An analysis of CO2 emissions in Italy through the Macro Multiplier (MM) approach

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ABSTRACT

The issue of policy design into the environmental economic literature is becoming a crucial point especially for the relevance of its implication on international agreements for climate change and for the definition of climate actions against GHGs emissions. The identification of economic drivers accountable for the CO_2 emissions, which represent the major part of GHGs emissions, represents a central topic on literature using Input-Output analysis. The paper proposes a methodological innovation on the study of suitable policy instrument against the raise of CO_2emissions, which is based on the approach of the Macro Multipliers (MM) that leads with the recognition of the impact of all those industries responsible for CO_2 emissions. From the policy perspective, the relevance of industries responsible for CO_2 emissions is also analysed in this approach in which we introduce the target efficiency index and the control effectiveness index across industries. As part of final demand vector, each commodity has its own relevance, or effectiveness, in pursuing the attainment of the target vector. On the other hand as part of the target vectors, each industry emission has its own efficiency in being conveniently modified by changing the policy control vector. The results deriving from the MM approach demonstrate the possibility to overcome the limits of the linkages analysis. In particular, the set of information deriving from the target efficiency and the control effectiveness indices for industries allows designing environmental policies in a framework where economic aggregates are defined in value and physical units. Using the input-output table, this study investigates the impacts of industries activities on CO_2 emission using the MM approach for the Italian economy.

1. Introduction

Between 1990 and 2015 the radiative force – the warming effect on world climate – increased by 37% because of long-lived greenhouse gases such as carbon dioxide, methane and nitrous oxide (WMO, 2016). The amount of CO_2 emissions represents the 65% of the total radiative forcing thus it is quite usual to focus only on this typology of gas when dealing with environmental issue (Wiedman and Minx, 2007). In this respect, researchers and policy maker are facing new challenges in designing economic policy measures and identifying the economic drivers for environmental development (Zhao et al., 2017). Within the international environmental concern, European countries had implemented the major practical environmental policy for twenty-five years (Delbeke and Vis, 2016). The commitment of the European Union against the climate change has been thoughtful and led to the definition of the Europe 2020 strategy for sustainable economic growth that identifies three main targets i.e. (a) drastic reduction of the carbon dioxide emissions, (b) increasing energy efficiency and (c) increasing the use of renewable energy sources. Each EU member, including Italy, acknowledged these targets as national objectives taking into account their own economic circumstances (EU, 2016). In this respect, the Italian government showed a great effort in reducing the CO_2 emission and developing a policy to sustain the use of renewable energy sources. This lead to a considerable reduction in overall greenhouse gas emissions compared to 1990 levels (−13%) but the level of Italian CO_2 emissions is still above the EU-27 average (OECD, 2013). Therefore, formulating policies for further reductions of CO_2 emissions is still a priority for the Italian Government environmental action. This issue should be addressed taking into account

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the strong interrelationships among economic sectors and production and consumptions choices made by the operators, in order to identify the proper channels through which the environmental policy should be implemented. This make the multi-sectoral analysis one of the most used methodology in determining the linkages among the economic and environmental flow because of its capacity to integrate monetary and physical data (Lenzen, 2003), (Moran et al., 2016), (Sheng et al., 2016), (Ali, 2015), (Ali et al., 2015). In particular, the Input-Output analysis is used to determine environmental indicators of human pressure on environment like carbon footprint (Wiedman and Minx, 2007; Zhang and Anadon, 2014; Monslave et al., 2016; Ali, 2017) and optimal embodied energy abatement strategy for several countries (Gemechu et al., 2014; Lenzen and Dey, 2002; Li et al., 2016; Cai, 2016; Liu et al., 2016).

Along this path, the present study made an effort to investigate the involvement of industries in CO_2 emissions, demonstrating the advantages of using the MM method (Ciaschini et al., 2010a,b,c) for policy analysis instead of the linkages analysis (Hirschman, 1985). More specifically, using the Input-Output table for Italy, through the linkages analysis the paper quantifies the impact on CO_2 emissions caused by an exogenous final demand shock (or output shock). Conversely, with the innovative approach of MM, we demonstrate the possibility to the rank each endogenous structure of policy target and policy control (including all industries in the economy) according to its effect on emissions.

The limits of theoretical interpretation given to the traditional Leontief forward linkage resulted in the study of several authors questioning the use of Leontief's forward linkage estimates (Jones, 1976). Jones proposed that the output is inversely derived from the output coefficient matrix (or market shares) generating a more meaningful measure of forward linkages. This led to the development of a forward linkage measure based on the elements of the Ghosh model (Miller and Blair, 2009), (Ali et al., 2014). Alcantara used the Rasmussen approach to identify the determinant industries responsible for CO_2 emissions in Spain (Alcantara, 2011). Alcantara and Padilla used this approach to identify key industries in CO_2 emissions from a production perspective in the Spanish economy (Alcantara and Padilla, 2006).

Nonetheless, the exercise presented in this study is based on the decomposition of the coefficient matrix, which includes the total environmental pollution impacts. It demonstrates the possibility to identify dominating structures for the economic policy (the dominating structure for the policy control and policy target) that allows stimulating industries in a proper way and achieving the CO_2 emission target.

In this perspective, the second section describes the methodology used to carry out the analysis and its rationale. In particular, we introduce the Environmental Pollution Input Output Model (EPIOM) that it has been developed on the Input Output table for Italian economy for the year 2005 (EUROSTAT, 2008); the linkages and MM approach which are based on the total environmental pollution impact coefficient matrix. The Carbon dioxide emissions data come from the environmental accounts of the Italian National Institute of Statistics (ISTAT, 2010). In the third and the fourth sections, some results on the impact of industries production processes on CO_2 emissions are presented. Finally, in the last section some final remarks and implication on environmental policy strategies for Italian economy are discussed.

2. Methodology

In the following sections, we discuss the methodological features and the results deriving from the application of two different approaches: the key sectors analysis and the MM approach. We aim to compare these approaches in order to demonstrate the relevance of the latter to go beyond the limits of the traditional analysis. For this purpose, we developed the Environmental Pollution and Input Output Model (EPIOM) that allows identifying the structural matrix regarding the formation of the emissions of the whole economy (Miller and Blair, 2009). Based on this structural matrix, the key sectors analysis provides a rank of industries according to the level of pollution, thus it identifies how each industry contributes to the global pollution when a component of final demand is stimulated. On the other side, the MM approach allows finding endogenous structures of policy instruments hidden by the structural matrix of the model. This feature represents a central innovation compared to the traditional linkages analysis since the policy instrument structure, as endogenous policy, is completely suggested by the multisectoral interdependencies of the production system, thus it does not affect results (Ciaschini and Socci, 2007).

The extraction of indices from structural matrix **M** can be also done considering the structure of final demand, as policy control vector. In other words, we can attempt to impose changes in the final demand structure according to the dominating policy structure in order to get the planed change in the emissions by industry, which in this sense will represent the policy target. For this purpose, we use the two indices: the target efficiency and the control effectiveness. If the policy target efficiency of one industry is greater than 1 then the role played by this industry within the "dominating" policy target is higher with respect to the other industries composing the target. On the other hand, if the policy control effectiveness is greater than 1, then demand of for this industry output is high with respect to the final demands of commodities produced by the other industries composing the "dominating" policy control.

The analysis is based on the Italian I-O table for the year 2005 (EUROSTAT, 2008), which provides a disaggregation of 58 × 58 industries. This dataset matches with data on CO_2 emissions from the National Accounting Matrix Including Environmental Accounts (NAMEA) (ISTAT, 2010). This latter, supplements the major economic aggregates (total output, value added and final demand) with data on 19 different GHG emissions[1] in physical terms according to the Input Output disaggregation. In this study however, we are interested only on CO_2 emissions and do not take into account to the others.

In Fig. 1 in particular, we plotted the share of CO_2 emissions by industry on total CO_2 emissions generated by all industries, that is to say, the contribution of each industry to the amount of CO_2 emissions derived from the production processes. As expected, industry (31) "Electricity, gas, steam and hot water supply", exhibits the highest share of emissions, followed by industry (33) "Construction", (8) "Manufacture of food products and beverages" and (36) "Retail Trade".

