Università degli Studi di Macerata

Dipartimento di Studi sullo Sviluppo Economico

Working paper n. 26

May/2010

The economic impact of the Green Certificate market through the Macro Multiplier approach

Maurizio Ciaschini, Rosita Pretaroli, Francesca Severini, Claudio Socci
University of Macerata, Politechnical University of Marche

ISSN: 1971-890X

The economic impact of the Green Certificate market through the Macro Multiplier approach

Maurizio Ciaschini, Rosita Pretaroli, Francesca Severini, Claudio Socci[1]
University of Macerata, Politechnical University of Marche

Abstract

In the last decade, as many other European countries, the Italian Government adopted several reforms in order to increase the use of Renewable Energy Sources (RES). The liberalization of the electricity market that represent one of these reforms aims to reach environmental benefits from the substitution of fossil fuel with renewable sources.The Italian Green Certificate market was introduced in 2002 in order to accomplish this objective and represents a mechanism where a quota of renewable electricity is imposed to suppliers in proportion to their sales. The electricity industries are obliged to meet this condition by producing the quantity of renewable electricity by means of a change in their production process, otherwise they must buy a number of certificates corresponding to the quota. This mechanism changes the importance of the electricity industry first in promoting climate protection, than in terms of the impact in the economy as a whole. A policy aimed to develop the market of green certificates may lead to environmental improvement by switching the energy production process to renewable resources. But above all an increase in demand for green certificates, resultant from a reform on the quota of renewable electricity, can generate positive change in all components of the industrial production. For this purpose, the paper aims to quantify the economic impact of a reform on Green Certificate market for the Italian system by means of the Macro Multiplier (MM) approach. The analysis is performed through the Hybrid Input-Output (I-O) model that allows expressing the energy flows in physical terms (GWh) while all other flows are expressed in monetary terms (€). Moreover, through the singular value decomposition of the inverse matrix of the model, which reveals the set of key structures of the exogenous change of final demand, we identify the appropriate key structure able to obtain both the expected positive total output change and the increase of electricity production from RES.

JEL classification: C67, E23, Q43, Q48.
Keywords: Environmental Policy, Hybrid I-O model, Macro Multiplier

Corresponding author: Claudio Socci (socci_claudio@unimc.it).

Department Informations:
Piazza Oberdan 3, 62100 Macerata - Italy Phone: +39 0733 258 3960 Fax: +39 0733 258 3970 e-mail: csampaoli@unimc.it

[1]University of Macerata, Dipartimento di Scienze del la Comunicazione, Via Armaroli 9, 62100 Macerata-Italy; Phone +39 0733 258 2560, Fax +39 0733 258 2553.

1 Introduction

The Italian Green Certificates scheme (GC) represents one of the four Italian basic mechanisms that took place in 2002 after the liberalization of electricity market, which was introduced by the energy market reform (legislative decree 79/99)[2]. According to the Italian GC system, all suppliers or distributors of electricity - that that lay on the network more than 100 GWh year - are compelled to produce a quota of renewable electricity in proportion to their extra sales: the quota is represented by the 2% of the excess in total production of electricity[3]. In better words, producers are obliged to produce or purchase a quota of renewable electricity in proportion to their extra sales when they exceed the annual quota[4]. The production of green electricity is certificated by the Italian Authority for the Energy Services (ESM) that emits the certificates, which represent the green quality of each unit of renewable electricity generation [5].

A green certificates market can be organized following two different schemes depending on the identity of the agent that purchases the certificate property right. It might correspond to the energy producer and/or distributor rather than the final consumer[6]. In both cases, since every unit of renewable elec-

[2]The other mechanisms introduced after the liberalization of the market are respectively: energy account both for solar photovoltaic and thermodynamic; grants form EU, National and Regional Governs; voluntary certification of quality.

[3]The quota has been incremented: +0.35% from 2004 to 2006 and +0.75% from 2007 to 2012.

[4]Many other reforms modified the Italian GC system during the last decade: financial law 2008, D.M. 18/12/2008 and law 99/09.

[5]At present, the market of GC and its development represents a crucial tool in the recent European energy policy, which fixed an an ambitious goal: the increase of 20% in the energy production by renewable sources for the year 2020.

[6]This mechanism supposes that energy consumers (households and firms) are responsible for environmental damage and gives the possibility to consider the generation of electricity from renewable sources. This setting is adopted in Denmark but it is also characterised by lofty transaction costs that make it unpopular within consumers judgment. According to the first scheme energy producers and/or distributers receive green certificates equivalent to the amount of renewable electricity produced. The policy maker imposes a quota of renewable electricity to suppliers in proportion to their sales. The operators that are subjected to the quotas have two possibilities to respect their quota: producing themselves the quantity of renewable electricity buying new technologies or, in alternative, buying each year the certificates corresponding to the quotas. The choice between this two arrangements depends on the opportunities to get a revenue from the certificate trading.

tricity generation is represented by the physical part and its associated green value, alongside the traditional physical electricity market, a new market is established. A market where green certificates can be accumulated and then sold, for example, when the value is increased as a result of market demand[7].

The GC scheme aims to create a market where electricity from renewable sources can be sold with high margins of profit so that traditional electricity producing industries are stimulated to change their processes towards ways of production characterized by less costs of production and lower emissions of CO_2[8]. As an incentive for renewable energy sources usage in electricity production processes, the GC scheme refers to the general issue concerning policy instruments for markets that are affected by externalities. As known, in presence of negative externalities, such as costs of pollution, the Government can restore economic efficiency using command-and-control regulations, or in alternative, market-based polices (Parry 2002). These approaches include taxes on Greenhouse Gas emissions by firms and subsidy programs that are known as policy instruments for dealing with externalities (Baumol and Oates 1988). In alternative to taxes and subsidies, which usually are discouraged because of their potential consequences on different income distribution between Household groups, there exist many other market-based instruments such as GC system that avoid the direct Government involvement (Goulder et al. 1999). Most European countries adopted a set of economic instruments based on price regulation mechanisms (feed-in tariffs)[9] or quantity regulation mechanisms (tradable energy quotas or "green certificate")[10] to encourage the production of RES electricity. Nevertheless neither the economic theory nor the practical experience in the appliance of green certificates or feed-in tariffs can suggest a clear advantage of one instrument over the other even though both two are distinct in terms of cost-efficacy[11].

[7] In this respect the GC mechanism facilitates trade of green electricity since the obligation may be fulfilled by buying GC either together with physical electricity or separately.

[8] It is commonly known that the potential of renewable to supply energy is very high. No resource constraints exist for solar, wind, geothermal and wave, but the expansion of the hydro energy production is limited and there is no consensus as regards the limits for sustainable bio energy (Stoutenborough and Beverlin 2008; Haug 2007).

[9] Used in Germany, Spain, France and Portugal.

[10] United Kingdom, Italy, Belgium, Sweden, Netherlands and Denmark.

[11] Exchangeable quotas of green certificates were introduced in Netherlands, United Kingdom, Belgium, Italy, Denmark and Sweden only in 2001 for the electricity market. For an extended analysis focused on institutional setting for green certificate in these countries see Schaeffer et al. (2000), Van Dijk (2003), Jensen and Skytte (2002). Recently

Under this aspect, the element that becomes more prominent is represented by the very closely interaction between policy on RES with climate change policy. It has to be stressed that the mechanisms of GC do not directly determine an environmental benefit in terms of reducing CO_2 emissions. However, the promotion of RES can be justified by the environmental improvement obtained each time the production process of energy will replace fossil fuels with renewable sources. Moreover the exigency to promote renewable energy sources in electricity generation allows considering the development of the market for GC as an opportunity to achieve economic objectives like as the positive change in total output. From that point of view, the policies designed to encourage RES usage through the green certificates system, might have major economic relevance in terms of positive impact on industrial production because of the existence of multisectoral interdependency between all components of total output. Since the level of demand for green certificates is imposed by Government through the obligation target, a policy establishing a higher target may lead both to a positive change in industrial output and a better balance between renewable and non-renewable energy.

