Economic and environmental impact of transport sector on Europe economy

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Accepted: 17 November 2017

Abstract Transport sector plays an important role in today economy and society by connecting people, businesses and resources. Efficient and effective transport facilitates the free flow of people, goods and services, and contributes to the productivity in all other sectors in the economy. Over the past 60 years, European Union (EU) transport sector has improved and contributed significantly to EU economy. In Europe, transport sector accounts for about 5% of gross domestic product (GDP) and more than ten million people are directly employed in 1.1 million transport companies (European Commission, EU transport in figures—Statistical pocketbook, 2012). However, transport sector does have fundamental environmental impacts on air, land, water, ecosystem and human health. In EU transport sector is responsible for around a quarter of greenhouse gas (GHG) emissions, making it the second biggest GHG emitting sectors after energy. In this paper, our objective is twofold. Firstly, our aim is to present an approach to look into the relation between transport sector and the economic system as a whole, based on the quantification of the impact of the "transport sector output" on total output and income. We compare the economic impact of the production of different types of transport industries, observed in the European countries. Secondly, we

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present an approach that allows to examine and identify the role, or impact of the transport sector responsible for CO_2 emissions in the European countries. Our approach shows the contribution of transport sector to CO_2 emissions both from demand and supply perspective. The comparative analysis is performed among four European countries which make up the large portion of the European GDP: France, Italy, Germany and United Kingdom (UK).

Keywords Transport impact studies · Transport policy · Input–output model · Macro multiplier · CO_2 emissions · EU

1 Introduction

Transport sector plays an important role in today's economy and society and has a large impact on the economy of a country or region. An efficient transport sector is a critical component of economic development. Certainly, the development of a country's transport sector has been an indicator for its economic welfare and success. In general terms, transportation means personal mobility from one place to another as well as access to goods, services and information. Transportation contributes to the economy by providing jobs to allows men and women to earn their living by driving, maintaining, regulating and manufacturing vehicles to allow for the safe and efficient movement of goods and people. In short, transport networks are at the heart of the supply chain and are the foundation of any country economy. Furthermore, transport sector is also an enabler of international trade. In the modern era of globalization, where no country is self-sufficient, transport sector is key to trade development, providing the opportunities for emerging markets to integrate into the global economy.

Over the past 60 years, Europe transport sector has progressed substantially and continues its role as a significant sector for the EU prosperity and economic growth. The geographical location of Europe divides the continent into over 50 sovereign territories and states. This displacement, along with increased movement of people since the 1950s, has led to a high level of cooperation between European states in developing and maintains transport system. Since the start of the European Economic Community (EEC) 1957, the transport sector, especially on international scale, was an important area of interest and joint actions of the member states. Integration of transport networks of the EU member states is one of the most important tasks included in the strategic documents presented by the European Commission (EC) (Mulley and Nelson 1999). The advancement in development of tools and methodologies to assess economic and regional impacts of transport policies has also been included in the scope of EU funded research since several decades. Future initiatives in the context of the Horizon 2020 framework program also emphasize the importance of smart, green and integrated transport (European Commission, 2013). As transport sector is a crucial infrastructure needed for the development process. It also significantly contributes to energy consumption and carbon dioxide emissions. The transport sector has the second biggest GHG emissions in the EU. In EU, while emissions from other sectors are generally decreasing, those from transport have increased 36% since 1990 (European Commission 2014a). To meet the Horizon 2020 strategy target, the EU has made a unilateral commitment to reduce overall GHG emissions from its member states by 20% compared to 1990 level. For this purpose, a significant reduction in GHG emissions from transport sector is also required to achieve the target.

The distinct experiences in each EU country induced many researchers to deal with the socioeconomic implications of each transport sector industry in a comparative way, following an empirical approach strongly based on econometric analysis. Due to this reason, while differences between countries and regions are well known in terms of socioeconomic variables, the scientific debates suffer from the lack of an approach that allows quantifying and comparing the economic relevance of the transport sector in the production process. In this paper, an effort is made to quantify, in four prominent European transport systems, the potential economic impact of transport sector among all different types of commodities that compose total output. Applying the Macro Multiplier (MM) approach on multi-industry model of the whole economy, we compare the economic impact of transport sector of different types of transport industries, observed in the European countries. Furthermore, we will be able to quantify all the outcomes that the industrial interdependencies are able to develop in connection with the transport sector both as stimulating output in other industries as well as and being stimulated by all the other industries in an economy. Our analysis aims to verify the impact across Europe of a policy of reform on transport sector under each different institutional and economic setting through a comparative analysis of four European states, i.e., France, Italy, Germany and United Kingdom (UK). These countries represent about the 66% of total GDP for 28 EU members. More specifically, in France the output of transport sectors is the 4.63% of total output; in Germany, it is the 4.97%; in Italy, it is the 6.20% and in UK it is 4.52%.

Furthermore, to address the issue of CO_2 emissions in the transport sector in the four prominent EU states, we have attempted to present an approach that allows to examine and identify the role, or impact of the transport sector responsible for CO_2 emissions. Our approach shows the contribution of each transport type industry to CO_2 emissions both from demand and supply perspectives. This approach will enable us to identify the most influential transport type industry responsible for the CO_2 emissions in the four prominent EU states. On the basis of this approach, we will be able to examine and identify those transport type industries which deserve more consideration for mitigation policies.

For this purpose, the second section of this paper describes some characteristics of the institutional framework of each transport type industry, i.e., Water transport, Air transport, Inland transport and other supporting auxiliary transport activities; activities of travel agents, and shows the results of the traditional multiplier analysis performed on the reduced form of the Leontief model and the Ghosh model. Third section provides a brief description of Macro Multiplier (MM) approach framework used to analyze and portray the transport-key-indices of key structures that the decomposition reveals. Fourth section describes the traditional extended multiplier approach to identify the key transport type industries responsible for the CO_2

emissions. Finally, the last section consists of two types of conclusions; one type presents the major results stressing the role played by the transport sector output as an economic policy variable across Europe and the second type identifies those key transport type industries which deserve more consideration for mitigation policies.

2 Main means of transport and its backward and forward linkages

Transport sector is vital to Europe's internal market and essential to the quality of life of citizens in economic and social terms. According to the report of new EU white paper on transport, further market opening in transport sector needed to go hand-in-hand with quality job and working conditions because human resources are crucial to an efficient, high quality transport system (European Commission 2011). France, Italy, Germany and UK attempted an extensive change on their national transport sector. In 2014, The European Commission (EC) compares members state performance in 22 transport relevant categories and highlights for most categories the five top and bottom performers (European Commission 2014b). According to the scoreboard, Germany receives top score in the Logistics Performance Index. It is amongst the top performers in most of the categories. However, its performance in open infringements in air transport is very low. From the EU transport scoreboard results, France receives good ranking for its rail and aviation infrastructure and placed third highest private investment in transport research and development. The UK recorded the second lowest number of road casualties in 2013 and placed in the biggest market share of competitors in rail passenger transport across the EU. It also placed in the list of countries with the biggest private investment in transport research and development. Finally, the EU transport scoreboard results show that Italy is among the countries with the highest share of electrified railway lines. It has also the lowest transportation rate of EU transport directives.

Transport sector modes are the means by which freight and people achieve mobility. In this study, our transport sector consists of four basics types, which are: (a) Inland transport, (b) Air transport, (c) Water transport and (d) other supporting auxiliary transport activities; activities of travel agents. The comparative analysis of the transport sector between Italy, UK, France and Germany needs a preliminary description regarding the flows on National Accounting Scheme (NAS) related to the production of Transport type industries. As a matter of fact the NAS of each country can reveal the differences pertaining to the sectoral value added and the absorption of intermediate goods by the production process of transport type industries. The data for this study come from recently constructed World Input Output Database (WIOD) and cover the symmetric I-O data for, France, Germany, Italy and United Kingdom for the year 2009. The I-O table used in this study was initially prepared at a high level of detail for 35 industries (Timmer et al. 2012). All the detailed national tables are organized according to the European System of National Accounts (ESA95) and are fully consistent with the worldwide guidelines on national accounting (System of National Accounts, SNA93).

For what concerns the description and detail of the transport type industries output flows as shown in the I-O tables of the four countries, we refer to output 23

“Inland transport”; 24 “Water transport”; 25 “Air transport” and 26 “other supporting auxiliary transport activities; activities of travel agents. The ratio of total transport’s value added on GDP in France is 4.6%, in Germany it is 3.9%, in Italy it is 5.3% and in UK it is 4.3%. In detail, the “Inland transport” industry shows substantial dissimilarities in percentage figures between all four countries. The Inland transport value added represents the highest share of 3.64% of the total in Italy and 2.34% in France. The UK and Germany Inland transport value added represents a low share of 1.97, and 1.45%, respectively.

In “Water transport” industry, there exist considerable dissimilarities in percentage terms between two countries, France and Italy, and the other two, UK and Germany. The Water transport industry value added represents a share of 0.17%, of the total in France and 0.18%, in Italy. This percentage ratio is high in Germany, 0.44 and 0.33%, in the UK. The “Air transport” industry value added represent a similar figure for the Germany and the UK, both have the same share of 0.35%, while there exist substantial dissimilarities in percentage terms between France and Italy, 0.41 and 0.19%. The “other supporting auxiliary transport activities; activities of travel agents” industry represents similarities in value added ratios between the four countries. The value added represents a share of 1.67% of the total in France, 1.75% in Germany, 1.34% in Italy and 1.43% in the UK.

Moreover, the transport type industries output weights differently on the whole economy output. The weight of “Inland transport” output on total output is: 1.54% for Germany, 2.07% for the UK, 2.11% for France while percentage is evidently higher for Italy 3.71%. The “water transport” industry output represents a share of 0.34% of the total output in France, 0.63% in Germany, 0.28% in Italy and 0.32% in the UK. The “Air transport” industry represents substantial dissimilarities in the output percentage figures between all four countries. The “Air transport” industry output represents a share of 0.41% of the total output in France, 0.61% in Germany, 0.32% in Italy and 0.49% in the UK. The “other supporting auxiliary transport activities: activities of travel agents” industry output represent a share of 1.76% of the total output in France, 2.18% in Germany, 1.89% in Italy and 1.64% in the UK.

Finally, the ratio between the final demand of transport and all final demand in France is 3.4%, in Germany 2.8%, in Italy 3.9% and in UK 2.6%.

