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Regional policy and energy efficiency:

a computable general equilibrium approach

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Introduction

The Computable General Equilibrium (CGE) modelling frameworks used in this thesis are single-Country dynamic models with myopic or forward looking expectation. The latter can be seen as an applied and more extensive version of the skeletal model presented in Abel and Blanchard (1983). Investment decisions follow a Tobin's q adjustment process, and are separated from savings decisions. The former reflect the intertemporal optimization of firms and the latter are the outcome of intertemporal optimization by households. In chapter 2 we introduce and outline common features of CGE models. Furthermore, a focus on the models dynamics is provided.

After European Structural Funds reform in 1988, the European Union (EU) stressed the importance to evaluate the effectiveness of the Cohesion Policy that aims to promote the development and structural adjustment of lagging regions.

For regions under Objective 1, structural funds represent the most important EU tool to generate an increase in productivity and competitiveness over the long term of less developed regions by financing investments on tangible, intangible and human capital. Thus, in chapter 2, we focus on the regional Research and Development (R&D) policy implemented to increase the stock of knowledge capital (intangible capital). In particular, we analyse two Operational Programs financed by SF that the Sardinia Regional Government made operational from 1994 to 2006: Programma Operativo Plurifondo (POP) 1994-1999 and Programma Operativo Regionale (POR) 2000-2006.

In chapter 3 we investigated a particular issue related with energy efficiency improvements. The International Energy Agency (IEA, 2009) suggests the importance of efficiency improvement to reduce energy use and, within the European Union, one of the targets for member states is to reduce energy consumption by 20% through increased energy efficiency (European Commission, 2009). Energy efficiency improvement has the unquestionable benefits to reduce the price of energy services. However, it is still debatable the extent to which, improvement in the productivity of energy, is effective in terms of reducing the consumption of energy and thus the associated negative externalities (e.g., carbon dioxide emissions, CO2). Thus policy makers are particularly interested to determine the size of the energy rebound effect. We attempt to quantify the magnitude of the system-wide rebound effects from an increase in energy efficiency in the industrial use of energy in Italy. To this end, we use a large scale numerical dynamic general equilibrium model calibrated using the Italian Social Accounting Matrix for the year 2006.

A number of authors have examined the impacts of increased energy efficiency within the demand and the production side of the economy using CGE models (Semboja, 1994; Grepperud and Rasmussen, 2004; Glomsrød and Taojuan, 2005; Hanley et al, 2006 and 2009; Allan et al, 2007; Turner, 2009). For instance, the works of Allan et al, (2007) and Turner (2009) for the UK, and Anson and Turner (2009) and Hanley et al, (2006; 2009) for Scotland evaluate the impact of an increase in energy efficiency in the industrial use of energy. From this literature, rebound effects are the more common finding.

While there is an increasing interest in US and UK to identify and quantify the rebound effects, it seems there is still a little interest in the rest of Europe and especially in Italy. To the best of our knowledge, do not exist in the energy economic literature estimations of energy rebound related to Italy. We then propose to fill the gap and take Italy as a case study. We believe it would be useful to compare rebound estimates with those of the existing literature, furthermore the estimation of the rebound would eventually provide a useful indicator to policymakers that are compelled to reduce carbon emission and transform the Country in a highly energy-efficient, low-carbon economy through policy aimed to increase energy efficiency (European Commission, 2009).

Chapter 1

1. Introduction

The needs to evaluate the economic and financial effect of the policy with robust and rigorous analytical tools have represented a strong boost towards the development of new methods that were able to predict the impact of the policy implemented.
In the last twenty years, there has been a substantial improvement and methodological innovations of the methods used for analyse the macroeconomic impact of policies. Computable general equilibrium models (CGE) are the result of this enhancement and innovation. CGE models are based on the walrasian equilibrium and on the subsequently equilibrium structure formalized by Arrow and Debrieu in 1950s.

General and partial equilibrium models are part of more general resource allocation models. A partial equilibrium model simulates the impact of policy changes only in one sector of the economy, giving a lot of details and information on the target sector. However this model takes the rest of the economy as exogenous, therefore they are not able to provide any information that derives from its interactions with the rest of the economy.

Conversely, CGE models are based on an input-output table that provides a framework to analyse linkages between markets and, thus, interactions between industries, factor resources and institutions.

The range of CGE models applications for policy evaluation includes issues such as international trade, public finance, and environmental policies. Robinson and Devarajan (2002) suggest that economic models, to be useful for policy impact analysis, should have three particular features: a) policy relevance, b) transparency and, c) timeliness: models should be implemented with recent data.

Criteria (a) and (b) suggest the use of structural models which are able to incorporate links between policy variables and economic outcomes, in order to identify the structural relationship. Policy relevance requires analysis of interest for the policy evaluation. In other words, while the academic research might lead to a focus on aggregate indicators as aggregate welfare, the policy maker is more interested on identifying who gains or losses from the implementation of a specific policy.

The issue of transparency argues that the model has to explain any empirical result and the causal chains involved by parameters, structural data, and behavioural specification. Timeliness is very important in the evaluation process since the impact analysis of past policies could be very useful in order to draw feedbacks for new policies designs (Robinson and Devarajan, 2002).

Moreover "the commonly made assumption of an underlying optimizing behaviour of all agents explains why…general equilibrium theory has strongly increased their relevance for policy analysis" (Conrad, 2002). Thus, the outcome of the model is not generated from a black box but can be traced back to rational behaviour.

The reminder of this chapter is as follows. In Section 2 a brief overview of the general characteristics of CGE models is outlined and, in Section 3, we present the way in which dynamics are introduced in the model, with particular reference to the inter-temporal equilibrium (Consumer and investment behaviour).

2. CGE models: an introduction and overview

Economic models focus both on the description of economic variables and on individual's behaviour acting on the markets, representing the economic system in a simplified way.

However, they seek to capture the simultaneous determination of the supply, demand and prices. The approach can be classified as micro or macro, depending on the disaggregation level by which these quantities are represented. Outputs of the model, usually, are the aggregated key variables which traditionally are used to describe the state of a country/regional economy such as the employment level, gross domestic product, social welfare etc.

In the recent past, the macroeconomic approach, in particular based on general equilibrium theories developed by Arrow-Debreu (Shoven & Whalley 1992), has been the most widely used (Don *et al*. 1991) in policy analysis. This approach allows expressing in a quantitative way the policies effects in order to identify which groups in the society enjoy benefits and who bear the costs.

These models are able to show explicitly the overall impact of policies on the economic system. CGE models belong to these macro-models and have been developed for global, national (Sanstad & Greening 1998) and for a regional scale (Partridge and Rickman, 2004).

