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Working Paper Series

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by

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08/2016

SEEDS Working Paper 08/2016
August 2016
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Abstract

The structural change of the economy towards an increasing share of services is seen in environmental economics as a fundamental driver of 'decoupling' between economic growth and environmental pressures. The environmental and socio-economic consequence of structural change, however, can be less straightforward when economic interdependencies are considered. In this paper we evaluate the implications of structural change towards services in the EU in terms of environmental pressures (aggregate and by sector, direct and indirect). The changing patterns in environmental pressures are analyses vis à vis the corresponding changes in the distribution of employment and value added. For carrying out this integrated assessment we use Environmentally Extended Multi Regional Input Output modelling applied to data from the World Input Output Database (WIOD). The results suggest that the service sectors is characterized by a lower emission intensity than the industrial sectors, when looking at direct emissions ('production perspective') but this gap is much smaller when considering also indirect emissions in a 'vertically integrated' approach ('consumption perspective'). Moreover, changes in the production structure of the EU economy in absence of relevant changes in the composition of the final demand induce an increased reliance on environmental pressures, employment and value added generated abroad. The integrated assessment of these 'global footprints' suggests that the EU is transferring worldwide more emissions that value added and employment. This form of 'unequal exchange' can be relevant for development and environmental policies, in particular those on global climate change.

Keywords: EE-MRIO; structural change; carbon leakage; production and consumption perspective; international trade

JEL Classification: C67, F18, Q52, Q55, Q56

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1 Introduction

The change of economic structure towards an increasing share of services is often looked at as favourable to the environment because services generally have lower direct pressures on natural resources. However, this positive 'service effect' cannot be taken for granted and some concerns can be raised about the real meaning of a transition to services for the environment.

A first concern is linked to the evidence about the usually lower opportunities for efficiency and productivity improvements in services compared to manufacturing sectors. This evidence could be linked to the ‘cost disease' theory (Baumol, 1967; Schettkat and Yocarini, 2006) according to which there is a systematic difference between productivity gains in services (lower) and manufacturing (higher). This idea can be extended to environmental efficiency, which is a form of productivity.

A second concern is that when considering the interrelations between manufacturing and services, the latter demand a high amount of industrial inputs, and then the final demand - as opposed to the production - of services can be highly intensive of pressures on natural resources. As seen through the inter-industry relationships in a ‘vertically integrated’ perspective, the transition to a service economy can be less green than expected.

A third concern is that the change in the production structure towards services is not accompanied by similar changes in the structure of final demand, which is changing very slowly. This asymmetric change in production and consumption patterns can, on the one hand, reduce the direct domestic environmental pressures ascribed to a country (‘production perspective’) but, on the other hand, can shift environmental pressures worldwide through trade flows (import) thus keep unchanged - or even increasing - the total 'footprint' of that country in a ‘consumption’ perspective. At the same time, however, the global redistribution of production, with domestic consumption structure that changes slowly in Europe, implies also a transfer of value added and employment worldwide, which must be taken into account when taking an integrated economic and environmental perspective.

This paper explores these integrated environmental and economic implications of structural change towards services of the EU economy. The aim is to show how structural change can drive a complex combination of economic and environmental effects that can be different from those expected from simplistic assumptions about the role of services and the increasing ‘environmental efficiency’ observed in the advanced economies - as those implicit, for example, in the Environmental Kuznets Curve debate (see Zoboli, 2012). These complex and possibly contradictory effects also involve both the traditional debate on the net benefit of international economic integration and the issues of international environmental cooperation associated, for example, to the new beginning of global climate change policy arising from COP21 and the Paris Agreement off 2015

To reveal these integrated economic and environmental implications of structural change, we need disaggregated inter-industry models open to international trade that include ‘environmental extensions’. Therefore, we use 'Environmentally Extended Input Output (EEIO)' models, referring to CO2 emissions as the best documented environmental pressure. The database of reference is WIOD (World Input Output

Database) which reports single country and worldwide input-output tables for 40 countries for the period 1995-2009 together with a set of economic and environmental accounts[1].

In Section 2 we briefly summarize the recent evidence, including a ‘cost disease’ effect, of the trend towards an increasing share of services in the EU economy. We then depict the environmental implications (‘footprint’) of this trend by differentiating between the ‘direct effects’ on of an increasing share of services on CO2 emissions and the ‘vertically integrated’ effects (direct and indirect) of the same process in an EEIO framework. In Section 3 we link to the literature on ‘trade embodied’ pollution by extending, within an EEIO approach, the analysis of ‘embodiment’ to value added and employment together with CO2 emissions. This analysis will allow us to quantify how much the structural change of the EU economy implies ‘value transfers’ (economic and environmental) at the global level.

2 The changing structure of the EU economy: do services really help the environment?

2.1 Structural change and 'cost disease' from services

The European economy is experiencing a slow but steady trend towards an increasing importance of services. In 2012, according to Eurostat data, the service sectors accounted for 69,8% of gross value added (VA) of EU27, which represents an increase of 4 percentage points of share compared to 2000.

The contribution of industry, business services and non-business services to aggregate value added (VA), in nominal (a) and real (b) terms is presented in Figure 1 for the EU27 and some selected countries (the ‘big four’ and the major Scandinavian country)[2]. For France, United Kingdom and Italy there has been a smooth and continuous decline in the contribution of manufacturing sectors to the nominal value added. In these same countries, there has been an increasingly contribution to VA by business service sectors while the trend of non-business service sectors has been generally flat. Instead, the nominal contribution of manufacturing to VA in Germany, Sweden and the EU27 as a whole was declining up to the early 2000s, after which these countries experienced a 're-industrialization' pattern. The sudden stop of this pattern of ‘re-industrialization’ in 2008-2009 coincides with the beginning of the crisis.

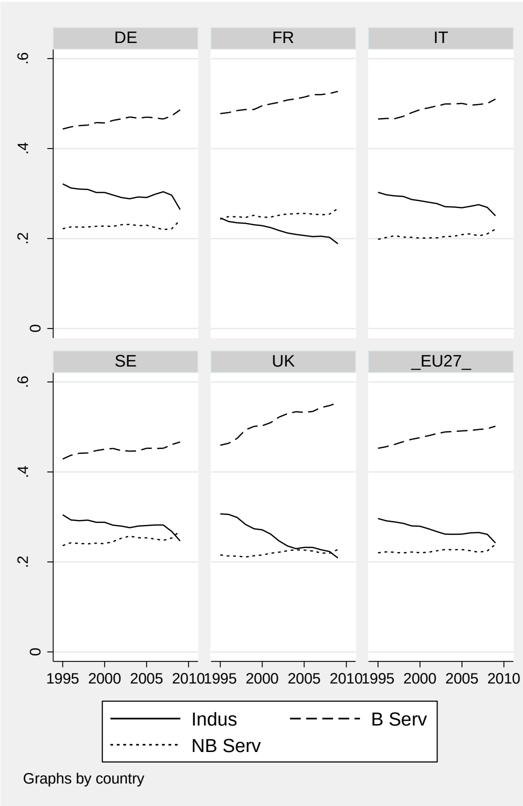
However, when looking at shares of VA in real terms (deflating for sector-specific price indexes) different trends emerge. First, the contribution of non-business services declined markedly in France, United Kingdom and Sweden. Second, the decline in the contribution of industry sectors in France is much less clear while there has been a

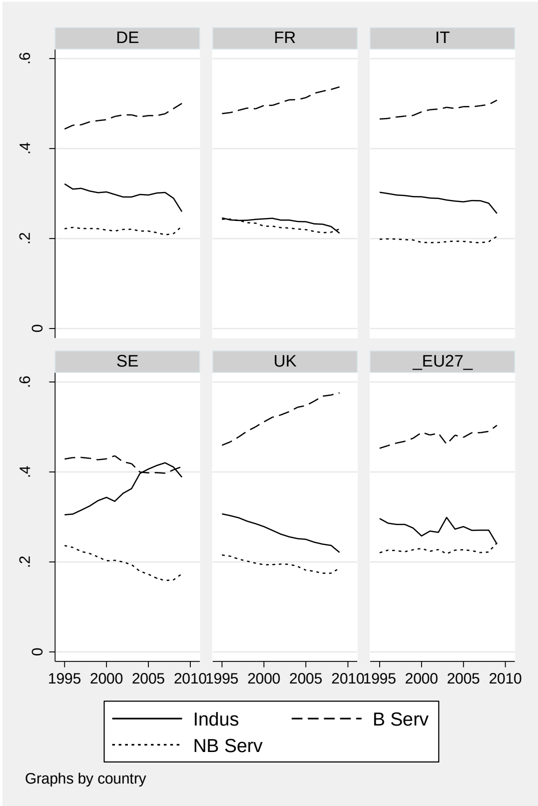
[1] More information on WIOD is reported in Annex A and is available at http://www.wiod.org.

[2] Based on the Nace 1.1 classification, industry includes Mining and quarrying (C), Manufacturing (D), Electricity, gas and water supply (E) and Construction (F). Business services include Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods (G), Hotels and restaurants (H), Transport, storage and communication (I), Financial intermediation (J) and Real estate, renting and business activities (K). Non-business services include Public administration and defense; compulsory social security (L), Education (M), Health and social work (N), Other community, social and personal service activities (O) and Activities of households (P). For the sake of simplicity, in this section we exclude agriculture and fishery from the analysis - this sector representing (in spite of their great importance for the environment) around 2.5% of value added for EU27.

strong increase in the contribution by industrial sectors in Sweden in real terms. The real share of VA in EU27 as a whole remained somewhat stable.