If we observe the CO_2 emissions form the demand side, it can be decomposed in terms of: final consumption expenditure by Household, final consumption expenditure by Non-Profit Organizations Serving Households (NPISH), final consumption expenditure by Government, Gross capital formation and export. The total relative impact of each type of final demand is given in Fig. 2.

As showed, final consumption expenditure by Household is accountable for approximately 50% of the total CO_2 emissions generated by industries. This result portrays that the living style

[1] GHG emissions in NAMEA are referred to 19 different pollutants: carbon dioxide (CO2), methane (CH4), nitrogen dioxide (N2O), nitrous oxides (NOX), sulphur oxides (SOx), ammonia (NH3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), particulate matter (PM10 and PM2,5), arsenic (As), cadmium (Cd), chrome (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se) and zinc (Zn).

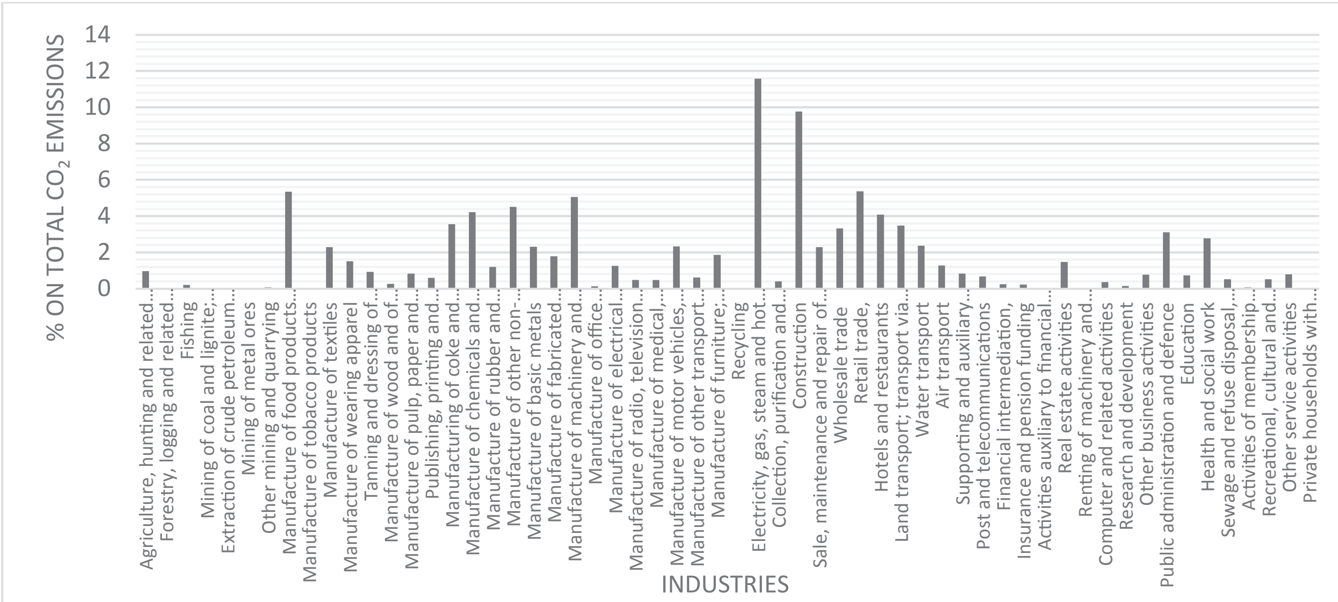

Fig. 1. CO_2 emissions by industry: percentage on total CO_2 emissions (year 2005).
Source: own elaboration on NAMEA data.

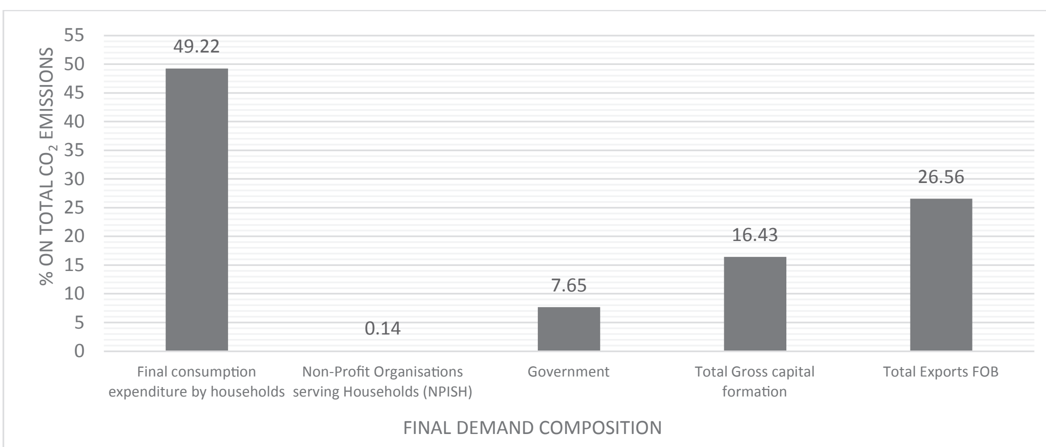

Fig. 2. CO_2 emissions by final demand components (year 2005, % on total CO_2 emissions).
Source: own elaboration based on NAMEA data.

and consumption pattern in Italy are the main source of emissions of one of the most important greenhouse gases. The second highest category responsible for the CO_2 emissions is exports, representing 26.56% of the emissions that all industries generate. Total gross capital formation is the third category of final demand responsible for the generation of CO_2 emission with the share of 16.43% of the emissions. Among the remaining categories of final demand, government consumption represents 7.65% of the total CO_2 emission and the non-profit organizations serving household (NPISH) contributes only for 0.14% of the total emission.

2.1. *Environmental pollution and input output model (EPIOM)*

The inter industry feature of the input output methodology allows for extending the analysis to other areas strictly connected with the production process such as the environment and pollution (Ciaschini, 1989). The increasing use of I-O analysis in different environmental studies has generated a number of input output tables with different names and objectives. In this paper, the theoretical structure of the environmental input output table is used for air emissions in order to account for pollution generation that is associated with the inter-industry activity.

In order to account for air emissions that are associated with inter-industry activity, let us to refer to the pollution output matrix $\mathbf{P}[p_{s,j}]$ which is observed from the statistical evidence. Matrix $\mathbf{P}$ shows the amount of pollutant types (carbon dioxide in this application) that is generated by industry j. Based on matrix $\mathbf{P}$, the pollution coefficient matrix is calculated by dividing the observed data on pollution with the observed data on industry outputs,[2] $\mathbf{Q} = \mathbf{P}_{obs}\,\widehat{\mathbf{x}}_{obs}^{-1}$. Denoting with $\mathbf{q}$ the row of matrix $\mathbf{Q}$, which refers to CO_2 emission, we can write:

[2] The index *obs* for denotes matrices that are not calculated but taken from official statistics.

$$y = \mathbf{q}\,\mathbf{x} \quad (1)$$

where $\mathbf{x}$ is output vector *per* industry, $\mathbf{q}$ is the row vector of the pollution coefficients by pollutant type (for example CO_2 per unit of industry output), y is a scalar that represents the total emission, direct and indirect,[3] of CO_2 pollutant *per* each million of euro. [4]

The total output vector x is determined from the Leontief model, $\mathbf{x} = \mathbf{Lf}$ where $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$. The technical coefficient matrix, $\mathbf{A}$, has been obtained considering the intersectoral flow-table in national accounts, $\mathbf{Z}_{\text{obs}}$, determining the intermediate requirements per unit of industry output $\mathbf{A} = \mathbf{Z}_{\text{obs}}\,\widehat{\mathbf{x}}_{\text{obs}}^{-1}$. Total CO_2 emissions can then be determined as a liner function of final demand:

$$\mathbf{y} = \widehat{\mathbf{q}}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \quad (2)$$

where $\widehat{\mathbf{q}}$ is the diagonal matrix with elements of vector $\mathbf{q}$ on the diagonal; therefore, the solution of the pollution extended I-O model is expressed by the equation:

$$\Delta\mathbf{y} = \left[\widehat{\mathbf{q}}(\mathbf{I} - \mathbf{A})^{-1}\right]\Delta\mathbf{f} \quad (3)$$

where $\mathbf{A}_{(nxn)}$ is the technical coefficient matrix, $\mathbf{f}$ is the vector of final demands with n components and $\mathbf{y}$ is a column vector of n elements of total emissions by industry that describes the relation between the change on policy control (final demand change, $\Delta\mathbf{f}$) and the resulting change in the policy target (total change in emission, $\Delta\mathbf{y}$). We can write:

$$\mathbf{M} = \left[\widehat{\mathbf{q}}(\mathbf{I} - \mathbf{A})^{-1}\right] \quad (4)$$

where $\mathbf{M}$ is the matrix of total environmental pollution impact coefficients of CO_2 emissions. Each element of this matrix is the total pollution impact generated *per* euro's worth of final demand existing in the economy. In other words, $\mathbf{M}$ is a linear operator that transforms increases in final demand into increases in the polluting emission vector. Matrix $\mathbf{M}$ will then provide the set of CO_2 emission multipliers of total emissions (direct and indirect) by the commodities composing final requirements from the demand side.

