As suggested by Gallego and Lenzen (2005), there is a sort of domination of producer-centric representation to view the environmental or social impacts of industrial production. When thinking about environmental impacts, crucial questions arise such as who is responsible for what? Moreover, the kind of pollutant considered influences policy implications when looking at the ratio between consumption-based emissions (C) and producer-based emissions (P). If we consider global pollutants, such as CO2, and C is bigger than P, the country responsibility is bigger than that reported by the official statistics. If we consider local pollutants and C is bigger than P, the country would be displacing environmental costs to other territories.

Gallego and Lenzen (2005) propose a method of re-tracing the flow of past inter-industrial transactions to allocate responsibility for production impacts consistently among all agents such as consumer, producers, workers and investors. According to them, the input-output analysis can be used as a descriptive tool to re-trace the flow of past-transactions and examine ex-post how, for example, inputs of resources or outputs of pollution were associated with these transactions.

Serrano and Dietzenbacher (2010) define two ways to evaluate the international responsibility of emissions generated by one country – in their analysis they consider Spain in 1995 and 2000 and nine gases - that were shown to be equivalent: the trade emission balance (as the difference between the emissions embodied in a country's exports and imports) and the responsibility emission balance (as the difference between the responsibility of one country as a producer and its responsibility as a 'consumer').

On the basis of the highlighted and hotter methodological issues, we present below our methodological framework.

3. Our Methodology and data

[9] The *consumption based* emissions are computed using domestic production based emissions minus the emissions embodied in exports (demanded by final users abroad) plus the embodied emissions in imports (demanded by domestic final users) assuming that the Rest of the World has the same technology as the country analyzed

In this section, we outline the main features of the domestic technology assumption (DTA henceforth) and we summarize the main issues related to the assessment of the aggregation bias in input-output analysis including NAMEA data.

3.1 Domestic technology assumption

The hypothesis behind the domestic technology assumption is that the imported commodities (either as intermediate inputs or final consumption) are produced with the same mix of intermediate inputs (in monetary terms) and with the same environmental efficiency (in terms of emissions per monetary unit of output) as domestic commodities.

Serrano and Dietzenbacher (2010) formally describe how and under which conditions a environmental extended multi-regional input-output model accounting for worldwide induced emissions could be reduced to a model using only domestic data with an explicit domestic technology assumption. In addition to assumptions on technology (i.e. the structure of intermediate inputs described by the input-output matrix) and on the vector of emission coefficients, the export of the country on which the analysis is focused should represent a negligible share of world output.

Another requirement, related to the validity of the domestic technology as a proxy of world technology, is that the country produces domestically at least part of all the commodities it consumes as intermediate inputs or final products. For example, this requirement is not fulfilled when a country has no particular raw materials in its soil or subsoil (oil, coal, gas, minerals, metals, etc.) and it is completely dependent on importing these commodities. As a result, the technology for the extracting industries (section C of NACE 1.1) in the input-output tables is biased towards secondary activities within the sector (e.g. basic transformation of raw materials) and it does not describe the main activity (i.e. extraction) properly. This problem is particularly relevant in environmentally extended input-output analyses in which extracting sectors are, in general, among the most polluting industries.

Although the DTA cannot be used to interpret the results as ‘actual worldwide emissions induced by domestic final demand’, it gives information on the potential emissions arising because of domestic final demand if the country has produced domestically the necessary final and intermediate goods (that is, using domestic technology). Estimates using the DTA, if interpreted properly, are therefore a particularly important indicator of consumer responsibility because of its low requirement for data, the possibility of replicating its results and the straightforward and clear hypothesis behind its implementation. For this reason, we claim that estimates based on the DTA should be used as a benchmark in more complex multi-regional environmentally extended input-output analysis aimed at assessing consumer responsibility.

However, the DTA and the overall EE-IOA results might be severely biased when the commodity/sector aggregation is very low and/or when the country which is analysed relies exclusively on import for certain commodities. In the latter case, in fact, either it will not possible to compute any domestic environmental coefficient (because both emissions and output are zero) or, if this sector is aggregated with other sectors, both the technology (the row of the matrix of technical coefficients when considering both imported and domestic intermediate inputs) and the emission coefficient of the aggregated sector could fail to represent technically-viable technologies. A possible solution to this problem, although not conclusive, would be to substitute the specific rows of the matrix of technical coefficients and the specific entries of the vector of emission coefficient for these sectors with data of similar countries which have domestic production in these sectors. However, on the one hand, this kind of manipulation is likely to unbalance the whole input-output system and on the other, the similarity is difficult to check due to the variety of dimensions included in this type of environmentally extended input-output analyses.

Before discussing the way in which aggregation is likely to introduce biases in the estimates of the level of emissions induced by final domestic demand, we will introduce some notation and explain how induced emissions are computed.

The notation is summarized in Table 1:

[table 1 here]

When estimating the emissions induced worldwide by domestic final demand, we need to account for the intermediate inputs induced worldwide (thus using $\mathbf{L}_{d+m}$ as Leontief inverse) and for domestic final demand only ($\mathbf{f}_d$).

Induced emissions (consumption perspective, $\mathbf{e}_{cp}$) classified by product/industry are given by:

$$\mathbf{e}_{cp} = (\mathbf{b}' \, \mathbf{L}_{d+m} <\mathbf{f}_d>)' \quad (1)$$

while total induced emissions ($\mathbf{e}_{cp}^{tot}$) may be obtained by post-multiplying $\mathbf{e}_{cp}$ by $\mathbf{i}$[10].

3.2 Aggregation biases

[10] For an exhaustive review on the accounting definitions related to environmentally extended input-output analysis, the reader should refer to Serrano and Diezenbacher (2010) and Moll et al. (2007).

The issue of the choice of the level of aggregation is crucial in any empirical analysis in economics[11]. Each aggregation results in losses of relevant information and in implicit compensations which are likely to affect the reliability of the results of any empirical analysis. However, aggregation is often unavoidable. First, the most common constraint regards the availability of sufficiently disaggregated raw data. Second, privacy legislation often prevents the diffusion of disaggregated data[12]. Third, time and computation constraints are likely to induce the researcher to employ readily available and small bases of aggregated data. Finally, when matching various sources of raw data, there is little alternative to aggregation if one or more of the sources is not sufficiently disaggregated, leading to an overall aggregation. This last issue is very common in multi-regional input-output models and the general approach involves reducing the overall level of disaggregation to the level of the most aggregated country/region[13].

In environmentally extended input-output analysis, aggregation consists of a reduction in *n* sectors due to data availability constraints. More generally, if either the intermediate input matrices ($\mathbf{Z}_d$ or $\mathbf{Z}_m$) or the vector of direct emissions (**e**) has low disaggregation, it is enough to force the researcher to reduce the level of aggregation of the model to the lowest '*n*' dimension.

More formally, the way in which we estimate embodied emissions under different aggregations ($\mathbf{e}_{cp}^{aggr}$) is described by equation 2:

$$\mathbf{e}_{cp}^{aggr} = ((\mathbf{e}'\ \mathbf{S}'\ \langle \mathbf{S}\ \mathbf{x}_d \rangle^{-1})\ (\mathbf{I} - \mathbf{S}\ \mathbf{Z}_{d+m}\ \mathbf{S}'\ \langle \mathbf{S}\ \mathbf{x}_d \rangle^{-1})^{-1}\ \mathbf{S}\ \langle \mathbf{f}_d \rangle\ \mathbf{S}')' \neq \mathbf{S}\ \mathbf{e}_{cp} \qquad (2)$$

where **S** is the aggregation matrix. An aggregation matrix is a rectangular matrix (in our case *m* x *n*, with $m<n$) composed by 1s and 0s. The column sum of S will be 1 for each column while the sum of all the entries equals *n*. Pre-multiplying a column vector by **S** results in a new vector composed by *m* rows in which some of the original cells are summed up in a unique entry. When dealing with a square matrix of dimension *n*, an aggregate square matrix of dimension *m* can be obtained by pre-multiplying the original matrix by **S** (*m* x *n*) and post-multiplying it by **S**' (*n* x *m*).