Figure 1 – Nominal and real value added shares





(a)

Nominal VA shares

Real VA shares

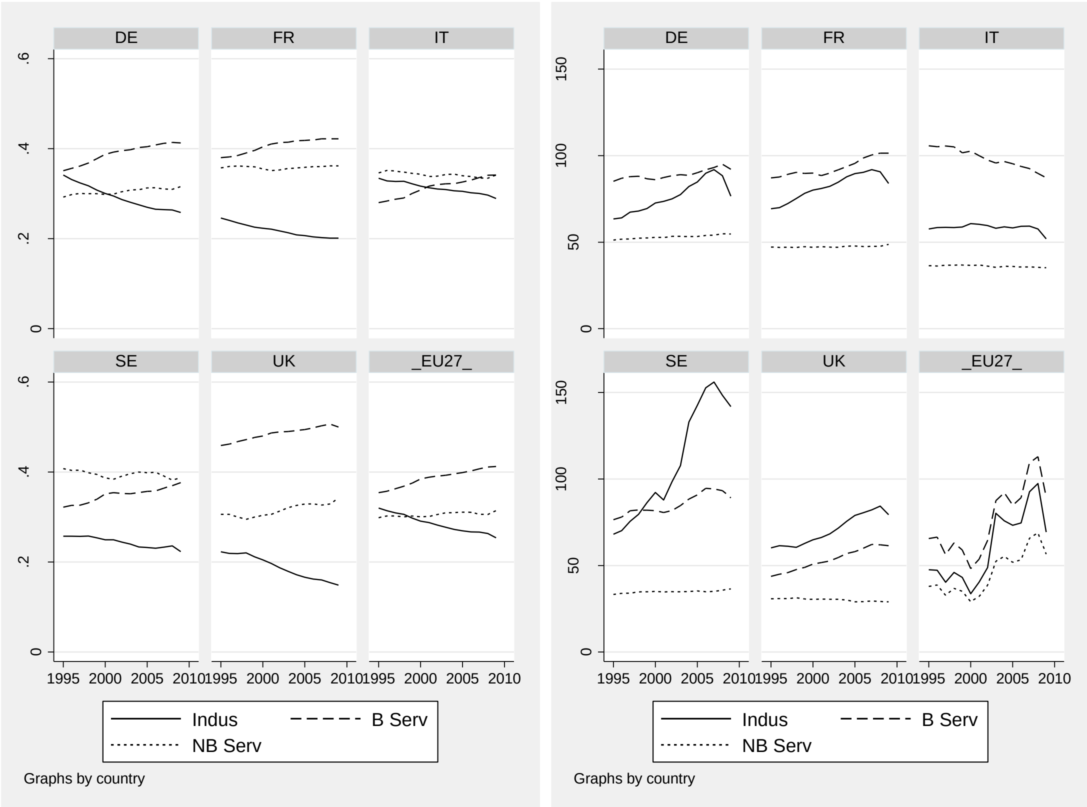
Source: own elaborations on the WIOD database

The reason for the difference between trends in nominal and real figures is the different dynamics of prices in industry and services. In all the countries, prices deflators of gross output and value added grew faster than average in non-business services while, with the exception of Germany and United Kingdom, price indices in industry recorded a slow growth.

Figure 2 reports employment share by macro sector in the left panel (a) and real labour productivity (real value added per employee) in the right panel (b). In all the countries employment shifted away from industry sectors to service sectors, the shift being particularly relevant in Germany and United Kingdom.

At the same time, the difference in the rate of labour productivity growth between industry and business services was in favour of industry in all countries except United Kingdom. Moreover, a reduction of real labour productivity in business services was observed in Italy. In all countries labour productivity in non-business services has been stagnating. Evidence for industry as a whole is more unstable, with a fast increase in labour productivity between 2000 and 2003, particularly relevant in the case of industry.

Figure 2 – Employment shares and labour productivity



(a) Employment shares

(b) Labour productivity (VA/L)

Source: own elaborations on the WIOD database

This evidence on changing shares, relative prices, and productivity in services and industry is in line with the ‘unbalanced growth' or 'cost disease' theory proposed by Baumol (1967) according to which: (i) to maintain constant output/final demand shares (in real terms), production inputs (labour, capital, intermediates, etc.) tend to be increasingly employed in so-called 'stagnant sectors' (i.e. less productive sectors)[1]; (ii) the transition to a service economy is more ‘nominal’ than ‘real’ because of the cross-sector differentials in terms of productivity growth rates and prices. Thus the results highlight the possible slowdown in overall economic productivity in many countries along with the service specialization path[2].

The evolution of domestic final demand in nominal (a) and real (b) terms by macro-sector is presented in Figure 3[3]. With the exception of the UK, no relevant change

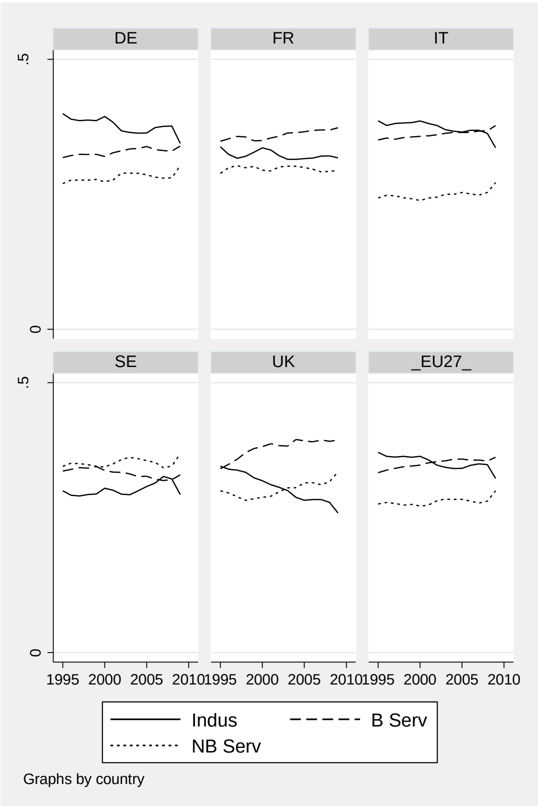
[1] Stagnant sectors are defined as those sectors for which, due to their particular nature, little improvement in the productivity of inputs is possible. On the contrary, progressive sectors tend to be characterized by sustained improvements in productivity.

[2] See also *The Economist*, week January 20, 2014.

[3] For domestic overall final demand we consider the expenditure in final demand by resident units, either of domestically produced or imported commodities. Domestic overall final demand thus included all import of commodities destined to satisfy final demand together with the part of commodities destined to final demand that is consumed in the country (export final commodities is excluded).

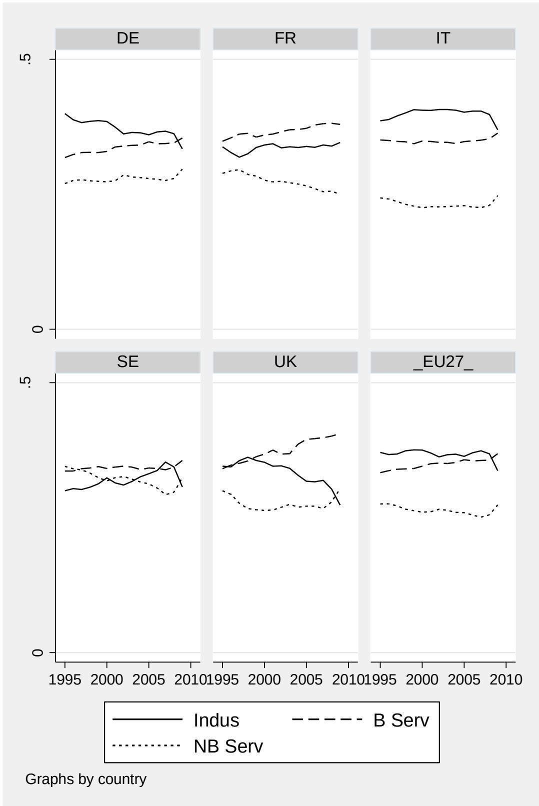
occurred in the five countries and in the EU27 as a whole in the years preceding the crisis (1995-2007). The apparent rapid shift away from industrial goods in the UK in nominal terms was, however, less pronounced when considering real figures. In the year of the crisis (2008-2009), we observe a strong reduction in the share of final demand for industrial goods (both in real and nominal terms) in all countries except France. These trends highlight the divergence between the change in production structure and the generally stable structure of final demand, which suggests that also the international trade specialisation of these European countries has changed.

Figure 3 – Nominal and real domestic final demand shares



(a)

Nominal domestic final demand shares



(b)

Real domestic final demand shares

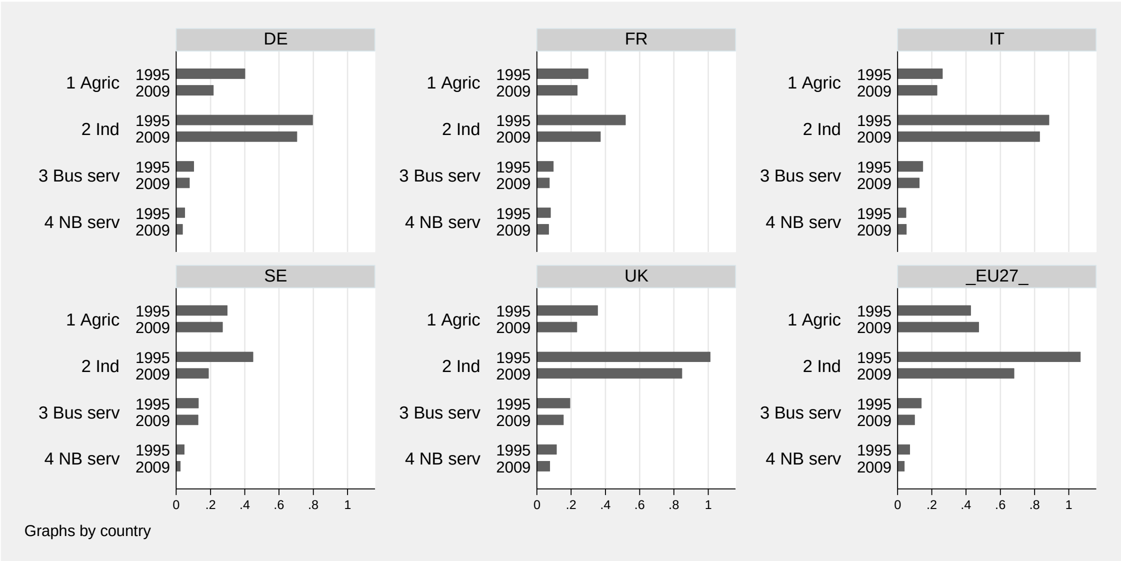
Source: own elaborations on the WIOD database

2.2 Environmental implications

2.2.1 A 'production footprint' perspective

What are the environmental implications of these changes? Taking carbon dioxide as the best documented environmental pressure, Figure 4 reports the CO2 emission intensity of real VA (ratio of direct emissions from production to VA) by country and macro-sectors for the years 1995 and 2009. Industrial sectors are, as expected, the most emission intensive sectors while non-business sectors are the least emission intensive sectors. The structural change towards services in terms of VA shares is thus expected to lead to a reduction in emissions even without any reduction in emission intensity in each sector, i.e. without technology-related emission improvements in the sector. However, the opposite should be true for Germany and Sweden, for which a re-industrialization pattern is expected to be accompanied by an increase in direct CO2 emission. Then, the change in the economic structure by itself can induce a change in direct emissions, which can be of a different sign depending on whether industrial sectors increased or decreased their role in the economy (see also EEA, 2014).