In this respect, the paper aims to quantify the economic impact of the GC market and the change in the renewable and non-renewable energy balance. The object is to verify the effects of policies designed to promote energy from RES by means of the Hybrid multisectoral approach, which evaluates both the interdependence between all production processes and the relevance of each commodity in the whole system. The Hybrid Input-Output (I-O) model is the suitable toll in order to analyze the energy commodity that is characterized by non unitary pricings, which are ruled by regulation in primary and finally markets. This feature is inconsistent with traditional Input-Output approach which assumes unitary pricing across all commodities (Dietzenbacher and Stage 2006)[12]. In this case, since the flows of energy commodity would be assessed in monetary terms the presence of administered pricings would lead to ambiguous results (Lahr 1993). Furthermore, the hybrid I-O is

the European Commission has strongly encouraged the adoption of these instruments in an harmonised way with the aim of limiting the cost of European policy by allowing the development of the renewable energy sources (EC 2004).

[12]The hybrid Input-Output model is commonly applied to analyse the impact of environmental and energy policies because it usually avoids the limits of a monetary approach (Miller and Balir 2009).

particularly useful in order to evaluate effects of policies designed for the GC market where the governmental quota is expressed in physical terms (GWh).

This approach allows expressing the flows in physical and monetary terms where the rows include flows measured in energy units (GWh) corresponding to energy deliveries. Thus by means of the hybrid I-O model it is possible to find the Leontief inverse, which can be used to compare the results between the innovative approach of the Macro Multipliers (MM) and the traditional analysis of multipliers (Ciaschini and Socci 2007). Through the MM approach that is based on the decomposition of the inverse matrix of the model, the key structure of the exogenous variable (final demand change) can be identified in order to obtain the expected total output change or the expected renewable and non-renewable energy balance (Ciaschini and Socci 2006). In fact, since the results of the traditional multipliers analysis are affected by the unrealistic structure of the exogenous shock (Ciaschini et al. 2009), the Macro Multipliers analysis overcomes this limit by the singular value decomposition (SVD) of the Leontief inverse. In fact, the MM approach allows for the identification and quantitative determination of the aggregated Macro Multipliers (MM), which lead the economic interactions, and the key structures of macroeconomic variables that either hide or activate these forces.

For this purpose, the second section illustrates the hybrid I-O model based on the Input-Output table for Italian economy for the 2005 (EUROSTAT 2008, 2009) which is integrated with the data on the RES demand in physical terms (GWh) (ISTAT 2007). The third section describes the innovative MM approach based on the Singular Value Decomposition of the inverse matrix of the Hybrid I-O model. In the fourth section the results of the policies are showed. In particular we will implement the empirical simulation focusing on three different scenarios. The first is based on an exogenous shock on final demand that has the same structure of the observed demand vector in the I-O table. The second scenario reproduces an exogenous shock on final demand according to the dominating key structure suggested by the MM approach. This type of policy, that is oriented to achieve the maximum output change, might allow reaching a better result in terms of a better balance between energy production through fossil fuel and renewable electricity. The third one aims to quantify the impact on both the balance between renewable and non-renewable energy and output change when the exogenous shock is modelled according to a policy control structure oriented to reach the maximum change of RES production.

2 Hybrid Input-Output model

As well as the traditional I-O approach, the Hybrid I-O model allows to evaluate the effects of a final demand change on the economy as a whole given the structural interrelations among industries (Polenske 1976). But the hybrid approach also allows evaluating the effects of a policy of reform modelled in physical and monetary terms (Miller and Blair 2009).

The Hybrid I-O model represents n commodities: the index m identifies nonenergy commodities whose flows are expressed in monetary term, and k identifies the energy commodity, whose flows are expressed in physical terms. Thus, the total requirement of the energy good by each commodity, which can be called "energy intensity", is expressed in physical terms (GWh) and can be easily determined by solving the Hybrid I-O model.

The fundamental equation of the model is given by:

$$\mathbf{x}^* = \mathbf{A}^* \cdot \mathbf{x}^* + \mathbf{f}^* \tag{1}$$

The vector $\mathbf{x}^*$ is the output vector and its elements are all expressed in monetary terms (€) with the exception of energy commodity, which is expressed in physical terms (GWh). The same detail is adopted for the elements of the the vector $\mathbf{f}^*$ that is the vector of the hybrid final demand. Moreover, $\mathbf{A}^*$ is the matrix of the hybrid technical coefficients that can be defined as:

$$\mathbf{A}^* = \mathbf{B}^* \cdot (\widehat{\mathbf{x}}^*)^{-1} \tag{2}$$

where matrix $\mathbf{B}^*$ is the hybrid matrix of I-O intermediate flows.

Matrix $\mathbf{B}$ is of dimension nxn and can be defined as the following:

$$\mathbf{B}^* = \begin{cases} \mathbf{b_{ij}} & \text{where } i \text{ is non energy commodity} \\ \mathbf{b_{kj}} & \text{where } k \text{ is energy commodity} \end{cases}$$

Vector $\mathbf{f}^*$ is of dimension nx1:

$$\mathbf{f}^* = \begin{cases} \mathbf{f_i} & \text{where } i \text{ is non energy commodity} \\ \mathbf{f_k} & \text{where } k \text{ is energy commodity} \end{cases}$$

Vector $\mathbf{f}^*$ is of dimension nx1:

$$\mathbf{x}^* = \begin{cases} \mathbf{x_i} & \text{where } i \text{ is non energy commodity} \\ \mathbf{x_k} & \text{where } k \text{ is energy commodity} \end{cases}$$

The matrices blocks whose elements are expressed according the same measurement unit can be represented as follow:

$$\mathbf{B}^* = \begin{bmatrix} € & € \\ GWh & GWh \end{bmatrix}, \quad \mathbf{f}^* = \begin{bmatrix} € \\ GWh \end{bmatrix}, \quad \mathbf{x}^* = \begin{bmatrix} € \\ GWh \end{bmatrix}$$

In this respect, according equation 2, matrix $\mathbf{A}^*$ is represented as:

$$\mathbf{A}^* = \begin{bmatrix} €/€ & €/GWh \\ GWh/€ & GWh/GWh \end{bmatrix} \quad (3)$$

Therefore, the solution of the hybrid model is expressed by the equation:

$$\Delta\mathbf{x}^* = [\mathbf{I} - \mathbf{A}^*]^{-1} \cdot \Delta\mathbf{f}^* \quad (4)$$

that describes the relation between the change on policy control (final demand change, $\Delta\mathbf{f}^*$) and the resulting change in the objective variable (total output change, $\Delta\mathbf{x}^*$).

The inverse matrix can be defined as:

$$\mathbf{R}^* = [\mathbf{I} - \mathbf{A}^*]^{-1} \quad (5)$$

and represents the Leontief inverse of the hybrid model, which quantifies the direct and indirect effects of final demand on total output.

3 Macro Multiplier approach

The traditional analysis that is based on matrix $\mathbf{R}^*$ allows to reach knowledge about the economic connection between the variables represented in the model (Round 2003). However, the predetermined structure of the exogenous shock, which must be adopted when the traditional multipliers analysis is performed, represents an important shortcoming that has led a major part of the literature to advise against this approach (Skolka 1986).