Although there are significant differences among CGE models, it is nevertheless possible to identify their common walrasian roots. As pointed out by Wing (2004), the starting point of CGE models is the circular flow of goods and services in which the main actors involved are families, firms and government.

The balance of the economic flows is derived from the product and the value conservation. The first reflects the principle that the amount of a factor held by households or a good produced by firms should be completely absorbed by the firms or by the households respectively. In other words, for a given factor, the amount demanded by the firms should cover the amount owned by families and, for a given good; the quantity produced should be equal to the quantity demanded (so that all markets "clear" simultaneously).

The conservation of the value denotes the accounting of a balanced budget so that, for all the economic activities the expenditure must be balanced by income. Each expenditure is intended to purchase goods or services. This principle implies that the total income should be allocated as a remuneration for the supply of primary factors (households), as payments for intermediate inputs (firms) and as tax payment (government).

Finally, in conventional neoclassical CGE models it is necessary that the factors held by households are fully employed, reflecting the principle known as "income balance."

As mentioned above, CGE models are based on the general structure proposed by Arrow and Debreu in the 1950's, and elaborated in Arrow and Hahn (1971) and, according to UNCTAD (2003) they can be described as a set of equations linked together by accounting identities and market equilibrium conditions.

Connections between endogenous and exogenous variables are conditioned both by the structure of the model (number of equations and functional form used) and by the numeric value of a set of parameters such as technological parameters and elasticities.

Greenaway et al., (1993) summarized four key issues in laying out the structure of a CGE model: i) dimensionality, ii) specification of key relationships, iii) collection of benchmark data and, iv), the calibration of the model's parameters to the data set. We will describe them in turn.

2.1 Dimensionality

Dimensionality is related to the level of sectoral disaggregation of the economic activity such us the number of products, production sectors and factors of production. Indeed, the choice of the model structure is directly related to the issues that the researcher intends to investigate so that the economic literature provides a wide range of possible theoretical models.

By and large, according to Greenaway (1993), the common structure of a simplest CGE model is characterized by two factors of production (capital and labour), a limited number of goods and, with regard to the inter-industry relationship, they are modelled by using fixed coefficients (Leontief - type coefficients).

This is so for at least for three reasons: in economic theory many issues are analysed by referring to that structure, the available data from national accounts or input-output tables follow the subdivision in capital and labour and this subdivision makes easier the calculations and simplifies the search for the equilibrium solution (Shoven and Whalley, 1992).

2.2 Specification of key relationships

As for the general specification of key relationships, an important step in the model design is the choice of the supply/demand equations and of the interactions between sectors.

Indeed, the equations have to be both consistent with the theory underlying the model (the conditions of the general equilibrium theory earlier mentioned) and they have to provide a solution to: i) the maximization of the utility function (from which the demand function is derived) and, ii) the minimization of costs in order to determine the demand for inputs.

2.2.1. Functional form

The most common functional forms in the CGE models are: constant elasticity of substitution (CES) function, Cobb-Douglas (CD) function and Leontief function (Z).

However, these functions in their specific (original) form embody some restrictions not useful in the equilibrium models so that, to overcome these limitations, researchers used hierarchical (or nested) functions where, for example, a CES function (or Cobb-Douglas) is contained in other CES functions (Shoven and Whalley, 1992). In particular, the choice of the functional form is very important given the implications that follow.

If we assume, for example, no substitution between intermediate inputs and primary factors of production, the Leontief function is used:

$$Z_j = \min\left(\frac{X_j}{cx_j}, \frac{Y_j}{cy_j}\right) \qquad (1)$$

Where X is the intermediate input, Y is value added and cx and cy are technical intermediate input coefficients and valued added coefficients respectively.

The CD function can be expressed as follows:

$$Y_j = b_j \cdot K^{\alpha} \cdot L^{\beta} \tag{2}$$

Where K is capital, L is labour, b is the technology and α and β are the elasticity of substitution; substitution between K and L is allowed. Furthermore we have to note that: $b_j > 0$, $0 < \alpha < 1$, $0 < \beta < 1$, and $\alpha + \beta = 1$. The latter means that constant returns to scale are imposed.

With regard to the CES production function, in its original form, it takes the form:

$$y = A\left[\sum_{i=1}^{n} \alpha_i x_i^{\rho}\right]^{\frac{s}{\rho}} \tag{3}$$

Where x is a generic input, y is the output, A is a multiplicative constant and s is a parameter related to the return to scale. In particular, if s is equal to 1 we have constant return to scale and so on. ρ is related to the elasticity of substitution (σ), defined as:

$$\sigma = \frac{1}{1-\rho} \tag{4}$$

For ρ equal to 1 we have no substitution (Leontief-type) and for ρ equal to 0, CES became a CD production function.

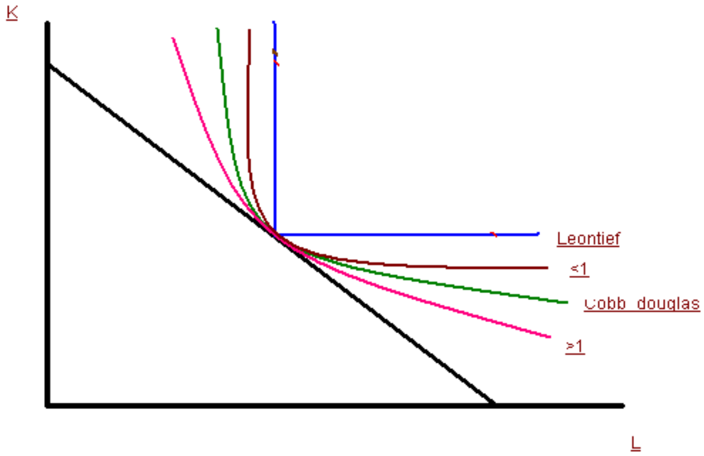
However, equation (3) implied that each factor included in the production function has to be substituted with the others at the same elasticity of substitution (equation (4)).

Thus, Uzawa (1962) introduced the possibility to differentiate the elasticity of substitution between *k* production factors couples (composite): this is named "nested CES"[1]. Formally (considering capital (K) and labour (L) as production factors):

$$y = \prod_{i=1}^{k} (\alpha_i K_i^{\rho i} + (1-\alpha_i) \cdot L_i^{\rho i})^{s/\rho i} \tag{5}$$

Figure 1, where isoquants for different level of elasticity of substitution are shown, summarises the implications of the above functional forms

Figure 1. Isoquants for different elasticity level.



In the Z function the isoquant assumes an L shape (L-shaped isoquants) so that, for any level of output, there is not substitution between K and L and the marginal productivity of the factors is equal to zero. In CD or CES (with elasticity <1 or >1) the isoquants are both strictly convex and negatively sloped. That is to say that they admit substitution between K and L.