Figure 4 – Direct emission intensity (CO2/VA) - VA measured in 1995 prices

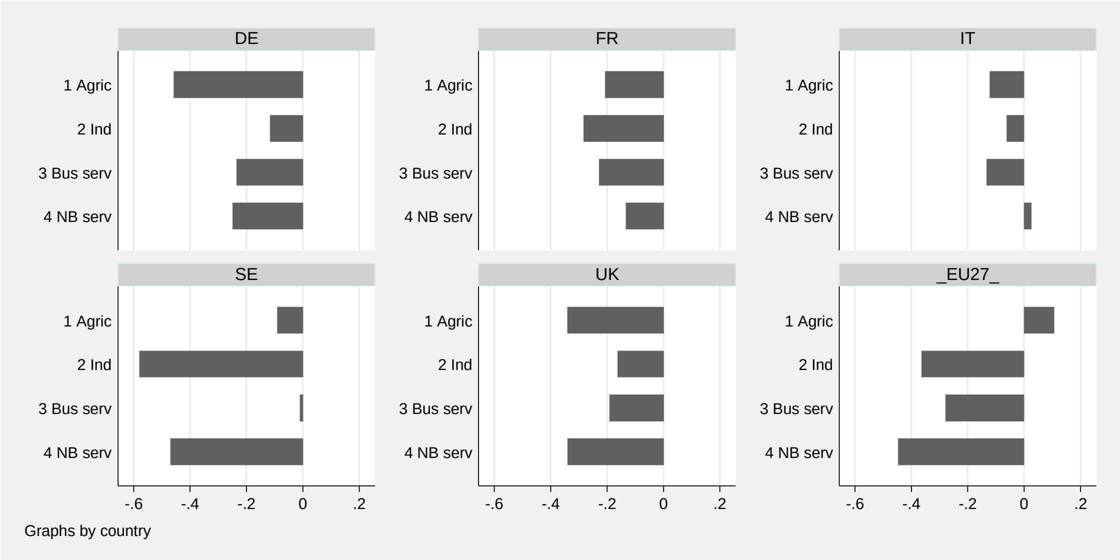


Source: own elaborations on the WIOD database

However also emission intensity (CO2/VA) of the sectors changed (Figure 5). Almost all macro-sectors in all countries experienced a decrease in emission intensity (direct emission at production level). With the exception of Sweden and EU27 as a whole, the reduction in emission intensity of real VA was greater in business services than in industry, while the performance of non-business sectors was more heterogeneous. For Sweden, EU27 and France we observe a very strong reduction in the emission intensity of industrial sectors (-58%, -36% and -28% respectively in 2009 with respect to 1995 levels) accompanied by a small improvement in the emission efficiency of business services (which include transports). For the other countries, however, the business service sectors reduced their emission intensity more than industry, while non-business sectors tend to have a relatively poor performance in France and Italy relative to other sectors.

This result suggest that, in term of direct emissions at the production level, even service sectors, and not only industry, can improve their emission efficiency although in a non uniform way across countries, but actually at the more aggregated level (EU27) industry greatly improves its emission efficiency. Coupled with the low direct emission intensity of services relative to industry, these results would suggest that transition to services could be good for the environment if service sectors are able to achieve improvements of their emission efficiency, as it is the case for some EU countries.

Figure 5 – Percentage change in emission intensity (CO2/VA) between 1995 and 2009



Source: own elaborations on the WIOD database

2.2.2 A ‘consumption footprint’ perspective

The above results are valid for ‘direct’ emissions at the production level ('production perspective' or ‘production footprint’) and must be reconsidered when looking at environmental implications of the final consumption of services ('consumption perspective' or ‘consumption footprint’) in which emission efficiency is evaluated at the level of final demand and along ‘vertically integrated’ industries.

The so-called ‘production perspective’, or 'production footprint', considers those environmental pressures directly arising from the production of goods and from consumption activities (direct emissions) and there is no consideration for those environmental pressures occurred along the value chains. These measures, built in accordance to national accounting principles (including the 'territorial' principle, according to which only pressures generated by resident units should be considered), are directly comparable to (direct) value added generation, (direct) employment and (direct) gross output production.

Production sectors, however, also purchase intermediate inputs to be combined with primary inputs (labour and capital) to produce their gross output and these intermediate inputs also require further intermediate inputs for their production. Total environmental pressures driven by final demand include all the environmental pressures (direct and indirect) occurring along the supply chain (upstream). These may occur either domestically or abroad for those intermediate inputs or final products that are imported from other countries. Therefore, the so-called ‘consumption perspective’ or 'consumption footprint' considers those environmental pressures generated to satisfy the final demand of a country or a region, independently on where the environmental pressures took place. ‘

While ‘production footprint' figures are widely available from environmental statistics or environmental accounts, ‘consumption footprint' figures need to be estimated. A widely used method to estimate ‘consumption perspective’ figures is environmentally extended input-output (EEIO) modelling. EEIO models allow to track all environmental pressures along the supply chain and to consider separately those pressures arising from the production of exported and imported goods.

The distinction tends to be relevant even for a policy point of view. Environmental policies generally identify objectives and targets in terms of ‘production footprint'. A typical example is the Kyoto Protocol that assigned to each country a target for CO2 direct emissions arising from domestic production. This approach has been challenged by newly industrialized countries in the negotiations on global climate policy. These countries claimed that most of their direct CO2 emissions are linked to the production of commodities which are exported to OECD countries for final consumption in those same countries, and then should not be accounted for as emissions of the producing countries Although the target of emission reduction adopted at the COP21 through the Paris Agreement of 2015 (the so called INDCs – Intended Nationally Determined Contributions) are still defined in terms of emissions from domestic production, this approach is increasingly challenged within the debate on global inequality and ‘carbon equity’ (see Chancel and Piketty, 2015).

To estimate ‘consumption footprint’ figures we define total (direct and indirect) environmental pressures generated to satisfy the final demand of a country (or region) as the overall amount of pressures exerted by production sectors to produce goods and services demanded by the population of the country (or area) under analysis. More specifically, these pressures include:

1. Direct pressures to produce gross output demanded domestically by residents (households, government, non-profit organizations, change in inventories and gross fixed capital formation); this means that the part of gross output that is exported (either as final good or as intermediate good), and the part that is used domestically as intermediate input should not be included in this first component;
2. Indirect pressures induced (domestically or abroad) along the whole supply chain to produce the domestic output destined to domestic final demand (as defined at point 1);
3. Direct and indirect pressures (that occur in any place) needed to produced goods and services imported and then destined to final demand of country residents.

These measures can be tracked by means of Environmentally Extended Multi Regional Input Output models (EE-MRIO) (see for example Serrano and Dietzenbacher, 2010). Without loss of generality, we assume that the world is composed by two regions, A and B, and that the square matrix $\mathbf{Z}_{ij}$ describes the inter-industry monetary transactions between industries of region *i* and *j* (with *i*=A, B and *j*=A, B). The global matrix of inter-industry and inter-regional monetary flows of intermediates is then defined by the square matrix **Z**:

$$\mathbf{Z} = \begin{bmatrix} \mathbf{Z}_{\mathrm{A,A}} & \mathbf{Z}_{\mathrm{A,B}} \\ \mathbf{Z}_{\mathrm{B,A}} & \mathbf{Z}_{\mathrm{B,B}} \end{bmatrix}$$

Similarly, we define a matrix of final consumption in which $\mathbf{f}_{ij}$ is a vector that measures the final demand of residents in country *j* of goods and services produced in country *i*. The matrix of inter-regional flows of final goods is then defined by the matrix **F**:

$$\mathbf{F} = \begin{bmatrix} \mathbf{f}_{A,A} & \mathbf{f}_{A,B} \\ \mathbf{f}_{B,A} & \mathbf{f}_{B,B} \end{bmatrix}$$

The vector of total output (**x**) is defined as the sum of goods and services produced and then used either as final goods or intermediate goods:

$$\mathbf{x} = \mathbf{Zi} + \mathbf{Fi}$$

where **i** is the summation vector. Finally, we define **W** as the matrix of country-industry specific amount of direct environmental pressures (or socio-economic variables, such as labour input) needed to generate the vector of gross output **x**. $\mathbf{E}=\mathbf{W}'\langle\mathbf{x}\rangle^{-1}$ is then a matrix of output coefficients (quantity of direct environmental pressures per unit of gross output) in which each column of the matrix **W** represents a different pressure on the environment, and $\langle\mathbf{x}\rangle$ is a diagonal matrix with the element of vector **x** on the main diagonal.

Following Serrano and Dietzenbacher (2010), we define the amount environmental pressures (direct and indirect) needed to satisfy the final demand in country A ($\mathbf{f}_{A,A}\mathbf{i}+\mathbf{f}_{B,A}\mathbf{i}$) as:

$$\mathbf{M} = \mathbf{E}'\mathbf{L} \begin{bmatrix} \mathbf{f}_{A,A} & 0 \\ \mathbf{f}_{B,A} & 0 \end{bmatrix}$$

where $\mathbf{L}=(\mathbf{I}-\mathbf{Z}\langle\mathbf{x}\rangle^{-1})^{-1}$ and I is the identity matrix.

E'L is a rectangular matrix that describes, for each sector and country, the overall amount (direct and indirect) of environmental pressures that occurs domestically or abroad to produce one monetary unit of final goods and service.

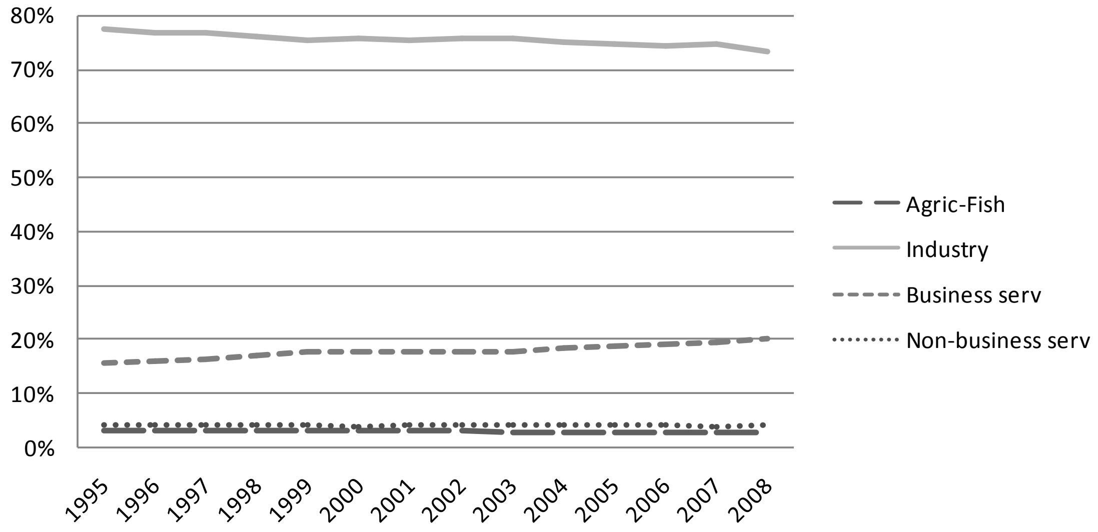
2.2.3 The vertically integrated impact of services

Figure 6 and Figure 7 report the relative contribution of four macro-sectors to 'production footprint' and 'consumption footprint' CO2 emissions respectively for the EU27 in 1995-2009.

Industry is the main contributor to total emissions for both the consumption and production footprint despite a slow but continuous reduction. The figure highlights a slow and continuous increase in the contribution of business services. The contributions of agriculture and fishing sectors and of non-business sectors did not experience any relevant change.