Avoiding the main criticisms associated to traditional analysis in this paper we use the Macro Multiplier (MM) in order to identifying the most convenient structure of the policy control (final demand for renewable energy) by which the shock on the economy is modelled. The innovative MM approach that is based on the Singular Value Decomposition of the Leontief inverse, can identify the most efficient structure (or a desired structure) of the control variable that generates the highest effect (or the desired one) in the policy variable (Ciaschini et al. 2009). All the measures built starting from matrix R are not independent from the structure of neither the exogenous shock vector nor of the vector on which we observe the effects. In this respect, the possibility to consider the scale effect in conjunction with the composition effect became crucial when we design the policy variable (Ciaschini 1988.

Matrix $\mathbf{R}^*$ can be decomposed through the Singular Value Decomposition (Lancaster and Tiesmenetsky 1985) and rewritten as the product of three different matrices:

$$\mathbf{R}^* = \mathbf{Z} \cdot \mathbf{M} \cdot \mathbf{P}^T \tag{6}$$

The matrix $\mathbf{Z} = [\mathbf{z}_1 \ldots \mathbf{z}_m]$ is a unitary matrix of dimension mxm whose columns 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 matrix $\mathbf{P} = [\mathbf{p}_1 \ldots \mathbf{p}_n]$ is a unitary matrix of dimension nxn whose rows represent the structures of the policies control. Such structures measure and establish the composition of all the possible policies control: they are called the key-structures of the policy-control. Finally, the matrix $\mathbf{M}$ is a diagonal matrix of dimension mxn with all elements equal to zero outside the diagonal. The elements along the diagonal represent aggregate multipliers, which are all real, positive and ordered according their magnitude as: $m_1 \geq m_2 \geq \ldots \geq m_p \geq 0$.

The structures identified play a fundamental role in determining the potential behaviour of the economic system: we can evaluate which will be the effect on total output of all possible final demand structures. In this respect, we note that matrix $\mathbf{R}$ hides the fundamental combinations of the policy variables (total output). Each of them is obtained multiplying the corresponding combination of final demand by a predetermined scalar, which has in fact the role of aggregated multiplier (Ciaschini et al. 2009, 2010).

The decomposition of the inverse matrix of the Hybrid I-O model can be compacted as:

$$\mathbf{R} = [\mathbf{Z}_1 \mathbf{Z}_2] \begin{bmatrix} M_1 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \mathbf{P}_1^T \\ \mathbf{P}_2^T \end{bmatrix} \tag{7}$$

that is

$$\mathbf{R} = \mathbf{Z}_1 \cdot \mathbf{M}_1 \cdot \mathbf{P}_1^T \tag{8}$$

where $\mathbf{M}_1$ is a rxr diagonal matrix where m are the non-zero Macro Multipliers. $\mathbf{Z}_1$ mxr represents the first r columns of matrix $\mathbf{Z}$ and is the orthonormal base in the objective space $\mathbf{Z}$ ($\mathbf{R}$). In the same way $\mathbf{P}_1$ (nxr) represents the first r columns of matrix $\mathbf{P}$ and corresponds to the orthonormal base in the policy control space $\vartheta(\mathbf{R})$.

From this considerations it is possible to emphasize some interesting features of the decomposition proposed. If $\mathbf{R}^T \cdot \mathbf{R} = (\mathbf{Z} \cdot \mathbf{M} \cdot \mathbf{P}^T)^T \cdot (\mathbf{Z} \cdot \mathbf{M} \cdot \mathbf{P}^T) = \mathbf{P} \cdot \mathbf{M}^2 \cdot \mathbf{P}^T$ Macro Multipliers are the square root of $\mathbf{R}^T \cdot \mathbf{R}$ eigenvalues, that is $m_i = \sqrt{\lambda_i(\mathbf{R}^T \cdot \mathbf{R})}$. Moreover the policy controls key-structures $\mathbf{p}_i$ are obtained as eigenvectors of $\mathbf{R}^T \cdot \mathbf{R}$.

Similarly, if we consider $\mathbf{R} \cdot \mathbf{R}^T = (\mathbf{Z} \cdot \mathbf{M} \cdot \mathbf{P}^T) \cdot (\mathbf{Z} \cdot \mathbf{M} \cdot \mathbf{P}^T)^T = \mathbf{Z} \cdot \mathbf{M}^2 \cdot \mathbf{Z}^T$ Macro Multipliers can also be calculated as square root of $\mathbf{R} \cdot \mathbf{R}^T$ eigenvalues, that is $m_i = \sqrt{\lambda_i(\mathbf{R} \cdot \mathbf{R}^T)}$. Moreover the vectors that represent the key structures of policy objective $\mathbf{z}_i$ correspond to the eigenvectors of $\mathbf{R} \cdot \mathbf{R}^T$.

It is worthwhile to mention that the key structures of policy objective are different from the key structures of policy control since the matrix $\mathbf{R}$ is not symmetrical.

$$\mathbf{R} \cdot \mathbf{p}_1 = m_1 \cdot \mathbf{z}_1 \tag{9}$$

$\mathbf{p}_1$ corresponds to the dominating key structure of policy control and $\mathbf{z}_1$ is the corresponding key structure of the policy objective[13].

Once implemented the set of key structures both for the policy variable and the policy objective, it is necessary to focus on some methodological aspects concerning the definition of a suitable measure that allows to evaluate changes on multidimensional variables as the final demand or the total output.

Given a vector that shows the value of the sectoral components of a macro variable, defining the structure of such macro variable, the delicate question of how to define its scale emerges. In other words it is fundamental to define which scalar should be associated to the disaggregate components of the macro variable in order to obtain consistent results in different levels of aggregation.

Our interest focus on multidimensional macro variables in order to operate on the multidimensional policy objectives using the multidimensional policy control. For this reason we need to consider the rotation effect with respect to the axis that all the policy vectors with constant absolute variation manifest. The matrixes through which we operate have the ability to compress and

[13]All methodological details about MM approach are defined in appendix B.

expand the vectors. The axis rotation alters vectors coordinates but the transformation is not uniform. It would be worth to take into account an aggregation criteria able to generate a set of vectors whose characteristics are neutral with the respect to an axes rotation. In this case the alteration of all vectors can be attributed only to the structural matrix transformation.

An aggregation criterion that overcomes these drawbacks is that of assigning to the vectors scale the value of its modulus. All the policy vectors that have the same modulus, by describing a circle whose radius corresponds to the modulus, are invariant with respect to rotations of the axis.

The most immediate aggregation criteria is represented by the sum of sectoral elements. If we consider that every single component can assume both positive or negative value - because they can represent the activities balance of some variables (foreign debt) or the modification of a pre-existing situation - we define this procedure synthetically as $sum = \sum p_i$. Vectors that show the same sum will be allocated along the same line. In the policy application, this aggregation procedure can be very interesting when simulating the zero-balance policies where the aggregate level of the macro variable is unchanged and all the variation are compensated within the same controlled macro variable. It is however apparent that the balance criteria is unable to define the scale of a macro variable since the balance may hide variation of very different relevance.

Another criteria adopted to quantifies the real amount of resources that have been activated is represented by the sum of the absolute values of the vector components: $abs\ change(p) = \sum |p_i|$. The absolute change of vector **p** quantifies the amount of the policy manoeuvre in terms both of expansion realized and the restraints imposed to sectors. In the income redistribution process for example, this measure indicates the total effort of higher revenues to maintain a certain level and the expansion of lower revenues. If the balance between these trends is positive, the policy maker can respond employing new resources.

In our application we decided to use the *absolute change* as the suitable and convenient aggregation criteria to synthesize the characteristics of the macro variable. In particular, the *absolute change* allows to observe all key structures focusing on the the amount of the policy manoeuvre both in monetary and physical terms.