Furthermore, we can also determine the degree at which various institutional sectors are accountable for the total emissions. For this purpose, from the national accounts, we consider the final demand in its disaggregation according to the institutional sectors. Notably final demand is exhibited by i) households, i.e. the final consumption expenditure by household, $\mathbf{f}^{h}$, ii) final consumption expenditure by *non* profit organizations serving households (NPISH), $\mathbf{f}^{NP}$, iii) final consumption expenditure by government, $\mathbf{f}^{G}$, iv) by firms i.e. total gross capital formation, $\mathbf{f}^{I}$, and by the rest of the world i.e. total export, $\mathbf{f}^{EX}$. Total final demand can then be expressed in its institutional components as:

$$\mathbf{f} = \mathbf{f}^{H} + \mathbf{f}^{NP} + \mathbf{f}^{G} + \mathbf{f}^{I} + \mathbf{f}^{EX} \quad (5)$$

In this way, total emissions can be consistently attributed to the demand shocks according to the institutional sectors where demands originate. The share of total emissions accountable to households consumption, $\mathbf{y}^{H}$:

$$\mathbf{y}^{H} = \mathbf{M}\mathbf{f}^{H} \quad (6)$$

where $\mathbf{f}^{H}$ is the household component of vector $\mathbf{f}$.

Multi sectoral analysis also develops through the assumption that is different and partially compatible with the Leontief hypothesis that prescribes the constancy of technical coefficients. The technical coefficient matrix, $\mathbf{A}$, is in fact obtained from the observed inter sectoral flow-table, $\mathbf{Z}_{\text{obs}}$, and represents the intermediate requirement per unit of industry output. A somehow alternative multisectoral model but useful to stress other features of the interactions among sectors in the Goshian model. It assumes the constancy of the market shares, and the transaction matrix under this hypothesis is determined starting from the observed inter-sectoral flow matrix, $\mathbf{Z}_{\text{obs}}$, however considering fixed the destination shares of intermediate flows per unit of industry total output $\mathbf{B} = \widehat{\mathbf{x}}_{\text{obs}}^{-1}\,\mathbf{Z}_{\text{obs}}$

Following the proposed choice, we can write the direct and indirect intermediate flows from the supply side viewpoint as:

$$\mathbf{x}^{g} = \mathbf{v}'(\mathbf{I} - \mathbf{B})^{-1} \quad (7)$$

where $\mathbf{v}'$ is the row vector of value added as long as it represents the primary inputs utilized in each of the n industries and vector $\mathbf{x}^{g}$ the corresponding output vector activated by vector $\mathbf{v}'$ of primary inputs. Similarly, to the demand oriented model in Equation (2), we will connect the emission vector $\mathbf{q}$ in supply side model as follows:

$$\mathbf{y}^{g} = \mathbf{v}'\left[(\mathbf{I} - \mathbf{B})^{-1}\right]\widehat{\mathbf{q}} \quad (8)$$

We can view the connected quantity as a linear operator that transforms value added, representing the costs of primary factors utilized in the production process into polluting emission. We express this matrix as:

$$\mathbf{G} = \left[(\mathbf{I} - \mathbf{B})^{-1}\widehat{\mathbf{q}}\right] \quad (9)$$

From the row sums of $\mathbf{G}$ matrix, we obtain a vector $\mathbf{y}^{g}$, which represents the total emission due to the expansion in primary factors utilization necessary for increasing output supply for industry *i*. Matrix $\mathbf{G}$ will then provide the set of CO_2 emission multipliers of total (direct and indirect) emissions by level of activation of primary factors used from the supply side.

We can consider matrices $\mathbf{M}$ and $\mathbf{G}$ as the structural matrices of the process regarding the formation of the emissions. Both matrices rely on the same inter sectoral flow table $\mathbf{Z}$, that provide the available statistical data on inter industry commodity flows and on vector $\mathbf{q}$. However, coefficients are determined in a way that, in matrix $\mathbf{M}$, the model is demand driven while in matrix $\mathbf{G}$ the model is supply driven (Miller and Blair, 2009).

2.2. Key sectors analysis for the identification of demand and supply driven emissions linkages

The key sector analysis can be designed in order to derive synthetic indices of emission-linkages and emission key-industry. As mentioned in Equation (6), the columns sum of $\mathbf{M}$ matrix represents the multiplier effect of the emissions accounted by different vectors of demand; therefore, the sum, $m_{\cdot j}$, of column elements ($m_{\cdot j} = \sum_{i=1}^{n} m_{ij}$) corresponds to the total increase in emissions from

[3] Direct and indirect Green House Gas emissions can be defined consistently both with reference with I-O analysis; in connection with the direct and indirect intermediate requirements and the GHG Protocol, that mentions Direct GHG and Direct GHG emissions. Direct GHG emissions are, then, emissions from the activities put in operation within the industry in the effort of obtaining the sector output. While Indirect GHG emissions are emissions that are a consequence of the activities of the industry, however implemented by the remaining industries.

[4] Following the usual notation, matrices are indicated by bold capitals, vectors by bold lowercases and scalars by normal character. Transpose is as usual represented by (′), while diagonalization is represented by (ˆ).

industries that needs to match an increase in the final demand for the product of industry *j* increased by one unit. We can take the average, $\frac{1}{\mathbf{n}} m_{\cdot\mathbf{j}}$, and it will represent an estimate of the increase in emission 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 inter industry comparisons, we need to normalize these averages by the overall average defined as $\frac{1}{n^2}\sum_{j=1}^{n} m_{\cdot j}$ and thus consider the backward linkage (Hewings et al., 1989; Guo and Hewings, 2001; Hewings and Sonis, 2009).

Backward linkage BL_j^R is defined as follows[5]:

$$BL_j^R = \frac{\frac{1}{n} m_{\cdot j}}{\frac{1}{n^2}\sum_{j=1}^{n} m_{\cdot j}} \tag{10}$$

The aim of the BL_j^R is to measure the potential stimulus to other activities from a demand shock in any industry j.

A more complete specification of the linkage indices cannot be done without referring to the assumption of constant market shares rather than the technical coefficients in the Leontief framework, since this gives additional information that mutually constrains the discussion and reliability of the results of linkage analysis.[6]

In this respect it possible to define the index of Forward linkage FL_i^R as follows:

$$FL_j^H = \frac{\frac{1}{n} g_{i.}}{\frac{1}{n^2}\sum_{i=1}^{n} g_{i.}} \tag{11}$$

The FL_i^R measures the degree to which one industry output is used by other industries as an input. From the row sums of matrix **G** in Equation (9), we obtain a vector that represents the total emission due to the expansion of value added necessary for increasing industry *i* supply. In other word, this is a set of emission multipliers from a supply side. Thus, the index of forward linkage in Ghosh matrix is obtained using the total of row in matrix **G.**

$$g_{.i} = \sum_{j=1}^{n} g_{ij} \tag{12}$$

In section 3 we show the results based on the backward linkage applied to matrix **M** in Equation (4), which represents the total emissions due to multiplier effect on output caused by the expansion of the components of final demand.[7] This represents the "pull effects" due to the expansion of final demand. Similarly, for the forward linkages we referred to matrix **G** in Equation (9). It has been stated above that this equation represents the total emissions due to the effects on output caused by the expansion of the primary inputs utilization as represented by value added in each industry. In this sense this emissions are now considered as a result of the pull effect of primary inputs utilization. If the normalized values of both backward and forward linkages are greater than 1, then the industry will be considered as a "*key industry responsible for the CO_2 emissions*". If only the normalized value of backward linkages is greater than 1 then the industry can be seen as a "*backward linkage oriented*" industry. Similarly, if only the normalized value of forward linkage of an industry is greater than 1, the industry will be referred to as a "*forward oriented industry*". This means that the total emission due to the expansion of primary inputs is necessary for industry *i* supply. The last group refers to the "*low linkage industry or low emission generation industries*", where the values of both the backward and forward linkages are less than 1.