2.1 Backward and forward linkages

In the I-O framework, production by a particular industry has two types of economic effects on the other industries in the economy: (a) the backward linkage or power of dispersion effect and the (b) forward linkage or sensitivity of dispersion effect. Focusing on the transport sector, the backward linkage effect means that the production activities of the individual transportation industry may induce greater use of other industries as an input for transportation production. On the other way, the forward linkage effect indicates that transportation production may be used as an input for other industries in their own production. The linkage methodology is based on the use of the Leontief open I-O model represented by the fundamental relationship:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f}, \tag{1}$$

where $\mathbf{x}$ is the vector of total output, $\mathbf{A}$ is the matrix of technical coefficients and $\mathbf{f}$ is the vector of final demand. Solving Eq. 1 to get the total output can be in the form

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}. \tag{2}$$

The equilibrium output vector can also be written as:

$$\mathbf{x} = \mathbf{R}\mathbf{f}, \tag{3}$$

where $\mathbf{R} = (\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse matrix. This matrix has the property of quantifying the direct and indirect effects of a predetermined set of final demands on each sectoral output. Starting from the Leontief inverse matrix, we can build two types of indices of linkages that are able to point out the role of any sectoral output. The debate on linkages dates back to the definition presented by (Rasmussen 1956) of "summary measures for the inverse matrix". By adopting the concept of Rasmussen, we consider the two indices as: Backward linkage BL_j as follows:

$$\mathrm{BL_j} = \frac{\frac{1}{n}\sum_{i=1}^{n} r_{ij}}{\frac{1}{n^2}\sum_{i,\,j=1}^{n} r_{ij}} \tag{4}$$

Forward linkage FL_i as follows:

$$\mathrm{FL}_i = \frac{\frac{1}{n}\sum_{j=1}^{n} r_{ij}}{\frac{1}{n^2}\sum_{i,\,j=1}^{n} r_{ij}}, \tag{5}$$

where r_{ij} are the elements of the inverse matrix R. The aim of the BL_j in the Rasmuseen definitions is to measure the potential stimulus to other activities from a demand shock in an industry j. While, the FL_i measures the degree to which one industry output is used by other industries as an input. The awkward interpretation given to the traditional forward linkage resulted in the study of several authors questioning the use of the traditional forward linkage estimates (Jones 1976). Jones proposed that the output inverse derived from the output coefficient matrix produces more meaningful measures of forward linkages. This interpretation led to the development of a forward linkage measure based on the elements of the Ghosh model (Miller and Blair 2009). Similar to the calculation of the Leontief inverse matrix derived from the technical coefficient matrix $\mathbf{A}$, the Ghosh inverse matrix is derived from the output coefficients matrix $\mathbf{B}$.

$$\mathrm{G} = (\mathrm{I} - \mathrm{B})^{-1}. \tag{6}$$

Thus, the normalized index of forward linkage is:

$$\mathrm{FL}_i = \frac{\frac{1}{n}\sum_{j=1}^{n} g_{ij}}{\frac{1}{n^2}\sum_{i,j=1}^{n} g_{ij}}. \tag{7}$$

Using the linkage analysis, a sector is considered as a key sector if both indices BL_j and FL_i are greater than 1 (Guo and Hewings, 2001) and (Ali 2015). Focusing on the transport type industries in the four prominent EU countries, we calculate the backward and forward indices. The symmetric I-O table (industry by industry) of each country has a structure of 35×35.[1] From this database, the inverse matrices of the reduced form of the I-O model for France, Italy, Germany and the UK are determined.[2] Inverse matrices enable building the linkage indices, focusing on the transport type industries, in order to determine its role as a key industry. Table 1 shows that there exist substantial dissimilarities in the ranking of the transport type industries in the four countries. As we can see from Table 1, the backward linkage values of the Inland transport industry are greater than one for Germany and UK, while this value is less than one for Italy and France. This shows that the development of Inland transport industry greatly promotes the progress of its upstream industries in the UK and Germany. The forward linkage values of Inland transport sector are greater than one in all four countries, which shows that Inland transport industry has contributed high shares in primary inputs. The forward linkage exhibits a sizeable impact of Inland transport industry since it is highly positioned in the ranking among all 35 industries. The Inland transport industry is the third for Germany, the seventh for Italy, the sixth for the UK and sixteen for the France. The backward linkage exhibits a sizeable impact of "water transport industry", which shows a value greater than one in any country. The backward linkage is also highly positioned in the ranking among all 35 industries: the Water transport industry is the second for France, the first for Germany, the second for Italy and the twenty-fourth for the UK.

For what concerns the forward linkage index, which reveals the role of water transport industry in activating total output, the value of the index is less than one and the ranking between the 35 industries did not show a good placement for the water transport industry in each country. The "Air transport industry" backward linkage values present substantial dissimilarities between two countries, Germany and Italy and the other two, France and the UK. The Air transport industry backward linkage value is greater than one for Germany and Italy, while its value is lower than one for the UK and France. The backward linkage index is highly positioned in the ranking for Italy and Germany, placed Air transport industry at fourth and seventh position, while this ranking is so low for the UK and France. As we can see from Table 1, the indices for "Other activities of travel agencies" show a value greater than one in any country. The backward linkage exhibits a sizeable impact of "other activities of travel agencies" industry since it is highly positioned in the ranking among all 35 industries: the "other activities of travel agencies" industry is the fifth for Germany, the seventh for Italy, the fifth for the UK and twenty-one for France. The backward linkage values of the "other activities of travel agencies" industry are greater than one for all the four countries, which shows that the development of this industry greatly promotes the progress of its upstream industries in these countries.

[1] The details of the 35 industries is illustrated in the "Appendix A", Table A1.

[2] Market shares and technical coefficients for the selected countries are displayed in "Appendix A" and Figures 3, 4, 5, 6, 7, 8, 9, 10.

Table 1 Backward and forward analysis of the transport type industries

	Inland transport	Water transport	Air transport	Activities of travel agencies
France				
Backward linkage	0.91 (26)[a]	1.25 (2)	0.89 (28)	1.00 (21)
Forward linkage	1.03 (16)	0.89 (19)	0.68 (30)	1.51 (1)
Germany				
Backward linkage	1.03 (16)	1.23 (1)	1.10 (7)	1.13 (5)
Forward linkage	1.43 (3)	0.82 (27)	0.99 (20)	1.52 (2)
Italy				
Backward linkage	0.98 (22)	1.23 (2)	1.21 (4)	1.13 (7)
Forward linkage	1.25 (7)	0.75 (30)	0.93 (21)	1.30 (3)
United Kingdom				
Backward linkage	1.03 (10)	1.01 (24)	0.95 (30)	1.09 (5)
Forward linkage	1.28 (6)	0.64 (34)	0.86 (21)	1.71 (1)

[a]Ranking among all 35 industries

The forward linkage values exhibits a sizeable impact of "other activities of travel agencies" since it is highly positioned in the ranking among all 35 industries: the "other activities of travel agencies" industry is the first for France, the second for Germany, the third for Italy and the first for the UK. The top forward ranking position shows the role of "other activities of travel agencies" industry in the activation of overall output.

3 Transport sector, macro multipliers (MM) and key structures

To analyze and interpret the economic impact of transport sector, it is imperative to find the adaptability between changes in this specific output and changes in total output. In traditional analysis, the main focus remains on the effects of final demand shocks at the industry level on total output by industry and the reduced form of the model will be expressed as in Eq. 3. However, traditional analysis does not provide a complete account of the changes in the structures of the macro variables. In this paper, our propagation analysis is centered on the macro multiplier (MM) approach that is based on an appropriate decomposition "Singular Value Decomposition" (SVD) of the Leontief inverse matrix. In our model, the structural matrix **R** can be easily decomposed in a sum of m different matrices through the SVD (Lancaster and Tismenetsky 1985). Further policies for transport type industries will be designed on the basis of characteristic structure obtained from the elements of inverse matrix of the extended model **R**, through the MM approach (Ciaschini and Socci 2006, 2007 Ali et al. 2015, 2017.

The model we propose can identify the most efficient structure that quantifies the aggregate scale effects and the associated structures of the impact of a change in final demand on total output (Ciaschini et al. 2010a). Further, through the MM approach determinant structure of the exogenous variable, i.e., final demand change can be identified to obtain the expected total output change (Ciaschini and Socci 2004). Avoiding the main flaws associated with the traditional multiplier analysis, which is affected by the unrealistic structure of the exogenous shock (Ciaschini et al. 2009), the MM approach overcomes this limit and identifies the most convenient structures of policy control (i.e., final demand for transport type industries) by which the shock on economy is modeled. The decomposition approach proposed, SVD, can be applied both to square and non-square matrices. Here, we generally discuss and show the case of square **R** matrix.

The Singular Value Decomposition of the square matrix R can be written as the product of three matrices:

$$\mathbf{R} = \mathbf{USV^T}, \tag{8}$$

where $\mathbf{U}[n,n]$ and $\mathbf{V^T}[m,m]$ are two unitary or orthonormal basis matrices and $\mathbf{S}[n,m]$ is a matrix whose diagonal elements consist of the s scalars s_i for $j = 1,\ldots m$ and zero for $j > n$. Scalars s_i are all positive and can be ordered in decreasing order. The columns of **U** matrix $\mathbf{u}_j$ represent the structures of the objective variables (the total output) through which all the results are observed and evaluated. These structures are called the key structures of the policy objectives. The rows of **V** matrix $\mathbf{v}_i$ represent the structures of the policies control (the final demand); these structures measure and establish the composition of all the possible policies control. The structure identified plays a fundamental role in determining the potential behavior of the economic system. In this respect, we note that matrix R hides the fundamental combinations of the policy variables (total output). Each of them is obtained by multiplying the corresponding combination of final demand by a pre-determined scalar s_h,[3] which has in fact the role of aggregated multiplier (Ciaschini et al. 2010b). The relevance of the SVD of the inverse matrix R can be expressed from Eq. 8 as a sum of n matrices:

$$\mathbf{R} = \mathrm{s}_1\mathbf{u}_1\mathbf{v}_1^{\mathrm{T}} + \mathrm{s}_2\mathbf{u}_2\mathrm{v}_2^{\mathrm{T}} + \cdots + s_n\mathbf{u_n}\mathbf{v_n^{\mathrm{T}}} = \sum_{i=1}^{n} s_j\mathbf{u_j}\mathbf{v_i^{\mathrm{T}}}. \tag{9}$$

As the columns of matrix **V** are orthonormal; therefore, each operator $s_j\mathbf{u}_j\mathbf{v_i^{\mathrm{T}}}$ acts as a filter. From this perspective component of the control vector, $\mathbf{v}_i$ is transmitted along the axis which is scaled by a scalar s_i and reoriented along the axis identified

[3] From this consideration matrices **U**, **S**and**V** can be easily shown working on Eq. (8). Further premultiplying matrix **R** by its transpose $\mathbf{R}^{\mathrm{T}}$ one obtain

$\mathbf{R^TR} = [\mathbf{USV^T}]^{\mathbf{T}}\mathbf{USV^T} = \mathbf{VS}^2\mathbf{V^T}$ The columns of matrix **V** are the set of orthonormal eigenvectors of the real symmetric matrix $\mathbf{R^T}.\mathbf{R}$ and that the elements of the diagonal matrix **S** are the square roots of the eigenvalues of matrix$\mathbf{R^T}\cdot\mathbf{R}$, that is $\mathbf{s_j} = \sqrt{\lambda_i(\mathbf{R^T}\cdot\mathbf{R})}$. By post multiplying matrix **R** by its transpose one obtains $\mathbf{RR^T} = \mathbf{USV^T}[\mathbf{USV^T}]^{\mathbf{T}} = \mathbf{US}^2\mathbf{U^T}$, where the columns of matrix **U** are the set of orthonormal eigenvectors of the real symmetric matrix $\mathbf{R}\cdot\mathbf{R^T}$ and the elements of the diagonal matrix **S** are the square roots of the eigenvalues of matrix$\mathbf{RR^T}$. It is worthwhile to mention that the square matrices $\mathbf{R}\cdot\mathbf{R^T}$and $\mathbf{R^T}\cdot\mathbf{R}$ have the same set of eigenvalues.

by $\mathbf{u}_j$. Furthermore, if we express the actual final demand vector f in terms of the structures identified by matrix $\mathbf{V}$, we obtain a new final demand vector $\mathbf{f}^0$, expressed in terms of the structures suggested by the inverse matrix $\mathbf{R}$:

$$\mathbf{f}^0 = \mathbf{V}^T f. \tag{10}$$

The above Eq. 10 is the representation of the control vector f, in the orthonormal basis defined by matrix $\mathbf{V}$, while the representation of the target vector x, in the orthonormal basis defined by matrix $\mathbf{U}$ is

$$\mathbf{x}^0 = \mathbf{U}^\mathbf{T}\mathbf{x}. \tag{11}$$

As $\mathbf{x} = \mathbf{U}.\mathbf{S}.\mathbf{V}^\mathbf{T}.\mathbf{f}$ putting this value of $\mathbf{x}$ in Eq. 11, we get:

$$\mathbf{x}^0 = \mathbf{S}\mathbf{f}^0 \tag{12}$$

which implies

$$x_j^0 = s_j f_j^0. \tag{13}$$

The above Eq. 13 represents the equations of the reduced form, which are completely independent of one another. The independent property expresses that when final demand assumes one of the characteristic structures defined by the orthonormal vector of matrix $\mathbf{V}$, then only one of the singular value is activated and the output coincides with the correspondent vector of matrix $\mathbf{U}$ scaled by the singular value s_j. Singular values s_j then determine the aggregated effect of final demand shock on output. For this reason, we will call the Macro Multiplier (Ciaschini and Socci, 2007); (Socci, et al., 2016). It is worthwhile to mention that the numbers of components of the key target structures are not necessarily equal to the number of the components of the key control structures, since inverse matrix $\mathbf{R}$ should not be necessarily a square matrix. Furthermore, the interpretation can be expressed as:

$$\mathbf{R}\mathbf{v}_1 = s_1\mathbf{u}_1, \tag{14}$$

where $\mathbf{v}_1$ represents the most influential key control structure and $\mathbf{u}_1$ is the most influential key target structure.