[11] In this section we refer to the aggregation of basic data as opposed to the aggregation of results. The aggregation of results of any empirical analysis in economics is a necessary step when giving an overall picture of the phenomenon under analysis.

[12] Due to privacy protection, ISTAT, the Italian National Institute of Statistics is not allowed to publish data for aggregates with less than three units and it is forced to further aggregate these branches.

[13] The aggregation to a the minimum common standard is the most widely used approach (Ahmad and Wyckoff, 2003; Nakano et al. 2009). However, a noticeable exception is represented by Huppes et al. (2005) who exploit the very detailed US input-output table and adapt it to the EU economic structure, thus using more disaggregated data relative to publicly available EU input-output tables. Although very interesting, this approach is affected by problems related to differences between US and EU classification structures within each macro-industry.

The aggregation in input-output models is related to two main dimensions: the resolution of sector/commodity disaggregation of input-output matrices and related extensions and the level of spatial/geographical aggregation (Miller and Blair, 2006).

The issues of sector/commodity aggregation in input-output models and quantification of its bias have been investigated for a long time (Hatanaka, 1952). The main concern at that time was related to computational constraints when dealing with big matrices. Aggregation was one way of easing the computation of the Leontief inverse. However, due to tremendous improvements in computational power, the issue of aggregation is currently related to constraints on the availability of or concerns over the quality of disaggregated data. The measurement and decomposition of the bias have been investigated by Morimoto (1970)[14]. The main contribution by Morimoto (1970) is related to four theorems which identify the cases in which the aggregation bias does not arise[15]. To summarize, the aggregation bias in static input-output models disappears if, alternatively:

- the sectors/commodities which are aggregated are characterized by the same interindustry structure;
- the vector of final demand remains unchanged for all aggregated sectors/commodities whereas it changes for all or some of the non-aggregated sectors/commodities.

However, when dealing with extensions (e.g. environmental data extensions) either these conditions should be used together or the additional condition of 'common emissions coefficient among aggregated sectors/commodities' should be satisfied. Other works provide complementary insights. Among others, Su et al. (2010) focus on a description of the aggregation bias and its generalization and they perform sensitivity analysis in order to identify a minimum level of disaggregation (around 40 sectors) to assure reliable estimates. Lenzen (2011) demonstrates that it is generally desirable to have approximations of disaggregated input-output relations when environmental information is available at a very disaggregated level instead of aggregating environmental information to the level of original actual input-output data.

In our case, the aggregation bias is likely to arise because, when assessing the consumer responsibility, we consider the vector of *domestic* final demand (thus excluding the vector of export) instead of *total* final demand. This is equivalent to estimating the effect of a particular impulse (different from the actual vector of final demand) with the risk of obtaining biased results.

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[14] The theoretical results obtained by Morimoto (1970) do not depend on the reason that induces aggregation.

[15] An important point, which often remains implicit, is that the aggregation bias only arises when the vector of final demand is modified relative to the original vector of final demand.

The main purpose of the current analysis is to aggregate our original Italian and Spanish data according to relevant aggregations used in other studies and to compare our benchmark estimates (i.e. the estimates arising from the most disaggregated model) with the estimates arising from less detailed aggregations. More specifically, our benchmark consists of a disaggregation of 50 commodities[16]. This benchmark will be compared with the sub-section NACE rev. 1.1 level (accounting for 30 sectors) and with an aggregation of 16 sectors roughly corresponding to previous studies based on OECD/IEA data sources such as Ahmad and Wyckoff (2003) and Nakano et al. (2009)[17]. Table 2 summarizes the sectoral detail of each aggregation we tested.

Even if several studies acknowledge that their results depend on the choice of the level of aggregation, to our knowledge, just two of them explicitly performed a sensitivity test for aggregation bias. Wyckoff and Roop (1994) found that aggregating their analysis[18] to 6 sectors (using a disaggregation of 33 sectors as a benchmark) downward biases the carbon embodied in manufacturing imports by about 30 percent. Su et al. (2010) perform a similar sensitivity analysis on a single country environmentally extended input-output model for China. Compared to their benchmark results obtained with a disaggregation of 122 sectors[19], the bias in the estimation of carbon emissions embodied in Chinese exports arising from aggregation is positive and around 12 percent when using a 10-sector aggregation whereas it almost vanishes when using a 42-sector aggregation.

[table 2 here]

3.3 Data sources

The current analysis relies on input-output tables for Italy and Spain for the years 1995, 2000 and 2005 with a disaggregation of 60 sectors/commodities and on NAMEA sector-level air emissions data with a disaggregation of 50 sectors for the same years and countries. To match the environmental extensions with the input-output table, we reduced the overall level of

[16] This level of disaggregation corresponds roughly to the 2-digit NACE rev. 1.1 classification (see Table B.1 for a description of each sector). For more details, refer to Section 3.2.

[17] OECD/IEA estimates use a disaggregation of 17 sectors. However, both OECD input-output tables and IEA CO_2 emissions from fuel combustion go beyond the 2-digit NACE Rev. 1.1 as regards sector 27. This sector is split into ‘Iron and steel’ (271+2731) and ‘Non-ferrous metals’ (272+2732). On the contrary, Italian and Spanish input-output tables and NAMEA do not allow this separation.

[18] They employ a multi-regional environmental extended input-output model for 6 OECD countries (USA, Canada, France, Germany, Japan and the UK) to estimate the embodiment of carbon in imports of manufacturing products.

[19] Note that the benchmark results are obtained by ‘disaggregating’ the original vector of emissions intensities (42 sectors) in order to meet the 122-sector aggregation of the input-output tables. This operation is likely to partly affect the reliability of the estimates for the 122-sector aggregation.

disaggregation to 50 sectors. In this section, we discuss the features and the limitations of our base data in detail.

3.3.1 Input-output tables

The Council Regulation (EC) No 2223/96 of 25 June 1996 on the European system of national and regional accounts in the Community (the so-called *ESA 1995*) requires each member country to compile and submit supply and use tables annually and symmetric (domestic and import) input-output tables every 5 years to Eurostat. The regulation is very precise as regards the methodology used to collect the data and the structure of the published data but allows some flexibility as regards the choice between 'commodity-by-commodity' and 'industry-by-industry' input-output tables. On the one hand, commodity-by-commodity input-output tables better describe the actual technology in terms of intermediate commodities to produce a specific product whereas industry-by-industry input-output table describe relationships among sectors regardless of the actual flows of commodities. On the other hand, most of the extensions (e.g. environmental extensions) refer to industries and not to commodities, making the 'industry-by-industry' approach more attractive (Eurostat, 2008, Miller and Blair, 2009). Out of the 31 countries which submit their input-output tables to Eurostat (EU27 plus Croatia, Macedonia, Turkey and Norway), 'industry-by-industry' tables are only supplied by 8 countries (Denmark, Italy, Hungary, Netherlands, Finland, UK, Turkey and Norway).

In our analysis, we use 'commodity-by-commodity' input-output tables in order to make the comparison between Italy and Spain possible. The procedure we use to assign 'industry' emissions to 'commodity' output is based on the hypothesis that direct emissions related to each commodity within a single industry are proportional to the share of the output of each commodity within the industry (Miller and Blair, 2009). Information on the commodity composition of industry output can be found in the make (supply) matrix.