4 Policies for electricity production from renewable energy sources: Italian case

The application that we propose aims to evaluate the impact of a policy that stimulates the production of energy by means the Italian production of energy from renewable sources. The analysis is based on the Italian I-O table for the year 2005 (ISTAT 2007) that has a disaggregation of 59x59 commodities. We emended the I-O flows with data in physical terms regarding the requirement of renewable energy per each commodity. Our manipulation on the Italian I-O table allows to construct a new data scheme which represents the Hybrid I-O table with a structure of 60x60 where 59 commodities are non-energetic and only the 60^{th} commodity represents the renewable energy source good.

The first block of the data base represents the flows of intersectoral relationship among commodities and they are expressed in monetary terms apart from the flows of "renewable energy sources" that can be expressed in euro and GWh[14]. The second block refers to final demand and the last row is still headed to renewable energy sources flows. The I-O table is closed by the block of value added and the row of imports that guarantees the correspondence between row and column totals. This new Hybrid I-O table represents the proper data set to implement the Hybrid I-O model.

The original problem of the I-O model consists in the search of the output vector consistent with the final demand vector for I-O sectors, given the structural interrelation among commodities. Such a vector faces both the predetermined final demand vector ($\mathbf{f}^*$) by commodities and the induced commodity demand. From the I-O matrix it is possible to identify the constant technical coefficients matrix ($\mathbf{A}^*$) and the inverse of the model, obtained according to the equation 4, shows the total requirements of commodity output per unit of final demand (exogenous variable).

The simulations proposed concern three different scenarios: i) the first analyses the impact on the balance between renewable and non-renewable electricity and total output of a shock in final demand of 0.10%. The shock is distributed according the predetermined structure of final demand observed in the I-O table; ii) the second scenario aims to achieve an increase on the balance between renewable and non-renewable energy with a policy oriented

[14]The official statistics distinguish the total demand of renewable energy sources expressed in GWh (ISTAT 2007), in intermediate requirement per each commodity and final consumption. The total renewable energy sources production is 59,600 GWh.

to maximise the total output change. In this second simulation the shock in final demand is of the same amount of the first simulation but the structure of the exogenous shock has the structure of the domination key policy revealed by the MM approach; iii) the third scenario considers the impact on total output of a policy oriented to maximize the balance between renewable and non-renewable energy. This balance is valuated with the ratio between renewable energy output and total energy output (RNR ratio). In this last instance the scenario assumes a change on final demand of the same amount of the first and second scenarios but here we adopt the key structure oriented to renewable energy source production.

i) The change in final demand for the first simulation is of 1,683 million of Euro[15] and has, in disaggregate terms, the same structure observed in the I-O table. Even though this assumption might be considered realistic, it does not represent the better policy structure in terms of economic performances. Looking at figure 1, a positive impact on aggregate and disaggregate output is verified and the most relevant result is observed for commodities pertaining to tertiary sector [16].

In aggregate terms the principal economic and energetic indicators are showed in second column ($\Delta\mathbf{f}^*$) of the table 1. The shock in final demand of 0.10% generates an increase in total production and thus in value added. The production of energy from renewable sources raises in absolute terms for 12 GWh [17], but the balance between renewable and non-renewable energy does not change in percentage terms (16.89% before the shock).

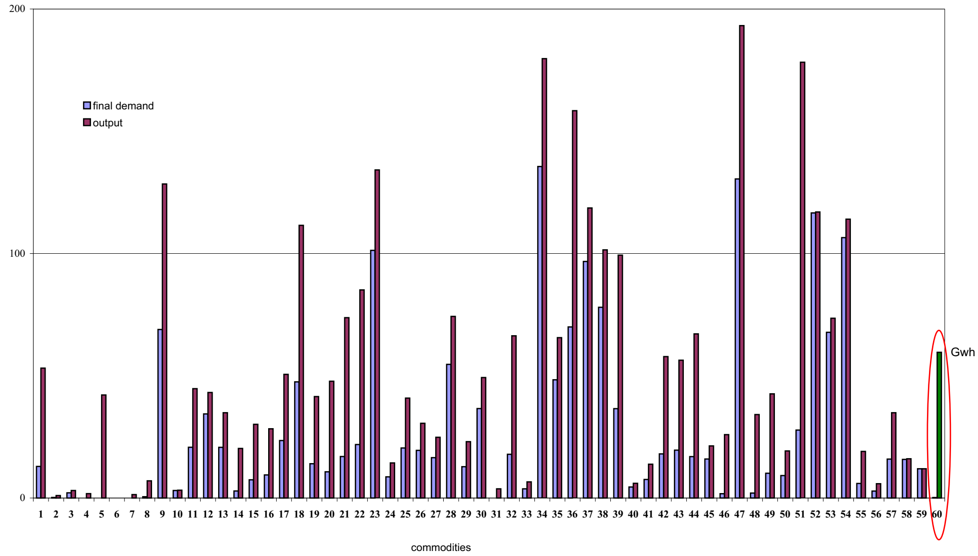
The structure used in this first simulation generates an increase in green certificates supply for 1.35%, and this can be interpreted as a positive result even though the policy on the whole is "neutral" in terms balance between renewable and non-renewable energy. The limit of this simulation derives from the fact that intersectoral linkages are completely ignored in favour of the composition of the policy variable. It is crucial at this point to identify alternative scenarios in which policy variable structures are oriented to a complex objective, as for example, the increase in total output or/and a

[15]The variation is determined according to the absolute value of vector elements that can be considered as the amount of the policy.

[16]The classification of commodities is shown in appendix B, table 2.

[17]In figure 1 the change in energy production is green coloured.

Figure 1: Impacts of the final demand change (0.10%) according the pre existing I-O structure



better balance between renewable and non-renewable energy.

ii) For this purpose in the second application we used the Macro Multiplier approach that allows to define the best composition of the policy control according to the objective of the policy maker. The singular value decomposition of the inverse matrix of the model permits to obtain the key structures ($m_i \cdot \mathbf{z}_i$) favourable for the selected good. In order to reach this result it is necessary to adopt a specific structure of the final demand ($\mathbf{p}_i$) according to the policy objective. Figure 5, in appendix A, illustrates the 60 key structure. Only the first one allows to achieve the policy objective that is interpreted as the maximum change on total output. This is the reason why the simulation considers this structure and assumes the same amount of the shock on final demand (0.10% corresponding to 1.683 million of euro). Figure 2 puts into evidence the differences between the final demand structure adopted in simulation (i) (I-O structure) and the structure chosen in this case (key structure 1 of policy control).

The distribution of total change of output is different from the previous one, even though the shock is of the same amount[18].

[18]The structure used for the second scenario is more balanced than the structure of final

Table 1: Aggregate results

		Final demand	
	I-O Structure ($\mathbf{f}$)	Structure 1 ($\mathbf{p}_1$)	Structure 51 ($\mathbf{p}_{51}$)
	$\Delta\mathbf{f}^* = 0.10\%$	$\Delta\mathbf{f}_1^* = 0.10\%$	$\Delta\mathbf{f}_{51}^* = 0.01\%$
Multiplier change[(a)]	1.874	2.005	1.514
RNR ratio[(b)]	16.89%	16.92%	17.05%
Green certificates variation	1.35%	3.32%	11.72%
Value added variation	0.10%	0.63%	-0.03%

[(a)] Indicator calculated as the ratio between the sum of output vector absolute values and the sum of final demand vector absolute value.
[(b)] Ratio between renewable energy output and total energy output.