The decomposition allows measuring the overall impact as the algebraic sum of a set of matrices that represent the single structures emerging from the SVD. The structures can record positive and negative values, the sum of which amounts exactly to the final value of the Leontief inverse matrix. Therefore, we can observe extensive and restrictive structures. More precisely, positive values in both control and target structures mean that these values directly contribute to the overall structure while the negative ones contribute to the result in the opposite way. Therefore, looking at Table 2, when we observe the structure 8 in the case of France for example, we note that there are many sectors showing negative values, such as 26 (− 0.63). This value means that a control variable with structure 8 generates positive and negative effects on singular outputs as reported in column 1.

Table 2 Key policies' structures for transport policies (France and Germany)

Key objective policies structures								Key control policies structures						
France				Germany				France				Germany		
	s8U8	s20U20	s25U25	s1U1	s23U23	s30U30	s35U35		V8	V19	V25	V23	V30	V35
×1	0.00	– 0.10	– 0.14	0.23	– 0.08	0.06	– 0.03	f1	0.00	– 0.15	– 0.16	– 0.07	0.06	– 0.02
x2	– 0.02	0.02	0.13	0.14	0.42	0.06	– 0.01	f2	– 0.02	0.06	0.12	0.42	0.06	– 0.01
x3	– 0.01	0.00	0.02	0.23	– 0.02	– 0.03	– 0.02	f3	– 0.01	– 0.03	– 0.02	– 0.02	– 0.03	– 0.02
x4	0.08	– 0.04	0.03	0.09	– 0.06	– 0.19	0.00	f4	0.07	– 0.06	0.02	– 0.06	– 0.19	0.00
x5	0.00	0.00	– 0.10	0.08	– 0.06	– 0.29	0.01	f5	0.00	0.13	– 0.10	– 0.06	– 0.29	0.01
x6	0.04	0.06	0.12	0.17	0.04	– 0.01	0.00	f6	0.03	0.05	0.10	0.05	– 0.01	0.00
x7	0.02	– 0.02	0.03	0.20	– 0.04	0.05	– 0.01	f7	0.01	0.02	0.02	– 0.04	0.05	– 0.01
x8	0.01	0.22	0.17	0.25	– 0.14	0.42	0.08	f8	0.01	– 0.20	0.18	– 0.12	0.45	0.13
x9	0.09	– 0.03	0.04	0.16	0.21	0.05	– 0.03	f9	0.08	– 0.09	0.03	0.21	0.05	– 0.03
x10	0.05	– 0.14	– 0.01	0.15	– 0.02	0.02	– 0.02	f10	0.05	0.11	– 0.02	– 0.02	0.03	– 0.01
x11	0.00	– 0.12	– 0.07	0.18	– 0.23	0.09	– 0.02	f11	– 0.01	– 0.16	– 0.08	– 0.21	0.09	– 0.02
x12	0.03	– 0.03	– 0.05	0.30	0.00	0.01	0.00	f12	0.03	0.00	– 0.07	0.01	0.02	0.01
x13	0.03	0.04	0.02	0.20	– 0.06	– 0.01	– 0.01	f13	0.03	0.16	0.01	– 0.06	– 0.01	– 0.01
x14	0.06	0.02	0.11	0.18	0.00	0.05	– 0.02	f14	0.06	– 0.36	0.09	0.01	0.06	– 0.01
x15	– 0.47	– 0.02	0.10	0.22	– 0.06	0.01	– 0.01	f15	– 0.39	0.01	0.10	– 0.06	0.01	– 0.01
x16	0.04	0.04	0.05	0.14	– 0.15	– 0.01	– 0.01	f16	0.05	0.09	0.05	– 0.14	– 0.01	– 0.01
x17	– 0.11	0.02	– 0.02	0.32	– 0.09	– 0.01	0.00	f17	– 0.09	0.04	– 0.02	– 0.09	– 0.02	0.00
x18	0.30	0.00	0.06	0.22	– 0.17	– 0.15	– 0.01	f18	0.25	0.05	0.05	– 0.17	– 0.15	– 0.01
x19	– 0.06	– 0.09	– 0.03	0.15	0.36	– 0.03	– 0.02	f19	– 0.06	0.02	– 0.03	0.36	– 0.03	– 0.02
x20	– 0.05	0.22	– 0.08	0.34	– 0.03	0.10	– 0.09	f20	– 0.05	0.35	– 0.11	0.00	0.09	– 0.08
x21	0.00	0.06	0.34	0.30	– 0.11	– 0.01	– 0.02	f21	– 0.01	0.00	0.32	– 0.09	– 0.01	– 0.02
x22	– 0.01	0.19	0.38	0.10	0.09	– 0.02	0.00	f22	– 0.01	0.21	0.37	0.10	– 0.02	0.00

Table 2 continued

Key objective policies structures								Key control policies structures						
France				Germany				France				Germany		
	s8U8	s20U20	s25U25	s1U1	s23U23	s30U30	s35U35		V8	V19	V25	V23	V30	V35
x23	− 0.24	− 0.70	− 0.10	0.35	0.59	− 0.19	− 0.20	f23	− 0.22	0.42	− 0.10	0.59	− 0.21	− 0.21
x24	0.63	− 0.08	− 0.01	0.23	− 0.09	0.46	− 0.56	f24	0.50	0.10	− 0.01	− 0.08	0.45	− 0.55
x25	− 0.11	0.27	− 0.50	0.19	− 0.29	− 0.58	− 0.39	f25	− 0.11	− 0.23	− 0.49	− 0.29	− 0.58	− 0.39
x26	− 0.63	0.10	0.05	0.63	− 0.09	− 0.05	0.40	f26	− 0.55	− 0.11	0.05	− 0.03	− 0.09	0.67
x27	0.13	− 0.03	0.03	0.23	− 0.01	0.01	− 0.03	f27	0.11	0.09	0.03	− 0.01	0.01	− 0.02
x28	− 0.34	− 0.01	0.03	0.67	− 0.06	0.03	− 0.02	f28	− 0.28	− 0.07	0.01	− 0.06	0.02	0.00
x29	0.00	0.53	− 0.24	0.35	0.14	0.09	0.01	f29	0.01	0.45	− 0.25	0.13	0.09	0.01
x30	0.21	− 0.06	− 0.08	1.23	0.04	− 0.07	0.08	f30	0.18	− 0.21	− 0.11	0.05	− 0.08	0.14
x31	0.04	− 0.03	− 0.28	0.12	− 0.16	0.10	− 0.01	f31	0.03	− 0.02	− 0.28	− 0.16	0.10	0.00
x32	0.00	− 0.05	− 0.22	0.08	− 0.04	0.02	0.00	f32	0.00	0.02	− 0.22	− 0.03	0.02	0.00
x33	0.01	0.04	0.40	0.07	0.03	0.01	− 0.01	f33	0.01	0.03	0.39	0.03	0.01	− 0.01
x34	0.05	− 0.16	0.05	0.30	− 0.02	0.00	− 0.02	f34	0.04	− 0.11	0.04	− 0.02	0.00	− 0.02
x35	0.00	0.01	− 0.02	0.00	0.00	0.00	0.00	f35	0.00	0.01	− 0.02	0.00	0.00	0.00

In the same structure, it is possible to observe a trade-off among the different categories of transports. In this perspective, it is possible to combine different structures favorable to different categories in order to design a policy that is able to overcome this trade-off. For example, it is possible to combine the structure 8 with the structure 20 in order to obtain an effect in the same direction for sectors 23 and 25 for France. For Germany, the structure 30 combined with the structure 35 allows generating an impact with the same direction for sectors 24 and 25. In other words, you can choose between all and then make the combination.

Focusing on the basis of target and control key structures in matrix **R**, we build two types of indices with respect to key structures of both the target variable and the control variable. These indices, which can be focused on each single industry, reveal the role of each commodity inside the set of key structures and quantify their relevance both in terms of target and control variable. For the key target structure, given matrix **U**, it is possible to define the index:

$$\mu_{\mathrm{ij}} = \frac{\frac{\left|s_j u_{ij}\right|}{1/n\left|s_j u_j\right|}}{1/n^2 \sum_{j=1}^{n}\left|s_j u_j\right|}. \tag{15}$$

Equation 15 quantifies the relevance of the *i*th industry in all the *n* key target structures. More precisely, this index reveals the role played by the selected industry inside the key target structures $\boldsymbol{u}_j$ when the corresponding MM s_j is activated. Also for the key policy control structures, it is possible to define the index starting from matrix **V**:

$$\gamma_{ij} = \frac{\frac{\left|v_{ij}\right|}{1/n\left|v_j\right|}}{1/n^2 \sum_{j=1}^{n}\left|v_j\right|}. \tag{16}$$

Equation 16, quantifies the importance of the *i*th industry in all the *n* key control structures. In more precise way, the index reveal the role played by the selected industry inside the key objective structures $\boldsymbol{v}_j$. When the indices μ_{ij} and γ_{ij} assume a value lower than 1, the good has a low importance inside both the key objective and control structures, i.e., $\mu_{ij} < 1$ and $\gamma_{ij} < 1$.

3.1 Policy key structures in European transport sector output

3.1.1 Key target structures index

For each European country considered in our research and with reference to the value of the key target structure index, Eq. 15, several structural differences emerge concerning the role played by transport type industries, i.e., by industry 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities". Equation 15 reveals the role played by these selected industries inside the target structures u_i when the corresponding MM s_i is activated. The key target structures for all the four countries are shown in the Fig. 1. In the

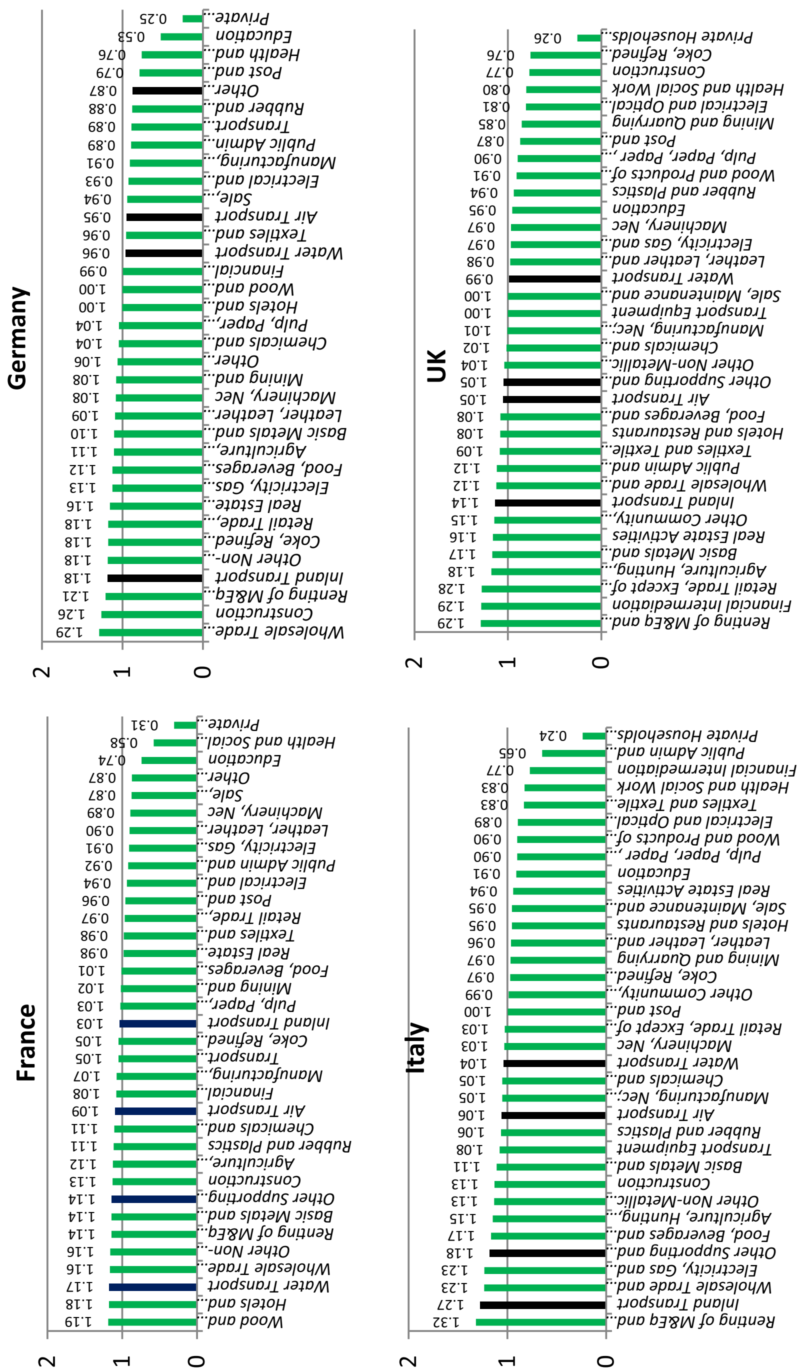

Fig. 1 The index of key policy for the objective variable

France case, we can see that all four transport type industries play an important role in 21 key objective structures. All the transport type industries, i.e., 23 “Inland Transport”; 24 “Water transport”; 25 “Air transport”; and 26 “Other transport and travel agencies activities” are placed in the key objective structures. In the France case, we notice that industry 6 “Wood and Products of Wood and Cork” plays an important role among 21 key objective structures. Among the transport type industries, 24 “Water transport” get a highest rank 3 in the whole economy, while the 26 “Other transport and travel agencies activities” get a rank 8.