2.3. The Macro Multiplier approach and environmental key policy for CO_2 reduction

The identification of those industries that contribute to the pollution emissions relies also on the comparison of different techniques and evolutions within the approach. We propose two new indices extracted from the structural matrices of the model more concentrated than the traditional analysis on the policy problem and relationship between the policy control variable and the policy target emerging in a multi sectoral framework (Ciaschini et al., 2010a,b,c). We know that different combinations of components in the policy control can determine impacts of different magnitude and composition, which can be observed on the target variable sectoral emissions (Ciaschini et al., 2010a,b,c). In this respect, the approach we propose aims to identify the most efficient structure of the control variable that generates the highest effect in the policy variable (Ciaschini et al., 2009).

The total environmental pollution impact coefficient matrix **M** can be easily decomposed through the singular value decomposition SVD (Lancaster and Tismenetsky, 1985) and rewritten as the product of three different matrices:

$$\mathbf{M} = \mathbf{U}\,\mathbf{S}\,\mathbf{V}^{\mathbf{T}} \tag{13}$$

Matrices **U** and **V** are two unitary or orthonormal basis matrices of dimension $n \times n$. The columns of matrix **U** represent the structures of the target variables (the total emission) on which the effects of specific policy control structures activated, **V**, can be determined.

The rows of unitary matrix **V** represent the key structures of the policies control, which measure and establish the composition of all the possible policies control. Finally, matrix **S** is a $n \times n$ diagonal matrix whose elements, the singular values, are scalars all positive. They play the role of aggregate multipliers, they are all real positive and can be ordered according to their magnitude as: $s_1 \geq s_2 \ldots\ldots\ldots s_n \geq 0$. The identified structures play a fundamental role in determining the potential behaviour of the economic system in connection with the impact of the structure of the policy variable in determining the scale and the structure of the policy target (Ciaschini and Socci, 2007; Ciaschini and Socci, 2005). In this respect, we note that matrix **M** hides the fundamental combinations of the policy variables (total emission). Each of these is obtained by multiplying the corresponding combination of final demand by a predetermined scalar, which has in fact the role of aggregated multiplier (Ciaschini et al., 2010a,b,c).

Concentrating on the highest, or dominant, macro-multiplier s_1 that is present in matrix **M.** we can write:

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

This shows that if the policy control (change in final demand) is given in the proportions determined by $\mathbf{v_1}$, which represents the dominating policy structure, then the policy target (change in industry emissions) will be given by the associated policy target structure $\mathbf{u_1}$ multiplied by the associated dominating macro multiplier s_1.

[5] The idea of using I-O analysis to measure structural interdependence through backward interindustry linkage was first proposed by Rasmussen (1956) and has developed empirically through the works of Chenery and Watanabe (1958) and Hirschman (1958).

[6] Rasmussen measures take into account the indirect effects. However, the awkward interpretation given to the traditional Leontief forward linkage resulted in the study of several authors questioning the use of Leontief forward estimates (Jones, 1976). Jones then proposed that the output inverse derived from the output coefficient matrix may produce more meaningful measures for forward linkages. This led to the development of a forward linkage measure based on the elements of Ghosh model (Miller and Blair, 2009).

[7] The normalized values of forward and backward linkages of fifty eight industries of the Italian economy for 2005 are showed in Table A3.

With reference to the target and control key structures in the total environmental pollution impact coefficient matrix **M**, we determine an index of the target efficiency, μ_{ij}, that evaluates the degree at which each industry-emission in the policy target vector is under the impact of the corresponding policy control. It quantifies the relevance of the ith industry in all the n target structures. In particular, the index can reveal the role played by the selected industry inside the target structures $\mathbf{u_i}$ when the corresponding Macro Multiplier s_i is activated. [8]

$$\mu_{ij} = \frac{\frac{|s_j u_{ij}|}{1/n\sum_{j=1}^{n}|s_j u_{ij}|}}{1/n^2\sum_{i=1}^{n}\sum_{j=1}^{m}|s_j u_{ij}|} \tag{15}$$

Consistently, we also determine the corresponding index for the policy control effectiveness, γ_{ij}, starting from matrix **V**:

$$\gamma_{ij} = \frac{\frac{|v_{ij}|}{1/n\sum_{j=1}^{n}|v_{ij}|}}{1/n^2\sum_{i=1}^{n}\sum_{j=1}^{m}|v_{ij}|} \tag{16}$$

The index quantifies the importance of the ith industry in all the n control structures. In particular, the index can reveal the role played by the selected industry inside the policy objective structures $\mathbf{v_i}$ (Ali et al., 2015).

The two indices identify the potential behaviour of each industries inside each policy structure by mean of the quantification of the power of each industry to be relevance into each structure. The indices determine those industries that are responsible for the most emissions of CO_2 in all policies control and policy variable. For this reason, we can have a rank of all industries according the normalized values of both target efficiency and control effectiveness indices and this rank is linked with e rank of policy structures, both for target and control. Thus, the analysis through the MM approach gives information about the pollutant behaviour of industries according the specific policy structure instead of the linkages analysis results that are focused only on industries and derived from an unrealistic structure of the shocking variable (Ciaschini et al., 2009).

3. Linkages analysis for the Italian economy: looking for key industry responsible for the CO_2 emissions

The exercise directed for the Italian economy through the linkages analysis of **M** and **G** matrices demonstrates the possibility to rank the industries in the economy according their power to affect the increase in CO_2 emissions. From the policy maker perspective, this result may represents a crucial information in order to identify both the instrument of emissions mitigation, as for example demand or supply incentives, and a crucial evidence to better direct the energy policy design toward national target emissions. Results on linkages analysis for the Italian economy are showed in Table A3 in Appendix A.

The positive feature of linkages analysis, both from demand and from supply side, is the possibility to categories industry according their power to pollute when activated by a final demand shock or by an increase in input consumption. For this reason, the results can support policy maker in the identification of the national strategy for reducing emissions in such industries.

We decide to group industries, according to the backward and forward linkages, into four categories (L, B, F, K) .[9] If the normalized values of both backward and forward linkages are greater than 1, then the sector is labelled as "*key industry responsible for the CO_2 emissions*" and included in category named K. If only the normalized value of backward linkages is greater than 1 thus the industry can be considered as a "*backward linkage oriented*" industry and included in category B. More precisely, these industries emissions are due to the expansion of final demand and it represents the total pollution potential from the demand side. Similarly, if only the normalized value of forward linkages of an industry is greater than 1, than the industry is considered as a "*strong forward oriented"* industry and included in category F. These potential effects are related to the expansion of primary inputs (i.e. value added) necessary for industry i supply. The last category, L, refers to the "*low linkage industry or low emission generation industry*", when the values of both the backward and forward linkages are less than 1.