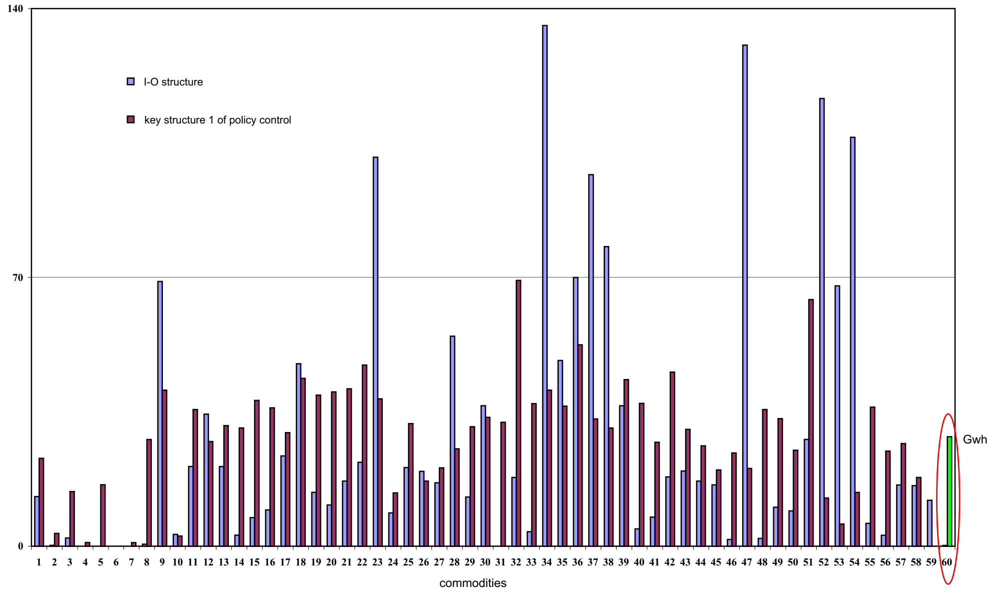
The figure 3 summarises the results in disaggregate terms whereas the aggregate results are described by the third column of table 1. According to key structure 1 of policy control, the increase of final demand of 0.10% generates a multiple effect in economic terms higher than the previous scenario. Value added in fact rises of 0.63% . At the same time the balance between renewable and non-renewable energy registers a slight improvement and the percentage reaches the 16.92%. This result depends on the increase in energy production from renewable sources that is equal to 147 GWh and generates an increase in green certificates emission (+3.32%).

As it can be seen from table 1 the policy on final demand structured as key structure 1 is the most favourable policy for the total output and the value added variables. Moreover the policy is consistent with a better balance between renewable and non-renewable energy.

iii) Finally, the third scenario aims to identify the final demand composition suitable for the best result in terms of balance between renewable and non-renewable energy: in this case the policy maker aims to reach the maximum level of the environmental indicator. For this purpose the proper key structure of the policy control variable (final demand) among the 60 key structures described in figure 5, is the one that activates the key structure of the policy variable that presents the highest effect on the production of renewable energy sources. The structure consistent with this objective is the

demand observed in the I-O table.

Figure 2: The differences between the composition of the final demand according to the I-O structure and the key structure 1 of policy control

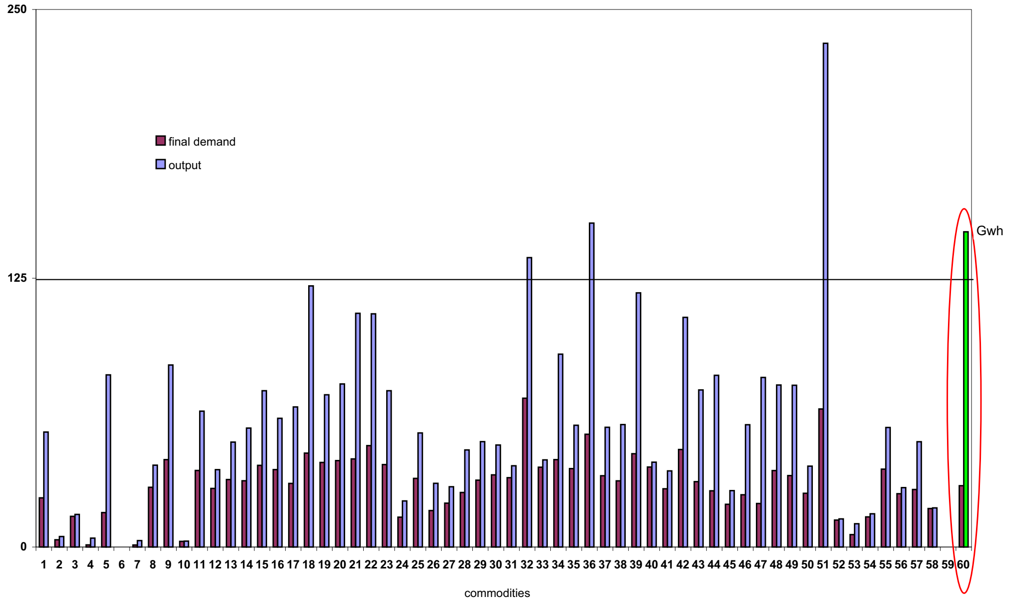


structure number 51[19]. Once the key structure has been identified (p_{51}) the final demand shock of 0.10% (1,683 million of euro) is distributed according to its structure and the results are showed in figure 4. The environmental objective can be achieved only implementing a policy based on a quite complex distribution of resources.

The aggregate results of this application are summarised in the fourth column of table 1. Even if the total value added decreases of 0.03%, the balance between renewable and non-renewable energy reaches the highest level assessing at 17.05%. The production of renewable energy sources increases of 518 GWh and the supply of green certificates raise of 11.72%. This policy can be interpreted as an environmental oriented policy that requests a new composition of the final demand change that favours the production of renewable energy intensive commodities. This policy, in fact, allows to generates the best results in terms of balance between renewable and non-renewable energy with a slight negative effect on the change of value added.

[19]In figure 5, appendix B, the structure 51 is different coloured with respect to the others.

Figure 3: Impacts of the final demand change (0.10%) according to the key structure 1 of policy control



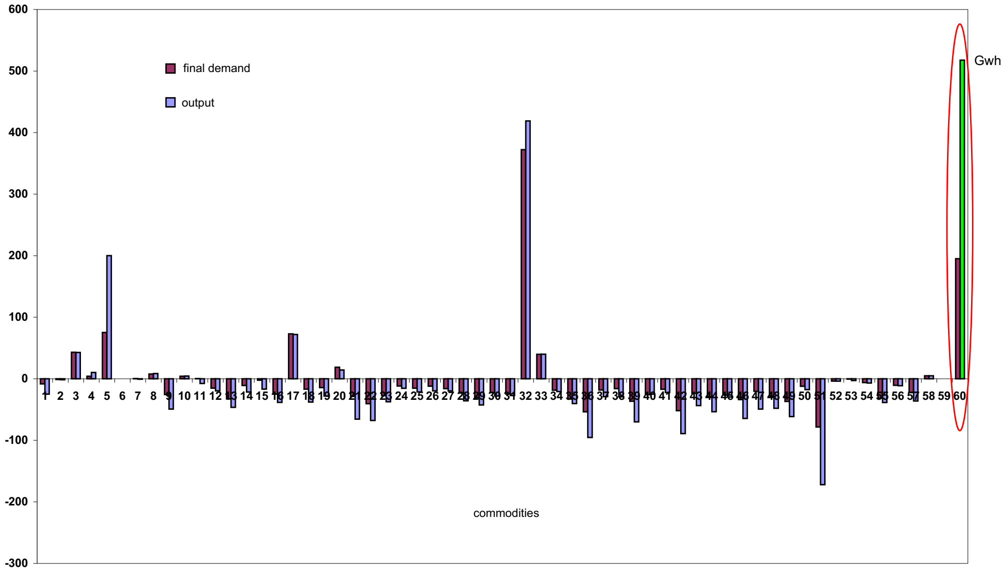
5 Conclusion

The promotion of renewable energy sources in electricity production have increased in the last 20 years in the wake of the recent consideration for environmental question. The concern for climate changes in fact led many countries to concentrate in designing optimal instruments to reduce Greenhouse Gas Emissions and face the environmental damage and depleting. Among all environmental policy instruments the promotion of renewable energy sources has received increasing favour from the public authorities and a special suggestion from the European Union.