The distribution of key objective structures obtained for the German case is not so interesting. From Fig. 1, we can observe 20 structures out of 35 for which the value of the index is greater than 1 and they are the key industries which play an important role in the Germany economy. We notice that there is only one transport type industry, i.e., 23 “Inland Transport” for which the index is greater than 1 and get a highest rank 4 among the entire economy.

The Italian case has an interesting distribution of structures according to the values of key objective structures index. From Fig. 1, we observe that 19 industries out of 35 for which the value of index is greater than 1. All the transport type industries, i.e., 23 “Inland Transport”; 24 “Water transport”; 25 “Air transport”; and 26 “Other transport and travel agencies activities” are placed in the key objective structures. Among the transport type industries, 23 “Inland Transport” industry get the highest rank 2 in the entire economy, while industry 26 “Other transport and travel agencies activities” get a rank 5.

For the UK case, we have proceeded in the same way decomposing the inverse matrix and identifying the key policy structures. From Fig. 1, we can observe 20 structures out of 35 for which the value of the index is greater than 1 and they are the key industries which play an important role in the UK economy. In the UK case, only three transport type industries, i.e., 23 “Inland Transport”; 25 “Air transport”, and 26 “Other transport and travel agencies activities”, are placed in the key objective structures. Inland transport industry gets the highest rank 8 among the entire UK economy.

3.1.2 Key control structures index

The index of key control structures is represented in Eq. 16, which quantifies the importance of the ith industry in all n key control structures. Following Eq. 16, it is possible to calculate the index of the key control structures for the transport type industries, i.e., 23 “Inland Transport”; 24 “Water transport”; 25 “Air transport”; and 26 “Other transport and travel agencies activities” that allow to identify the key structures of final demand in which transport type industries play a significant role. In this respect, the key control structures index has the potential to reveal which type of industry is favoured by the key policies to choose according to the value of the index. For the French case, as shown in Fig. 2, we identified 22 key structures of final demand that have an index major than one. On the basis of these key structures of final demand, we can identify which are the industries that get the major change in terms of output. From Fig. 2, we can see that there are several sectoral outputs favoured by the key structures of final demand which are strongly oriented to the

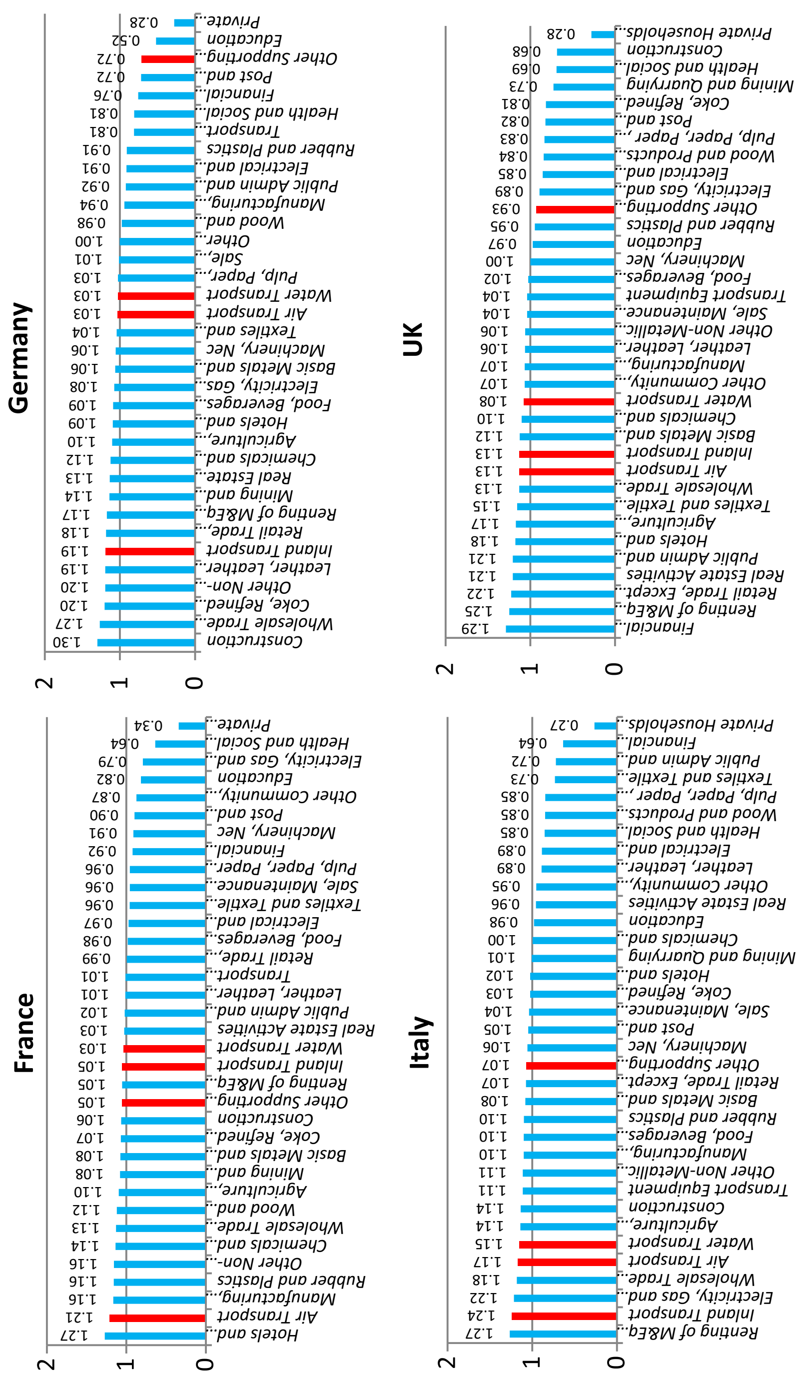

Fig. 2 The index of key structures of final demand

final demand of transport type industries. All the transport type industries, i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities" are placed in the key control structures.

Among the transport type industries, 25 "Air Transport" industries get the highest rank 2 in the entire French economy. Another influential transport type industry is the 26 "Other transport and travel agencies activities" which have ranked 14.

The German case has different distribution of structures according to the value of key control structures index. The distribution of key control structures obtained for the transport type industries is not so interesting as compared to France. From Fig. 2, we can observe 23 key structures of final demand out of 35 for which the value of the index is greater than one. We also notice that there are only three transport type industries, i.e., 23 "Inland Transport" 24 "Water transport"; 25 "Air transport" for which the index is greater than one. Among the transport type industries, 23 "Inland Transport" industries get the highest rank 6 in the entire economy, while industry 25 "Air transport" industry get a rank 19.

The results of the index of the key control structures for the Italy case are shown in Fig. 2. We can see that there are several sectoral outputs favoured by the key structures of final demand which are strongly oriented to the final demand of transport type industries. All the transport type industries, i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities" are placed in the key control structures. Among the transport type industries, 23 "Inland transport" industries get the highest rank 2 in the entire Italian economy. Other influential transport type industries are the 25 "Air transport" and 24 "water transport" which have ranked 5 and 6, respectively.

Also for the UK case we have proceeded in the same way decomposing the Leontief inverse matrix and identifying key control structures. From Fig. 2, we can observe 22 key structures of final demand out of 35 for which the value of the index is greater than one. It is possible to elaborate on the composition of the 22 key structures of final demand in order to identify which are the industries that get the major change in terms of output. In the UK case, only three transport type industries, i.e., 23 "Inland Transport"; 25 "Air transport"; and 24 "Water transport" are placed in the key structures of final demand. Among the transport type industries, 25 "Air transport" industry get the highest rank 10 in the entire economy.

3.2 Policies target and policy control for transport type industries

In this subsection, we will identify the demand control policies (policy variable) that promote the transport type industries (i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities") within the realized total output (objective policy variable). The reachable policy objective of a demand control can be designed with reference either to the whole production in the economy or to specific industry outputs. However, in the case of specific outputs, the whole production structure cannot be neglected, given the interactions among industries. Focusing on the fundamental approach of intersectoral relationship between the policy control on final demand, Δf, and the resulting change in the objective variable (total output) Δx is given by

$$\Delta \mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1} \cdot \Delta \mathbf{f}. \tag{17}$$

The problem associated with Eq. 17 is that of quantifying, given the aggregate change of the policy control that we need to activate, the resulting aggregate value of total output, and that of identifying which structures will be the most suitable in order to activate structures most favorable to transport type industries within the objective variable. Therefore, we determine a particular structure of final demand, which has a positive effect on the growth of transport type industries as a whole and also taking into consideration the effects on the remaining industries outputs. Using the Macro Multiplier approach, we will identify the convenient final demand and output vectors, operating on the whole structures. Using the MM approach for every specified country in the study, we obtain a set of 35 MM, a set of 35 structures of demand control matrix **V** and a set of 35 structures of objective matrix **U** for each country. The structures identified my matrix **U** and **V** play an important role to determine the potential behavior of the economic system. From the set of structures of the target variables, $s_i \cdot \boldsymbol{u}_i (i = 1 \ldots 35)$ for each country, it is possible to choose the most effective policies for the transport type industries, i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities". Tables 2 and 3 show the most effective policies for France, Germany, Italy and UK. These policies give the highest push to at least one of the industries composing the transport type industries in the specified countries.

3.2.1 Policies for France

Table 2 shows a subset of effective policies for France that gives the highest push to at least one of the industries composing the transport type industries. Policy structures 8 has an MM s_8, a demand control structure $\mathbf{v}_8$ and an overall policy effect on the objective, $s_8 \cdot \mathbf{u}_8$, which is shown in the second column of Table 2. We notice that the most relevant components are industry 24 "Water transport" and industry 26 "Other transport and travel agencies activities". Policy 8 shows a greater impact, 0.63, on industry 24 "Water transport" and on industry 26 "Other transport and travel agencies activities", − 0.63. However, the impact is in opposite direction. Policy 20 has a modulus multiplier s_{20}, a demand control structure $\mathbf{v}_{20}$ and an overall policy effect on the objective, $s_{20} \cdot \mathbf{u}_{20}$. It can be seen from the third column of Table 2 at row 23 that the most relevant component is − 0.70, which shows that a demand control tends to have the greatest impact, but in opposite direction, on industry 23 "Inland transport".