We can see that ten industries in the whole economy compose the category of K, thus they are responsible for the most of CO_2 emissions from both the demand and supply side point of view[10]. Among the K industries, the most influential production industry is, as expected, the number (31) *Electricity, gas, steam and hot water supply*. This industry has the highest impact indices, both from demand and supply point of view. The reason behind this is that the 73% of its production represent an intermediate good of other industries. Thus, we can conclude that a unitary increase of the demand inputs into the economy implies an increase of 35.13% in total CO_2 emissions in industry number (31). Moreover, results identify the industry (38) *Land transport; transport via pipelines*, which includes railway transport but the largest part is represented by road transport, it shoes a supply emission impact of 6.43% and a demand emission impact of 3.48%. Then the third most influential industry that stands out is industry (19) *manufacture of other non-metallic mineral products*, which has a supply emission impact of 12.54% and a demand impact of 4.51%. The group of S industries, the industry (1) *electricity, gas, steam and hot water supply* has a highest rank. Industry (19) which manufacture other non-metallic mineral products are placed in the second position in the strong backward oriented industries. Similarly the remaining top ten strong backward oriented industries are (39) water transport, (40) air transport, (16) manufacture of coke, refined petroleum products, (20) manufacturing of basic metals, (14) manufacturing of pulp, paper and paper products, (7) other mining and quarrying, (10) manufacture of textiles and (32) collection and distribution of water. See Fig. B1 in Appendix B.

With respect to forward linkage category, the importance of the emission of industry (4) Mining of coal and lignite; extraction of peat is worth noting. It is important to note that the emission index of this industry is quite close to electricity, gas, steam and hot water supply industry. The other strong forward linkage oriented industries are shown in Fig. B2 in the appendix B. The second most influential forward industry is (5) Extraction of crude petroleum and natural gas, which has a high emission. The overall total emissions of forward linkage industries are low as compared to backward linkage oriented industries. The reason is the emissions pull effects from other industries that provide them with inputs to

[8] When the index assumes a value lower than 1 the industry has a low importance inside both the key objective and control structures i.e. $\mu_{ij} < 1$ and $\gamma_{ij} < 1$.

[9] As mentioned above, according the value of indices we labelled industry with letters K, B, F and L, denoting respectively, "*key industry responsible for the CO_2 emissions*", "*backward linkage oriented*", "*strong forward oriented*" and "*low linkage industry or low emission generation industry*".

[10] Category K includes: (7) Other mining and quarrying, (14) Manufacture of pulp, paper and paper products, (16) Manufacture of coke, refined petroleum products, (19) Manufacture of other non-metallic mineral products, (20) Manufacture of basic metals, (31) Electricity, gas, steam and hot water supply, (38) Land transport; transport via pipelines, (39) water transport, (40) Air transport and (54) Sewage and refuse disposal, sanitation and similar activities.

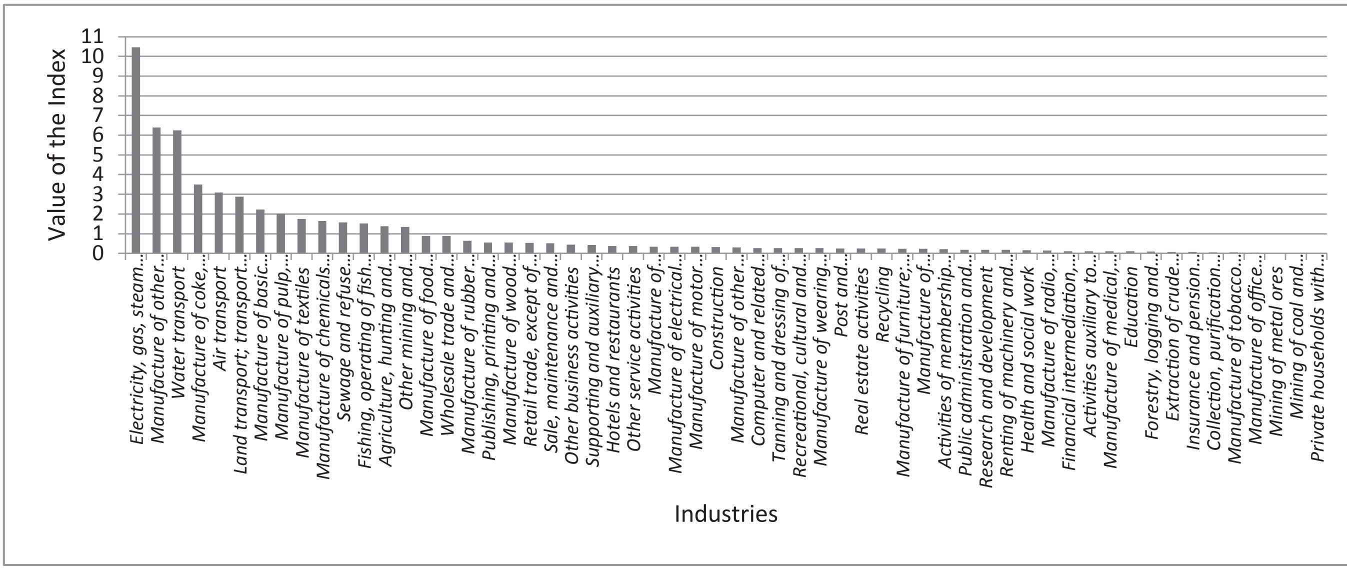

Fig. 3. MM Target Efficiency Index of industries accountable for emission (year 2005).
Source: own elaboration.

meet their final demand. The above findings can support the decision makers to explore effective mitigations on CO_2 emission from the key industries of Italy.

4. Target efficiency and control effectiveness indices with the MM approach

Through the Macro Multiplier approach we decompose the total environmental pollution impact coefficient matrix, **M**, and we calculate two different indices. The results account for the role played by each industries inside each endogenous policy structure, both for the control and the target variable (Ciaschini et al., 2010a,b,c). As for the linkages analysis, this second exercise shows the rank of Italian industries according the level of the two indices, the target efficiency and the control effectiveness indices, but in the MM approach, the pollutant power of industries is investigated inside each policy structure. Since the environmental policy problem infrequently refers only with environmental issue but on the contrary, it gets influence into the economic policy as a whole, results from MM approach may represent a set of crucial information in order to test and build national economic policies in accordance with the emissions target.

Results on MM approach are showed in Table A4 in Appendix A, where industries are ordered considering the couple of indices with reference to the policy control effectiveness and the policy target efficiency of each industry. Results of target efficiency index and policy effectiveness index are presented respectively in Figs. 3 and 4.

For six of the industries the two indices are each greater than one: they are responsible for the 54% of the total emission in 2005 according the data on NAMEA (ISTAT, 2010). Together with this aspect, we can determine the associate key structure in which the industries represent the powerful engine responsible for the emissions related to each key policy.[11] Industries with this characteristics are: (10) *manufacturing of textile*, (14) *Manufacture of pulp, paper and paper products*, (17) *Manufacture of chemicals and chemical products*, (20) *Manufacture of basic metals*, (31) *Electricity, gas, steam and hot water supply* and (38) *Land transport; transport via pipelines*.

Concentrating on the Target Efficiency index, among the relevant industries the most relevant industry is (31) *Electricity, gas, steam and hot water supply* attesting the role both in emissions and in activity. The target efficiency index, in Fig. 3, for this industry is high since this industry is crucial in supporting all other industries with intermediate inputs. The target efficiency index as resulting shows 14 industries out of 58 with an index value greater than 1 and they are the most influential industries responsible for the most CO_2 emissions. They are also highly responsive to changes in the composition of the final demand vector. It has been noticed that the industry (19) in which *manufactures other non-metallic mineral products* get an important role in the emission of CO_2 and place this industry at the second position 2. The third most important industry after (31) *electricity, gas, steam, and hot water supply* and (19) *manufacture of other non-metallic mineral products* is the industry (39) *water transport*, which has a third highest rank. The supply emission of water transport industry is 2.75% while its demand emission is 2.36% in 2005. The other most important industries from the target efficiency side are (16) *manufacture of coke, refined petroleum products, nuclear fuels* and (40) *air transport*, which get a highest rank of 4 and 5 in the whole economy.

From Fig. 4 we can see that industry (35) *whole sale trade and commission trade* plays a relevant role within the policy control. An interesting information from the *wholesale trade and commission trade* industry is that, from a pollution standpoint an apparently innocuous industry of activity turns out to be the most influential emission industry for its role strictly connected the all commodities, which are marketed. The second most important industry after *wholesale trade and commission trade* in which the productive industries accountable for CO_2 emissions is (50) *other business activities*. The third most influential is the industry (38) *Land transport; transport via pipelines*.[12]

[11] This result can be seen in Table A4: the column of “Key policy target” and the column of “key policy control”.