A set of measures focused on encouraging energy efficiency and promoting renewable energy sources in electricity generation has been activated by Governments from the ending of Nineties. The liberalisation of electricity market and the introduction of economic incentives when renewable energy technology are employed, are some examples of these measures. Germany, France, Spain and Portugal adopted policies based on feed-in tariffs while Italy, Belgium, Sweden, Netherlands, Denmark and United Kingdom implemented a system based on exchangeable quotas and tradable green certificates.

Economic theory and practical experience do not confirm the advantage of

Figure 4: Impacts of the final demand change (0.10%) according to the key structure 51 of policy control



one instrument on the other, nevertheless the European Union has strongly promoted the adoption of exchangeable quotas in order to harmonise all national support scheme. In Italy the green certificate market have been introduced in recent time and there is no agreement on his effectiveness in terms of environmental and economic benefits. The renewable energy technologies in fact are still immature or have not reached an adequate level of economic performance even though the production of energy from wind, solar and geothermal sources has been growing according to the emission of green certificates.

In this paper an effort was made both to analyse the relevance of renewable energy sources in electricity production and to find the convenient policy structure able to achieve different objectives of the policy maker: environmental and economic objectives.

For this purpose we integrate the I-O data for the Italian economy with the statistics on renewable energy sources requirements by goods in physical terms and we implemented a Hybrid I-O model which was used to simulate three scenarios comparing the effects of a final demand change of the same amount using three different structures of the exogenous shock.

When supposing a change in final demand according the observed I-O structure (first scenario) the increase in final demand generates an increase in energy production from renewable sources and a consequent raise in green certificate emission. From environmental point of view this policy can be considered neutral but on the economic side, there is a small increase in value added.

A better economic and environmental performance is verified in the second scenario where the macro multiplier approach is used. Focusing on the identification of the policy structure able to reach the best results in terms of total output, the shock in final demand can be distributed according the first key structure showing a positive impact on aggregate value added and on balance between renewable and non-renewable energy. This is confirmed by an increase in green certificate exchange.

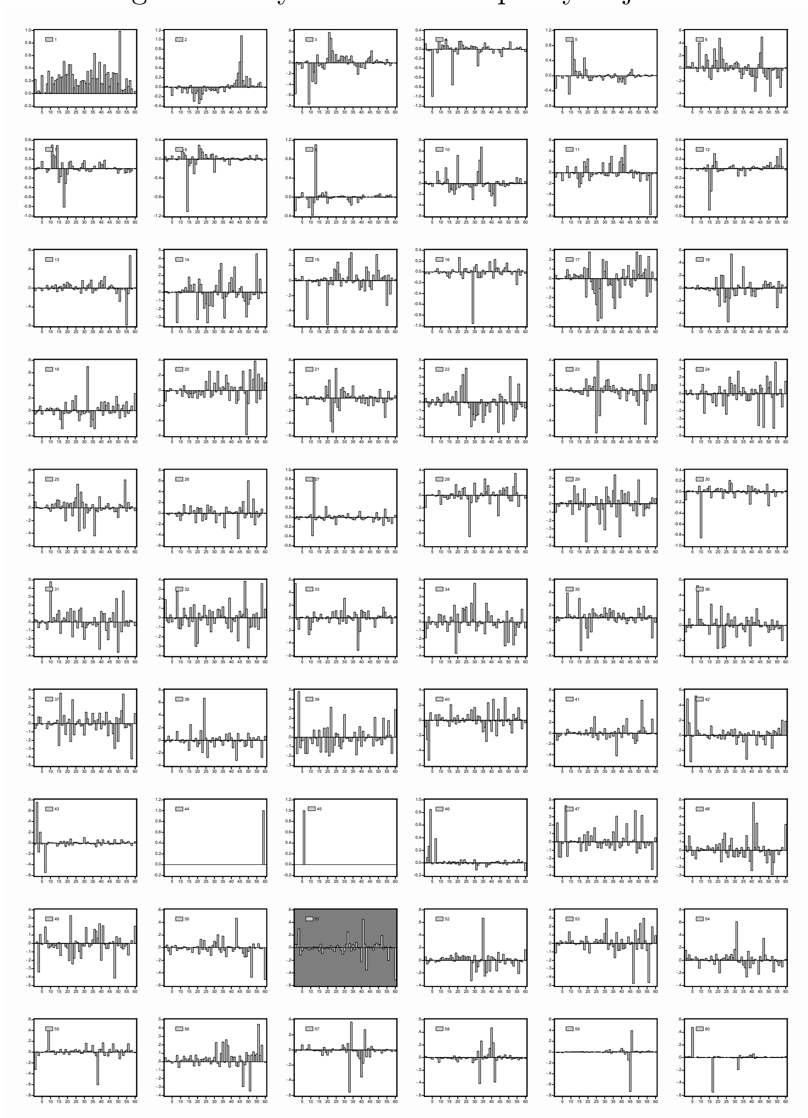
When the policy maker focuses on the environmental target, the key structure 51 is the most suitable policy for the production of renewable energy commodities. In this case (third scenario) the final demand shock creates an improvement in environmental performance and an increase in the supply of green certificates. This result is extremely significant if the aim of the policymaker is to encourage the production of renewable energy through the green certificate market. Nevertheless it is worth to put in evidence the small negative impact on value added that is of short size compared with the increase in the balance between renewable and non-renewable energy.

A Tables and figures

Table 2: Commodity classification

1	Products of agriculture, hunting and related services
2	Products of forestry, logging and related services
3	Fish and other fishing products; services incidental of fishing
4	Coal and lignite; peat
5	Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying
6	Uranium and thorium ores
7	Metal ores
8	Other mining and quarrying products
9	Food products and beverages
10	Tobacco products
11	Textiles
12	Wearing apparel; furs
13	Leather and leather products
14	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials
15	Pulp, paper and paper products
16	Printed matter and recorded media
17	Coke, refined petroleum products and nuclear fuels
18	Chemicals, chemical products and man-made fibres
19	Rubber and plastic products
20	Other non-metallic mineral products
21	Basic metals
22	Fabricated metal products, except machinery and equipment
23	Machinery and equipment n.e.c.
24	Office machinery and computers
25	Electrical machinery and apparatus n.e.c.
26	Radio, television and communication equipment and apparatus
27	Medical, precision and optical instruments, watches and clocks
28	Motor vehicles, trailers and semi-trailers
29	Other transport equipment
30	Furniture; other manufactured goods n.e.c.
31	Secondary raw materials
32	Electrical energy, gas, steam and hot water
33	Collected and purified water, distribution services of water
34	Construction work
35	Trade, maintenance and repair services of motor vehicles and motorcycles; retail sale of automotive fuel
36	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
37	Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods
38	Hotel and restaurant services
39	Land transport; transport via pipeline services
40	Water transport services
41	Air transport services
42	Supporting and auxiliary transport services; travel agency services
43	Post and telecommunication services
44	Financial intermediation services, except insurance and pension funding services
45	Insurance and pension funding services, except compulsory social security services
46	Services auxiliary to financial intermediation
47	Real estate services
48	Renting services of machinery and equipment without operator and of personal and household goods
49	Computer and related services
50	Research and development services
51	Other business services
52	Public administration and defence services; compulsory social security services
53	Education services
54	Health and social work services
55	Sewage and refuse disposal services, sanitation and similar services
56	Membership organisation services n.e.c.
57	Recreational, cultural and sporting services
58	Other services
59	Private households with employed persons
60	Renewable energy