Objective policy structure 25 can be seen from the 4th column of Table 2. This policy has a relevant impact − 0.50, on industry 25 "Air transport". However, the impact is in opposite direction. From the set of structures for the policy control, $\mathbf{v}_i (i = 1 \ldots 35)$, it is possible to choose the most effective policies that use the transport type industries (i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities") as instrument of

Table 3 Key policies' structures for transport type industries (Italy and United Kingdom)

Key objective policies structures							Key control policies structures						
Italy			United Kingdom				Italy			United Kingdom			
	s1U1	s35U35	s4U4	s22U22	s30U30	s32U32		V19	V35	V4	V22	V30	V32
x1	0.20	0.03	− 0.18	0.08	− 0.06	0.03	f1	0.10	0.02	− 0.14	0.07	− 0.07	0.03
x2	0.13	0.03	0.24	− 0.01	− 0.01	0.02	f2	− 0.07	0.03	0.15	− 0.01	0.00	0.02
x3	0.35	− 0.02	− 0.26	0.00	0.16	− 0.04	f3	− 0.05	− 0.05	− 0.20	0.00	0.19	− 0.06
x4	0.25	0.03	− 0.05	0.39	0.01	0.07	f4	− 0.01	0.02	− 0.05	0.38	0.01	0.07
x5	0.23	0.04	− 0.08	− 0.13	0.00	0.11	f5	− 0.02	0.03	− 0.08	− 0.13	0.00	0.11
x6	0.22	0.02	− 0.06	0.05	− 0.06	0.02	f6	0.06	0.02	− 0.05	0.05	− 0.05	0.01
x7	0.30	0.04	− 0.14	0.03	− 0.01	0.02	f7	0.06	0.04	− 0.11	0.03	− 0.01	0.01
x8	0.12	− 0.12	0.15	0.01	− 0.03	0.00	f8	0.10	− 0.16	0.15	0.01	− 0.03	0.01
x9	0.29	0.02	− 0.05	− 0.27	0.12	0.03	f9	− 0.12	0.01	− 0.04	− 0.27	0.12	0.02
x10	0.23	0.04	− 0.06	0.11	− 0.03	0.04	f10	0.19	0.03	− 0.05	0.11	− 0.03	0.04
x11	0.23	0.02	0.03	0.23	− 0.26	0.13	f11	− 0.01	0.01	0.03	0.22	− 0.24	0.12
x12	0.47	0.01	− 0.08	0.04	− 0.01	0.00	f12	− 0.10	0.01	− 0.06	0.04	− 0.02	− 0.01
x13	0.24	0.03	− 0.06	0.10	0.04	0.01	f13	− 0.26	0.02	− 0.05	0.10	0.04	0.00
x14	0.24	0.03	− 0.05	0.06	0.08	0.01	f14	− 0.07	0.02	− 0.05	0.06	0.08	0.01
x15	0.25	− 0.08	− 0.07	0.03	0.09	0.01	f15	0.61	− 0.11	− 0.06	0.03	0.10	0.01
x16	0.21	0.00	− 0.05	− 0.27	− 0.01	0.05	f16	− 0.21	− 0.01	− 0.05	− 0.27	− 0.01	0.05
x17	0.34	− 0.02	0.19	− 0.03	0.02	− 0.03	f17	− 0.09	− 0.03	0.17	− 0.05	0.03	− 0.04
x18	0.33	0.04	0.25	0.01	0.05	0.03	f18	0.21	0.05	0.18	0.02	0.06	0.03
x19	0.29	0.03	− 0.05	− 0.27	− 0.24	0.05	f19	0.18	0.02	− 0.03	− 0.27	− 0.24	0.05
x20	0.76	− 0.11	− 0.04	− 0.14	− 0.46	− 0.12	f20	− 0.05	− 0.17	0.02	− 0.15	− 0.46	− 0.14
x21	0.45	− 0.10	− 0.23	0.15	0.05	0.07	f21	0.02	− 0.14	− 0.15	0.14	0.06	0.05
x22	0.24	0.05	− 0.11	− 0.02	− 0.26	0.09	f22	− 0.05	0.05	− 0.11	− 0.02	− 0.26	0.09

Table 3 continued

Key objective policies structures							Key control policies structures						
Italy			United Kingdom				Italy			United Kingdom			
	s1U1	s35U35	s4U4	s22U22	s30U30	s32U32		V19	V35	V4	V22	V30	V32
x23	0.51	0.17	0.08	− 0.17	0.49	− 0.35	f23	0.41	0.17	0.10	− 0.18	0.54	− 0.37
x24	0.18	0.55	0.31	− 0.07	− 0.17	− 0.58	f24	− 0.23	0.55	0.31	− 0.07	− 0.17	− 0.58
x25	0.19	0.43	0.09	0.63	− 0.09	− 0.19	f25	0.01	0.42	0.09	0.62	− 0.09	− 0.19
x26	0.46	− 0.46	0.95	0.00	0.02	0.29	f26	− 0.19	− 0.62	0.69	0.00	0.05	0.40
x27	0.26	0.02	− 0.08	0.04	0.01	− 0.02	f27	− 0.07	0.02	− 0.06	0.04	0.02	− 0.03
x28	0.49	− 0.02	− 0.12	− 0.06	0.22	0.25	f28	0.01	− 0.03	− 0.10	− 0.06	0.26	0.28
x29	0.29	0.02	− 0.06	− 0.10	− 0.20	− 0.37	f29	0.04	0.03	− 0.04	− 0.11	− 0.18	− 0.37
x30	1.15	0.00	− 0.16	0.05	0.04	− 0.04	f30	− 0.20	− 0.01	− 0.12	0.05	0.06	− 0.05
x31	0.07	0.01	− 0.04	− 0.22	− 0.30	0.20	f31	0.02	0.01	− 0.04	− 0.21	− 0.30	0.22
x32	0.04	− 0.03	− 0.04	0.05	0.00	0.01	f32	− 0.01	− 0.03	− 0.04	0.05	0.00	0.00
x33	0.08	0.01	− 0.44	0.00	− 0.01	0.02	f33	0.12	0.01	− 0.35	0.00	− 0.01	0.01
x34	0.25	0.00	− 0.16	− 0.02	0.00	0.00	f34	0.05	0.00	− 0.12	− 0.02	0.01	− 0.01
x35	0.00	0.00	0.00	0.00	0.00	0.00	f35	0.00	0.00	0.00	0.00	0.00	0.00

economic policy. Table 2 shows the most effective key control policies structures that use industries composing the set of transport type industries in French economy. From the section "Key control policies structures" of Table 2, we can see that policy structure 8 uses industry 24 "Water transport" and industry 26 "Other transport and travel agencies activities". Policy 8 has an impact 0.50 on industry 24 "Water transport" and on industry 26 "Other transport and travel agencies activities" − 0.55. However, the impact is in opposite direction. Policy 19 is another most influential and effective control policy in the case of France, which uses industry 23 "Inland transport" and has an impact 0.42. Finally, policy structure 25 uses industry 25 "Air transport" and has an impact -0.49 on this industry.

3.2.2 Policies for Germany

Table 2 shows the most effective policies that give the highest push to at least one of the industries composing the transport type industries in Germany. For the German case, policy structure 1 has an MM s_1, a demand control structure $\mathbf{v}_1$ and an overall policy effect on the objective, $s_1\mathbf{u}_1$, which is shown in the fifth column of Table 2. We notice that the most relevant component is 0.63, which shows that a demand control tends to have the greatest impact on industry 26 "Other transport and travel agencies activities". Policy structure 23 has an MM s_{23}, a demand control structure $\mathbf{v}_{23}$ and an overall policy effect on the objective, $s_{23}\mathbf{u}_{23}$. This policy has a relevant impact 0.59 on industry 23 "Inland transport". Objective policy structure 30 can be seen from the 7th column of Table 2. This policy has an impact − 0.58 on the industry 25 "Air transport". However, the impact is in opposite direction. Finally, the objective policy structure 35 can be seen from the 8th column of Table 2. This policy has an impact − 0.56 on industry 24 "Water transport". Since policy objective structure 1 is a dominating policy, which is a demand driven policy that has the highest multiplier effect on output and becomes an expensive one for all industries. The control policy structure $\mathbf{v}_1$ of all positive final demand changes generates a vector of all positive total output changes $s_1\mathbf{u}_1$.[4] From Fig. 12, we can see that the highest impact is borne by industry 30 "Renting of M&Eq and Other Business Activities".

The second highest impact is borne by a group of two industries: 28 "Financial Intermediation" and 26 "Other transport and travel agencies activities". Four industries are part of a third group with the highest impact: 23 "Inland transport", 29 "Real estate activities", 17 "Electricity, gas and water supply" and 20 "Wholesale trade". Four industries are part of a fourth group with highest impact: 34 "Other Community, Social and Personal Services", 21 "Retail trade", 12 "Basic metals and fabricated metal" and 8 "Coke, Refined Petroleum". The remaining group of industries bears an impact of intermediate intensity or a low intensity. Among the 35 industries, a hierarchy of industries is to be stimulated to get the result of policy 1 for Germany. From Fig. 11, we can see that three industries must

[4] The policy control structure V_1 and the structure of policy objective 1 for Germany are shown in Figs. 11 and 12 in Fig. 12 in the "Appendix B".

be stimulated at a very high degree, i.e., 30 “Renting of M&Eq and Other Business Activities”, 28 “Financial Intermediation” and 26 “Other transport and travel agencies activities”. Nine industries are part of second set highly stimulated industries.[5] The remaining industries are activated at a low level or very low level.

Focusing on the Set of structures for the policy control, $\mathbf{v}_i$ $(i = 1\ldots\ldots35)$, it is also possible to choose the most effective policies that use transport type industries as instrument of economic policy. Table 2 shows the most influential control policies for the transport type industries based on the German economy. From Table 2, policy structure 23 uses industry 23 “Inland transport”. Policy structure 30 uses industry 25 “Air transport”; however, the impact is in opposite direction and finally policy structure 35 uses industry 24 “Water transport” and industry 26 “Other transport and travel agencies activities”; however, the impact is in opposite direction.

3.2.3 Policies for Italy

For the Italy case, we have proceeded in the same way decomposing the inverse matrix and identifying the most effective policies that give the highest push to at least one of the industries composing the transport type industries. Table 3 shows a subset of such policies for the Italy transport type industries (i.e., 23 “Inland Transport”; 24 “Water transport”; 25 “Air transport”; and 26 “Other transport and travel agencies activities”). Policy structure 1 has an MM s_1, a demand control structure $\mathbf{v}_1$ and an overall policy effect on the total output, $s_1\mathbf{u}_1$, which is shown in the second column of Table 3. We can notice that the most effective and relevant component is industry 23 “Inland transport”, which shows that a demand control tends to have the greatest impact 0.51 on inland transport industry. Objective policy structure 35 can be seen from the third column of Table 3. This policy has a relevant impact 0.55 on industry 24 “Water transport”, an impact 0.43 on industry 25 “Air transport” and an impact − 0.46 on industry 26 “Other transport and travel agencies activities”, which is in opposite direction.

Since in the Italian case, policy objective 1 is a dominating policy, which is a demand-driven policy that has the highest multiplier effect on output and becomes an expensive one for all the industries in the Italian economy. The aggregated policy control effect $\mathbf{v}_1$ on the objective variable (total output) in modulus terms[6] is given by $s_1\mathbf{u}_1 = 2.14 \times 100 = 214$. This effect will be observed along the policy structure $\mathbf{u}_1$ and will be equal to $s_1 \cdot \mathbf{u}_1$ as shown in Fig. 13 in the “Appendix B”. This figure further interprets that the highest impact is produce by a group of two industries, i.e., 30 “Renting of M&Eq and other business activities” and 20 “Wholesale trade”. A second group of four industries borne a second highest impact which are 23 “Inland transport”, 26 “Other transport and travel agencies activities”, 28 “Financial intermediation” and 12 “Basic metal and fabricated metals”. The remaining industries bear an impact of intermediate intensity or a lower intensity.

[5] Second set highly stimulated industries are: 23, 24, 20, 21, 17, 12, 8, 3, 1.

[6] The policy control structure V_1 aggregated value is 100 and is determined in terms of its modulus V_1.