[12] The other commodities composing the dominating control structure are number 8, 10, 11, 13, 14, 15, 17, 18, 20, 21, 22, 24, 25, 28, 29, 31, 33, 34, 36, 37, 42, 45, 46,47, 48, 49 and 55.

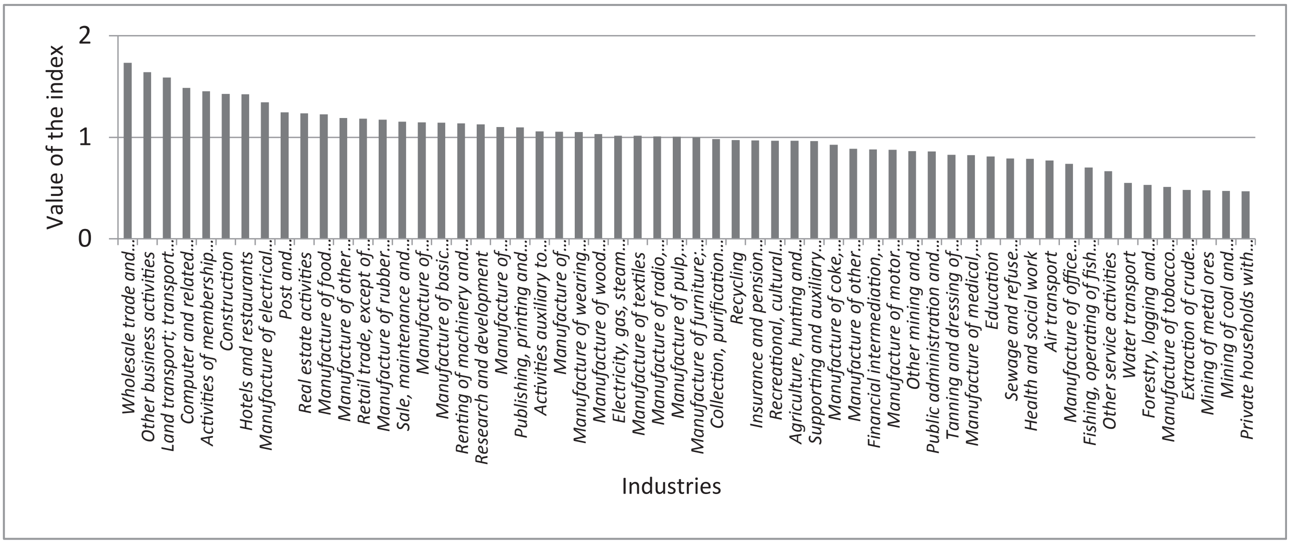

Fig. 4. Policy Effectiveness index of industries responsible for emission (year 2005).
Source: own elaboration.

5. Conclusion

Input Output analysis for environmental policy is significantly focused on the problem of policy design and methodological instruments for giving support to policy maker in determining the economic engine responsible for the rise of GHGs emissions. In this paper, we propose an innovative approach in order to analyses the behaviour of industries in affecting CO_2 emissions. Even though it offers only the partial view of the economic production system, the analysis proposed in this study allows overcoming the traditional limits of the linkages analysis usually used for the environmental policy issues. As stressed in the paper, linkages analysis is strongly linked with the unrealistic structure of policy shock needed to find both the backward and forward linkages (Ciaschini and Socci, 2006). With the MM approach, policy design can count on a set of information including not only the behaviour of industries but also their relevance into the set of key policies that are endogenous and determined by the structure of the economy. In other words, the identification of those activities that more directly contribute to the environmental gap is a crucial topic for economic policies that might include the industrial and environmental aspects. We conduct two different exercises through the EPIOM model in order to demonstrate the different implications between the linkages analysis and the MM approach. In both cases, we demonstrate that the reduction of CO_2 emissions by a specific producing system can be obtained through oriented policies only when the set of activities that contribute directly or indirectly to this effect has been clearly identified. In the first exercise the analysis performed suggests that within the whole production system a set of activities can be identified as relevant in both perspectives, demand and supply side. However, in the second exercise, using the MM approach we stressed the possibility to achieve a reduction of CO_2 emission using a specific structure of policy control (i.e. the final demand) or achieving a specific structure of policy target (i.e. the industrial production) taking into consideration all industries in the economy. According to the linkages analysis, we conclude that among the 58 industries taken into consideration, an exclusive group of 10 can be considered key industries accountable for relevant emission of CO_2. This result holds in two cases: i) when the steadiness of technical coefficients is assumed in an inter industry framework that, for this feature, focuses on the supply side, ii) when results are obtained from a model of inter industry interactions based on the constancy of the market shares, privileging the steadiness of the demand side. However, the knowledge of the role of the industries could not be useful enough for modelling and evaluating policy controls oriented to the reduction of CO_2 emissions in Italy. For this consideration, the Macro Multipliers, with the target efficiency and the control effectiveness, can be used in order to better understand the relevance of the key industries responsible for CO_2 emissions into the set of the endogenous key policy. Modelling a punctual policy control, as for example subsidies or taxes on specific activities need to take into consideration all components of policy variable, which are determined because of the existing technological links. Thus, the identification of an environmental target need to be related with a compatible economic target. The results of the analysis in terms of the two proposed indices show that for the target efficiency 14 industry-output out of 58 are highly responsive to changes in the composition of the final demand vector. More sensitive industries are (31) Electricity, gas, steam and hot water supply, (19) Manufacture of other non-metallic mineral products and (39) water transport with index value higher than 6. The connotation of the proposed approach stands, then, on the determination of the changes in the economic transactions that lead to the greatest changes in emissions levels and identifies those production linkages through which these emissions spread within the economic system.

Appendix A

Table A1
Industries classification (NACE-REV.2).

nr	Industries
1	Agriculture, hunting and related service activities
2	Forestry, logging and related service activities
3	Fishing
4	Mining of coal and lignite; extraction of peat
5	Extraction of crude petroleum and natural gas
6	Mining of metal ores
7	Other mining and quarrying

(*continued on next page*)

Table A1 (*continued*)

nr	Industries
8	Manufacture of food products and beverages
9	Manufacture of tobacco products
10	Manufacture of textiles
11	Manufacture of wearing apparel;
12	Tanning and dressing of leather and footwear
13	Manufacture of wood and of products of wood and cork
14	Manufacture of pulp, paper and paper products
15	Publishing, printing and reproduction of recorded media
16	Manufacture of coke, refined petroleum products
17	Manufacture of chemicals and chemical products
18	Manufacture of rubber and plastic products
19	Manufacture of other non-metallic mineral products
20	Manufacture of basic metals
21	Manufacture of fabricated metal products,
22	Manufacture of machinery and equipment
23	Manufacture of office machinery and computers
24	Manufacture of electrical machinery and apparatus
25	Manufacture of radio, television and communication
26	Manufacture of medical, precision and optical instruments
27	Manufacture of motor vehicles, trailers and semi-trailers
28	Manufacture of other transport equipment
29	Manufacture of furniture; manufacturing
30	Recycling
31	Electricity, gas, steam and hot water supply
32	Collection, purification and distribution of water
33	Construction
34	Sale, maintenance and repair of motor vehicles and motorcycles
35	Wholesale trade
36	Retail trade,
37	Hotels and restaurants
38	Land transport; transport via pipelines
39	Water transport
40	Air transport
41	Supporting and auxiliary transport activities
42	Post and telecommunications
43	Financial intermediation,
44	Insurance and pension funding,
45	Activities auxiliary to financial intermediate.
46	Real estate activities
47	Renting of machinery and equipment
48	Computer and related activities
49	Research and development
50	Other business activities
51	Public administration and defence;
52	Education
53	Health and social work
54	Sewage and refuse disposal, sanitation and similar activities
55	Activities of membership organisation n.e.c.
56	Recreational, cultural and sporting activities
57	Other service activities
58	Private households with employed persons
	TOTAL

Table A2
The Emission coefficient for CO_2 emissions of each Italian industries.