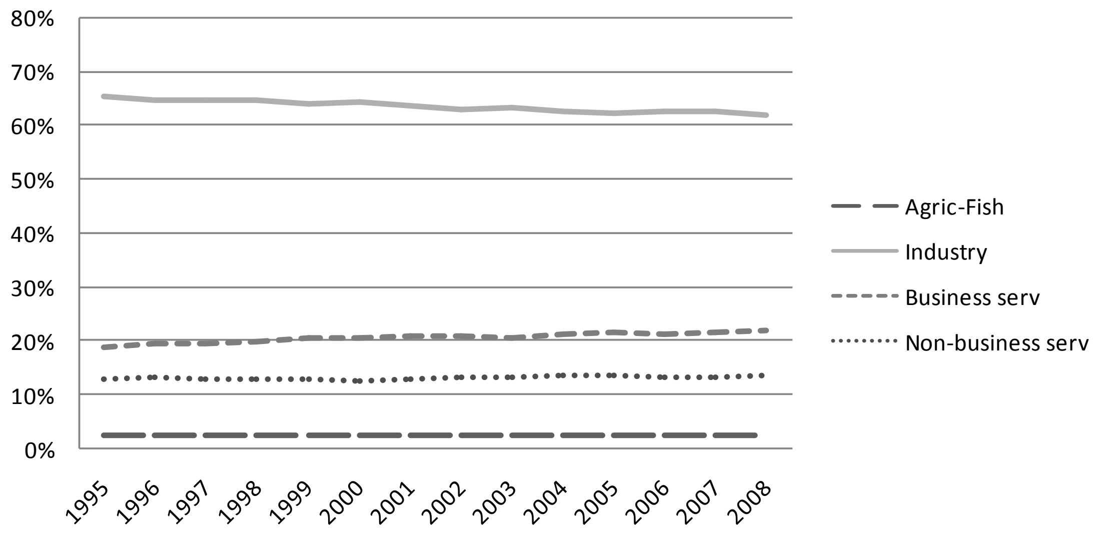
However, Figure 8 reports the ratio between the consumption and production perspective of each macro-sector. Macro-sectors with a ratio above unity induce more emission to satisfy their final demand than what they directly emit in production. Their consumption footprint is higher than their production footprint. Industry and agriculture lie below unity while business services and, even more so, non-business services, lie substantially above unity. The key factor is that a shift to a service-based economy is likely to lead to a remarkable increase in the demand for intermediate inputs from industry and services themselves and of the associated emissions, wherever they are generated.

Figure 6 - Direct CO2 emissions (production perspective) for EU27 by macro-sector (% of total)



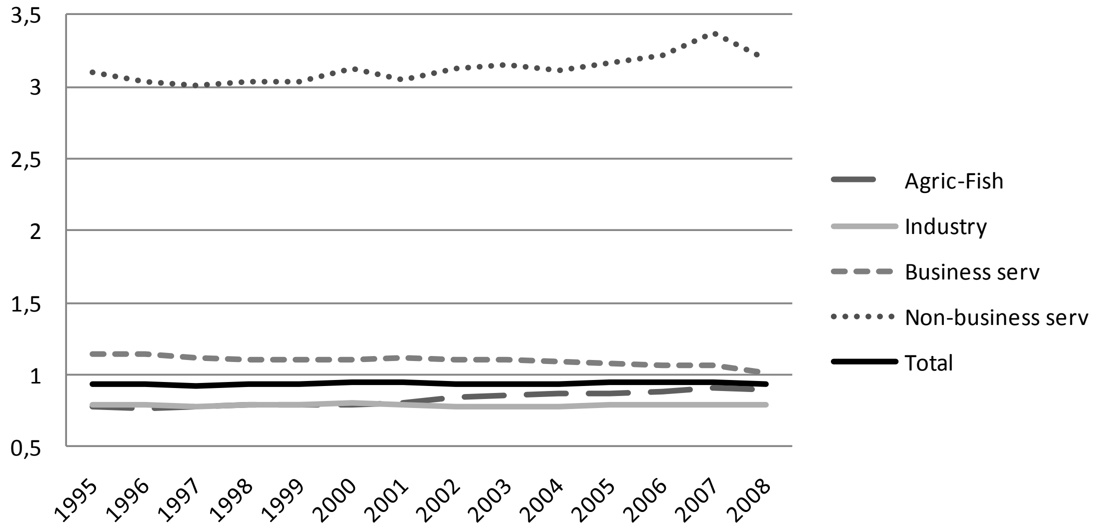
Source: own calculation based on WIOD data-

Figure 7 - Direct and Induced CO2 emissions (consumption perspective) for EU27 by macro-sector (% of total)



Source: own calculation based on WIOD data

Figure 8 - Ratio between consumption and production perspective by macro-sector (CO2 emissions, EU27)



Source: own calculation based on WIOD data-

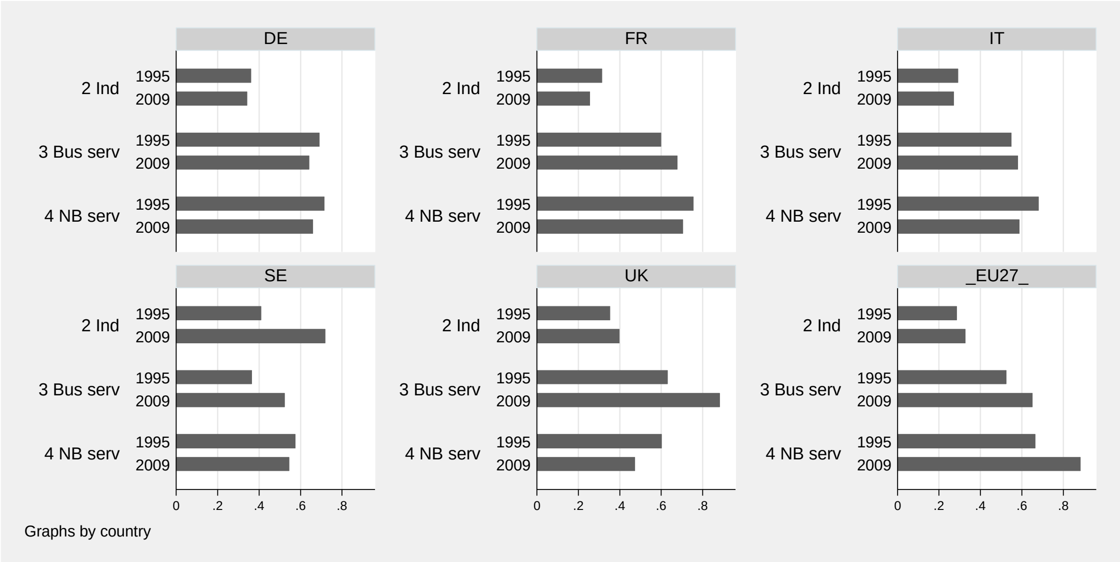
Similarly, Figure 9 shows the ratio between CO2 emission intensity of domestic final demand ('consumption footprint' per euro of domestic final demand) and CO2 emission intensity of value added ('production footprint' per euro of value added) for the five countries considered above and for EU27 as a whole.

The ratio between these two measures is greater for services (both business and non-business services) than for industry, the only exception being Sweden in 2009. This means that the difference between service sectors and industry sectors in terms of ‘consumption perspective’ emission intensity is reversed with respect to ‘production footprint' , which was substantially in favour of services.

Figure 10 reports the change in ‘consumption footprint' emission intensity of final demand in real terms between 1995 and 2009. There is evidence of a decline in the emission intensity of final demand in all countries and macro-sectors, the only exception being business services in Sweden and the UK. Emission intensity of final demand for industrial goods shrank more than the corresponding figure for business services in all countries but Germany, while non-business services performed better than average in all countries but Italy and France.

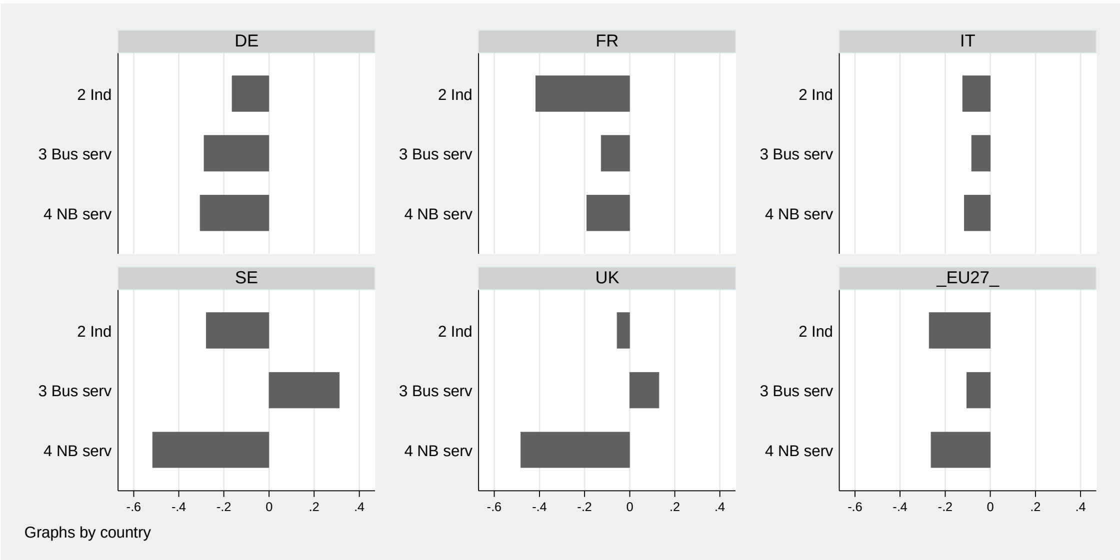
While the dynamic performance of services in terms of direct emission intensity was generally better than average, when considering all emissions occurring throughout the supply chain to satisfy final demand (consumption footprint) the evidence is less clear, with services having better performance than industry just for Germany, while the EU27 as a whole shows a generally better dynamic performance in the industrial sector.

Figure 9 – Ratio between ‘consumption perspective’ emission intensity of real final demand and ‘production perspective’ emission intensity of value added



Source: own elaborations on the WIOD database

Figure 10 – Change in ‘consumption perspective’ emission intensity of real final demand between 1995 and 2009



Source: Own elaborations on the WIOD database

The results can be summarised as follows. There is not a general evidence that direct emission intensity (production footprint) is improving more in industry than in services, the latter also having a lower direct emission intensity. Then services can be good for the environment. However, when considering indirect emissions along the value chains (‘consumption footprint’) the service sectors have an emission intensity (of final demand) that is closer to the one of industry sectors and, more importantly, shows slower improvements of efficiency compared to industry. Therefore, the transition to services seems to be beneficial for the environment just when taking a narrow sectoral production perspective but this conclusion can be even reversed when taking into account the indirect pressure of services demand along the value chains and long run trends of efficiency improvements.

3 International effects: global economic and environmental footprints of Europe

3.1 'Trade embodied' pollution

As a result of structural change in the EU economies, the sectoral mix of domestic production differs more and more from the final demand mix (see Section 2.1), and this necessarily implies changing levels and composition of international trade in goods and services. This changing production and trade specialisation of the EU has many implications from the economic point of view, including the weakening of the global industrial role of the EU and international employment redistribution. It also has environmental implications, including the possible role of trade in shifting internationally the location of environmental pressures.