From the policy control structure $\mathbf{v}_1$, a hierarchy of industries can be stimulated to get the results of policy 1. The policy control structure $\mathbf{v}_1$, is shown in Fig. 14. From Fig. 14, we see that two industries must be stimulated at a very high degree, i.e., 30 "Renting of M&Eq and other business activities" and industry 20 "Wholesale trade". Four industries are part of a second set highly stimulated, i.e., 23 "Inland transport", 26 "Other transport and travel agencies activities" 12 "Basic metal and fabricated metals" and 3 "Food, Beverages and Tobacco". The remaining industries are activated at an intermediate level, low level or very low level.

3.2.4 Policies for the UK

The UK case has an interesting distribution of effective policies structures, as there is no dominating policy structure observe. Table 3 shows a subset of such policies for the UK transport type industries (i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities"). Policy structure 4, characterized by Macro Multiplier s_4, by a demand control structure $\mathbf{v}_1$ and by an overall policy effect on the objective, $s_4\mathbf{u}_4$, is shown in the fourth column of Table 3. We can see that the greatest component is 0.95, which shows that a demand control tends to have the greatest impact on industry 26 "Other transport and travel agencies activities". Policy structure 22 is convenient structure for industry 25 "Air transport" which has an impact 0.63 on this industry. Objective Policy structure 30 can be seen from the sixth column of Table 3. This policy has a relevant impact on industry 23 "Inland transport". Finally, objective policy 32 has a relevant impact, -0.58, on industry 24 "Water transport". The impact, however, has opposite direction.

From the set of structures for the policy control, $\mathbf{v}_i(i = 1\ldots 35)$, it is possible to choose the most effective policies that use the transport type industries, i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities" as an instrument of economic policy. Table 3 shows the most effective control policies that use industries composing the transport type industries in the UK economy. Policy structure 4 is shown in the 11th column of Table 3. We can see that policy structure 4 uses industry 26 "Other transport and travel agencies activities". Control policy structure 22 uses industry 25 "Air transport". Policy structure 30 uses industry 23 "Inland transport" while policy structure 32 uses industry 24 "Water transport; however, the impact is in opposite direction.

4 Key transport type industries responsible for the CO_2 emissions

Transport is a crucial infrastructure needed for the development process in EU. However, most of the EU transport type industries depend on oil as a fuel source. The gas emissions from these fossil fuels harm the world atmosphere as well as causes irreparable damages to the green environment. According to the (EDGAR 2007) report, the CO_2 emissions, caused by fossil energy consumption, were accounted for 56.6% of the total global green house gases GHG emissions. In this context, the issue relating to climate change has risen dramatically to the top of political agenda, and the importance of transport sector in contributing to reducing CO_2 emissions levels is clearly evident. As all the transport type industries are major users of carbon-based fuels, and achievements of the targets set at the Kyoto Protocol mean that the EU must reduce CO_2 emissions in all sectors, including transport. To address the issue and lessen its harmful effects on environment, CO_2 emissions and other GHG's must be reduced. In this section, we have attempted to present an approach that allows to examine and identify the role or impact of the transport type industries (i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities") responsible for CO_2 emissions in the specified economies. The ratio between direct CO_2 emissions of the transport's sectors on total emissions is in France 13.5%, in Germany 7.1%, in Italy 10.5% and in UK 19.1%.

The approach we proposed is able to identify key industries, which have a direct or indirect contribution to the CO_2 emissions. It shows the contribution of various industries to CO_2 emissions both from demand and supply perspectives. This approach allows us to examine and identify those transport type industries which deserve more consideration for mitigating policies.

4.1 Total CO_2 emissions and Intensity: a traditional environmental Linkage approach

The environmental I-O model which is derived from the structure of the traditional I-O model is symmetric in nature, as it is based on a one-to-one industry and product relationship, i.e., each industry is assumed to produce only one product and each product is produced by only one industry.

We extend the theoretical structure of the I-O model to account for CO_2 emissions associated with interindustry activity. A direct approach to accounting for CO_2 emissions associated with interindustry activity is to first estimate the direct CO_2 emissions intensity. The direct CO_2 emission intensity is estimated as the ratio of direct CO_2 emissions to the total output:

$$\boldsymbol{\varepsilon}_{\mathbf{i}} = \frac{\mathbf{c}_{\mathbf{i}}}{\mathbf{x}_{\mathbf{i}}}, \tag{18}$$

where $\boldsymbol{\varepsilon}_{\mathbf{i}}$ is the direct CO_2 emission intensity of sector i, and x_i is the total output of sector i. The total direct and indirect CO_2 emission intensities are calculated by multiplying the direct CO_2 emission intensity vector $\boldsymbol{\varepsilon}$, by the Leontief Inverse matrix. The total CO_2 emissions can be calculated by multiplying $\boldsymbol{\varepsilon}$ by Eq. 2:

$$C = \hat{\varepsilon}\mathbf{X} = \hat{\varepsilon}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f}, \tag{19}$$

where C is the total CO_2 emissions of the economy.

Let

$$\mathbf{M} = \hat{\varepsilon}(\mathbf{I} - \mathbf{A})^{-1} \tag{20}$$

where $\mathbf{M}$ is the pollution impact coefficient matrix and $\hat{\varepsilon}$ is the diagonal CO2 emission intensity matrix. Each element of matrix **M** is the total CO_2 emissions impact generated per dollar's worth of final demand presented to the economy. The column sums of this matrix represent the multiplier effect of the CO_2 emissions accounted for by the different demands. Similar to the Eq. 19, we will connect the total CO_2 emissions in supply side using Eq. 6 as follows:

$$\mathbf{C}^* = \mathbf{v}(\mathbf{I} - \mathbf{B})^{-1}\hat{\varepsilon} \tag{21}$$

Let

$$\mathbf{P} = (\mathbf{I} - \mathbf{B})^{-1}\hat{\varepsilon}, \tag{22}$$

where $\mathbf{C}^*$ is the total CO_2 emissions of the economy and P represents the total direct and indirect CO_2 emissions due to the expansion of value added necessary for increasing a given sector supply. In short term, this is a set of emissions multipliers from a supply side. The idea of using I-O analysis was first proposed by (Rasmussen 1956) to measure structural interdependence through backward and forward interindustry multipliers. Further, the familiar (Chenery and Watanabe 1958) and (Hirschman, 1958) key sector analysis provided empirical evidence about the economic structure of sectors with in an economy. As the column sums of **M** matrix represents the multiplier effect of the emissions accounted for by the different demands. Therefore, the sum m_j of column elements $\left(\sum_{i=1}^{n} m_{ij}\right)$ corresponds to the total increase in emissions from the whole system of industries needed to match an increase in the final demand for the product of industry j by one unit. We can take the mean $\frac{1}{n}m_j$ and it will represent an estimate of the direct and indirect increase in emissions to be supplied by an industry chosen at random if final demand for the products of industry j expands by one unit. To carry out consistent interindustry comparison, we need to further normalize these averages by the overall average defined as $1/n^2 \sum_{i=1}^{n} m_i$ and, thus, consider the normalized indices.

Backward CO_2 linkage:

$$\mathbf{BL_j} = \frac{\frac{1}{\mathbf{n}}\sum_{\mathbf{i}=1}^{\mathbf{n}} \mathbf{m_{ij}}}{\frac{1}{\mathbf{n}^2}\sum_{\mathbf{i},\mathbf{j}=1}^{\mathbf{n}} \mathbf{m_{ij}}}. \tag{23}$$

T forward CO_2 linkage index will be obtained from the row sum of the **P** matrix explained in Eq. 22. Thus, the forward CO_2 linkage index will be presented as:

$$\mathbf{FL_i} = \frac{\frac{1}{\mathbf{n}}\sum_{\mathbf{j}=1}^{\mathbf{n}} \mathbf{p_{ij}}}{\frac{1}{\mathbf{n}^2}\sum_{\mathbf{i},\mathbf{j}=1}^{\mathbf{n}} \mathbf{p_{ij}}} \tag{24}$$

Table 4 Backward and forward CO_2 linkages for the transport type industries

	Inland transport	Water Transport	Air Transport	Activities of travel agencies
France				
Backward CO_2 linkage	1.77 (4)	1.64 (6)	7.80 (1)	0.18 (29)
Forward CO_2 linkage	1.80 (6)	1.50 (7)	7.57 (1)	0.76 (12)
Germany				
Backward CO_2 linkage	0.79 (9)	0.71 (12)	4.14 (2)	0.76 (10)
Forward CO_2 linkage	1.27 (6)	0.50 (15)	4.29 (2)	1.24 (7)
Italy				
Backward CO_2 linkage	1.03 (8)	3.89 (3)	3.77 (4)	0.49 (20)
Forward CO_2 linkage	1.21 (7)	3.90 (3)	3.85 (4)	0.79 (11)
United Kingdom				
Backward CO_2 linkage	1.05 (8)	4.28 (3)	9.01 (1)	0.19 (30)
Forward CO_2 linkage	1.19 (8)	4.34 (3)	9.33 (1)	0.89 (9)

5 Transport type industries and its backward and forward CO_2 linkages

Transport sector is the second biggest GHG emissions in the EU. According to the (European Commission 2014a) report, GHG emissions in other sectors decreased 15% between 1990 and 2007 but emissions from transport increased 36% during the same period. France, Germany, Italy and the UK governments are making great efforts to reduce the CO_2 emissions and to develop renewable energy sources. According to official statistics, there has been a reduction in the intensity of domestic CO_2 emissions in the specified countries. Table 4 shows the normalized values of forward and backward CO_2 linkages of transport type industries (i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities") of each country for 2009.[7] According to our criteria if the normalized values of both backward and forward linkage are greater than one, then the sector is called a "key sector most responsible for the CO_2 emissions in the economy". If only the backward linkage value is greater than 1, then the industry can be considered as a backward-oriented industry. In short, the backward-oriented industry emissions are due to the expansion of final demand, representing the total pollution potential from the demand side. Similarly, if only the value of forward CO_2 linkage of an industry is greater than 1, then the industry will be considered as a strong forward-oriented industry, which means the total direct and indirect emissions due to the expansion of primary inputs (i.e., Value added) necessary for industry *i* supply. Table 4 shows that there exist substantial

[7] The direct CO_2 emissions data for each country obtained from (http://www.WIOD.org).

dissimilarities in the values and ranking of the transport type industries in the four countries. As we can see from Table 4, the backward and forward CO_2 linkage values of the Inland transport industry are greater than one for France, Italy and UK, which shows that "inland transport" industry is the most responsible for the CO2 emissions in these three countries.

The backward CO_2 linkage index of inland transport industry is less than 1 for Germany, while the forward CO_2 linkage value is greater than one, which shows that Inland transport industry has contributed high CO_2 emissions shares in primary inputs. We can see from Table 4 that the forward CO_2 linkage values of Inland transport industry are greater than 1 for each country, which show that this industry relevance in CO_2 emissions comes from other industries in the economy. Water transport is another most influential industry responsible for the CO_2 emissions, both from demand and supply point of view. The backward and forward CO_2 linkage values of the water transport industry are greater than 1 for France, Italy and UK and positioned this industry in the high ranking among all 35 industries. The backward and forward linkage ranking of water transport industry is 7 and 8 for France, 3 for Italy and UK. The backward and forward CO_2 linkage value of the water transport industry is less than I for Germany, which shows that this industry is low CO_2 emission generation industry. As we can see from Table 4 the backward and forward CO_2 linkage indices of air transport industry are greater than 1 in any country. These indices exhibit a sizeable impact of air transport industry since it is highly positioned in the ranking among all the 35 industries.

Air transport industry shows substantial similarity in the ranking among all 35 industries: the air transport industry is the first most responsible CO_2 emitter industry for France, the second most responsible CO_2 emitter industry for Germany, the fourth most responsible CO_2 emitter industry for Italy and the first most responsible CO_2 emitter industry for the UK. From Table 4, we can see that the backward and forward CO_2 linkage values of the "other activities of travel agencies" industry are less than one for France, Italy and UK and positioned this industry in the lowest ranking among all 35 industries. More precisely, this result interprets that "other activities of travel agencies" industry is a low CO_2 emission generation industry. With respect to the forward CO_2 linkage index, the importance of direct emission of industry "other activities of travel agencies" in Germany is worth noting. It is important to note that the forward CO_2 emission index is greater than 1 and placed "other activities of travel agencies" industry at rank 7. The above findings are important to decision makers to explore effective mitigations on CO2 emissions from the transport type industries of these countries.