nr	Industries	Total Emission of CO_2 (tons)	Emission Coeff. (q) (CO_2/Meuro)
1	Agriculture, hunting and related service activities	7689664	144.58
2	Forestry, logging and related service activities	19384	19.05
3	Fishing	770859	252.00
4	Mining of coal and lignite; extraction of peat	300	0.17
5	Extraction of crude petroleum and natural gas	377573	8.86
6	Mining of metal ores	6306	5.44
7	Other mining and quarrying	1168160	163.60
8	Manufacture of food products and beverages	9662979	78.42
9	Manufacture of tobacco products	34858	10.50
10	Manufacture of textiles	7883900	181.99
11	Manufacture of wearing apparel;	949683	24.48
12	Tanning and dressing of leather and footwear	920057	27.28
13	Manufacture of wood and of products of wood and cork	1103103	50.55
14	Manufacture of pulp, paper and paper products	5358607	224.29
15	Publishing, printing and reproduction of recorded media	1473261	53.77
16	Manufacture of coke, refined petroleum products	24723265	491.08
17	Manufacture of chemicals and chemical products	16095305	145.17
18	Manufacture of rubber and plastic products	2581944	58.59
19	Manufacture of other non-metallic mineral products	48910563	1053.52
20	Manufacture of basic metals	20410481	295.17
21	Manufacture of fabricated metal products,	1543163	15.39
22	Manufacture of machinery and equipment	3892558	29.80
23	Manufacture of office machinery and computers	43835	4.75
24	Manufacture of electrical machinery and apparatus	1147458	25.40
25	Manufacture of radio, television and communication	425893	15.12
26	Manufacture of medical, precision and optical instruments	324117	13.53
27	Manufacture of motor vehicles, trailers and semi-trailers	2670541	35.74
28	Manufacture of other transport equipment	589446	23.45
29	Manufacture of furniture; manufacturing	1119205	25.03
30	Recycling	93723	28.44
31	Electricity, gas, steam and hot water supply	137003180	2044.86
32	Collection, purification and distribution of water	42874	6.40
33	Construction	3846150	20.69
34	Sale, maintenance and repair of motor vehicles and motorcycles	3214646	48.05
35	Wholesale trade	8572563	48.05
36	Retail trade,	6412948	48.05
37	Hotels and restaurants	2822587	27.41
38	Land transport; transport via pipelines	25071076	239.28
39	Water transport	10712084	1345.85
40	Air transport	7374449	501.82
41	Supporting and auxiliary transport activities	1935982	33.72
42	Post and telecommunications	1064416	18.41
43	Financial intermediation,	634515	8.78
44	Insurance and pension funding,	189661	8.78
45	Activities auxiliary to financial intermediate.	188756	8.78
46	Real estate activities	3039995	16.15
47	Renting of machinery and equipment	160158	16.15
48	Computer and related activities	767655	16.15
49	Research and development	195747	16.15
50	Other business activities	2769536	16.15
51	Public administration and defence;	2897771	24.66
52	Education	1023703	13.92
53	Health and social work	2472761	21.87
54	Sewage and refuse disposal, sanitation and similar activities	3514544	203.76
55	Activities of membership organisation n.e.c.	102333	17.55
56	Recreational, cultural and sporting activities	854194	23.71
57	Other service activities	1086681	63.28
58	Private households with employed persons	0	0.00
	TOTAL	389961155	

Source: our own elaboration from NAMEA.

Table A3
Linkages analysis for the Italian industries according the Backward and Forward Linkages (year 2005)

nr	Industries	Backward Linkages	Rank according Backward Linkages	Forward Linkages	Rank according Forward Linkages	Group
31	Electricity, gas, steam and hot water supply	8.41	1	7.81	1	K
39	Water transport	5.22	3	4.66	3	K
19	Manufacture of other non-metallic mineral products	5.24	2	4.06	5	K
7	Other mining and quarrying	1.57	8	2.58	6	K
16	Manufacture of coMe, refined petroleum products	2.04	5	2.28	7	K
40	Air transport	2.18	4	1.84	8	K
20	Manufacture of basic metals	1.86	6	1.41	10	K
14	Manufacture of pulp, paper and paper products	1.82	7	1.29	11	K
54	Sewage and refuse disposal, sanitation and similar activities	1.28	12	1.25	13	K
38	Land transport; transport via pipelines	1.31	11	1.24	14	K
4	Mining of coal and lignite; extraction of peat	0.01	57	5.18	2	F
5	Extraction of crude petroleum and natural gas	0.05	55	4.07	4	F
6	Mining of metal ores	0.04	56	1.51	9	F
30	Recycling	0.79	20	1.27	12	F
3	Fishing	1.24	13	0.96	15	B
17	Manufacture of chemicals and chemical products	1.19	14	0.93	16	B
10	Manufacture of textiles	1.55	9	0.86	17	B
18	Manufacture of rubber and plastic products	1.01	16	0.60	22	B
32	Collection, purification and distribution of water	1.40	10	0.56	23	B
8	Manufacture of food products and beverages	1.09	15	0.45	32	B
41	Supporting and auxiliary transport activities	0.62	31	0.83	18	A
1	Agriculture, hunting and related service activities	0.96	18	0.82	19	A
2	Forestry, logging and related service activities	0.14	54	0.66	20	A
47	Renting of machinery and equipment	0.55	36	0.66	21	A
35	Wholesale trade	0.58	34	0.55	24	A
15	Publishing, printing and reproduction of recorded media	0.86	19	0.54	25	A
50	Other business activities	0.37	40	0.53	26	A
42	Post and telecommunications	0.44	37	0.50	27	A
48	Computer and related activities	0.35	44	0.49	28	A
13	Manufacture of wood and of products of wood and corM	0.77	21	0.49	29	A
28	Manufacture of other transport equipment	0.61	32	0.48	30	A
43	Financial intermediation,	0.18	50	0.48	31	A
21	Manufacture of fabricated metal products,	0.76	22	0.41	33	A
49	Research and development	0.33	46	0.40	34	A
55	Activities of membership organisation n.e.c.	0.34	45	0.40	35	A
34	Sale, maintenance and repair of motor vehicles and motorcycles	0.64	30	0.40	36	A
24	Manufacture of electrical machinery and apparatus	0.75	24	0.39	37	A
45	Activities auxiliary to financial intermediate.	0.25	48	0.36	38	A
56	Recreational, cultural and sporting activities	0.42	38	0.32	39	A
23	Manufacture of office machinery and computers	0.30	47	0.30	40	A
36	Retail trade,	0.72	25	0.30	41	A
22	Manufacture of machinery and equipment n.e.c.	0.71	26	0.29	42	A
27	Manufacture of motor vehicles, trailers and semi-trailers	0.57	35	0.26	43	A
29	Manufacture of furniture; manufacturing n.e.c.	0.76	23	0.24	44	A
37	Hotels and restaurants	0.69	27	0.23	45	A
12	Tanning and dressing of leather and footwear	0.61	33	0.22	46	A
57	Other service activities	0.64	29	0.21	47	A
44	Insurance and pension funding,	0.19	49	0.20	48	A
46	Real estate activities	0.16	51	0.20	49	A
33	Construction	0.97	17	0.20	50	A
25	Manufacture of radio, television and communication	0.36	41	0.20	51	A
26	Manufacture of medical, precision and optical instruments	0.41	39	0.20	52	A
11	Manufacture of wearing apparel;	0.66	28	0.16	53	A
52	Education	0.14	53	0.08	54	A
51	Public administration and defence;	0.36	42	0.08	55	A
53	Health and social works	0.35	43	0.08	56	A
9	Manufacture of tobacco products	0.15	52	0.04	57	A
58	Private households with employed persons	0.00	58	0.00	58	A

Source: own elaboration.