Starting with the make matrix (**V**) and the vector of total output by industry (**x**), we compute a matrix which describes the commodity composition of industry output ($\mathbf{C}=\mathbf{V}'\langle\mathbf{x}\rangle^{-1}$). Each row of the matrix sums to 1 and indicates the relative weight of the different commodities in the total output of the industry (Roca and Serrano, 2007; Miller and Blair, 2009)[20]. To obtain the measure of direct emissions generated by the production of a specific commodity (by all of the industries producing that commodity), indicated with $\mathbf{e}_{pp}$, we multiply the transpose of **C** by the vector of direct emissions by industry ($\mathbf{e}_{ii}$):

[20] Note that when the make matrix is diagonal (that is, when all industries produce only their primary commodity), then the **C** matrix is an identity matrix.

$$\mathbf{e}_{pp}=\mathbf{C}'\mathbf{e}_{ii} \quad (3)$$

In Appendix A we compare our results obtained using the commodity-by-commodity approach for Italy with the results we obtain using the industry-by-industry approach[21]. The estimates for total emissions induced by domestic final demand differ by less than 1 percent in all cases except for CO in 2000 and 2005, thus confirming the validity of the ‘commodity-by-commodity’ approach.

3.3.2 The NAMEA data

The NAMEA approach to identify environmental pressures across production sectors was developed in the late 1980s and 1990s at the Central Bureau of Statistics of the Netherlands (CBS) under the supervision of Steven Keuning (De Boo et al., 1991). NAMEA data are constituted by a matrix form statistical source where economic (output, value added, final consumption expenditures and full-time equivalent job) and environmental (emissions) indicators can be observed at sector level. In NAMEA, environmentally-relevant information is compiled consistently with the way economic activities are represented in national accounts (for an overview of NAMEA study we refer to Costantini et al. 2011). This framework divides the economy into production sectors and household consumption categories and shows how each industry branch or the household categories contribute to a set of environmental pressures. This allows quite robust analyses on dynamics, correlation, even causation regarding performance and resource productivity indicators.

Both the Italian, which dates back to 1990 (first published data in 2000), and the Spanish NAMEA include several air pollutants: carbon dioxide (CO_2), nitrogen oxides (NO_X), methane (CH4), sulphur oxides (SO_X), nitrous oxide (N_2O), ammonia (NH3), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) among others. In the current paper, we report results for emissions of five different substances (CO2, NOx, SOx, NMVOC, CO)[22] for which NAMEA with the same aggregation of sectors is available both for Italy and Spain[23].

4. Results and discussion

[21] This comparison is not feasible for Spain because the Instituto Nacional de Estadistica (INE) does not produce industry-by-industry input-output tables.

[22] We also perform all the estimates for 12 additional substances available in the Italian NAMEA only (NH3, PM10, PM2.5, As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn). Results are available upon request.

[23] The Spanish NAMEA used in this paper is available on the Eurostat website with a 50 sector aggregation and only 5 pollutants. The Instituto Nacional de Estadistica (INE) divulgates a NAMEA with even more pollutants but with only 30 sectors and for this reason is not useful for our purposes.

4.1 Overview: consumption vs. production perspective in the benchmark case

Before facing the issue of aggregation and its related bias, in this section we briefly discuss the results for Italy and Spain of our benchmark (50 sectors) estimates for the years 1995 and 2005. The 50-sector aggregation level has been obviously considered as the benchmark; as stated by Su et al. (2010), in empirical studies it is logical to take the view that the finer the level of sector disaggregation, the more refined the decomposition results obtained.

Figures 1-2 and Figures 3-4 report the contribution of three macro-sectors[24] to emissions induced by domestic final demand and domestic direct emissions for Italy and Spain respectively.

[figures 1-4 here]

In Italy, for all emissions except NOx and CO/1995, the contribution of the demand of final products from industry is above 50 percent. There has been a general shift towards services in the 1995-2005 decade for CO2, NOx and SOx induced emissions. Regarding those pollutants, a weak reduction in environmental pressures caused by industrial activities from 1995 to 2005 appears; efficiency improvements in production processes and product design could be present but a composition effect cannot be excluded.

Agriculture appears almost irrelevant since most of its final products is used as intermediate inputs (the direct emissions by sector are in fact bigger that those induced by domestic final demand).

Table 3 (and Figure 5) and Table 4 (and Figure 6) show the comparison between the consumption and production perspective for Italy and Spain respectively. A consumption/production ratio greater than 1 indicates that the emissions arising from the production needed to satisfy the domestic final demand are greater than the emissions directly generated by domestic production sectors. This is equivalent to saying that the amount of emissions embodied in imports is greater than the amount of emissions embodied in export (i.e. the country is a net exporter of emissions)[25]. The interpretation should be reversed when the consumption/production ratio is smaller than 1.

[figure 5, table 3]

[24] Agriculture + fishing (A-B NACE Rev. 1.1), Industry (C-F NACE Rev. 1.1) and Services (G-O NACE Rev. 1.1). Results at 2-digit NACE are available upon request.

[25] The equivalence is explained in Dietezenbacher and Serrano (2010).

Though close to 1, the consumption/production ratios for Italy are always below unity except for CO emissions in 2000 and 2005. Furthermore, the average pattern is either stable (CO2, NMVOC and CO) or even decreasing (NOx and SOx). This result, in line with previous analyses such as Moll et al. (2007) but still quite surprising for an OECD country, may have two main explanations. First, Italy maintained industrial specialization in the manufacturing sector, especially in more traditional (and relatively energy intensive) industries, during the considered period. Second, it may be that, within each 2-digit industry, there has been a shift from polluting sub-industries (whose products, formerly produced domestically, have been substituted by import) to cleaner sub-industries. This possible shift may lead to a reduction in direct sector emissions in presence of unchanged aggregate monetary domestic output (though with a different sub-industry composition not visible in aggregate monetary data), thus artificially improving the environmental efficiency of the aggregate sector. This hidden structural change worsens the DTA prediction because it affects the sub-industry composition and the real average environmental efficiency of imports. This possible explanation further highlights the importance of using disaggregate data.

The comparison between the patterns of different emissions suggests other somewhat unexpected and interesting results. Local negative externalities generated by NOx and SOx (and not by CO2) emissions, coupled with relatively strict environmental policies controlling these emissions during the considered period[26], are expected to increase the incentive to move the production of commodities intensive in these emissions abroad (to pollution havens). This should result in an increase of emissions embodied in imports and an increase in the consumption/production ratio. However, we find the opposite which suggests that Italy, due to low stringency of environmental regulation and to lacks of enforcement, is to some extent behaving as a pollution haven within the EU (Marin and Mazzanti, in press).

[figure 6, table 4 here]

Spain is characterized by the opposite situation and pattern. For all emissions/years the consumption/production ratio is greater (often far greater) than 1 and the ratio tends to increase in time, reaching the maximum for SOx in 2000 with 1.395. This means that SOx emissions induced by domestic final demand are 39,5 percent greater than SOx emissions directly

[26] Among others, at EU level, the Council Directive 1980/779/EC substituted by the Council Directive 1999/30/EC of 22 April 1999 '*relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air*', the Council Directive 85/203/EEC of 7 March 1985 '*on air quality standards for nitrogen dioxide*', as last amended by Council Directive 85/580/EEC and the Council Directive 1999/13/EC '*on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations*'.

generated by Spanish industries. These results are in line with the findings of Arto et al. (2010) and Serrano and Dietzenbacher (2010).

Spain was a very dynamic economy during the 90s and the early 2000s, with growth mainly driven by the construction and tertiary sectors whereas the share of manufacturing in employment, output and value added has declined steadily[27]. This process, coupled with an increased volume of final demand of manufacturing goods (Roca and Serrano, 2007), gave rise to a rapid increase in foreign emissions to produce these goods thus worsening the balance of emissions embodied in import.