6 Conclusion

This study is focused on an I-O model and investigated empirically the ways in which the application of this model can be extended so as to explore the impacts of transport type industries (i.e., 23 "Inland Transport"; 24 "Water transport"; 25 "Air transport"; and 26 "Other transport and travel agencies activities") in a policy analysis context. As the traditional I-O models are the simplest approach, both in construction and implementation, and are still widely used for economic impact analysis, but the limitations, such as linearity properties, are also widely recognized. More precisely, to some extent, I-O models overestimate the static flow on effects of an impact or shock to the economy. It is for this biasness's more alternative complex models are being designed and built. Our study in fact proposes an innovative approach to the problem of comparing quantitatively the European transport type industries under the production point of view, mainly determined by "automation and technology". A simple evidence of this induction is provided by the results of the traditional linkage analysis that has been preliminary performed. This type of approach starts from the assessment of the intensity of the economic flows implied in the production of transport type industries. Then, the linkage analysis has been applied to the inverse matrix of the multisectoral model implemented for each country specified (France, Germany, Italy and UK) showing that all transport type industries are the key and most influential industries in the economies taken into consideration. In particular, the 26 "Other transport and travel agencies activities" industries show a high ranked positioned both from demand and supply side.

Furthermore, the forward linkage exhibits a sizeable impact of inland transport industry among all 35 industries in each country. The backward linkage reveals a high potential stimulus to other activities from a demand shock in Water transport industry. Overall linkage results indicate that transport industries are the key and highest rank industries which play an important role in the specified economies.

In all countries, Inland transport is important from an FL perspective while Water is important from a BL viewpoint. Air transport is important only from a BL perspective in Germany and Italy. Travel agency is a key sector in all countries, while air transport is relevant only in Italy and Germany. Therefore, when designing policy measures, it is important to consider that promoting the reduction of emissions related to these production processes is not neutral and may have recessionary effects.

To get a more precise picture of the actual and potential impacts of transport type industry outputs, the analysis has been refined through the implementation of our approach of macro multiplier (MM). Our proposed approach checks the relevance of the transport type industries from a policy perspective in a two-dimensional way: as a part of final demand to be stimulated in order to generate changes in GDP-transport type industries as a policy control- and as a sectoral output to be kept up-transport type industries as a policy objective. Thus, focusing from a policy standpoint, a set of key structures both for the policy objective variable (total output) and policy control variable (final demand) are identified which presents an exclusive importance in the operation of the producing network. The results obtained from these analysis show that transport type industries play a relevant role in the composition both of the policy target variable and the policy control for all the specified countries. The policy problem is then transformed into the choice of a convenient structure for the policy control. This proposed structure is taken out from a set of structures that are predetermined by the data of the problem. Each of the 35 MM is associated with a structure of a policy control that activates each multiplier effect. This MM effect is directed towards specific industry component of the policy target according to the target key structures. Focusing on the dominant policy means a positive effect on the system as a whole. Both the control and target key structures associated with the dominant policy have all positive components; thus, the policy control increases both the scale of total output and each industrial component. The results of the analysis performed on key structures show that transport type industries plays a relevant role in the composition of both the policy target and the policy control variable in each country. Furthermore, the analysis reveals which are the policies of final demand, in terms of composition of the policy variable that must allocate resources directly to transport type industries in order to generate a general increase in total output. In addition, the analysis also reveals the policy targets where transport type industries are more stimulated. The outcomes of the analysis show that transport type industries are much effective as other key industries in generating changes in GDP if conveniently stimulated. In particular, transport type industries assume a clear leading role among all industries when the final demand policy tends to privilege transport type industries demand compared to other industries.

Moreover, the structures also show that in the countries we considered that there is a divergent impact on transport type industries. Therefore, it is necessary to combine the structures to achieve a target in which the impact of the policy in all transport types is oriented in the same direction. This objective represents simultaneously the aim and the innovation proposed by the present study.

Final section identified those transport type industries (i.e., 23 “Inland Transport”; 24 “Water transport”; 25 “Air transport”; and 26 “Other transport and travel agencies activities”) which deserve more consideration for mitigating policies. According to our approach, it becomes clear that among the 35 industries analyzed in each country three transport type industries, i.e., Inland transport, Water transport and Air transport are the key industries in the emissions of CO_2, both from demand and supply side. We conclude that the most important transport type industries that deserve more attention are 25 “Air transport” and 23 “Inland transport”, respectively. These industries concentrate most of the CO_2 emissions produced with economic growth. The results derived through our research study provide important policy implications. The formulation of policies to control the emissions in these transport type industries could help partially reduce direct CO_2 emissions in included countries.

Appendix A: Tables

See Table 5

Table 5 35 Sectors of the economy

ID	Sectors
1	Agriculture, hunting, forestry and fishing
2	Mining and quarrying
3	Food, beverages and tobacco
4	Textiles and textile products
5	Leather, leather and footwear
6	Wood and products of wood and cork
7	Pulp, paper, printing and publishing
8	Coke, refined petroleum and nuclear fuel
9	Chemicals and chemical products
10	Rubber and plastics
11	Other non-metallic mineral
12	Basic metals and fabricated metal
13	Machinery, nec
14	Electrical and optical equipment
15	Transport equipment
16	Manufacturing, nec; recycling
17	Electricity, gas and water supply
18	Construction
19	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
20	Wholesale trade and commission trade, except of motor vehicles and motorcycles
21	Retail trade, except of motor vehicles and motorcycles; repair of household goods
22	Hotels and restaurants
23	Inland transport
24	Water transport
25	Air transport
26	Other supporting and auxiliary transport activities; activities of travel agencies
27	Post and telecommunications
28	Financial intermediation
29	Real estate activities
30	Renting of M&Eq and other business activities
31	Public admin and defence; compulsory social security
32	Education
33	Health and social work
34	Other community, social and personal services
35	Private households with employed persons

Appendix B: Figures

See Figs. 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14.