The environmental redistribution effects generated by the changing economic specialisation of countries have been addressed by a stream of analyses on 'trade embodied pollution' or the 'environmental footprint' of international trade. The many empirical studies on this topic try to measure the extent to which industrialized countries rely on products (import) whose environmental pressures have been generated abroad.

'Trade embodied' pollution analysis is generally based on two main categories of EEIO models: (i) single country/region EEIO using the so called 'domestic technology assumption' (DTA), according to which imported goods are assumed to be produced by the same technology and environmental efficiency as domestically produced goods; emissions embodied in imported goods could be then interpreted as 'emissions avoided' domestically as a consequence of trade; (ii) multi-regional input-output (MRIO) models for which imported goods are modelled differently from domestic goods in terms of production technology and/or environmental efficiency. Also other methodologies have been used (see ETC/SCP 2011).

Looking at studies including European countries, a report of the EEA (EEA, 2013) uses an EEIO model with pure DTA. They use hybrid economic-environmental accounts (NAMEA[4]) and input-output tables to estimate air emissions and material flows embodied in trade flows for 9 EU countries separately. Results are mixed, with some country being a net exporter and some other a net importer of emissions. Arto et al (2014) assume that direct emissions are proportional to the weight of imported goods (still produced with the same set of intermediate inputs as domestic goods) and not to the monetary value of the goods as the in the classical DTA. Results show that the estimated trade imbalance (emissions embodied in imports higher than emissions embodied in exports) of Spain is greater for the physical DTA relative to the monetary

[4] NAMEA is the National Account Matrix with Environmental Accounts, produced for Italy by ISTAT, see http://dati.istat.it/Index.aspx?DataSetCode=DCCN_CONTIEMATM

DTA which significantly underestimates emissions embodied in imports. Marin et al. (2012) use a DTA approach to estimate the gap between production and consumption perspective emissions for Italy and Spain and highlight the potentially large bias that may arise when only information for aggregated sectors is available.

Other studies apply alternative methods relative to the DTA which is taken as a benchmark. Li and Hewitt (2008) estimate that the DTA underestimates emissions embodied in import for UK-China bilateral flows by 63% relative to an input-output model accounting for bilateral trade.

Another set of studies uses ad hoc MRIO models. Ahmad and Wyckoff (2003) and Nakano et al (2009) use a MRIO model based on OECD and IEA data including, respectively, 24 and 41 countries/regions, with specific assumption for the 'Rest of the World'. Results show a general trend for 'carbon leakage' in Western European countries. Kratena and Meyer (2010) focus on Austria and they describe the 'Rest of the World' with the EU27 input-output matrix and environmental coefficients, finding significant (though decreasing in time) carbon leakage for Austria. Peters and Hertwich (2006) build a MRIO model for Norway including the seven most important trade partners and finding that Norway is a net emission importer. Wiedmann (2009) compares results from a MRIO for the UK with the results obtained by applying LCA coefficients to physical quantities of imported and exported goods. The two approaches differ substantially as regards sector-level results although aggregate figures are quite similar.

Other studies use combinations of MRIO and computable general equilibrium (CGE) models. Atkinson and Hamilton (2002) employ a model accounting for inter-sectoral flows for 95 countries and find that OECD countries are net consumers of global resources. Muñoz and Steininger (2010) find that emissions induced by domestic consumption for Austria are 44 % greater than direct emissions from production by using a MRIO model with GTAP data. Turner et al (2009) compare a 3 sectors CGE model with the results of a MRIO model for Scotland – Rest of the UK trade flows. Atkinson et al (2011) use a MRIO model with GTAP data highlighting that developing countries are characterized by more carbon-intensive export relative to developed countries.

Finally, certain studies use other approaches. Grether and Mathys (2008) apply the concept of 'pollution terms of trade' introduced by Antweiler (1996) and find confirmation for the Pollution Haven Hypothesis. Wagner (2010) focuses on energy embodied in trade using bilateral trade data and discusses the implications of environmental impacts embodied in trade flows for studies on the Environmental Kuznets Curve. Finally, Peters et al. (2011) compute emissions embodied in trade flows by means of two different methodologies based on GTAP and UNSD (United Nations Statistics Division) data. The authors find that emissions embodied in global exports grew faster than global GDP, population and CO2 emissions, thus generating a huge global transfer of emissions.

Machado et al (2001) use an IO model to assess the impact of trade on Brazilian energy use and on CO2 emissions in year 1995. They find that Brazil is a net exporter of energy and carbon (10% of inflow of energy use compared to 12% of outflow and 10% of carbon inflows compared to 14% of outflows) and quantify that each dollar spent on exports embodies 40% more energy and 56% more carbon than each dollar spent on imports. Sánchez-Chóliz and Duarte (2004) analysed the impact of Spanish international trade on atmospheric pollution, adopting a sectoral perspective and using CO2 emissions produced in Spain and abroad as an indicator of air pollution. Results show that beside being a net exporter of CO2 emissions, Spanish flows of pollution are polarized around a few sectors: exporters of CO2 emissions are primarily transport material, mining, energy, non-metallic mineral metals, basic metals and chemical; importers of CO2 emissions are construction, transport material and food, whose final demands constitutes more than 70% of CO2 emissions. Spanish major polluters are concentrated in a few highly polluting sectors which supply both national and foreign demands.

This complex picture for results, which depends on the plurality of methodologies and on data limitations, does not prevent from getting a general suggestion. There is an international emission re-location associated to trade: environmental pressures embodied in imports by industrialized countries are generally greater than environmental pressures embodied in their total exports. Although this evidence is quite robust when considering the set of industrialized countries as a single region, its quantitative assessment at country level varies substantially according to the methodological approach, the level of aggregation of data, and the specific year or period considered.

Furthermore, the use of these analyses in policy making can be limited as the results of different models may be contradictory. A comparison of two approaches which are based on two different datasets assessing the trend of the Dutch carbon footprint (CO2 only) shows that the '*annual changes are sometimes very different in magnitude and in four out of the 14 years, the sign is even different*' (Hoekstra et al., 2013, p. 6) meaning that one approach shows a year-to-year increase in CO2 emissions and the other approach a decrease. As a consequence, it can be very difficult to adopt trade policy measures – to be discussed for implementation in the importing countries - attempting to discriminate imported products based on 'embodied pollution' also because they may be not in accordance with WTO rules (Yungfeng et al., 2011)[5]. International 'green' technology transfer can be a better approach (see Section 6). As Yungfeng et al. (2011) state: '*This* [consumption-footprint] *approach is not meant to fuel a meaningless blame-game of political rhetoric. Rather, it is meant to help inform climate change mitigation efforts by promoting greater accountability among nations and economic blocs*' (Yungfeng et al., 2011, p. 13).

A correlated issue is the fact that certain countries are not actually reducing their emissions but only moving it to countries where environmental regulation is weaker or absent altogether. Kanemoto et al (2014) investigate the phenomenon of emission leakage in countries signing the Kyoto Protocol, using data from 1970 to 2011. Their results highlighted three important facts: first, when accounting for trade, emissions produced in developed countries increase rather than decrease; second, sectors which achieved a better domestic emission reduction are at the same time increasing the share

[5] One of the often referred policies in this context is Border Tax Adjustments (BTA) meaning that for example a tax is levied on imports by carbon-taxing countries on goods and products originating from non-carbon taxing countries and goods and products from carbon-taxing countries will be exempt from the carbon tax when exported to non-carbon taxing countries thereby guaranteeing a level playing field. There is an on-going debate whether WTO rules are preventing carbon taxes the introduction of carbon taxes. See for a detailed discussion: Hillman (2013).

of CO2 emitted abroad; third, it is outside the 'Kyoto countries' that flows of embodied CO2 are growing faster and often originating in developing countries towards advanced and developed economies. A similar result is shown in Peters and Hertwich (2006), who studied emissions embodied in trade for Norway, and found that one third of the Norwegian emissions are coming from carbon leakage in Non-Annex I countries of the UNFCCC.

The extent to which regulation can influence carbon leakage is investigated in Arroyo-Curras et al (2015), who analysed the implications for Europe, the United States and China of being a "pioneer" for climate policy actions. Interestingly, they observe that the re-allocation of emissions due to carbon leakage depends mostly on the energy system structure of the country or area that takes the abatement action, in other words whether the region is a fossil resource importer (e.g. Europe), exporter (e.g. the United States) or a carbon intensive economy (e.g. China). Moreover, they found that the leakage due to a more stringent climate action set up in pioneering countries remains below 16% of the emissions reductions.

Alternative policies such as border carbon adjustments (BCAs, which consist in taxing the carbon content of a good at the nations' border) have been proposed to overcome issues related to both leakage and firms competitiveness losses. For example, Branger and Quirion (2015) conduct a meta-analysis on the effect of BCAs on carbon leakage, calculating that these adjustments might reduce leakage by 6% on average. However, the use of these instruments is still controversial because they appear to be directed more towards the protection of national firms' competitiveness than towards a reduction of negative environmental impacts.

The main interest of studies in trade embodied pollution is that they can help clarifying if and how resource efficiency gains recorded in the EU countries (production footprint) can depend on changing trade patterns, in particular increasing import and less production of environmentally intensive goods, instead of the diffusion of greener technological and organisational innovations in the domestic economic system.

3.2 Integrated environmental and economic footprints

'Trade-embodied pollution' analysis focuses on just one effect of the change in international specialisation, i.e. international emission re-location, whereas it generally does not include the broader set of effects, in particular the international re-location of value added and employment. If structural change of the EU economies induces a re-location of emissions outside Europe through the changing composition and level of international trade, the same change in trade specialisation implies also relocation of value added and employment. For example, the analysis based on a MRIO approach by Arto et al. (2014) concludes that in 2008 24% of global GHG emissions and 20% of employment are linked to international trade. Even more interesting are the data for China as one of the countries with which the EU has a GHG trade deficit. China increased the export volume noticeably over time so that 28.9% of Chinese employment and 33.6% of national GHG emissions are linked to the production of exported goods satisfying the demand in other countries. China, as the main exporting country at the global level, benefitted from the increase in international trade as 37.5% of total employment generated by trade worldwide in 2008 was created in China. The rise in employment induced by the increase in export (113 million jobs) outpaced the increase in total employment (94 million jobs) in China (Arto et al., 2014).

Parallel to the literature that looks at the environmental content of trade, there is an extensive literature based on input-output vertically integrated approaches that looks at the displacement of jobs due to the changes in the location of production activities. Among the most recent contributions, Alsamawi et al. (2014) analyse the average wages paid for the production of direct and indirect imports of countries, using employment and income footprint. The results highlight the existence of two groups of countries, characterized by different employees' skills level and wages, as well as by a substantially different employment footprint. Moreover, the analysis highlights that the same skills are often characterized by different levels of wages across the two groups of countries. Gómez-Paredes et al. (2015) follow a 'labour footprint' approach to assess differences in principles and rights of labour force across different countries, while Simas et al. (2015) quantify the impacts of development and globalization using a 'consumption perspective', which allows more equitable comparison of requirements of lifestyles and final consumption between European and developing countries. The analysis of the European labour footprint highlights that Europe mainly depends on developing countries for primary goods and that European demand contributes substantially to the creation of employment in these countries. However, a substantial discrepancy is found in the qualification level of jobs created in the EU to satisfy the external demand and jobs created by European demand in developing countries: they estimate that 30% of labour embodied in imports is low skilled, whereas the proportion of low-skilled labour embodied in the EU's exports is three times lower. Finally, the authors argue that moving industries as well as manufacturing stages to developing countries increases overall energy use because of differences in energy efficiency between the two groups of countries.