Table A4
MM Target Efficiency and Control Effectiveness for CO_2 emissions (year 2005).

nr	Industries	Control Effectiveness	Key control policy	Target Efficiency	Key target policy
10	Manufacture of textiles	1.01	27	1.75	9
14	Manufacture of pulp, paper and paper products	1.01	29	2.02	8
17	Manufacture of chemicals and chemical products	1.15	16	1.64	10
20	Manufacture of basic metals	1.14	17	2.22	7
31	Electricity, gas, steam and hot water supply	1.01	26	10.47	1
38	Land transport; transport via pipelines	1.59	3	2.88	6
1	Agriculture, hunting and related service activities	0.96	35	1.38	13
3	Fishing	0.70	50	1.52	12
7	Other mining and quarrying	0.86	41	1.35	14
16	Manufacture coke, refined petroleum products and nuclear fuels	0.93	37	3.50	4
19	Manufacture of other non-metallic mineral products	0.89	38	6.40	2
39	Water transport	0.55	52	6.24	3
40	Air transport	0.77	48	3.08	5
54	Sewage and refuse disposal, sanitation and similar activities	0.79	46	1.57	11
8	Manufacture of food products and beverages	1.22	11	0.89	15
11	Manufacture of wearing apparel; dressing and dyeing of fur	1.05	24	0.26	34
13	Manufacture of wood and of products of wood and corM	1.03	25	0.55	19
15	Publishing, printing and reproduction of recorded media	1.10	21	0.56	18
18	Manufacture of rubber and plastic products	1.17	14	0.64	17
21	Manufacture of fabricated metal products, except machinery	1.06	23	0.24	39
22	Manufacture of machinery and equipment n.e.c.	1.10	20	0.34	26
24	Manufacture of electrical machinery and apparatus n.e.c.	1.35	8	0.33	27
25	Manufacture of radio, television and communication equipment	1.01	28	0.15	45
28	Manufacture of other transport equipment	1.19	12	0.31	30
29	Manufacture of furniture; manufacturing n.e.c.	1.00	30	0.24	38
33	Construction	1.43	6	0.33	29
34	Sale, maintenance and repair of motor vehicles and motorcycles	1.15	15	0.52	21
35	Wholesale trade and commission trade	1.73	1	0.88	16
36	Retail trade, except of motor vehicles and motorcycle	1.18	13	0.53	20
37	Hotels and restaurants	1.42	7	0.37	24
42	Post and telecommunications	1.25	9	0.25	35
45	Activities auxiliary to financial intermediation	1.06	22	0.11	47
46	Real estate activities	1.24	10	0.25	36
47	Renting of machinery and equipment without operator	1.14	18	0.17	43
48	Computer and related activities	1.49	4	0.27	31
49	Research and development	1.13	19	0.17	42
50	Other business activities	1.64	2	0.44	22
55	Activities of membership organisation	1.45	5	0.22	40
2	Forestry, logging and related service activities	0.53	53	0.09	50
4	Mining of coal and lignite; extraction of peat	0.47	57	0.00	57
5	Extraction of crude petroleum and natural gas	0.48	55	0.08	51
6	Mining of metal ores	0.48	56	0.02	56
9	Manufacture of tobacco products	0.51	54	0.05	54
12	Tanning and dressing of leather	0.83	43	0.26	32
23	Manufacture of office machinery and computers	0.74	49	0.03	55
26	Manufacture of medical, precision and optical instruments, watches	0.82	44	0.11	48
27	Manufacture of motor vehicles, trailers and semi-trailers	0.88	40	0.33	28
30	Recycling	0.97	32	0.25	37
32	Collection, purification and distribution of water	0.98	31	0.05	53
41	Supporting and auxiliary transport activities; activities of travel agencies	0.96	36	0.42	23
43	Financial intermediation, except insurance and pension funding	0.88	39	0.12	46
44	Insurance and pension funding, except compulsory social security	0.97	33	0.08	52
51	Public administration and defence; compulsory social security	0.86	42	0.18	41
52	Education	0.81	45	0.11	49
53	Health and social works	0.79	47	0.16	44
56	Recreational, cultural and sporting activities	0.96	34	0.26	33
57	Other service activities	0.67	51	0.37	25
58	Private households with employed persons	0.47	58	0.00	58

Source: own elaboration.

Appendix B. Figures

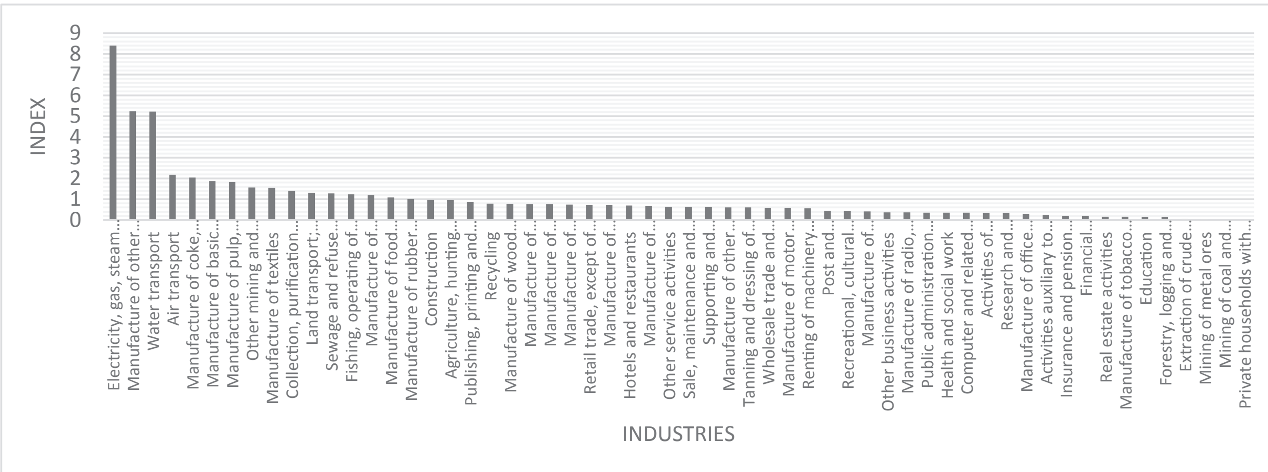

Fig. B1. Backward CO_2 linkages (year 2005).
Source: own elaboration.

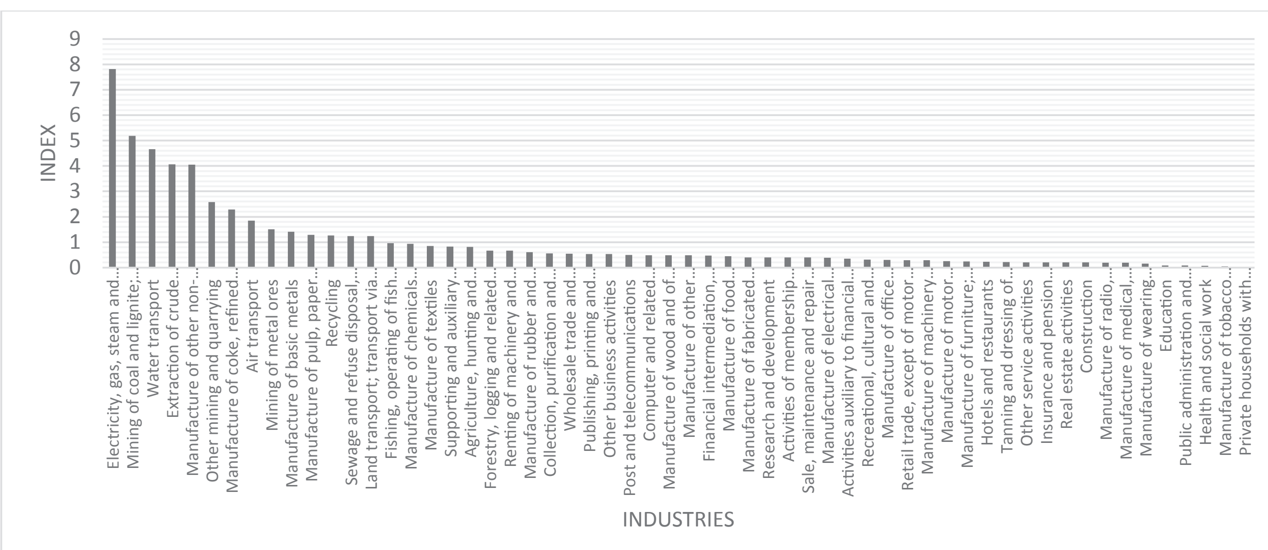

Fig. B2. Forward CO2 linkages (year 2005).
Source: own elaboration

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