Figure 5: Key structures for policy objective



B Methodological aspects on the MM approach

The decomposition proposed in section 3 can be applied both to square and non-square matrices. Here the general case of square matrix $\mathbf{R}$ will be shown[20]. For example, given 2x2 model we will show a Singular Values Decomposition. Let us consider matrix $\mathbf{W}$ $[2,2]$, for example, the square of matrix $\mathbf{R}$:

$$\mathbf{W} = \mathbf{R}^T \cdot \mathbf{R}$$

Matrix $\mathbf{W}$ has a positive definite or semi definite square root. Given that $\mathbf{W} \geq 0$ by construction, its eigenvalues λ_i for $i = 1,2$ shall be all real non negative (Lancaster and Tiesmenetsky 1985). The nonzero eigenvalues of matrices $\mathbf{W}$ and $\mathbf{W}^T$ coincide. The system of eigenvectors $[\mathbf{z}_i \ i = 1,2]$ for $\mathbf{W}$ and $[\mathbf{p}_i \ i = 1,2]$ for $\mathbf{W}^T$ are orthonormal basis.
We get then

$$\mathbf{R}^T \cdot \mathbf{z}_i = \sqrt{\lambda_i} \cdot \mathbf{p}_i \qquad i = 1,2$$

We can construct the two matrices

$$\mathbf{Z} = [\mathbf{z}_1, \mathbf{z}_2] \qquad \mathbf{P} = [\mathbf{p}_1, \mathbf{p}_2]$$

As defined above, the eigenvalues of $\mathbf{W}$ coincide with singular values of $\mathbf{R}$ hence $m_i = \sqrt{\lambda_i}$ and we get

$$\mathbf{R}^T \cdot \mathbf{Z} = [m_1 \cdot \mathbf{p}_1, m_2 \cdot \mathbf{p}_2] = \mathbf{P} \cdot \mathbf{M}$$

Structural matrix $\mathbf{R}$ in equation 5 can be then decomposed as

$$\mathbf{x} = \mathbf{Z} \cdot \mathbf{M} \cdot \mathbf{P}^T \cdot \mathbf{f} \qquad (10)$$

where $\mathbf{P}$ is an $[2,2]$ unitary matrix whose columns define the 2 reference structures for final demand:

$$\mathbf{p}_1 = \begin{bmatrix} p_{11} & p_{12} \end{bmatrix}$$

$$\mathbf{p}_2 = \begin{bmatrix} p_{21} & p_{22} \end{bmatrix}$$

$\mathbf{Z}$ is an $[2,2]$ unitary matrix whose columns define 2 reference structures for output:

$$\mathbf{z}_1 = \begin{bmatrix} z_{11} \\ z_{21} \end{bmatrix}, \mathbf{z}_2 = \begin{bmatrix} z_{12} \\ z_{22} \end{bmatrix}$$

[20]The non-square matrix case is easily developed along the same lines.

and $\mathbf{M}$ is an $[2, 2]$ diagonal matrix of the type:

$$\mathbf{M} = \begin{bmatrix} m_1 & 0 \\ 0 & m_2 \end{bmatrix}$$

Scalars m_i are all real and positive and can be ordered as $m_1 > m_2$. Now we have all the elements to show how this decomposition correctly represents the MM that quantify the aggregate scale effects and the associated structures of the impact of a shock in final demand on total output. In fact, if we express the actual vector $\mathbf{f}$ in terms of the structures identified by matrix $\mathbf{P}$, we obtain a new final demand vector, $\mathbf{f}^0$, expressed in terms of the structures suggested by the $\mathbf{R}$:

$$\mathbf{f}^0 = \mathbf{P} \cdot \mathbf{f} \tag{11}$$

On the other hand we can also express total output according the output structures implied by matrix $\mathbf{R}$:

$$\mathbf{x}^0 = \mathbf{Z}^T \cdot \mathbf{x} \tag{12}$$

Equation 10 then becomes through equations 11 and 12:

$$\mathbf{x}^0 = \mathbf{M} \cdot \mathbf{f}^0 \tag{13}$$

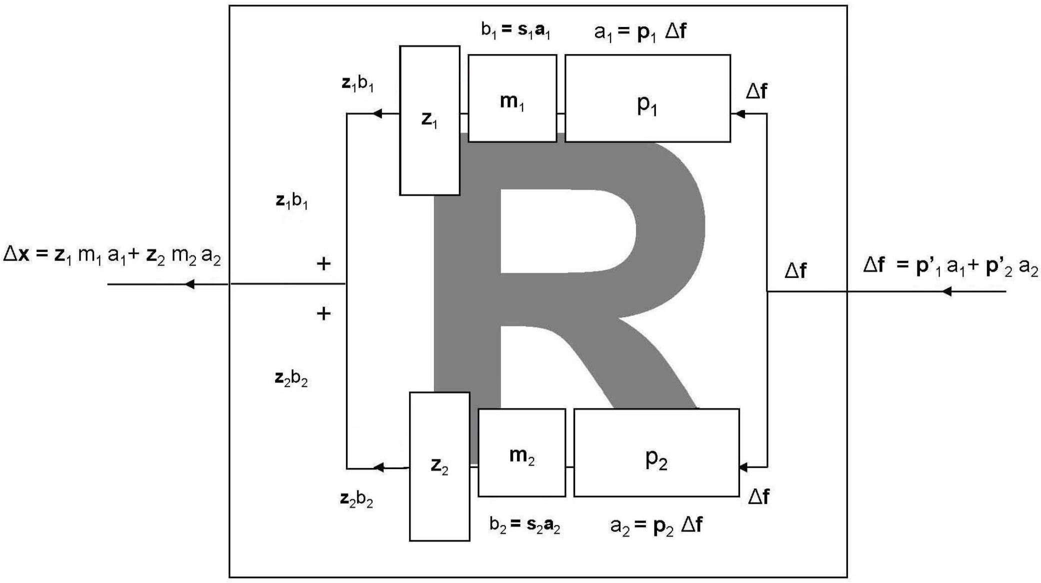
which implies:

$$x_i^0 = m_i \cdot f_i^0 \tag{14}$$

where $i = 1, 2$.

We note that matrix $\mathbf{R}$ hides 2 fundamental combination of the outputs (figure 6). Each of them is obtained multiplying the corresponding combination of final demand by a predetermined scalar which has in fact the role of aggregated Macro Multiplier. The complex effect on the output vector of final demand shocks can be reduced to a multiplication by a constant m_i. The structures we have identified play a fundamental role in determining the potential behavior of the economic system, i.e. the behavior of the system under all possible shocks. We can in fact evaluate which will be the effect on output of all final demand possible structures. As we can see in figure 6, when final demand vector crosses a structure in $\mathbf{P}$, the vector of total output crosses the corresponding structure in $\mathbf{Z}$. Singular values m_i, then, determine the aggregated effect of a final demand shock on output. For this reason we

Figure 6: The Macro Multipliers in the Leontief inverse



will call them Macro Multipliers (Ciaschini and Socci 2007). These MM are aggregated, in the sense that each of them applies on all components of each macroeconomic variables taken into consideration, and are consistent with the multi-industry specification of the model. Given the problems connected with aggregation in multisectoral models, this feature of singular values m_i is not of minor relevance. They are aggregated multipliers consistently extracted from a multisectoral framework and their meaning holds both if we speak in aggregated or disaggregated terms. In our original $[m,m]$ model, we can say that, given our matrix $\mathbf{R}^*$, we are able to isolate impacts of different (aggregate) magnitude, since that MM present in matrix $\mathbf{R}^*$, m_i can be activated through a shock along the demand structure $\mathbf{p}_i$ and its impact can be observed along the output structure $\mathbf{z}_i$.