Therefore, an integrated assessment of environmental and economic effects of the changing European specialisation can provide more relevant results with respect to a simple 'trade-embodied pollution' analysis.

In the next section, we compare the 'environmental content' of trade with the 'socio-economic (labour and value added) content' of trade to evaluate whether or not there has been a symmetry in the internationalization of production activities according to their environmental and 'socio-economic' implications.

First, we compare the share of environmental pressures, labour and value added generated abroad to satisfy the final demand of EU27 countries and the aggregate trends decomposed by the 'domestic component' and 'foreign component'. As a second step, we provide some preliminary evidence on the extent to which changes in the share of environmental pressures, labour and value added generated abroad are due to differences in the trend of 'efficiency' (environmental pressures, labour and value added per unit of output) of production between the EU27 and its trading partners. Finally, we dig deeper in bilateral trade patterns with specific partners outside the EU.

From a methodological point of view, the assessment of environmental pressures and socio-economic variables embodied in trade is strictly linked to the direct-indirect-total environmental pressures issue described in Section 2.2.2. The objective is, in this context, the assessment of where environmental pressures, value added and employment occurred in order to satisfy the final demand of a specific country/region.

To illustrate, let us consider a world composed by three countries: A, B and C. To simplify notation, we now assume that the matrix of environmental pressures is composed by only one pressure at a time (i.e. **W** and **E** are now column vectors, **w** and **e**). We define <**e**> a square matrix of environmental pressures coefficients (direct pressures per unit of output). The matrix will be composed by three blocks, each including coefficients for each of the three countries.

To evaluate the source of environmental pressures to satisfy the final demand (of domestic and imported goods) of country A, we define the vector **k** as:

$$\mathbf{k} = <\mathbf{e}> \mathbf{L} \begin{bmatrix} \mathbf{f_{A,A}} & \mathbf{0} & \mathbf{0} \\ \mathbf{f_{B,A}} & \mathbf{0} & \mathbf{0} \\ \mathbf{f_{C,A}} & \mathbf{0} & \mathbf{0} \end{bmatrix}$$

Vector **k** will be composed by three blocks.

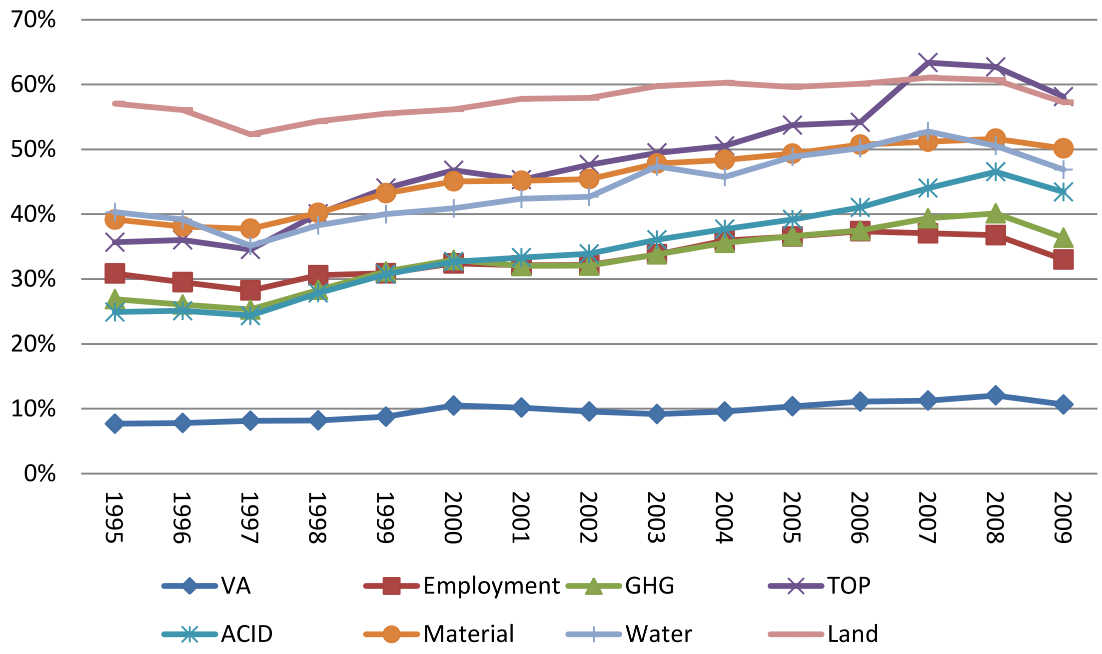
$$\mathbf{k} = \begin{bmatrix} \mathbf{k_A} \\ \mathbf{k_B} \\ \mathbf{k_C} \end{bmatrix}$$

$\mathbf{k_A}$ is a column vector that describes the amount of environmental pressures occurring in country A (each element of the vector is a sector in country A) to satisfy final demand of country A. Similarly, $\mathbf{k_B}$ shows the distribution across sectors of country B of environmental pressures generated to satisfy the final demand of country A. In relative terms, $\mathbf{k_A i/ki}$ is the share of pressures occurring in country A over total worldwide pressures generated to satisfy the final demand of country A, while $\mathbf{k_B i/ki}$ is the share of pressures occurring in country B (over total worldwide pressures) generated to satisfy the final demand of country A.

3.3 Results for the EU27

Figure 10 reports the trends in the share of environmental pressures, employment and value added that were generated out of the EU27 over the total required to satisfy the final demand of the EU27. This is a relative indicator of how much the EU27 is relying on its trading partners to satisfy its final demand. Changes in this set of indicators reflect a combination of changes in the relative importance of domestic production (either of final products or of intermediate products) to satisfy domestic final demand and of differences between the EU27 and the rest of the world in the evolution of intensity coefficients (related to environmental pressures, labour and value added) of output. For example, even in presence of a completely unchanged composition of international trade, a faster improvement (e.g. reduction in CO_2 emissions per monetary unit of production) in environmental efficiency in the EU27 *vis-à-vis* the rest of the world would result in an increase in the relative amount of environmental pressures occurring abroad to satisfy domestic demand.

Figure 11 – Share of environmental pressures and economic activity occurred out of the EU27 to satisfy the final demand of EU27



Source: own elaboration based on WIOD database

The share of 'foreign' environmental pressures that have been generated to satisfy the domestic final demand of the EU27 over total generated environmental pressures has increased steadily between 1995 and 2007 and decreased afterwards. Throughout the period, more than half of the land ('Land') used to satisfy the final demand of the EU27 was situated out of the EU. Land use is mostly linked to agricultural products and products that intensively use agricultural products as an intermediate input (e.g. food products). The share has remained rather stable and around 55-60% of total land use. A steady but slow increase is visible starting from 1997.

For what concerns 'TOP' (tropospheric ozone precursors), material use ('Material') and water use ('Water'), the foreign component corresponded to around 35-40 % of total requirements in the mid 90s and increased to about 50% (over 60% for TOP) in the late 2000s. This represents a high share of total environmental pressures induced by the final demand of the EU27. Due to the localized harmful impact on the environment and local health of tropospheric ozone precursors, this rapid increase of pollution generated abroad has shifted the burden for environmental costs away from the EU27.

Greenhouse gases ('GHG') and emissions with acidifying potential ('ACID') follow similar patterns, with the foreign component accounting for about 25% of the total in 1995 and for about 40-45% (GHGs and acidification, respectively) in 2008. While greenhouse gases represent a global externality, acidifying emissions produce rather localized environmental and health costs. This means that off-shoring production activities that contribute substantially to greenhouse gas generation has no effect on the contribution to the global externality (i.e. carbon leakage effect), while the displacement in production activities that are intensive in the generation of local pollutants (e.g. acidification or tropospheric ozone precursors) just displaces the social cost of pollution, possibly generating hot-spots in other countries. This latter shift in production reduces the external costs for ‘domestic’ population while it increases the social costs of pollution for ‘foreign’ population.

All in all, with few exceptions (i.e. land use), the environmental burden needed to satisfy EU27 final demand has experienced a substantial shift abroad.

When looking at the a employment and value added ('VA') generated abroad as a share of total employment and value added generated worldwide to satisfy the domestic final demand of the EU27, trends are rather flat. For what concerns employment, about 30% of the total employment is generated abroad in 1995, which increases to about 35% in 2008. For what concerns value added, the average figure is much smaller, with about 8 % of total value added generated abroad in 1995 that increased to around 11% in 2008. The low share of value added generated abroad is mostly due to the large share of total final demand in Europe that is directed to those service sectors that cannot be off-shored. Moreover, by combining the evidence for value added with the one for employment, we deduce that the EU tended to offshore those activities with a systematically lower than average value added per employee and that wages in non-EU27 countries are, on average, systematically lower than wages in the EU27.

As a first conclusion, in the period we are considering, the relative share of economic activity (employment and value added) generated abroad to satisfy EU27 final demand was smaller than the share of the environmental pressures generated abroad. Moreover, while the range of variation of most of the pressures has been remarkable during the period, both value added and employment trends have been rather flat. In particular, value added just fluctuates around its initial value (8-10%) while employment patterns appeared to be slightly more hectic. It appears that to satisfy its domestic demand, EU27 exports more pollution and resources exploitation than labour and value added.

To shed some light on the differences in sectoral composition of goods and services produced domestically and abroad we refer to Table 1which describes the top five sectors in which production occurs to satisfy the final demand of EU27 consumers, split into ‘domestic sectors’ (EU27) and ‘foreign sectors’ (non-EU27). Results are reported for years 1995 and 2009. In 1995, top five foreign sectors (C, 71-74, 30-33, 51 and A-B) accounted for 43 % of value added, 54 % of employment and 37 % of greenhouse gas emissions over the total arising from production abroad. On the other hand, the profile of top five sectors in EU27 countries in 1995 (70, 71-74, L, N and F) shows that these sectors accounted for 40 % of value added, 32 % in employment and just 5 % in greenhouse gases. These profiles remain rather stable also in 2009. The main message is that ‘domestic’ production (EU27) is disproportionately allocated to sectors with greater than average labour productivity (their share in value added is greater than their share in employment) while the opposite occurs for ‘foreign’ production. Moreover, top-sectors account for a very small share of greenhouse gas emissions for production occurring within the EU27 while this share is much greater for the top five sectors in terms of production outside the EU27.

This means that the EU27 off-shores systematically more polluting and less productive sectors towards non-EU27 countries. These include the agriculture sector (code A-B) and the mining and quarrying sector (code C). On the other hand, a large role is played by service sectors (top four) for what concerns top five ‘domestic’ sectors.