[1] This is the production specification we use in Chapter 2 and 3.

2.2.2. Dynamic vs. static

Dynamic models allow the analysis of transmission and adjustment processes over time. Alternatively, static models analyse the difference between different equilibria resulting from different assumptions about the data or exogenous political variables (Tongeren *et al.,* 2001). In the latter approach the variable "time" is not included in the analysis.

In dynamic models the accumulation of capital (or labour) gives the possibility to capture how the economic system evolves after a static shock. Whilst in static models is quite difficult to assess the changes in production possibilities implied by new policies since, in this models, they have no effect on the accumulation capital stock (Tongeren *et al.,*, 2001), except for a single period model in which the period is one over which capital stock is at its new long-run equilibrium levels (or is fixed). Dynamics can be incorporated into CGE models essentially in two ways: the recursive model specification and the intertemporal forward – looking specification[2].

The former involves the introduction of a specific sequence of recursive equilibria. In any period of time the model is solved for a new equilibrium. Recursive dynamic models imply that economic agents are expected to behave on the basis of the past situation. Furthermore, in the recursive dynamic specification it is common to adopt an exogenous saving rate as in the neoclassical growth theory described by the Solow model (1956).

In the forward-looking specification the economic agents make their decision not only on the basis of past and current state of the economy but also on the rational prediction of future events. Forward looking models generally assume perfect

[2] See section 3.

foresight agents. Therefore since the beginning of the time agents have perfect knowledge of long run equilibrium at least in deterministic models. In this kind of specification the saving rate is assumed to be endogenous in the model.

2.2.3. Neoclassical vs. Keynesian specification

The choice between these specifications is very important since they imply strong assumption in the model so that also the simulations lead to different results.
In particular, the neoclassical specification implies full-employment and nominal wages are free to adjust in order to achieve the equilibrium in the labour market without unemployment. That is to say that the labour is paid at its marginal productivity and labour supply is vertical.

Furthermore, the equilibrium in saving and investment is called saving-driven: there are no fixed investments so that the equilibrium is achieved throughout a mechanism by which investment equals saving at full employment.
Instead in the Keynesian specification unemployment is allowed. Each activity employs labour according to an increasing production function and to a decreasing in real wages so that, households' income, is determined. In order to achieve the investment-saving equilibrium, savings have to adjust.

2.3. Collection of benchmark data

A data set can be used in the CGE models if it reflects the equilibrium conditions: the demand is equal to the market supply for all goods, zero profits in all sectors and the income balance condition. The second condition means that each productive sector has costs higher than (or equal to) revenues at equilibrium. The latter condition means that at equilibrium, each income agents level is equal to the level of their factor endowments.

In the choice of the dataset the deterministic or stochastic approach matters since the parameters will be estimated in a different way. While in the stochastic approach the data used are referred to many years (as time series data) in a deterministic approach data are referred to a single year by using a Social Accounting Matrix (SAM); a snapshot of the economic system related to one year. Because of the lack of time series data the SAM is the data set most widely used in general equilibrium models, often called SAM-based CGE models (Hosoe, 2010).

2.3.1. The social accounting matrix

SAM is a way to present accounts. The basic economic principle is that to any income corresponds an equal expenditure. This principle emphasizes the dual accounting procedure that forms the macro-economic accounts of each country/region. From an analytical point of view it is a square matrix and it is a way to rearrange appropriately disaggregated national accounts tables. It facilitates an analysis of the economic and social structure that underlies the formation of the macroeconomic aggregates.

By convention, the revenues are listed in the rows and expenditures in the columns of the matrix. Thus, by the SAM is possible to construct an interrelations matrix of the economy at sectors, production, factors, public institutions and foreign transactor level.

Thus, the SAM can be seen as an extension of Input Output (IO) tables to capture the flows of income and expenditure of other institutions: families, government and the rest of the world.

In figure 2 we present a very schematic SAM where bold capital letters (T,U,V,W, X and Y) represent sub-matrices. Along the rows, the income flows received from the transactors (households, firms and Government) is shown and, conversely, along the columns the expenditure of the transactor.

Where there are not letters no interaction takes place so that for example none of the production activities receive income from the factors of production.

Figure 2. A Schematic SAM

Expenditure by / Income to	Production activities	Institutions	Factors of production
Production activities	**T**	**U**	
Institutions	**V**	**W**	**X**
Factors of production	**Y**		

We denote production sectors with the subscripts l, institutions/aggregate transactors with A, and factors of production by B. Thus, T is an "l X l" matrix of intersectoral transactions between the production sectors of the economy, U is an I x A matrix of final demand expenditures by the institutional transactors on the output of the local production sectors (the entries are given by the final demand block of the IO table), V is an A x I matrix of income flows from the production sectors to the institutional transactors, X is an A x B matrix of factor income payments to each of the aggregate transactors based on factor services supplied and, finally, Y is a B x I matrix of payments to value added/factors of production by each of the production sectors.

However, we have to note that to use the SAM for CGE models additional data regarding investment demand and labour supply have to be collected.
For example, even if both IO table and SAM embody data about which sector output is used for capital formation, they do not provide information on which sector the demand for this capital formation emanates.

Furthermore, IO tables report full time equivalent employment (FTE) by sector but more information is required on the labour market supply conditions if the CGE model embodies an active supply side[3].

Finally, since the base year database is assumed to represent a long-run equilibrium, the total labour demand has to be equal to the total labour supply. The latter is derived from the total labour force[4] minus the number of the unemployed. Thus, information on the structure of the aggregate labour market (base year working age population, participation rate and unemployment) is required.

2.4. Calibration

After choosing the model structure, the production and demand structure and the benchmark equilibrium, the next step is to determine the structural parameters of the model.

After the calibration, the model is able to reproduce the benchmark equilibrium values as a model solution (replication check). Then, as we explain later, the value of the parameters obtained can be used for the construction of alternative equilibrium (counterfactual equilibrium or policy replacement) associated with the policy changes.

[3] See labour market specifications in Chapter 2
[4] The total labour force is obtained by the working age population minus non-participants.

The parameters values are generally determined in a non-stochastic (deterministic) way solving the equations representing the equilibrium conditions of the model using data on prices and quantities that characterize the benchmark equilibrium (SAM). The particular advantage of this method is that the equilibrium solution of the model is already known so that the calibration is just a check.

Furthermore, since the calibration requires the use of observations referred to a year or to an average of years, throughout the SAM is not possible to identify a set of values for all the parameters of the model. Thus, the values of behavioural parameters such as the elasticities of substitutions between inputs are obtained from econometric estimation of individual relationships both by modeller and by external literature.

The former is the approach suggested by Jorgenson (1984) who construct one of the few "pure" econometric CGE model.