References

Baumol, W., and Oates, W., The *Theory of Environmental Policy* (1988).

Ciaschini, M., and Socci, C. (2006), Income distribution and output change: Macro Multiplier approach, in *Economic Growth and Distribution: On the Nature and Cause of the Wealth of Nations* ed. N. Salvadori, Edward Elgar, chap. 10, pp. 247-270.

Ciaschini, M., and Socci, C. (2007), Final demand impact on output: a Macro Multiplier approach, *Journal of Policy Modeling*, 29(1), 115-132.

Ciaschini, M. (1989), Scale and structure in economic modelling, *Economic Modelling*, 6, 355-373.

Ciaschini, M., Pretaroli, R., and Socci, C. (2009), A conveniet multi sectoral policy control for the ICT in the USA economy, *Metroeconomica*, 60(4), 660-685.
Ciaschini, M., Pretaroli, R., and Socci, C. (2010), Multisectoral structures and policy design, *International Journal of Control*, 83, 281-296.

Dietzenbacher, E., and Stage, J. (2006), Mixing Oil and Water? Using Hybrid Input-Output Tables in a Structural Decomposition Analysis, *Economic Systems Research*, 18(1), 85-95.

EC, (2004), *The share of renweable energy in the EU Country profiles. Overview of RES in the enlarged European Union*, Commission staff working document SEC (2004), 547.

EUROSTAT, (2008), Energy - Yearly statistics 2006.

EUROSTAT, (2009), Panorama of Energy - Energy statistics to support EU policies and solutions.

Goulder, L., Parry, I., Williams III, R., and Burtraw, D. (1999), The Cost-Effectiveness of Alternative Instruments for Environmental Protection in a Second Best Setting, *Journal of Public Economics*, 72, 523-554.

Haug, M. (2007), Renewable Energy in Future Energy Supply: A Renaissance in Waiting, *Quarterly Journal of International Agriculture*, 46(4), 304-324.

ISTAT, I bilanci energetici, Roma: ISTAT (2007).

Jensen, S., and Skytte, K. (2002), Interactions between the power and green certificate markets, *Energy Policy*, 30, 425-435.

Lahr, M.L. (1993), A Review of the Literature Supporting the Hybrid Approach to Constructing Regional Input-Output Models, *Economic Systems Research*, 5(3), 277-293.

Lancaster, P., and Tiesmenetsky, M. (1985), The Theory of Matricies, second ed., New York: Academic Press.

Miller, R.E., and Blair, P.D., (2009) *Input-Output Analysis: Foundations and Extensions*, Cambridge University Press.

Parry, I. (2002), *Are Tradable Emissions Permits a Good Idea?, Resources for the future*, 02, Washington, D.C.

Polenske, K.R. (1976), Multiregional interactions between energy and transportation, in *Advances in Input-Output Analysis* eds. K.R. Polenske and J.V. Skolka, Cambridge, Mass: Ballinger.

Round, J. (2003), Social Accounting Matrices and SAM-based Multiplier Analysis, in *Techniques for Evaluating the Poverty Impact of Economic Policies* eds. L.A.P. da Silva and F. Bourguinon, World Bank and Oxford University Press, chap. 14.

Schaeffer, G., Boots, M., Mitchell, C., Anedersono, T., Timpe, C., and Cames, M. (2000), Option for design of tradable green certificate systems, Report ECN-C-00-032, Petten.

Skolka, J.(1986), Input Output Multipliers and Linkages, paper presented at the 8th International Conference on Input-Output Techniques - Sapporo.

Stoutenborough, J.W., and Beverlin, M. (2008), Encouraging Pollution-Free Energy: The Diffusion of State Net Metering Policies, *Social Science Quarterly*, 89, 1230-1251.

Van Dijk, M.e.a. (2003), Renewable Energy Policies and Market Developments, Report ECN- C-99-072, Petten.

DiSSE Working Papers

- n.25: Ciaschini M., Pretaroli R., Severini F., Socci C.*Environmental tax reform and double dividend evidence*
- n.24: Atkinson A. B. *Poverty and the EU: the New Decade*
- n.23: Cutrini E., *Moving Eastwards while Remaining Embedded: the Case of the Marche Footwear District, Italy*
- n.22: Valentini E., *On the Substitutability between Equal Opportunities and Income Redistribution*
- n.21: Ciaschini M., Pretaroli R., Socci C. *La produzione di servizi sanitari e la variazione dell'output nei principali paesi UE*
- n.20: Cassiani M., Spigarelli F. *Gli hedge fund: caratteristiche, impatto sui mercati e ruolo nelle crisi finanziarie*
- n.19: Cavicchi A. *Regolamentazione e gestione del rischio nel settore agroalimentare. Alcune riflessiioni sull'approccio economico al Principio di Precauzione*
- n.18: Spalletti S. *The History of Manpower Forecasting in Modelling Labour Market*
- n.17: Boffa F., Pingali V. *MIncreasing Market Interconnection: an analysis of the Italian Electricity Spot Market*
- n.16: Scoppola M. *Tariffication of Tariff Rate Quotas under oligopolistic competition: the case of the EU import regimes for bananas*
- n.15: Croci Angelini E., Michelangeli A. *Measuring Well-Being differences across EU Countries. A Multidimensional Analysis of Income, Housing, Health, and Education*
- n.14: Fidanza B. *Quale comparable per la valutazione tramite multipli delle imprese Italiane?*
- n.13: Pera A. *Changing Views of Competition and EC Antitrust Law*
- n.12: Spigarelli F., *Nuovi investitori globali: le imprese cinesi in Italia*
- n.11: Ciaschini M., Pretaroli R., Socci C. *A convenient multi sectoral policy control for ICT in the USA economy*
- n.10: Tavoletti E., te Velde R. *Cutting Porter's last diamond: competitive and comparative (dis)advantages in the Dutch flower industry. Which lessons for Italian SMEs?*

- n.9: Tavoletti E. *The local and regional economic role of universities: the case of the University of Cardiff*
- n.8: Croci Angelini E. *Resisting Globalization: Voting Power Indices and the National Interest in the EU Decision-making*
- n.7: Minervini F., Piacentino D. *Spectrum Management and Regulation: Towards a Full-Fledged Market for Spectrum Bands?*
- n.6: Spalletti S. *Dalle analisi della crescita all'economia dell'istruzione e al capitale umano. Origine e sviluppo*
- n.5: Ciaschini M., Fiorillo F., Pretaroli R., Severini F., Socci C., Valentini E. *Politiche per l'industria: ridurre o abolire l'Irap?*
- n.4: Scoppola M. *Economies of scale and endogenous market structures in international grain trade*
- n.3: De Grauwe P. *What have we learnt about monetary integration since the Maastricht Treaty?*
- n.2: Ciaschini M., Pretaroli R., Socci C. *A convenient policy control through the Macro Multiplier Approach*
- n.1: Cave M. *The Development of Telecommunications in Europe: Regulation and Economic Effects*

Centro eum edizioni Università di Macerata

ISSN: 1971-890X