Table 1 - Top five sectors (in terms of VA) to satisfy EU27 final demand

Sector	Value added (millions of US$)	Employment (thousands of employees)	GHG (thousand tonnes of CO2-eq)
Top 5 sectors in non-EU27 countries in terms of VA generated abroad to satisfy EU27 demand (1995)			
C	66516	4115	225063
71-74	64334	1830	11191
30-33	51680	2065	13916
51	46551	2232	5532
A-B	37017	34115	268729
Total top 5 sectors	266098	44357	524430
Total non-EU27	622273	81593	1436238
Share of top 5 sectors over total non-EU27	43%	54%	37%
Top 5 sectors in EU27 countries in terms of VA generated (domestically) to satisfy EU27 demand (1995)			
70	805378	2905	15284
71-74	655562	11395	31983
L	546582	14231	39342
N	515241	15783	32044
F	483550	13910	61610
Total top 5 sectors	3006313	58224	180263
Total EU27	7466181	182765	3825293
Share of top 5 sectors over total EU27	40%	32%	5%
Top 5 sectors in non-EU27 countries in terms of VA generated abroad to satisfy EU27 demand (2009)			
C	293102	4508	276559
71-74	178141	3641	14361
51	100178	3143	4517
30-33	93973	3115	12925
A-B	80496	35410	321197
Total top 5	745890	49816	629559
Total non-EU27	1555808	98813	1897714
Share of top 5 sectors over total non-EU27	48%	50%	33%
Top 5 sectors in EU27 countries in terms of VA generated (domestically) to satisfy EU27 demand (2009)			
70	1603919	4137	13518
71-74	1472362	20222	33834
N	1112609	20777	30843
L	959433	15161	32551
F	900827	15791	55287
Total top 5 sectors	6049150	76088	166033
Total EU27	13038644	200513	3251287
Share of top 5 sectors over total EU27	46%	38%	5%

Source: own elaboration based on WIOD database

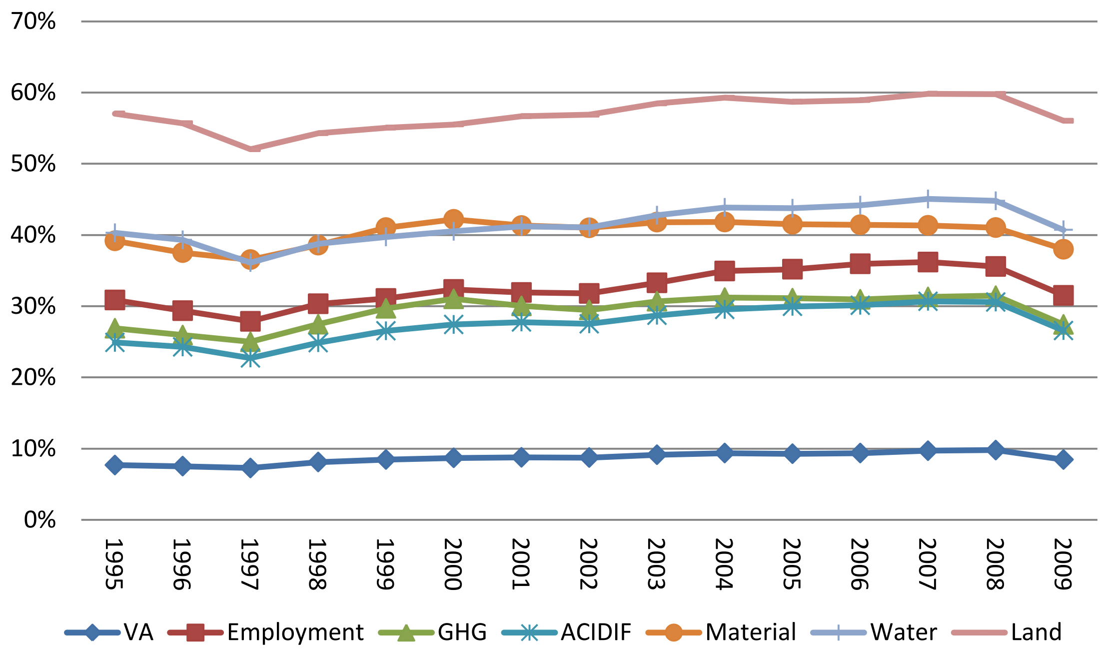
To evaluate the contribution of differential patterns of ‘intensity’ coefficients we replicate the same analysis by using the environmental, labour and value added coefficients of 1995 throughout the whole period[6]. By doing that, all changes will be determined by changes in trade patterns between the EU27 and its partners and by changes in the production technology (intermediate input mix). Results are reported in Figure 12.

We still observe increasing trends for all measures. However, in most cases they appear to be much more stable than the ones observed in Figure 11, in which we were considering also changes in the ‘efficiency’ components. This is due to the fact that the environmental pressures per unit of output of the EU27 increased much less (or

[6] In terms of the various component of overall emission intensity, we here constrain environmental, labour and value added intensities of gross output ($\mathbf{e}=\mathbf{w}'\langle x\rangle^{-1}$) to remain at their levels of 1995 while differences are driven by changes in the mix of intermediate inputs (production technology as described by the Leontief matrix, **L**) and changes in the mix of final demand (**F**).

decreased much more) than the environmental pressures per unit of output of the rest of the world. In fact, European Union implemented a series of policies aimed to the reduction of both air pollution and non-renewable resources exploitation. In particular, this has favoured the development and the broader diffusion of cleaner technologies which are generally less pollution-intensive as well as cost- and resource-saving.

Figure 12 – Share of environmental pressures and economic activity occurred out of the EU27 to satisfy the final demand of EU27 assuming 'efficiency' fixed at the level of 1995



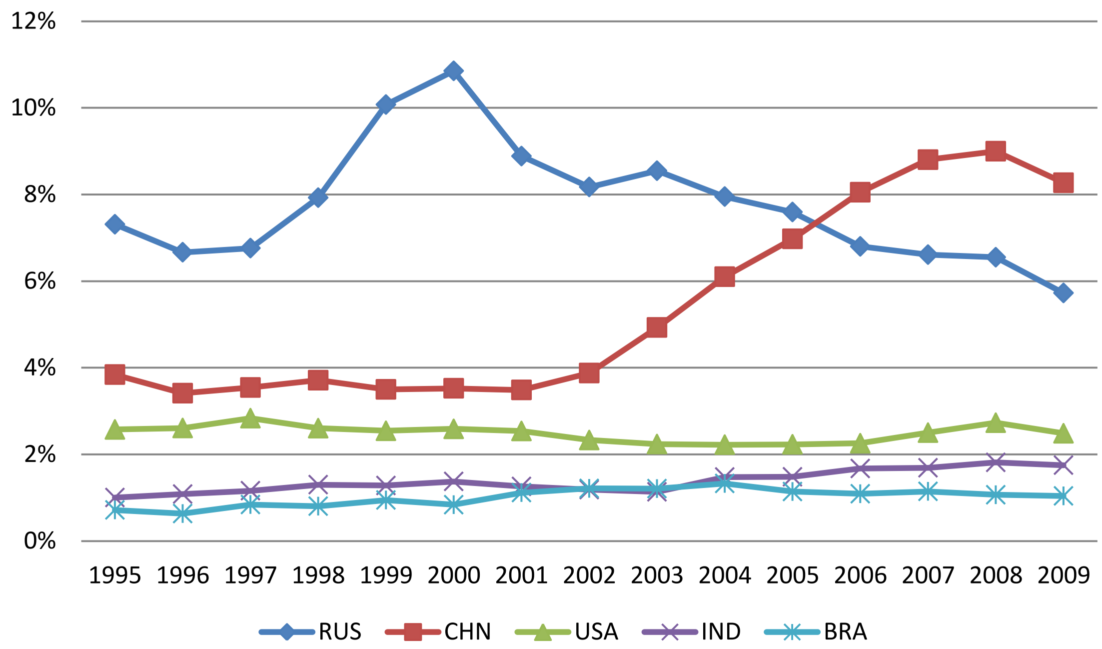
Source: own elaboration based on WIOD database

3.4 Evidence on major trading partners

The trends of the share of GHG generated to satisfy EU final demand is heterogeneous across different non-EU partner countries, as it is illustrated in Figure 13. Until 2005, Russia was the country accounting for the greatest share of GHG emissions to satisfy European demand, with a peak at the end of the '90s. The importance of Russia in terms of contribution to global GHG generation from EU27 final demand is due, besides differences in emission intensity of production activities (that was much higher in Russia than in EU27), to the sectoral composition of Russian production induced by European final demand. Among the top five Russian sectors in terms of output driven by EU27 demand, we observe, in 1995, three of the most emission-intensive sectors, that is mining and quarrying, basic metals and fabricated metals, and electricity, gas and water supply. After 2001, the Russian trend steadily decreases and in 2005 China took over in terms of share of generated emissions. The Chinese trend, however, has been quite flat from 1995 to 2001, when it started to grow faster in conjunction with rapid process of industrialization and penetration into international markets experienced by China since around 2000. Compared to Russia, China's contribution was mostly concentrated in relatively less emission-intensive sectors such as electrical and optical equipment and textiles and textile products. For both China and Russia, however, GHG shares decrease in 2009. China accounted in 2009 for about 9 % of total GHG generated all over the world to satisfy EU final demand, that is bigger than the share of GHG emissions generated in big EU countries like Italy, France and Poland.

For what concerns the US, India and Brazil, the trends of GHG shares are more stable than those for Russia and China. On average, the US accounted for more than 2% of GHG emissions driven by European demand while India and Brazil were steadily below 2%.