4.2 Aggregation bias

In the following paragraphs, we discuss to what extent the estimates of the consumption perspective change when aggregating our base data.

Figures 7 and 8 show the relative magnitude of the bias in the consumption perspective emissions arising from the aggregation of sectors into 30 NACE Rev 1.1 sub-sections and in 16 sectors according to the IEA/OECD studies[28] in the Italian case.

[figure 7 and 8 here]

First note that, with few exceptions (CO2 in 1995 and CO in 1995 and 2000 for the 30-sector aggregation), an higher level of aggregation tends to overestimate the relevance of the consumption perspective, and this effect is even more evident in the 16-sector aggregation. Moreover, the bias tends to increase in time. The bias tends to be greater for the 16-sector aggregation as opposed to the 30-sector aggregation[29].

With regard to the 16-sector aggregation, the magnitude of the bias is particularly evident for SOx (with a maximum bias of almost 40 percent in 2005) and it is also relevant for NMVOC, CO2 and NOx.

[table 5 here]

[27] The output share of manufacturing was 32,6 percent, 31,1 percent and 26,7 percent in 1995, 2000 and 2005 respectively.

[28] IEA/OECD studies such as Nakano et al. (2009) and Ahmad and Wyckoff (2003) use a disaggregation of 17 sectors which, for sector 27 (Manufacture of basic metals), goes beyond the 2-digit detail. IEA/OECD data distinguish between ‘Iron and steel’ (27.1 and 27.31) and ‘Non-ferrous metals’ (27.2 and 27.32). On the contrary, input-output tables and NAMEA published by ISTAT and INE treat sector 27 as a unique sector. This aggregation potentially introduces a bias in our results due to the high emissions intensity of sector 27 and to the heterogeneity in technologies and emissions intensity within sector 27.

[29] Note that there is no perfect link between the 16-sector aggregation and the 30-sector aggregation. This fact does not allow the monotonicity of the bias with respect to the number of sectors to be interpreted as a stylized fact. In fact, monotonicity is not found for Spain.

The detailed estimates of the consumption/production perspective ratio for the different levels of aggregation (Table 5) show to what extent the aggregation bias is likely to affect our main synthetic indicator, the consumption/production perspective ratio. In all cases (again except CO), moving from the benchmark result (50 sectors) to the result for 16 sectors (to be compared with the set of IEA/OECD multi-regional analyses) artificially makes Italy a net exporter of emissions even within the framework of a pure DTA. Moreover, the relative gap between consumption and production perspectives in the 16-sector case in 2005 becomes quite high for SOx (+21,6 percent), NMVOC (+7,9 percent) and CO2 (+7,7 percent)[30], suggesting that Italy is a net exporter of emissions. We also tried different apparently reasonable aggregation and obtained quite volatile results.

[figures 9,10 here]

Figures 9 and 10 report the relative aggregation bias for Spain. Results for Spain are less straightforward than the Italian ones. The bias for the 30-sector aggregation is generally negative (with the only exceptions of very small positive biases for NOx in 1995) and it is particularly high for NMVOC. No clear trend is found from 1995 to 2005. Moving to the bias for the 16-sector aggregation, it is generally positive (except for NMVOC for which it remains negative though less important relative to the 30-sector aggregation). Moreover, it tends to decrease in time for CO2, NOx and SOx and to increase for CO.

Unlike the Italian case, aggregation does not alter the status of Spain as net exporter of emissions for the full set of emissions and years (Table 6).

[table 6 here]

[1]

The aggregation bias in EE-IOA depends both on the biasedness of the vector of total (worldwide) induced production[31] and on the combination of this vector with an aggregated vector of emissions coefficients (for which aggregation is made according to domestic production shares). The weighted average of emissions coefficients for aggregated sectors uses

[30] The figure for the benchmark case of the 50-sectors disaggregation was of -12,9 percent for SOx, -4,6 percent for NMVOC and -3,6 percent for CO2.
[31] In the disaggregated case the vector of worldwide-induced production is given by $(\mathbf{I} - \mathbf{Z}_{d+m} <\mathbf{x}d>^{-1})^{-1} \mathbf{f}_d$.

as, weights, domestic production instead of worldwide-induced production, giving rise to an additional bias[32]. Table 5 and Figures 7-10 are thus the result of the combination of the two biases and of the compensation of sector-level biases. *The* analytical and mathematical *investigation of the contribution of the different sectors to the overall bias is beyond the objective of the current paper* (refer to Su et al (2010) for the analytical investigation of the bias).. To give an idea of the results (available upon request), we report some facts on the bias for Italian input-output estimates[33]. The average positive bias in worldwide-induced production is about 0.36%, with 5 sectors characterized by a bias greater than 1%[34]. However, when considering the final results of the estimates for the consumption perspective, the aggregation bias is much bigger. There are four sectors for which the bias is greater than 10%[35] and five sectors for which the bias ranges between 5% and 10%[36]. Sector CB (Mining and quarrying, except of energy producing materials), which is the sector characterized by the most severe bias, is composed by two very different sub-sectors (2-digit Nace: sector 13 (Mining of metal ores) with an emission coefficient of 5.4 tons of direct CO2 emissions per million of Euro and sector 14 (Other mining and quarrying) with a coefficient of 163.6 tons per million of Euro. Moreover, the share of domestic production and of worldwide-induced production of the two sub-sectors relative to the aggregate sector CB differs substantially: sector 13 (the less emission-intensive) accounts for 14% of domestic production and for 24% of worldwide-induced production of sector CB. As a consequence, sector 13, the less emission-intensive, is under-weighted in the aggregate emission coefficient when considering worldwide-induced production, leading to a positive aggregation bias.

The results arising from this simple example should be kept in mind when discussing our benchmark results (50 sectors). Within the 2-digit Nace classification, there are several sectors for which we expect relevant sub-sector heterogeneity regarding emissions coefficients and domestic worldwide-induced production patterns. This unobservable heterogeneity is source of possibly severe bias even when using the 50 sectors classification. Unfortunately, no input-output table has been published yet with greater detail for most EU countries[37].

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[32] Note that this bias is still related to the aggregation bias in the estimates of the vector of worldwide-induced production.

[33] The results reported in the following example refer to Italian input-output tables for 2005 and CO2 emissions and to the 30-sectors aggregation.

[34] CB -1.87%, DD +1.49%, A +1.43%, DJ +1.32% and DM 1.05%.

[35] CB +48.9%, DJ -15.4%, DN +11% and DB -10.1%.

[36] J, CA, O, E and DJ.

[37] Huppes et al. (2005) use the US input-output table (with a disaggregation of about 500 sectors) and modify it to fit European aggregates. The main shortcoming of that approach is the necessity to perform several manual manipulations to the original data which limit the possibility to replicate and compare the results.

4.3 Comparison with previous studies

In the last decade, as previously indicated, some empirical studies have been conducted focusing on carbon or other pollutants embodiments in trade using international-comparable data especially from OECD sources (Input-Output, CO2 emissions and Bilateral Trade) (e.g. Nakano et al., 2009 and Ahmad and Wyckoff, 2003), Eurostat sources (e.g. Moll et al., 2006) and single country sources (e.g. Arto et al., 2010 and Serrano and Dietzenbacher, 2010 for Spain; Su et al., 2010 for China). Other recent studies and ongoing projects inherent this theme relates to the construction of a world input-output database (WIOD project, www.wiod.net) – that includes various environmental indicators - and a new environmental accounting framework using Externality Data and Input-Output Tools for Policy analysis (EXIOPOL) set up respectively under the EU's 7th and EU's 6th framework Program[38]. These projects represent good examples of standardisation and harmonization processes involving input-output tables of several countries and environmental data[39].