Finally, throughout the calibration procedure in the CGE models could be the prospect that the model produces a multiplicity of equilibria without the possibility of excluding a model specification even if it replaces the benchmark equilibrium (Mansur and Whalley, 1984).

2.5. Simulation and Solution

When parameters are determined the model can be solved and can be used to simulate the effects on the economic system of a specific economic policy by specifying new values corresponding to the changes that are the focus of the implemented policy.

After the simulation a new equilibrium is obtained and by comparing the solution results with the benchmark equilibrium the researcher is able to assess the policy impact on the whole economic system.

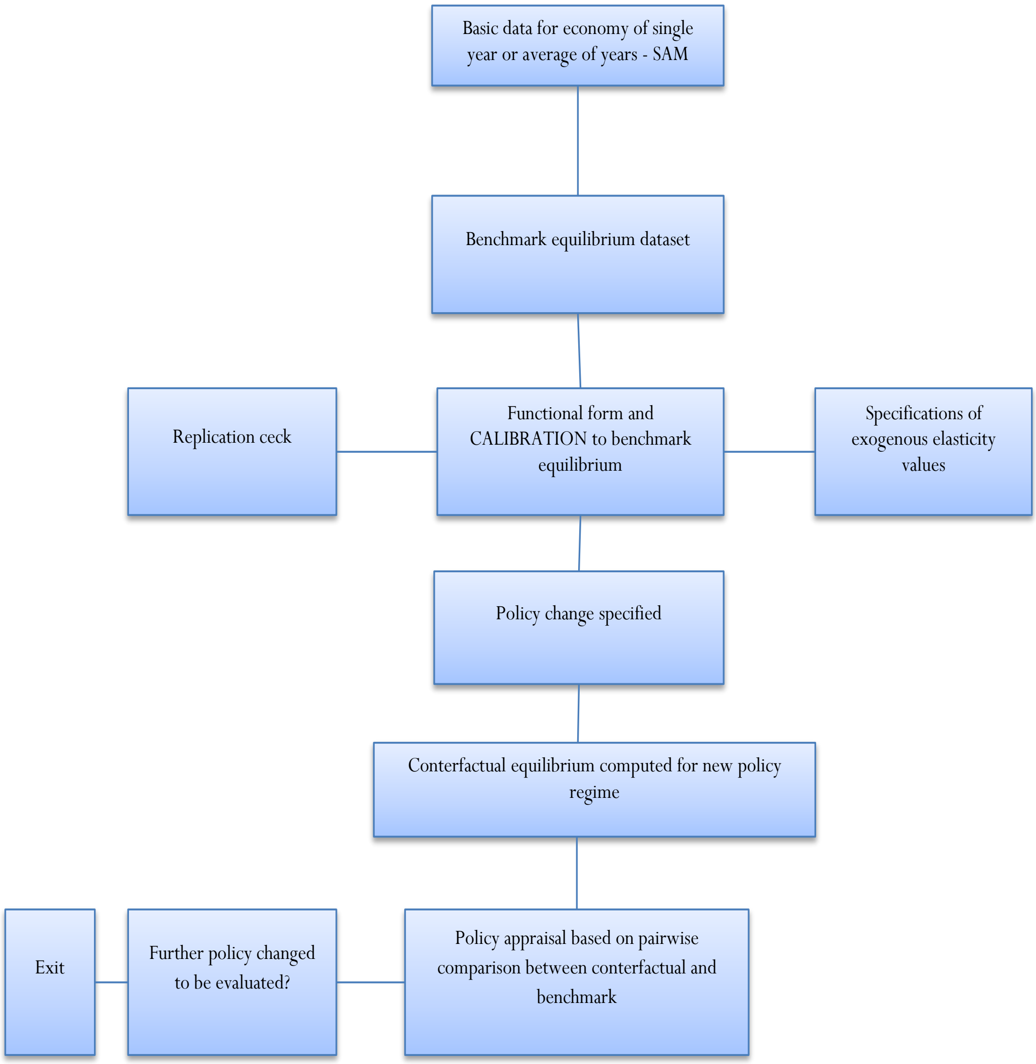
To sum up, when a political change is introduced the model simulates a new equilibrium on the base of representative agents that optimize their object function (utility function or profit function) subject to some constraint equations.

Consistent with the principles of microeconomic theory, for each traded commodity on the market the demand and the supply curve are defined and, the equilibrium, is achieved at the prices by which the supply is equal to the demand for all goods traded in the market. That is to say that the equilibrium of the economy is determined by the feedback loops that act on the overall economic system due to the price changes: general equilibrium requires that all markets clear simultaneously.

As mentioned above, in addition to the intra-temporal equilibrium (static models) obtained in this way, more advanced models can operate in a dynamic way, identifying a sequence of temporary equilibra[5]. Finally, Figure 3 provides in a schematic way how the evaluation process takes place.

[5] See Section 3

Figure 3. Evaluation process in a typical CGE model



Source: Greenaway (1993).

3. The dynamic setting: inter-temporal equilibrium

As outlined in section 2, dynamics can be incorporated into CGE models essentially in two ways: the recursive model specification (myopic) and the forward - looking inter-temporal specification.

A fundamental point of departure of a dynamic model from a static one is the incorporation of inter-temporal structure of consumption and investment decision. In fact, while static CGE models examines one – period sectoral reallocation of resources, dynamic models allow analysing the path of transitional dynamics toward a new steady state after an initial shock.

In this work we use both the above specifications[6] so that, in this section we focus only on the forward looking specification and, in Appendix A we show how the equations change in order to run the model in a myopic specification.

3.1. Household consumption

According to Go (1994) and Devarajan et al., (1998), the representative consumer maximizes his utility (U) function of aggregate consumption, as summarized by the lifetime utility function which takes the following form:

$$MaxU = \sum_{t=0}^{\infty}\left(\frac{1}{1+\rho}\right)^{t} u(C_t) = \qquad (10)$$

$$= u(C_0) + \frac{1}{1+\rho}u(c_1) + \left(\frac{1}{1+\rho}\right)^{2} u(c_2) + ...$$

[6] Myopic dynamics are used in Chapter 2 for the Sardinian CGE model and Forward – looking in Chapter 3 for the Italian CGE – Energy model.