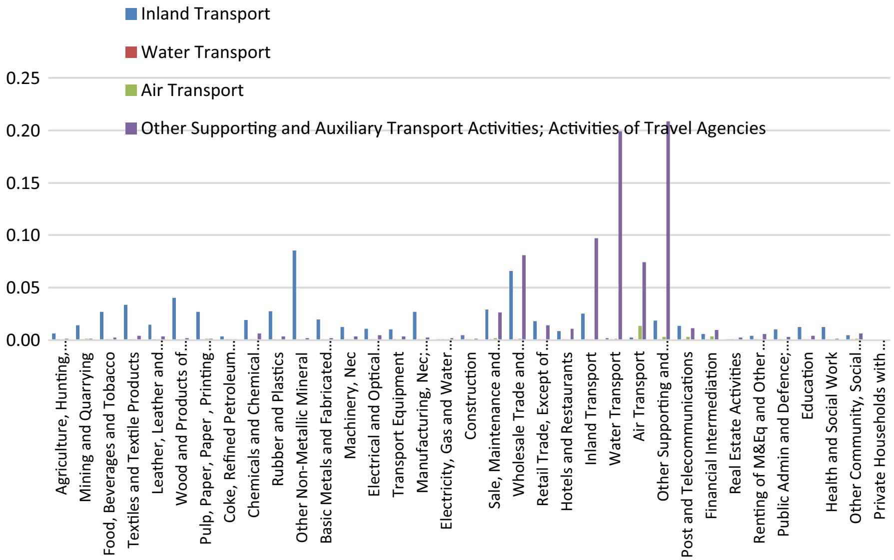

Fig. 3 Market shares in France

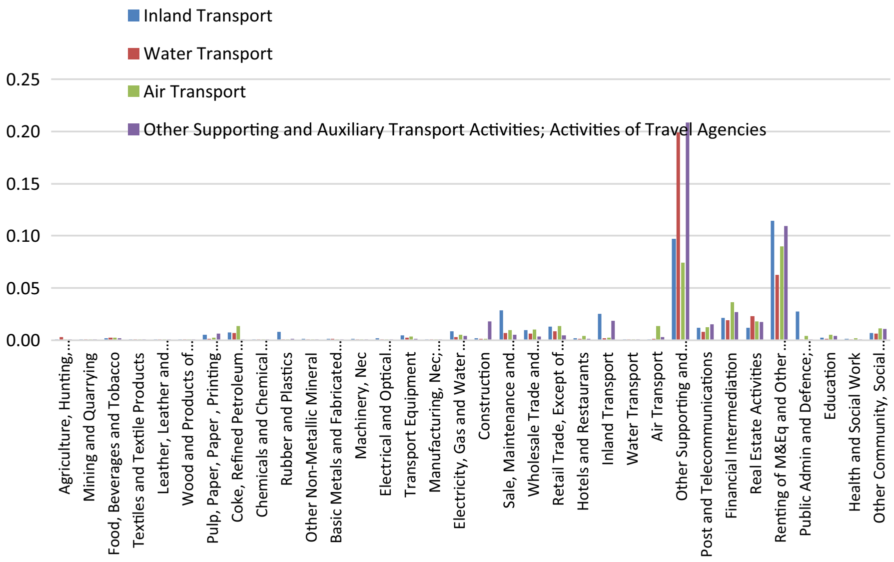

Fig. 4 Technical coefficients in France

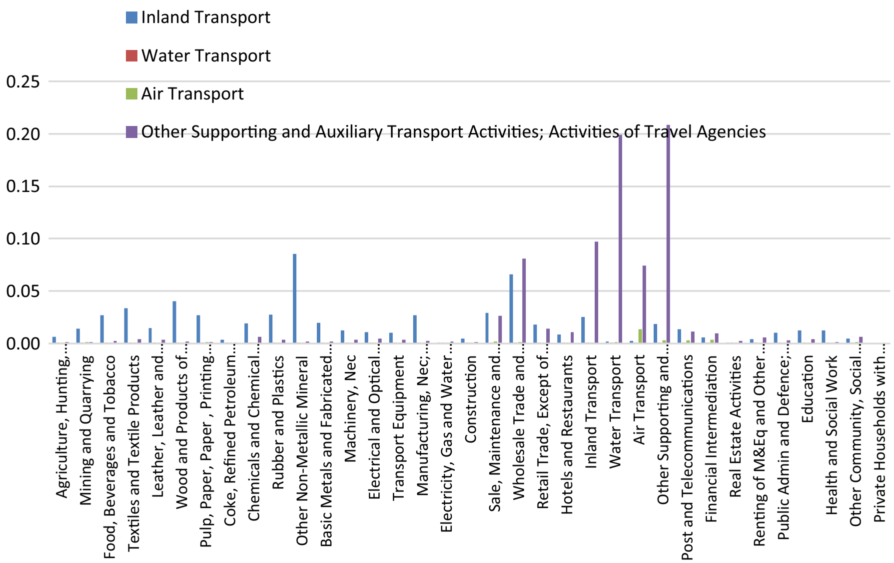

Fig. 5 Market shares in Germany

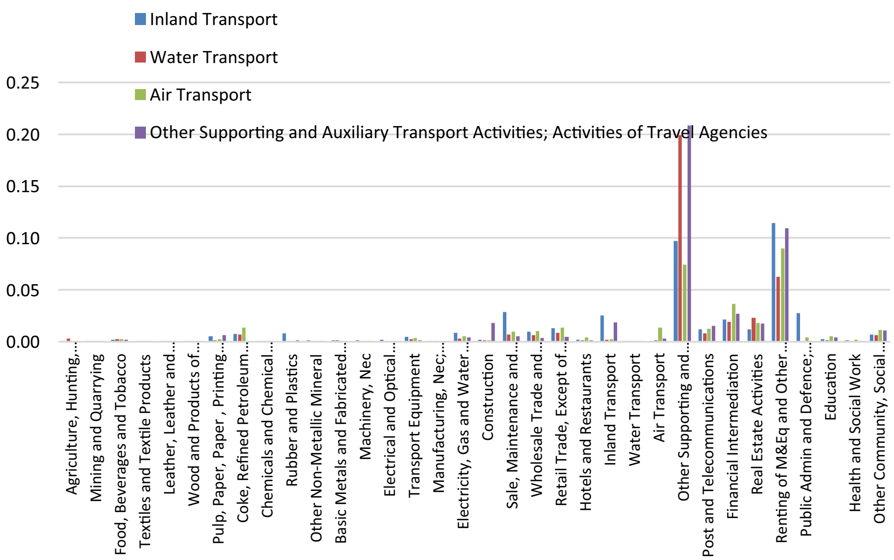

Fig. 6 Technical coefficients in Germany

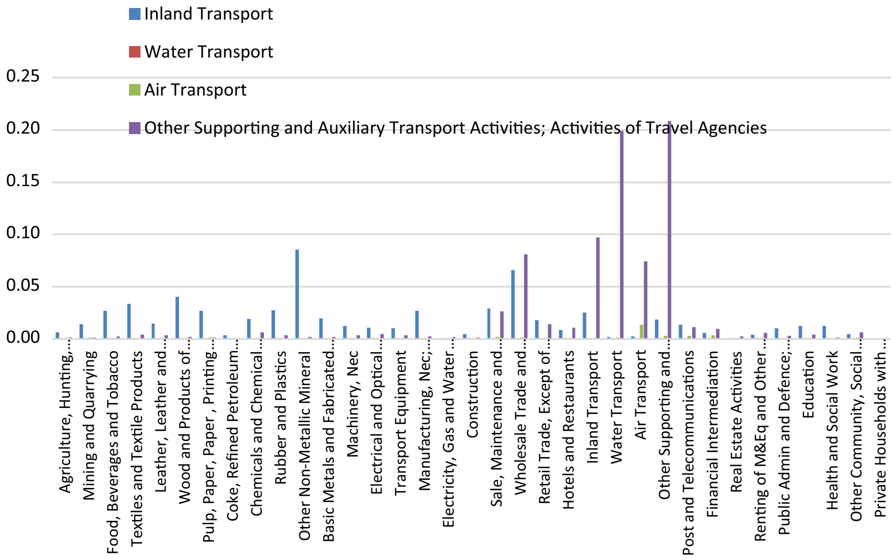

Fig. 7 Market shares in Italy

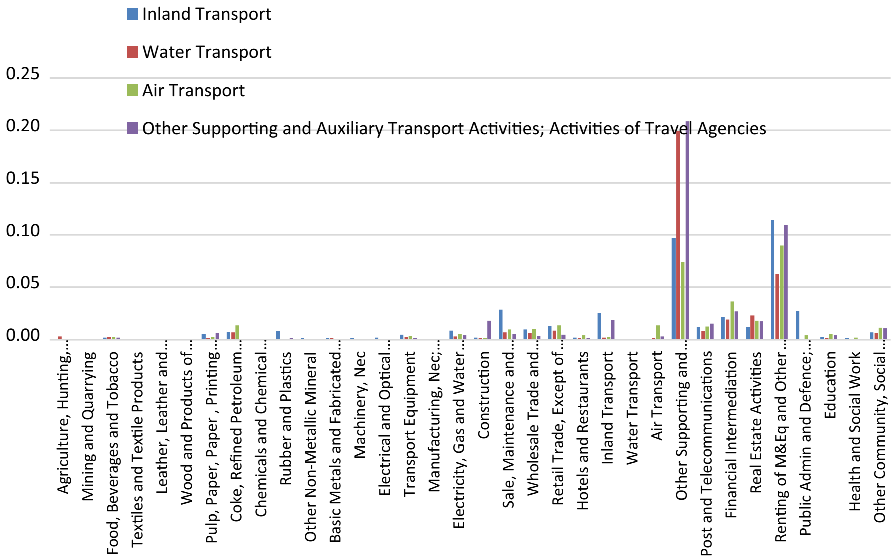

Fig. 8 Technical coefficients in Italy

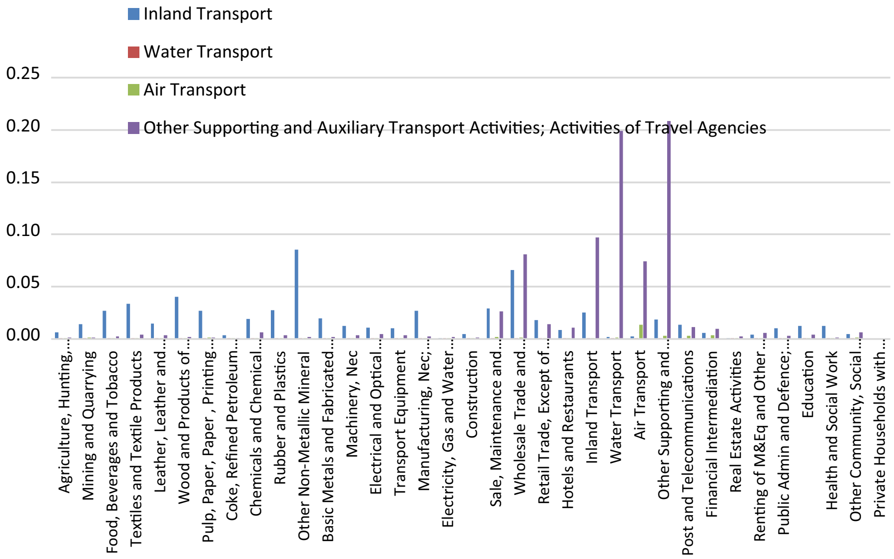

Fig. 9 Market shares in UK

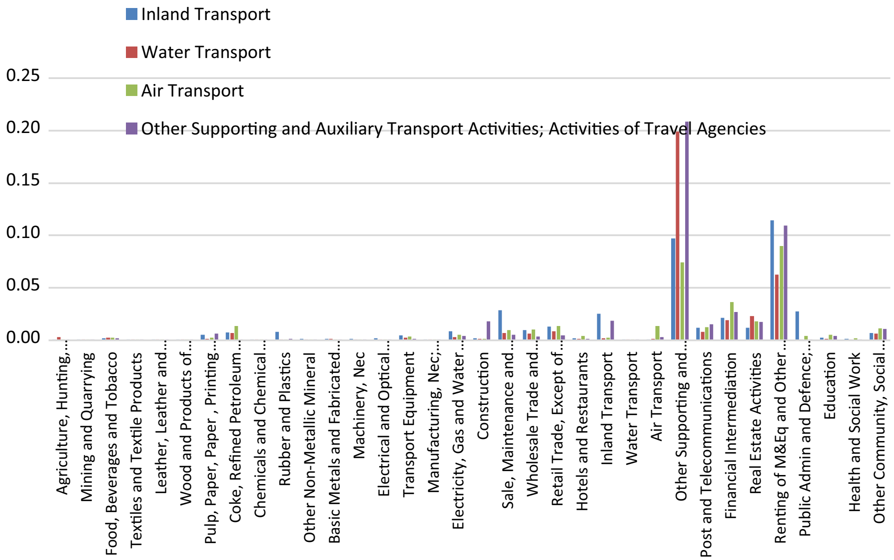

Fig. 10 Technical coefficients in UK

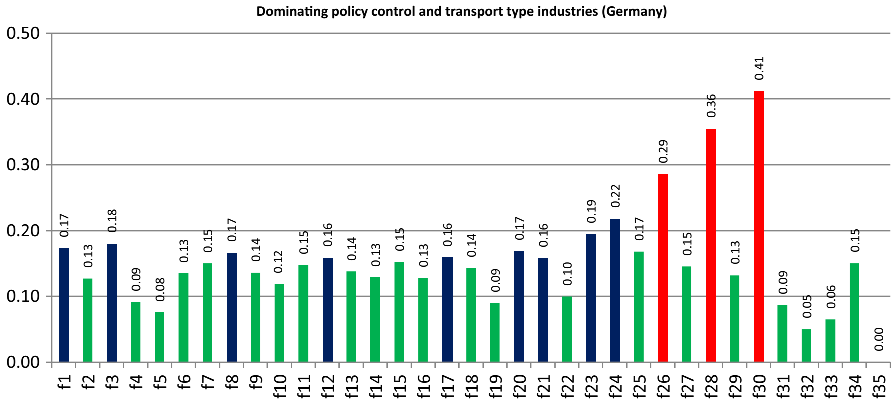

Fig. 11 Dominating policy control and transport type industries (Germany)

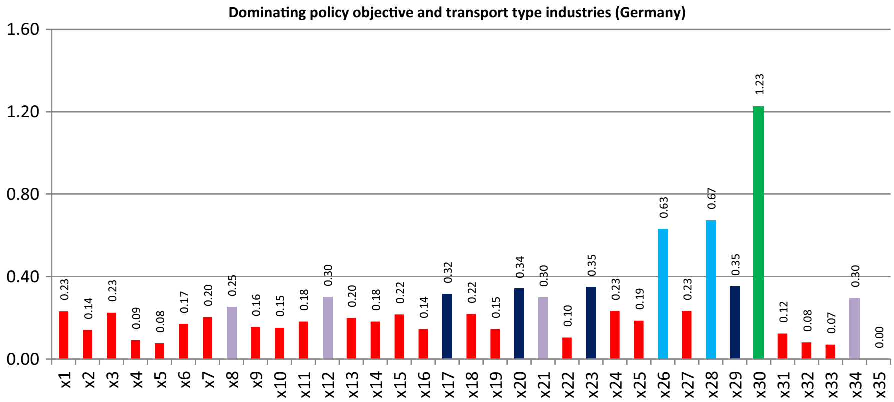

Fig. 12 Dominating policy objective and transport type industries (Germany)

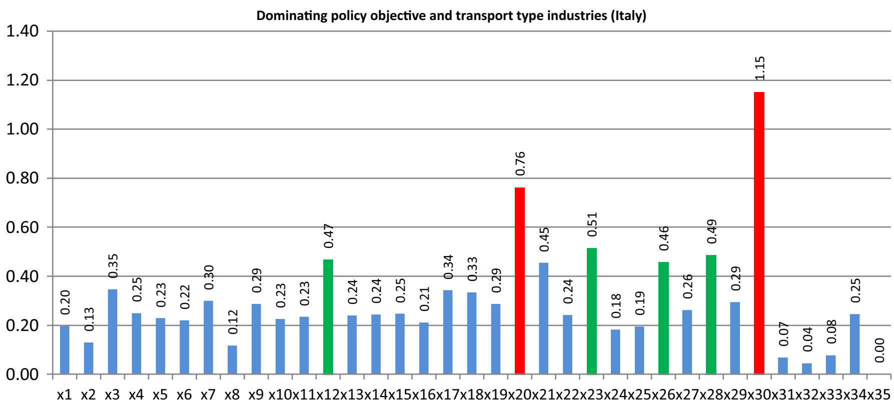

Fig. 13 Dominating policy objective and transport type industries (Italy)

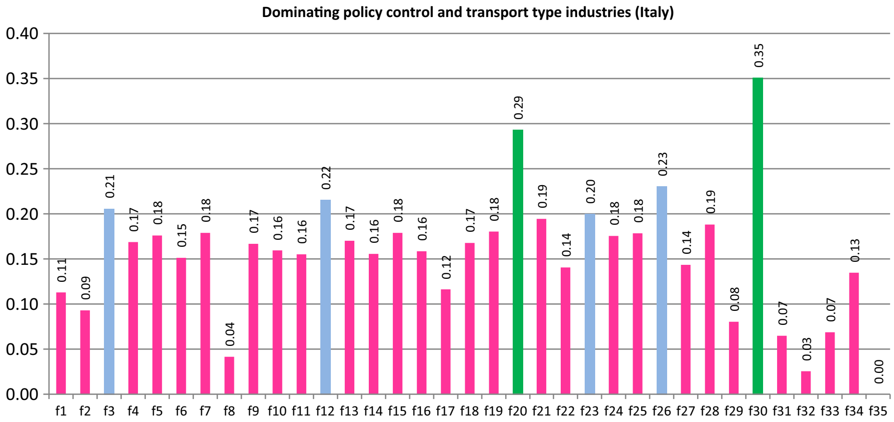

Fig. 14 Dominating policy control and transport type industries (Italy)

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