Among the empirical studies provided by the literature, for comparison purposes, we only consider those that include Italy or Spain or both. Ahmad and Wyckoff (2003) in their OECD study consider 24 countries responsible in 1995 for 80 percent of global emissions and global GDP (in nominal prices); following this study, Nakano et al. (2009) increase the former OECD analysis to 41 countries/regions so that more than 90 percent of world GDP is covered. The study of Moll et al. (2006) includes 8 EU countries[40] selected on the basis of data availability and the high coverage purpose of European economic contexts.

A comparison of our CO2 results with the empirical evidence for the same pollutant found in the recent EE-IOA studies suggests that as far as the Italian case is concerned (Table 7), some of the studies are affected by aggregation bias due to a small number of considered sectors. This results in a strong and significant difference among empirical findings with respect to both the consumption and production perspective emissions and the corresponding ratio. In Nakano et al. (2009) and Ahmad and Wyckoff (2003), the C/P ratios reported for the Italian case, in 1995 and

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[38] Some possible but *preliminary* applications with environmental extensions of the WIOD database have been presented in occasion of the World Bank workshop "The Fragmentation of Global Production and Trade in Value Added" (June 9-10, 2011). New studies based on the EXIOPOL and follow-up projects are currently under way as reported in the Sixth Meeting of the UN Committee of Experts on Environmental-Economic Accounting (New-York, 15-17 June 2011).

[39] On the side of the standardisation of environmental accounts, the new System of Environmental and Economic Accounting (developed by the United Nation Statistics Division) represent an important development.

[40] The selected 8 economies represent more than two thirds of EU25's GDP and more than 60 percent of EU25's population. The geographical coverage comprises ES, UK (1995) and DE, DK, HU, IT, NL, SE (1995 and 2000).

2000, are larger than ours and always higher than 1[41]. The Moll et al. (2006) figure is the closest to our 2000 figure for the C/P ratio (0.96); they use a 38-sector aggregation level and if we considers the sensitive results found by Su et al. (2010) (levels around 40 sectors appear to be sufficient to capture the overall share of emissions embodied in a country's export), it may be considered more reliable than other authors' findings. From a policy point of view, a C/P ratio that ranges from 1.24-1.30 to 0.96-0-97 suggests that while large studies that involve several countries have to be encouraged because they permit macro area analysis, in the meantime if they require a low level of sectoral detail to assure countries' homogeneity and comparability, their empirical results require caution when they are interpreted.

Table 8 shows a similar comparison for Spain. With regard to this country, the empirical findings reported in the different studies are more homogeneous than the Italian case both for the absolute values of production and consumption perspective CO2 emissions and the corresponding ratio. This could be interpreted, at least partially, as a confirmation of the higher relative reliability of our 50-sector estimates. However, in the light of the Italian results, we could conclude that after a certain degree of aggregation, there is a concrete risk of having biased and volatile results which depend on the specificities of the economic structure of the country and the type of emission considered.

[tables 7-8 around here]

5. Conclusions

The integration of the National Accounting Matrix including Environmental Accounts (NAMEA) and input output (I-O) tables (often referred to as Environmental Extended-Input Output Analysis - EE-IOA – based on NAMEA data) represents a new way to analyse the determinants of the income-environment relationships in international settings. Moreover, EE-IOA provides analyses of the emissions embodied in domestic consumption and domestic production by considering the structure of intermediate inputs and environmental efficiency in each production sector.

A comparison of a production and consumption perspective may have relevant policy implications. A consumption and production emission ratio greater than one denotes a country

[41] However, the comparison has to take into account that there is a severe heterogeneity in the methodologies used by different authors. For example, differently with respect to our study, Ahmad and Wyckoff (2003) do not use the NAMEA data framework but IEA data; moreover they use, as in Nakano et al. (2009), MRIO and not DTA. A consistent comparison of the absolute levels of CO2 emissions between IEA/OECD studies and NAMEA-based studies is not possible. In fact, IEA records CO2 emissions from fuel combustion only and, differently from NAMEA, the principle of recording the emissions generated by resident agents only is not applied in the collection of these data.

that is a net exporter of emissions in the sense that it requires an amount of emissions embodied in imports, and thus produced abroad, that is greater than the amount of emissions embodied in export. Usually, the environmental policy points mainly to production activities as responsible actors of impacts to be targeted by legislation and regulation. Looking at the final consumption demand for vertically integrated domestic and international environmental impacts can push policy attention towards the possible role of consumers as actors to be targeted with particular environmental policies, together with the international responsibility for environmental externalities of pollutants' emissions produced abroad but domestically demanded.

However, similar comparisons require particular assumptions, such as the technology associated with the imported goods, and could be affected by some biases. In this paper we have analysed and discussed the aggregation bias due to different levels of production sector aggregation for Italy and Spain in 1995, 2000 and 2005. Our empirical findings, for the Italian and the Spanish cases, show that different sectoral aggregation significantly biases the amount of emissions both for the consumption and the production perspective. At the level where we consider only 16 production sectors, the results obtained in both the consumption and production perspective are quite different from those for higher levels of sector disaggregation (e.g. 50 which is our benchmark) both for the amounts of calculated emissions and for the corresponding C/P ratios. With regard to Italy, the 16-sector aggregation level in 2005 shows an emissions amount for CO2, NOx and NMVOC which is more than 10 percent higher that those calculated with the 50-sector aggregation level. Moreover, considering SOx, the gap between 16- and 50-sector aggregation reaches almost 40 percent. With regard to Spain, between 16- and 50-sector aggregation levels in 2005, there are differences of below +5 percent for CO2, NOx and SOx, and almost 5 percent for CO. NMVOC shows the biggest gap for the Spanish case with an underestimation of almost -8 percent compared with the benchmark aggregation level due to the use of a 16-sector aggregation level.

Our results suggest that special attention must be paid when interpreting the EE-IOA of country estimated amounts of embodied emissions, both in domestic final demand and those directly associated with the production sectors when the sectoral aggregation level has a low definition as considered in some recent similar studies.

Acknowledgments

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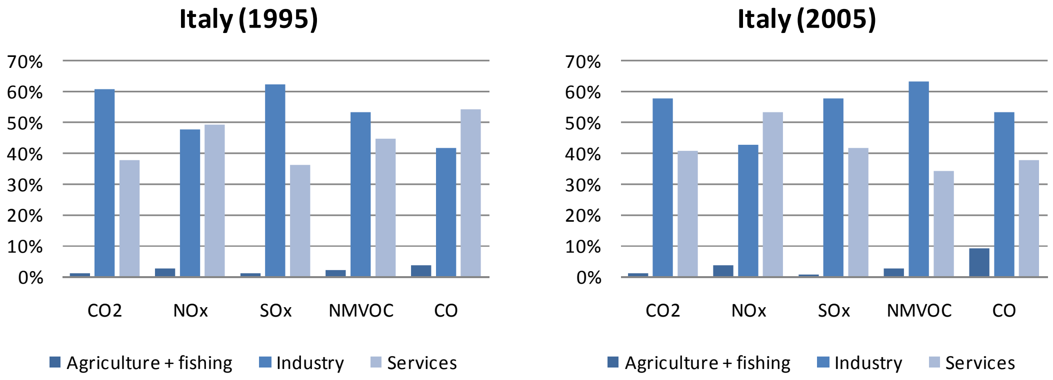

Figure 1 - Emissions induced by domestic final demand by sector (Italy)