Where C_t is the aggregate consumption, t denotes time periods, ρ is the time preference (or discount rate) and u(.) is the instantaneous consumption in period t. The instantaneous utility function $u(C_t)$ is assumed to be of the constant inter-temporal elasticity of substitution (CIES) type[7]:

$$u(C_t) = \begin{cases} \dfrac{C_t^{1-\nu} - 1}{1-\nu} & \text{For } \nu \neq 1 \\ \ln(C_t) & \text{For } \nu = 1 \end{cases} \qquad (11)$$

Where, ν, is called the coefficient of relative risk aversion. Notice that the marginal utility of consumption is $u^{'}(C_t) = C_t^{-\nu}$. Thus, the elasticity of marginal utility with respect to consumption is given by:

$$-\frac{du'(C_t)/u'(C_t)}{dC_t/C_t} = -C_t \frac{u''(C_t)}{u'(C_t)} = -C_t \frac{-\nu C_t^{-\nu-1}}{C_t^{-\nu}} = \nu > 0 \qquad (12)$$

Larger ν values denote more curvature in the utility function and, thus, less willingness to substitute consumption inter-temporally. Finally, we re-write equation (10) that takes the form[8]:

$$Max \sum_{t=0}^{\infty} (1+\rho)^{-t} \frac{C_t^{1-\nu} - 1}{1-\nu} \qquad (13)$$

[7] This is a very popular preference specification in the consumption literature since the works of Hansen and Singleton (1982 and 1983).

[8] The same we use in Chapter 3, section 4.

Then, we define the inter-temporal budget constraint which requires that the present value consumption expenditures not exceed the household's total wealth[9] :

$$\sum_{t=0}^{\infty} \frac{PC_t C_t}{(1+r)^{t+1}} \leq W_0 \tag{14}$$

Where W is wealth, and r is the interest rate facing consumers. Therefore, we can derive[10] the forward change of consumption between two adjacent periods as a function of the relative prices of the two periods, the rate of time preference and the discount rate for consumption:

$$\frac{C_{t+1}}{C_t} = \left(\frac{PC_{t+1}(1+\rho)}{PC_t(1+r)} \right)^{-\frac{1}{v}} \tag{15}$$

To sum up, combining the Euler equation (15) with the budget constraint (14) and the transversality condition, the level of full consumption (Ct) can be determined each period; the intra-period consumption.

3.2. Investment behaviour

The investment function used follows the neoclassical theory modified by the inclusion of installation costs for new capital goods. The idea on the modified neo classical investment function was introduced in the work of Lucas and Prescott (1971) where they argue that, adding the installation costs to the neoclassical theory of investment developed by Jorgenson (1963), reconciliation with the Q-theory of investment by Tobin (1969) was possible.

[9] In order to avoid the so called Ponzi-Game, households are subject to the transversality condition, that is, in each period, the total present value of current and future income receipts has to be equal to the present value of current and future spendings.
[10] See Devarajan and Go (1998) for a detailed presentation of the optimization process.

With regard to how this can be done was showed by Hayashi (1982) and this is the approach we use in modelling investment behaviour.

In particular, the representative firm in Jorgenson (1963) is assumed to have perfect foresight of future cash flows so that it chooses an investment rate able to maximise the present discounted value of future net cash flow. However, Lucas (1967) criticised this theory because of some lack as the indeterminacy of the rate of investment and indicated, as possible solution, the inclusion of a distributed lag function for investment.

The insight is that, if installing capital goods incurs in a cost this can be seen as the adjusting capital stocks cost. Tobin (1969) explains the rate of investment by the ratio of the market value of additional investment goods to their replacement cost[11]. Thus, the higher the ratio, the higher is the investment rate. Furthermore, Tobin argued that an unconstrained firm increase or decrease its capital until Q is equal to unity.

Hayashi (1982) proposed a synthesis of the above two theories by the introduction of an installation function[12] to the profit maximisation problem of the firm. The typical installation function is monotone increasing and concave in investment[13] and it takes the value of zero when no investment is taking place.
The general form of the investment function proposed for a function that is linear

[11] This ratio is known as Tobin's marginal Q.
[12] The installation function quantifies the portion of gross investment that turns into capital and, clearly, the vanishing portion is the cost of installation.
[13] It is increasing since for a given capital stock the cost of installation per unit of investment is greater, the greater the investment rate, and concave due to diminishing marginal costs of installation.

homogenous in investment ***It*** and capital stock ***Kt*** is the following[14]:

$$\frac{I_t}{K_{t-1}} = F(Q_t) \tag{16}$$

Where the left hand side is approximately the rate of change of Kt. Note that, since marginal Q is unobservable, Hayashi shows that, for a price taking firm subject to linearly homogenous production and installation functions, marginal and average Q (observable) are essentially the same. Thus, with Tobin Q we refer to the average Q.

Finally, the decision problem of the representative firm is to choose the time path of investments which maximise the present value of its cash flow, CF (Hayashi (1982) and Abel and Blanchard (1983)):

$$Max\ VF = \int_0^\infty CF(t)\ e^{-\rho_t} \tag{17}$$

Subject to the capital accumulation equation:

$$\dot{k}_t = I_t - \delta k_t \tag{18}$$

Where, ρ is the discount factor, VF is the value of the firm, K is the capital stock at time t, δ is the depreciation rate and I represents gross investments at time t. Furthermore, CF is given by the gross profit $\pi_{i,t}$ less investment expenditure $J_{i,t}$, defined as:

$$J_{i,t} = Pk_t I_{i,t}(1 - bb - tk + \theta(x_t)) \tag{19}$$

[14] Summers, for empirical estimation, assumed the linear functional form: $\frac{I_t}{K_{t-1}} = \alpha + \frac{1}{\beta}Q$

Where α and β are parameters from a quadratic adjustment – cost function.

And

$$x_t = \frac{I_{i,t}}{k_{i,t}} \qquad (20)$$

Where Pk is the price of capital, bb is the rate of distortion (or incentive to investment), tk is the corporation tax and θ are the adjustment costs. The latter signifies the presence of adjustment costs in investments and increases as a function of the ratio $\frac{I_{i,t}}{k_{i,t}}$ defined as x_t (Devarajan and Go, 1998).

We define θ as a quadratic function with parameters α and β:

$$\theta(x_t) = \frac{\beta}{2}\frac{(x_t - \alpha)^2}{x_t} \qquad (21)$$

It is treated as external to the firm and implies that production does not adjust instantaneously to changes in prices and, more important, that desired level of capital stock are achieved gradually over time.

Finally, the solution of this intertemporal problem produces the time path of investments (see Appendix A).

Chapter 2

1. Introduction

After European Structural Funds reform in 1988, the European Union (EU) stressed[1] the importance to evaluate the effectiveness of the Cohesion Policy that aims to promote the development and structural adjustment of lagging regions.
For regions under Objective 1[2], structural funds (SF) represent the most important EU tool to generate an increase in productivity and competitiveness over the long term of less developed regions by financing investments on tangible, intangible and human capital.