Figure 13 – Top 5 non-EU27 countries for GHG emissions generated to satisfy final demand of EU27 (share of total)



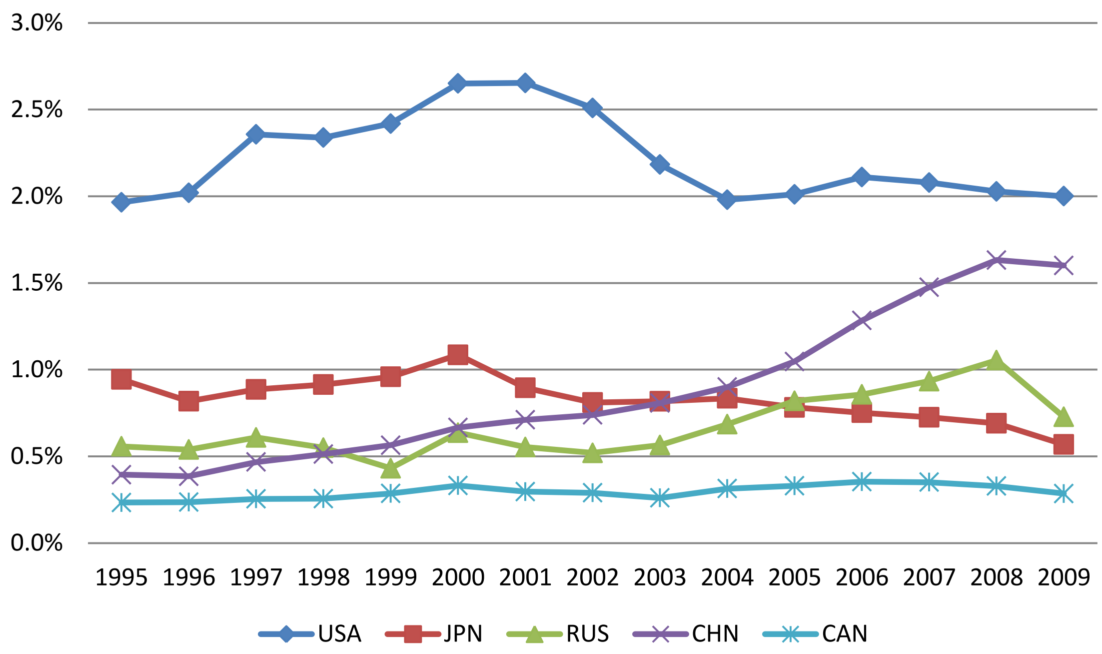
Source: own elaboration based on WIOD database

Figure 14 shows the plot for value added. Notwithstanding the plots in the previous subsections highlighted that both Russia and China were leader in environmental pressures driven by the European demand, here it can be appreciated that a large share of the value added driven by the EU demand outside EU borders is generated in the US, which plays the lion's share for the whole period. Thus a conclusion is that European import from Russia generates a much greater environmental pressure than the import from the US but generates less value added in the country. This is explained, at least partly, by the sectoral composition of US output generated to satisfy EU27 final demand: the first two sectors are renting of machinery and equipment and other business activities (including R&D services) and financial intermediation. These sectors require very little amounts of energy and material inputs while they generate high value added per unit of monetary output. It should be noted, however, how small the share is relative to the share of environmental pressures discussed above: this is in line with the results discussed in Section 3.1

China increased its value added share only starting from the mid-2000s but did not reach the US level. Here, the economic performance and the environmental pressures are following the same trends. Also for China, however, the role in terms of value added generation is much smaller than the role in emission generation and material use, denoting a systematically worse environmental performance of Chinese production sectors (relative to the EU), a specialization in the export of emission/material intensive products and systematically lower wages in China than in the EU27.

The Japanese, Russian and Canadian trends are generally below 1% of value added produced to satisfy EU final demand for the whole period.

Figure 14 – Top 5 non-EU27 countries for value added generated to satisfy final demand of EU27 (share of total)



Source: own elaboration based on WIOD database

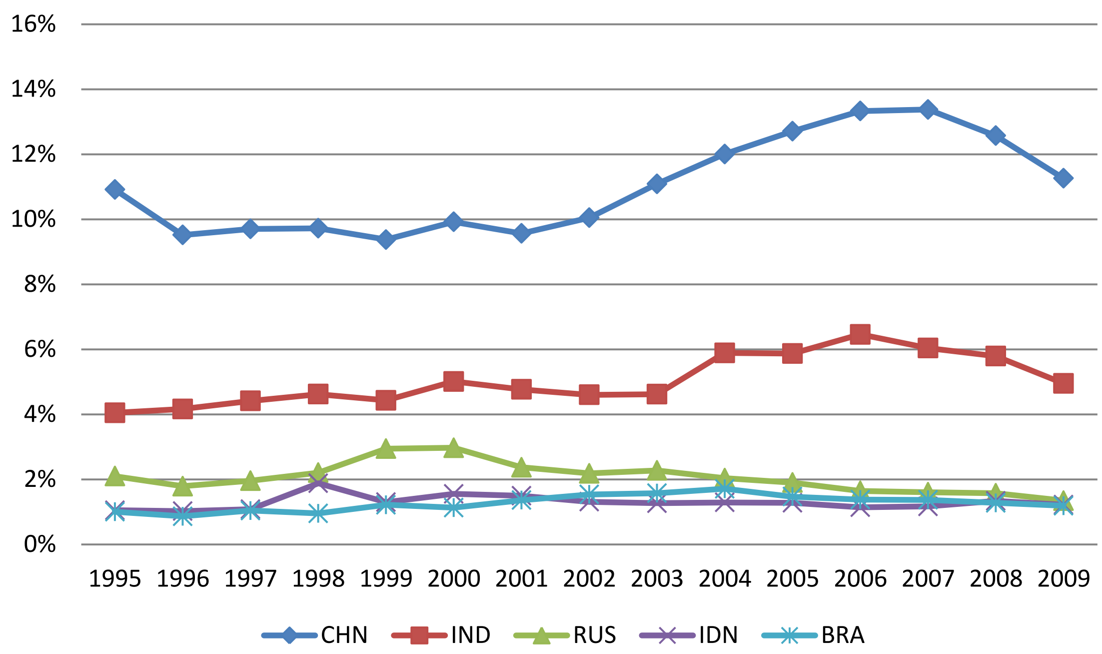
Finally, Figure 15 exhibits the same figures for employment. It is clear that EU demand mostly generated employment in China and these figures perfectly match with the overall picture of this country, in terms of environmental and economic performances. The share was pretty high since the beginning of the period (in 1995 it was 11%) but it increased even more, reaching its maximum in 2007 (13%). In 2009 the share was 11%.

The second country is India, which also presents an increasing trend in employment generation for European demand. It started from 4% in 1995, peaked to more than 6% in 2006 and fell back to 5% in 2009.

The last three countries, Russia, Indonesia and Brazil, show similar trends but are quite far from China and India. Concerning Russia, in particular, the same reasoning for value added can apply: the products imported from Russia to Europe generate high environmental pressures but small employment per unit of output.

All in all, a large share of employment created outside of the EU to satisfy European final demand is located in emerging countries rather than in affluent countries. This evidence, combined with the prevalence of affluent countries in the ranking on value added generation, reflects the systematic differences in wages between affluent and emerging countries but also systematic differences in the sectoral composition between these two groups of countries, with labour and environmental intensive productions being prevalent in emerging countries while more value added intensive productions being prevalent in affluent countries.

Figure 15 – Top 5 non-EU27 countries for employment generated to satisfy final demand of EU27 (share of total)



Source: own elaboration based on WIOD database

4 Conclusion

Together with a 'cost disease effect', the structural change towards services in the EU generates ambiguous effects on the domestic and international environment. These effects can be seen vis à vis those generated on value added and employment worldwide.

There is a systematic difference in 'production-related' and 'consumption-related' environmental pressures of the EU economy. The service sector, which is growing faster than the industrial sector (at least in terms of employment and nominal VA), has smaller emission intensity than industry but this difference shrinks substantially when considering both direct emissions and emissions generated in upstream sectors in 'consumption perspective'. Moreover, even though heterogeneity exists across countries, there seem to be larger opportunities for improvements in environmental efficiency in the industrial sector than in the service sector. Therefore, an increasingly service-based economy is not a panacea for the environment when considering the environmental pressures of intermediate inputs used to produce services.

With a rather stable composition of the real domestic final demand of the EU27, the changing production specialization of the EU economy towards services is accompanied by an increasing reliance on imported goods to satisfy domestic demand. This change will influence both environmental pressures and economic activity (employment and value added) generated abroad to satisfy EU final demand. Evidence shows that a large share of total environmental pressures generated to satisfy EU final demand occurs outside the EU borders. Moreover, this share has increased in recent decades. A large component of the growth in the share of environmental pressures occurring abroad is the systematic difference in environmental performance between the EU and its trading partners, with the former improving its environmental performance (environmental pressure per unit of produced output) much faster than the latter.

At the same time, however, the share of economic wealth (value added) and employment generated abroad to satisfy EU domestic demand were substantially lower than the corresponding environmental pressures, and have been stable in the period we consider. Therefore, the structural change of the EU economy is distributing worldwide more 'bads' than 'goods' as a share of those generated to satisfy final domestic demand.

Looking at the geographical location of pressures, value added and employment 'exported' by the EU the picture is heterogeneous and depends on three factors: (i) the specialization of the trading partner relative to the EU (e.g. Russia specialized in exporting raw materials to the EU, China specialized in exporting manufacturing goods, and the US specialized in exporting business services); (ii)the heterogeneous environmental performance of trading partners and (iii) the heterogeneous level of wages in different countries. This results in low-income countries (with lower wages and worse environmental performance) being responsible of a large share of environmental pressures and employment generated to satisfy EU final demand, while wealthy countries receive the largest share in value added generated to satisfy EU final demand.

While this evidence cannot be used to support the 'pollution heaven hypothesis' (see for example Kellenberg, 2009), it suggests the possible relevance of the 'unequal exchange' approach when seen in a perspective of integrated economic and environmental consequences of structural change and international specialisation (see Heintz,2003; Chancel and Piketty, 2015),

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Annex A – Data sources

All analysis is based on the World Input Output Database (WIOD, www.wiod.org). The database provides annual world input output tables in monetary terms that estimate inter-sectoral transactions between 40 countries (plus the Rest of the World) with a disaggregation of 35 industries (Table A1). The 40 countries covered by WIOD are: all EU27 countries, US, Canada, Mexico, Brazil, Australia, Japan, China, Indonesia, India, Russia, Korea, Turkey and Taiwan. World input output tables are available for the period 1995-2011. In addition to world input output tables, the WIOD database provides information on socio-economic and environmental accounts (only for the period 1995-2009). More specifically, for each sector, country and year WIOD provide information on value added, compensation to labour and capital, gross output, gross fixed capital investments, capital stock, number of employees, hours worked and additional information on environmental pressures directly exerted by these sectors. These environmental pressures include: energy use (by fuel), emissions into the air (CO2, N2O, CH4, NOx, SOx, VOC, PM10 and NH3), water use (green, grey and blue water), land use and material use (by category of material). Economic accounts and world input-output tables are evaluated in US dollars. Country-sector-variable specific deflators are provided (base year: 1995).

Table A1 - Sector codes and descriptions

Sector Code	Sector description
A-B	Agriculture, Hunting, Forestry and Fishing
C	Mining and Quarrying
15-16	Food, Beverages and Tobacco
17-18	Textiles and Textile Products
19	Leather, Leather and Footwear
20	Wood and Products of Wood and Cork
21-22	Pulp, Paper, Paper , Printing and Publishing
23	Coke, Refined Petroleum and Nuclear Fuel
24	Chemicals and Chemical Products
25	Rubber and Plastics
26	Other Non-Metallic Mineral
27-28	Basic Metals and Fabricated Metal
29	Machinery, Nec
30-33	Electrical and Optical Equipment
34-35	Transport Equipment
36-37	Manufacturing, Nec; Recycling
E	Electricity, Gas and Water Supply
F	Construction
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
H	Hotels and Restaurants
60	Inland Transport
61	Water Transport
62	Air Transport
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
64	Post and Telecommunications
J	Financial Intermediation
70	Real Estate Activities
71-74	Renting of M&Eq and Other Business Activities
L	Public Admin and Defence; Compulsory Social Security
M	Education
N	Health and Social Work
O	Other Community, Social and Personal Services
P	Private Households with Employed Persons