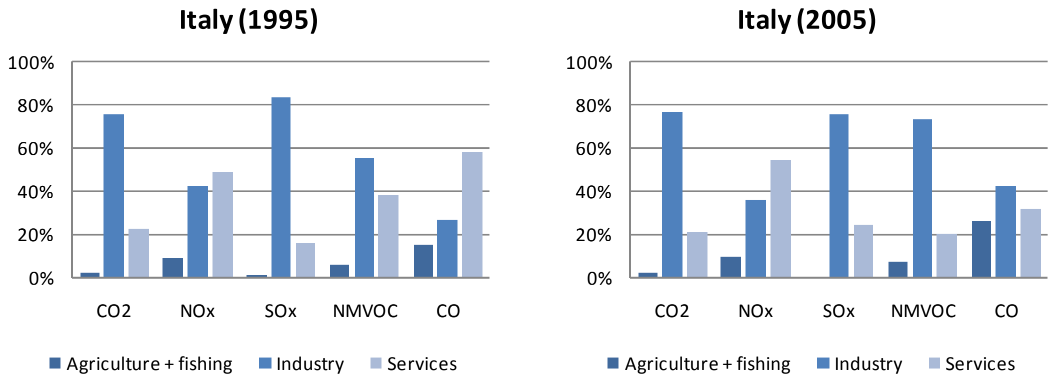

Figure 2 – Direct emissions by sector (Italy)

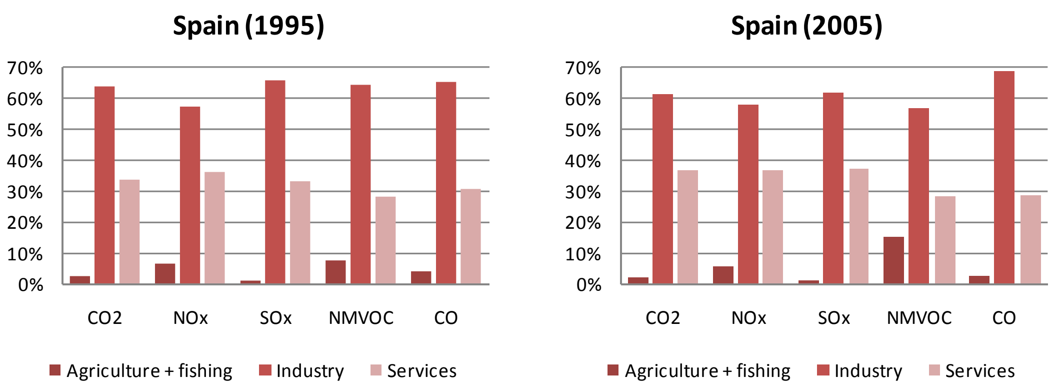

Figure 3 - Emissions induced by domestic final demand by sector (Spain)

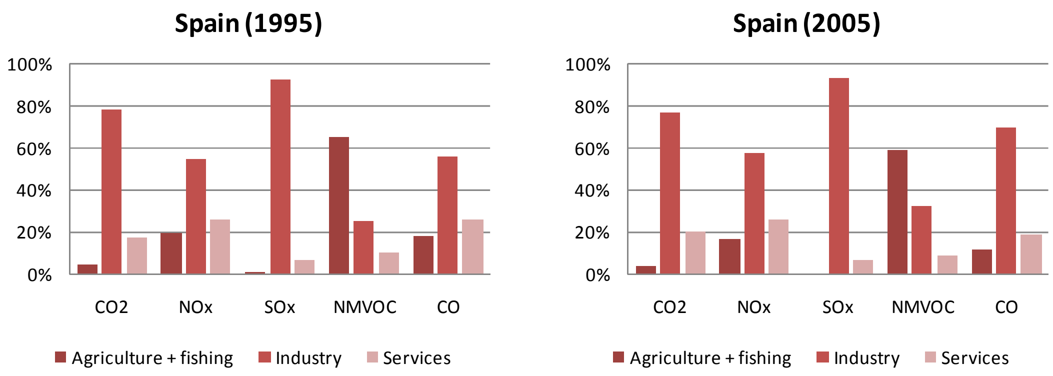

Figure 4 – Direct emissions by sector (Spain)

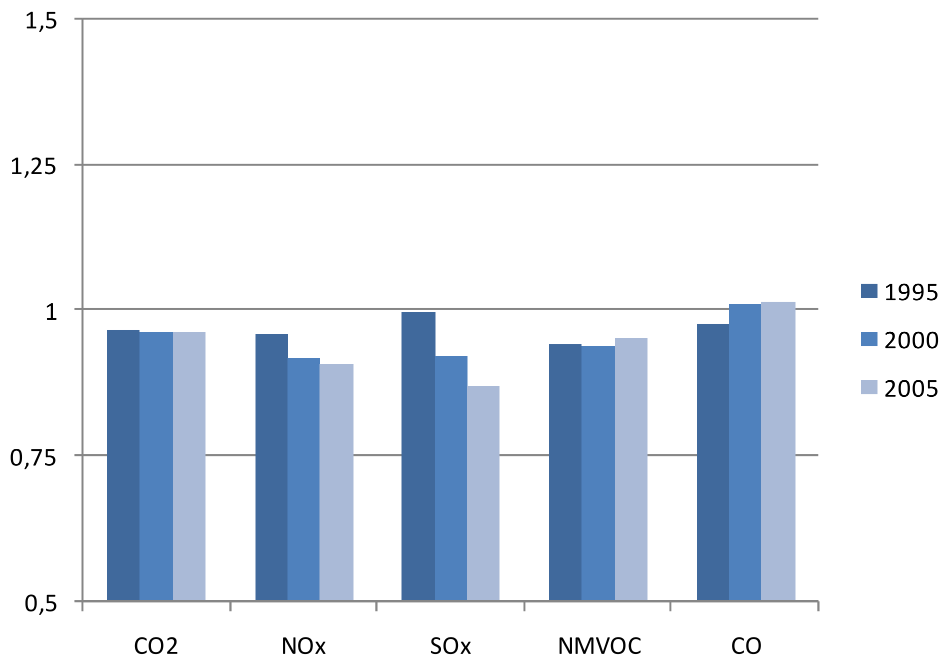

Figure 5 - Consumption/production perspective (Italy, 50 sectors)

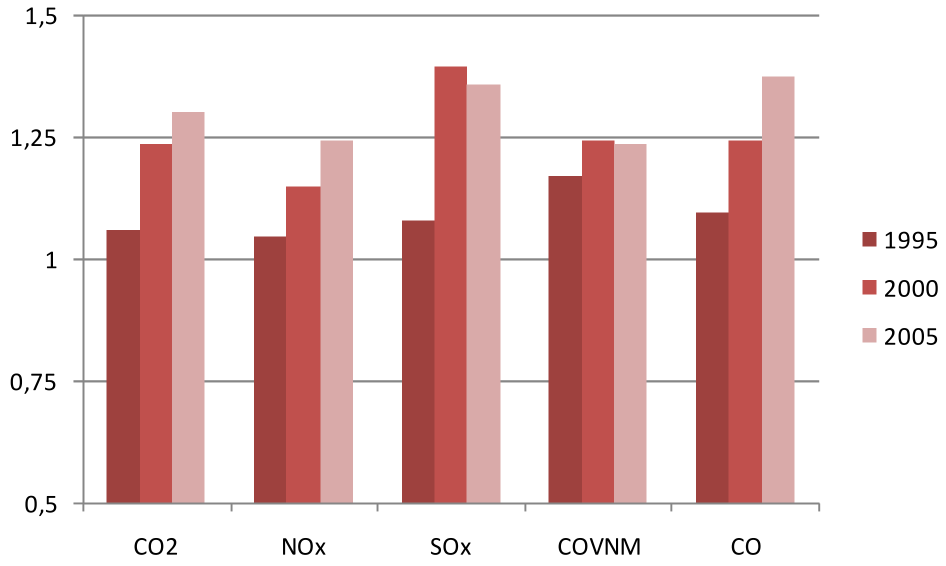

Figure 6 - Consumption/production perspective (Spain, 50 sectors)