In this chapter, we focus on the regional Research and Development (R&D) policy which are implemented to increase the stock of knowledge capital (intangible capital) in a region[3].
In particular, we analyse two Operational Programs financed by SF that the Sardinia Regional Government made operational from 1994 to 2006[4]: Programma Operativo Plurifondo (POP) 1994-1999 and Programma Operativo Regionale (POR) 2000-2006.

[1] Art. 6 of Reg. CEE n.2052/88 and Art. 26 Reg. CEE n.4253/88.
[2] In Italy, there are six regions under the so called Objective 1: Apulia, Basilicata, Calabria, Campania, **Sardinia** and Sicily (Commission Decision 1999/501/EC, Official Journal L194 of 27.7.1999).
[3] Among economic activities, R&D has some peculiarities. While it can be considered a real investment as it uses current resources to stimulate future consumption, on the other hand, unlike tangible investments (leading to relatively faster and lower effects), R&D produces its effects only indirectly and in the longer term. Although the aim of expenditure on R&D is the creation of new products, new techniques or new services (or improvement of existing ones), the time periods involved are very long. This makes the returns to R&D difficult to detect.
[4] Each region is required to produce an Operational Programme (OP) for approval by the European Commission prior to implementation. The OP defines the targets and policy instruments.

R&D policies date from 1983, when the University of Cagliari and Sassari signed an agreement with the Regional Government to coordinate and promote R&D activities in Sardinia. Subsequently, at the end of the 1990s the regional government, with 37 billion of lire (the old currency), became the most important funder of research (more than the Ministry of University, Education and Research itself), which represents a very distinctive feature of the policy.

The principal target of R&D investments was both to stimulate the scarce innovation previously undertaken by local firms and to address their inadequate innovative capacity, as reflected in the low ratio R&D/GRP (Gross Regional Product). This was in 2007 only 0.53%. This indicator was the lowest among Italian regions and represents the very lower response of Sardinian firms to the innovation incentives. Moreover, private expenditures on R&D were really low in Sardinia (an average 0.04% of GRP from 1994 to 2007) as a consequence of Sardinian firms' small scale, principally oriented towards meeting internal demand (Crenos[5], 2010).

Thus, in order to try to overcome these problems, Sardinian regional government defined a complex strategy, that involved mixing incentives, infrastructures and real business services aimed to providing a combination of innovation services for small and medium sized firms, attracting research centres and promoting network policies.
In this context, Sardinia has invested a considerable amount of public resources in R&D. However, despite this financial effort, almost no attempt has been made to analyse the effects of these policies.

Thus, the purpose of this chapter is to provide the first quantitative analysis of the effects of these investments in R&D undertaken by the Region. The analysis is

[5] Center for North South Economic Research, University of Sassari and Cagliari (Sardinia).

performed by using a Computable General Equilibrium (CGE) model that takes account of the public nature of knowledge as a factor of production that exhibits a substantial degree of constraint in the short term.

R&D investments, but SF in general, are inherently supply-side policies and CGE models seem to be the best choice of modelling approach since they explicitly incorporates a full specification of the supply side of the host region.

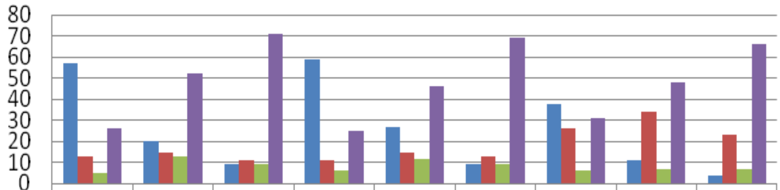
Conversely, policy evaluation is often based on a typical Keynesian model with fixed nominal wages and excess labour supply or on static fixed-price models, such as Input-Output (IO) model. This is the case of the Regional Department of Policy Evaluation of each Regional Government (Nuclei di Valutazione) where IO model are widely used (see Garau and Lecca, 2013). However IO analysis may not be the most appropriate modelling environment for this type of analysis since the expected supply-side effects would be neglected.

The reminder of the chapter is organized as follows. In section 2 a brief overview of the Sardinian economy (in particular, its competitiveness) is described. In Section 3, a brief literature review on R&D growth models and on the most used tools in the SF impact analysis is provided. In section 4 we provide a description of the model used in this study and, in section 5, two illustrative simulations, results and the main finding of our empirical analysis are presented. Section 6 presents a sensitivity analysis to test the finding robustness and, finally, in section 7, conclusions are drawn.

2. The interaction between Sardinia and the Rest of Italy

We start defining the major structural changes in production that have occurred in Sardinia compared with those in the South and in the Centre-North of Italy. In Figure 1 the composition and evolution of the Sardinian production structure, by using the percentages of the labour force employed in each sector, from 1951 to 2007 is shown.

Figure 1. Employment shares by sector (values in %)



	Sardinia			South Italy			Center-North Italy		
	1951	1975	2007	1951	1975	2007	1951	1975	2007
Primary sector	57	20	9	59	27	9	38	11	4
Industry	13	15	11	11	15	13	26	34	23
Constructions	5	13	9	6	12	9	6	7	7
Services	26	52	71	25	46	69	31	48	66

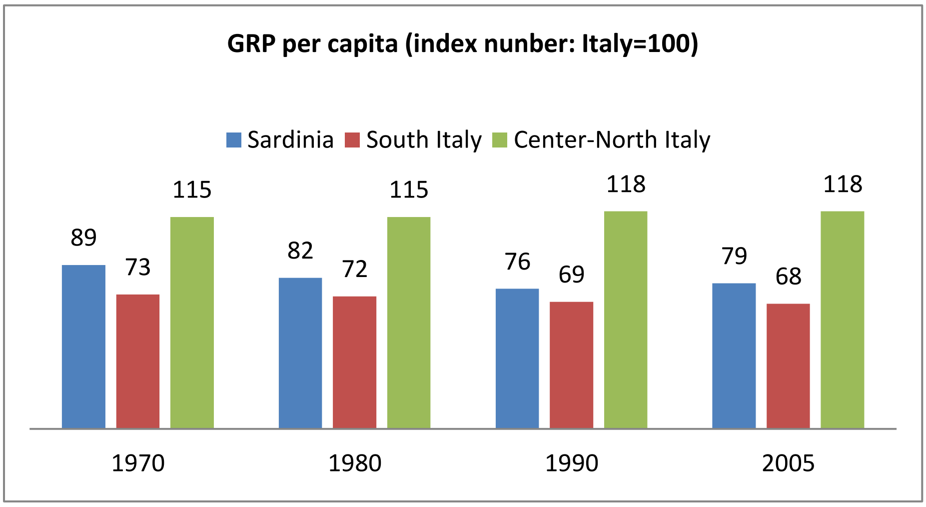
Source: elaboration on ISTAT (2010) and CRENOS (2010) data

As we can see, after the Second World War, 57% of employment was concentrated in the primary sector. Over 50 years, economic structure has changed dramatically: in 2007 only 9% of employees worked in the primary sector. In 2007, for every 100 persons employed, 71 are employed in the services sector but the percentage is slightly lower in the South (69%) and in the North Central regions (66%).