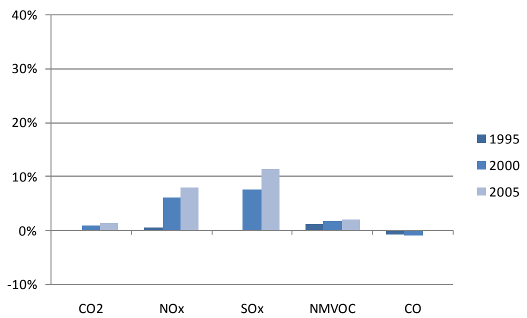

Figure 7 - Aggregation bias %: 30 vs. 50 sectors (Italy)

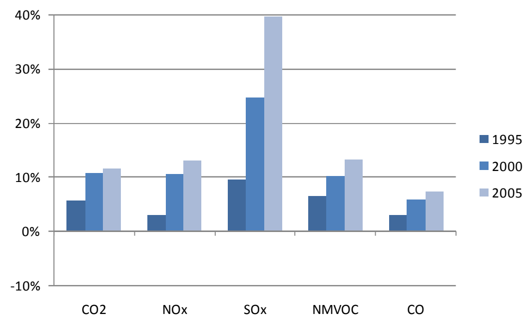

Figure 8 - Aggregation bias %: 16 vs. 50 sectors (Italy)

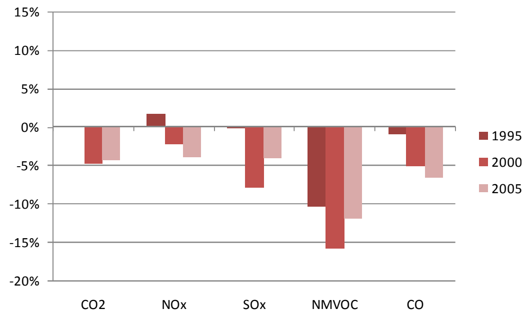

Figure 9 - Aggregation bias %: 30 vs. 50 sectors (Spain)

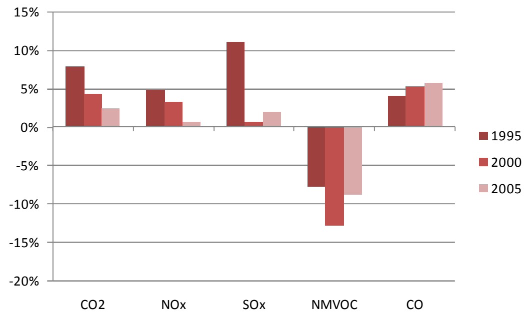

Figure 10 - Aggregation bias %: 16 vs. 50 sectors (Spain)

Table 1 - Summary of the relevant notation

Symbol	Dimension	Description
$\mathbf{Z}_d$	n x n	Matrix of domestic intermediate inputs
$\mathbf{Z}_m$	n x n	Matrix of imported intermediate inputs
$\mathbf{f}_d^d$	n x 1	Vector of domestic final demand for goods produced domestically
$\mathbf{f}_d^m$	n x 1	Vector of domestic final demand for goods produced in foreign countries (import of final goods)
$\mathbf{f}_x^d$	n x 1	Vector of foreign final demand for goods produced domestically (export of final goods)
$\mathbf{f}_x^m$	n x 1	Vector of foreign final demand for goods produced in foreign countries (re-export)
$\mathbf{e}$	n x 1	Vector domestic direct air emissions
$\mathbf{i}$	n x 1	Summation vector (column vector of 1s)
$\mathbf{I}$	n x n	Identity matrix
$\mathbf{S}$	m x n	Aggregation matrix
$\mathbf{x}_d$	n x 1	Domestic output ($\mathbf{Z}_d\mathbf{i} + \mathbf{f}_d^d + \mathbf{f}_x^d$)
$\mathbf{x}_{d+m}$	n x 1	Domestic + imported output ($\mathbf{x}_d + \mathbf{Z}_m\mathbf{i} + \mathbf{f}_d^m + \mathbf{f}_x^m$)
$\mathbf{A}_{d+m}$	n x n	Matrix of technical coefficients under the domestic technology assumption ($[\mathbf{Z}_d+\mathbf{Z}_m]<\mathbf{x}_{d+m}>^{-1}$)*
$\mathbf{L}_{d+m}$	n x n	Leontief inverse under the domestic technology assumption $(\mathbf{I} - \mathbf{A}_{d+m})^{-1}$
$\mathbf{f}_d$	n x 1	Domestic final demand ($\mathbf{f}_d^d + \mathbf{f}_d^m$)
$\mathbf{b}$	n x 1	Emission coefficients ($\mathbf{e}<\mathbf{x}_d>^{-1}$)

* $<\mathbf{r}>$ refers a diagonal matrix with the diagonal composed by the elements of the vector **r**

Table 2 - Sector aggregation

Aggregation level	**Detail**
50-sector aggregation	2-digit NACE Rev. 1.1 except 50-52, 65-67 and 70-74
30-sector aggregation	Sub-sections NACE Rev. 1.1 (2-digit capital letters): A (01-02), B (05) CA (10-12), CB (13-14), DA (15-16), DB (17-18), DC (19), DD (20), DE (21-22), DF (23), DG (24), DH (25), DI (26), DJ (27-28), DK (29), DL (30-33), DM (34-35), DN (36-37), E (40-41), F (45), G (50-52), H (55), I (60-64), J (65-67), K (70-74), L (75), M (80), N (85), O (90-93), P(95)
16 sector-aggregation (source: Ahmad and Wyckoff, 2003)	Agriculture, hunting, forestry and fishing (01-05); Mining and quarrying and petroleum refining (10-14, 23); Food products, beverages and tobacco (15-16); Textiles, apparel and leather (17-19); Wood and wood products (20); Pulp, paper, printing and publishing (21-22); Chemicals (24); Other non-metallic mineral products (26); Iron and steel (271, 2731) + Non-ferrous metals (272, 2732); Fabricated metal products, machinery and equipment (28-32); Motor vehicles, trains, ships, planes (34-35); Plastics, other manufacturing and recycling (25, 33, 36-37); Electricity, gas (40); Construction (45); Transport and storage (60-62); All other services (41, 50-93 excl 60-62)

Table 3 - Emissions for production and consumption perspective (Italy, 50 sectors; in tons, CO2 in 1000 tons)

	Production perspective			*Consumption perspective*		
	1995	**2000**	**2005**	**1995**	**2000**	**2005**
CO2	360.071	368.511	389.961	348.183	355.362	376.104
NOx	1.569.712	1.233.273	1.139.097	1.507.256	1.132.557	1.035.779
SOx	1.375.635	840.127	457.795	1.374.334	774.669	398.884
NMVOC	1.064.689	713.566	584.124	1.002.686	670.275	557.370
CO	3.034.181	1.539.949	1.212.926	2.965.820	1.559.251	1.232.689

Table 4 - Emissions for production and consumption perspective (Spain, 50 sectors; in tons, CO2 in 1000 tons)

	Production perspective			*Consumption perspective*		
	1995	**2000**	**2005**	**1995**	**2000**	**2005**
CO2	208.054	248.692	294.655	220.225	306.978	382.698
NOx	1.028.209	1.155.724	1.257.268	1.074.762	1.328.240	1.560.148
SOx	1.752.362	1.453.493	1.290.977	1.891.531	2.028.020	1.750.648
NMVOC	1.865.274	1.913.460	1.987.809	2.181.989	2.380.397	2.453.815
CO	908.522	932.967	904.531	993.401	1.158.443	1.243.147

Table 5 - Consumption/production perspective emissions for Italy according to different levels of aggregation

Year	50 sectors	30 sectors	16 sectors
		CO2	
1995	0,967	0,966	1,021
2000	0,964	0,972	1,067
2005	0,964	0,977	1,077
		NOx	
1995	0,960	0,965	0,990
2000	0,918	0,974	1,016
2005	0,909	0,980	1,027
		SOx	
1995	0,999	1,001	1,093
2000	0,922	0,991	1,150
2005	0,871	0,970	1,216
		NMVOC	
1995	0,942	0,952	1,003
2000	0,939	0,956	1,035
2005	0,954	0,973	1,079
		CO	
1995	0,977	0,970	1,006
2000	1,013	1,004	1,072
2005	1,016	1,016	1,091

Table 6 - Consumption/production perspective emissions for Spain according to different levels of aggregation

Year	**50 sectors**	**30 sectors**	**16 sectors**
		CO2	
1995	1,059	1,060	1,142
2000	1,234	1,176	1,288
2005	1,299	1,242	1,331
		NOx	
1995	1,045	1,062	1,096
2000	1,149	1,123	1,186
2005	1,241	1,193	1,249
		SOx	
1995	1,079	1,079	1,198
2000	1,395	1,285	1,405
2005	1,356	1,301	1,383
		NMVOC	
1995	1,170	1,049	1,079
2000	1,244	1,047	1,084
2005	1,234	1,088	1,125
		CO	
1995	1,093	1,083	1,137
2000	1,242	1,179	1,306
2005	1,374	1,283	1,453

Table 7 – CO2 Emissions for production and consumption perspective in Italy in different studies (Mton CO2)

			Italy					
Source[ς]	*MRIO or DTA*	*Agg. level (#sectors)*	*Production perspective*		*Consumption perspective*		*C/P*	
			1995	**2000**	**1995**	**2000**	**1995**	**2000**
Nakano et al. 2009	MRIO	17	413	427	511	554	1,24	1,30
Ahamd-Wyckoff 2003	MRIO	17	398[§]		445[§]		1,12	
Moll et al. 2006	DTA	38		358		362		1,01
Own elaboration	DTA	50	360	369	348	355	0,97	0,96

[ς]*Author(s), publication year*

[§] 1992

Table 8 – CO2 Emissions for production and consumption perspective in Spain in different studies (Mton CO2)

			Spain					
Source[ς]	*MRIO or DTA*	*Agg. level (#sectors)*	*Production perspective*		*Consumption perspective*		*C/P*	
			1995	**2000**	**1995**	**2000**	**1995**	**2000**
Nakano et al. 2009	MRIO	17	236	280	275	330	1,17	1,18
Ahamd-Wyckoff 2003	MRIO	17	235		252		1,07	
Serrano-Dietzenbacher 2010	DTA	46	204	239	222	279	1,09	1,17
Arto et al. 2010	DTA	46		364[^]		429[^°] 453[^§]		1,18 1,24
Moll et al. 2006	DTA	46	209		228		1,09	
Own elaboration	DTA	50	208	249	220	307	1,06	1,23

[ς] *Author(s), publication year*

[^] MtCO2e;

[^°] MtCO2e with Monetary DTA;

[^§] MtCO2e with Physical DTA.

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Appendix A

The methodology we used to employ in a consistent way commodity-by-commodity input-output tables as a proxy of industry-by-industry tables has been explained in section 3.2. While the main analysis relies on results obtained using commodity-by-commodity input-output tables, in this appendix we report the differences between the industry-by-industry approach and the commodity-by-commodity approach as regards the estimation of the emissions induced by domestic demand. This comparison is only possible for Italy because Spain does not publish industry-by-industry input-output tables. The main results are summarized in Table A.1.

With the only exception of CO emissions, the absolute value of the gap for aggregate consumption perspective emissions is always below 1 percent. On average, the commodity-by-commodity approach tends to underestimate the emissions induced by the final demand of agriculture-fishing goods and industrial goods whereas it overestimates the emissions induced by the final demand of services. Finally, we do not observe relevant changes in the magnitude of the gaps over time.

Table A.1 - Commodity-by-commodity (cc) versus industry-by-industry (ii) approach for Italy (1-ii/cc)

1995	**CO2**	**NOx**	**SOx**	**NMVOC**	**CO**
Agriculture + fishing	-4,74%	-4,64%	-4,34%	-4,34%	-5,41%
Industry	-2,79%	-0,83%	-2,33%	-2,08%	-1,09%
Services	2,60%	-0,70%	1,94%	1,66%	-0,14%
Total	-0,84%	-0,88%	-0,83%	-0,48%	-0,74%
2000	**CO2**	**NOx**	**SOx**	**NMVOC**	**CO**
Agriculture + fishing	-4,61%	-4,37%	-4,54%	-4,63%	-5,25%
Industry	-4,17%	-2,42%	-3,37%	-4,37%	-5,93%
Services	5,95%	3,24%	5,87%	7,62%	4,95%
Total	-0,55%	0,34%	-0,02%	-0,41%	-1,61%
2005	**CO2**	**NOx**	**SOx**	**NMVOC**	**CO**
Agriculture + fishing	-4,69%	-4,57%	-4,47%	-5,36%	-6,17%
Industry	-3,91%	-2,52%	-3,36%	-4,27%	-6,48%
Services	4,57%	2,48%	4,17%	7,62%	6,71%
Total	-0,63%	0,02%	-0,37%	-0,51%	-1,88%

Appendix B

Table B.1 - NACE Rev. 1.1; 2-digit

01 Agriculture, hunting and related service activities	36 Manufacture of furniture; manufacturing n.e.c.
02 Forestry, logging and related service activities	37 Recycling
05 Fishing, fish farming and related service activities	40 Electricity, gas, steam and hot water supply
10 Mining of coal and lignite; extraction of peat	41 Collection, purification and distribution of water
11 Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction, excluding surveying	45 Construction
12 Mining of uranium and thorium ores	50 Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
13 Mining of metal ores	51 Wholesale trade and commission trade, except of motor vehicles and motorcycles
14 Other mining and quarrying	52 Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
15 Manufacture of food products and beverages	55 Hotels and restaurants
16 Manufacture of tobacco products	60 Land transport; transport via pipelines
17 Manufacture of textiles	61 Water transport
18 Manufacture of wearing apparel; dressing and dyeing of fur	62 Air transport
19 Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	63 Supporting and auxiliary transport activities; activities of travel agencies
20 Manufacture of wood and of products of wood and cork, except furniture; manufacture	64 Post and telecommunications

of articles of straw and plaiting materials	
21 Manufacture of pulp, paper and paper products	65 Financial intermediation, except insurance and pension funding
22 Publishing, printing and reproduction of recorded media	66 Insurance and pension funding, except compulsory social security
23 Manufacture of coke, refined petroleum products and nuclear fuel	67 Activities auxiliary to financial intermediation
24 Manufacture of chemicals and chemical products	70 Real estate activities
25 Manufacture of rubber and plastic products	71 Renting of machinery and equipment without operator and of personal and household goods
26 Manufacture of other non-metallic mineral products	72 Computer and related activities
27 Manufacture of basic metals	73 Research and development
28 Manufacture of fabricated metal products, except machinery and equipment	74 Other business activities
29 Manufacture of machinery and equipment n.e.c.	75 Public administration and defence; compulsory social security
30 Manufacture of office machinery and computers	80 Education
31 Manufacture of electrical machinery and apparatus n.e.c.	85 Health and social work
32 Manufacture of radio, television and communication equipment and apparatus	90 Sewage and refuse disposal, sanitation and similar activities
33 Manufacture of medical, precision and optical instruments, watches and clocks	91 Activities of membership organizations n.e.c.
34 Manufacture of motor vehicles, trailers and semi-trailers	92 Recreational, cultural and sporting activities
35 Manufacture of other transport equipment	93 Other service activities