Another interesting feature is the lower development of the industrial sector which reached its peak with 15% of employees in the mid-seventies, thanks to industrialization policies focused in the metallurgical and petrochemical industries. Conversely we can see that in the north the industrial sector continues to maintain an important role with 23% of employment in 2005 (11% in Sardinia). Finally, in Sardinia the construction sector (with 9% of employees) has a weight almost similar to the Industry sector, in contrast to the North, where it is approximately a third of the industry sector's scale.

Figure 2, where the values of the gross regional product per capita in the 1970, 1980, 1990 and 2005 are reported[6], shows that, despite the radical change in production structure, and indeed perhaps because of it (CRENOS, 2010), Sardinian living conditions are better than those in the South.

Figure2. GRP per capita (values in %)

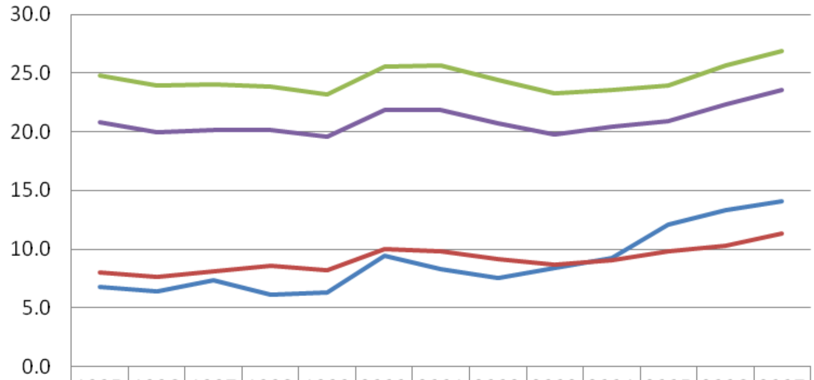


Source: elaboration on ISTAT (2010) and CRENOS (2010) data

The domestic regional market is too small to enable firms to achieve sufficient production efficiency levels (Crenos, 2010) and this is made clear by the analysis of data on Sardinian and other territorial divisions' exports in the period from 2000 to 2007 (Figure 3).

[6] Italian GDP per capita is normalized to 100.

Figure 3. Sardinian exports. Values in % on GRP



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Sardinia	6.8	6.4	7.4	6.2	6.3	9.4	8.3	7.6	8.4	9.2	12.1	13.3	14.1
South Italy	8.0	7.6	8.1	8.6	8.2	10.0	9.8	9.2	8.7	9.1	9.9	10.3	11.3
Centre-North Italy	24.8	23.9	24.0	23.9	23.2	25.6	25.6	24.4	23.3	23.5	24.0	25.6	26.9
Italy	20.8	20.0	20.1	20.2	19.6	21.9	21.9	20.8	19.8	20.4	20.9	22.4	23.6

Source: elaboration on ISTAT 2010) and CRENOS (2010) data

From above, we notice a trend improvement in Sardinia's ability to export, reflected in a rise of total exports in 2000 (to 9.4%), a fall in 2002 (to 7.6%) and an improvement in 2007 (14.1%) in 2007 but, it is a very small compared with total export capacity of the regions in the north and in the centre (27%).

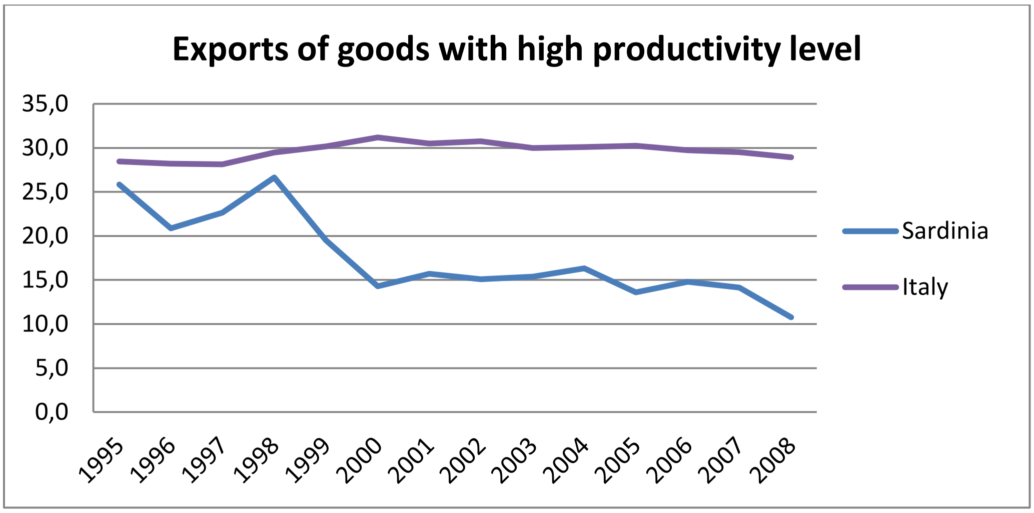
Furthermore, note that a significant proportion of exports in Sardinia consists of oil products that represented 72% of the total Sardinian exports in 2007[7]. Thus, if the contribution of the oil sector is excluded, not only does the apparent increasing ability to export disappear, but the export ratio falls to very low levels, close to 4% of GRP (Crenos, 2010).

Further difficulties of the economic system to compete in the international markets can be found by examining the share of exports of the goods with high productivity levels (chemical products, electric machines and informatics products). Figure 4

[7] Since exports are calculated in current euros, it is likely that a large part of the explanation of improvement in exports lies in the increasing relative price of oil in recent years.

presents the percentage share of these products on the total exports for Sardinia and Italy.

Figure 4. Sardinian exports of goods with high productivity level (values in percentage)



Source: elaboration on ISTAT (2010) and CRENOS (2010) data

While in the 1995 Sardinia was slightly below the national average (25.8% against 28.4%), from 1998 the share of Sardinia shows a steady decline. The value in 2008 is significantly below the national average (10.8% against 29%). Thus, Sardinia seems not able to be competitive in the strategic products that in the future will have an increasing demand.

3. Review of the literature

In the next paragraphs we provide a literature review both on the way in which R&D investments are, usually, modelled and on the most used tools in the SF impact analysis.

3.1 R&D: a brief review

Technical progress is considered one of the most important factors underlying the continuing increases in productivity over the time. However, the debate on this point is still open.

While the empirical analysis of Blomstrom *et al.* (1996) and Carroll and Weil (1994) show that investment in R&D (given no investments in physical capital) determines a higher rate of economic growth (output growth determines savings and, in turn, more investments in machinery and equipment), Young (1994, 1995), by conducting an analysis on the growth process that has characterized the economies of South Korea, Hong Kong, Singapore and Taiwan since 60s, shows that the contribution of R&D investment in increasing Total Factor Productivity (TFP) was almost negligible, unlike the role played by the accumulation of physical capital and the increase in the labour force level.

We start from the pioneering article by Solow (1956). The most important feature of the Solow model[8] is the role assigned to technological progress as a fundamental driving force behind the development of an economic system. Furthermore, in addition to technological change, the propensity to save (savings) plays an important role since it is able to directly influence the levels of steady state variables expressed in per capita terms even if savings are considered as a simple exogenous variable. The assumptions of exogenous technological progress and savings rates imply two properties of steady state economic growth rates.

[8] In the Solow model the rate of long-run growth is exogenously determined by assuming a given rate of savings and a given rate of technological progress. This model does not explain the origins of growth and, according to the neoclassical assumptions, all countries have access to the same production function and so they should converge at the same rate of growth and, conditionally to the propensity to save, at the same level of income.

First, technological progress is not the result of economic agents' decisions and, secondly, the independence of the growth rate from the agent's propensity to save. Indeed, the independence of growth from the preferences of private agents eliminates the public decision-maker's ability to influence the economic growth rate either by changing the incentive to save or by investing in R&D. The development of *endogenous* growth theory may be seen as an attempt to recover a space for the role of economic policy in the economic growth, which is denied by the Solow model.

Thus, in the 1960's, the research on the economic growth determinants was developed around the following two lines: i) the explicit introduction of the idea of representative agent, an attempt to provide a microeconomic foundation for the savings function (Cass, 1965; Koopmans, 1965), ii) explaining the technological change throughout deliberate investments in R&D. In this literature review we analyse the latter.

Arrow (1962) hypothesized that the level of technology rises on the basis of a process called "learning by doing" which can be approximated by the level of the capital stock: capital accumulation produces externalities in terms of technological change and generates increasing returns in the aggregate production function. Innovation is endogenously generated as a side effect of capital accumulation.

Uzawa (1965) considers the case in which innovation is represented by human capital accumulation and the technological level coincides with the stock of human capital. Every employee may divide his time between production and human capital accumulation. In this model the growth rate of per capita income is not only explained through the idea of human capital, but it is also endogenous in the sense that it depends on the preferences between labour and human capital accumulation;

a change in these preferences results in a permanent change in the per capita income growth rate.

Shell (1973) has explicitly demonstrated the nature of pure public good of Innovation so that it may be provided by public investments in R&D.
Romer (1986) and Lucas (1988) developed the first endogenous growth models[9] but even in these approaches, as in Solow (1956), the economy is modelled by using only one sector that produces a single, homogeneous good that can be either consumed or accumulated as physical capital. The presence of a single production sector makes these theoretical schemes of limited use to account for the notion of technological innovation, since in most cases, it takes the meaning of introduction of new goods, new production processes, new organizational forms and new markets. However, innovation may simply consist of the ability to differentiate their product from those of its competitors.

A radical change occurs in the early 90's with the works of Grossman and Helpman (1991), Aghion and Howitt (1992), Segerstrom *et al.* (1990) and Romer (1990). They use different approaches to explain the meaning and the main aspects of technology. In particular, all these authors agree that technological change is characterized by non-rivalry and (even if only partially) by non-excludability, like a public good. The first attribute of the technology (non-rivalry), in particular, has an important implication for growth theory: it introduces non-convexity (increasing returns to scale) in the production possibilities of the economy and it requires the explicit use of concepts of market power and imperfect competition (Romer, 1990; 1991).

[9] The endogenous growth theories have been developed in response to the neoclassical growth model. They were so called because the engine of the economic growth is endogenous to the model and is a result of optimal behavior of economic agents.

The models developed by the above authors are called R&D-based growth models. Essentially they have two common features: i) it is assumed that the increases in productivity that occur over time (technical progress) are the result of a formal R&D activity undertaken by firms seeking to maximize their profits and, ii) the assumption of perfect competition is no longer used since the incentive to invest in R&D for the individual firm is represented explicitly by obtaining ex-post monopoly returns.

On the other side, these models differ in the manner in which technical progress is assumed to occur: from a continuous "horizontal innovation" of capital goods (Romer, 1990; Grossman and Helpman, 1991), to continuous quality improvement on the same intermediate input; "vertical innovation" (Aghion and Howitt, 1992, Grossman and Helpman, 1991, Segerstrom et al., 1990).

In particular, in the case of horizontal innovation, technological progress is synthesized by the increase in the variety of intermediate goods used in production. The basic hypothesis is to consider the marginal product of innovation independently of the marginal product of goods already in place. This allows us both to overcome the effects of diminishing marginal productivity of each product and to force the model towards a path of endogenous growth. The economy described by these models consists of three sectors: the sector of the final good, the intermediate goods sector and the R&D sector. In the first firms operate under perfect competition and the intermediate goods producers are monopolists.

In the case of vertical innovation, the models (also called Quality-ladder models) study mainly the improvement in the quality of existing products through a continuous improvement of goods and production processes.

In particular, the model of Aghion and Howitt represents an economy with three sectors: a final good sector in which the final output is produced using one intermediate input and a given technology; a sector in which the intermediate good is produced using just work, and an R&D sector in which a proportion of skilled workers is used in order to produce innovation, monopolized through patents. The innovation lies to the invention of a new variety of intermediate goods, which replaces the previous one, making it obsolete (they can be considered "Schumpeterian" models since innovation is "creative destruction" because it destroys the value of existing capital). The monopoly generates profits, but there are not barriers to entry and profits are both reduced slowly over time and spent on R&D.

The key element of the model is that the innovation process is not a reliable event but it is stochastic: the probability that innovation occurs depends directly on the share of workers employed in R&D, on the productivity returns of the R&D and on the importance of the innovation. This stochastic element implies that growth movements are non-linear so that the steady state has to be considered as a trend, subject to cycles of lower and higher growth.

To sum up, the endogeneity of growth in R&D models depends on a number of factors such as the choices of firms in terms of R&D investments, the individual choices in terms of investment in human capital (which depend, for example by the wage gap between the R&D and the intermediate sector), public investment in R&D and the legal system (property rights).

To conclude this brief overview on the R&D literature we have to note that other models were developed (Jones, 1995, Segerström, 1998 and Young, 1998) seeking to overcome one of the less acceptable implications of the models described above: the "scale effect" that implies both that the most populous countries have higher rates of growth and, possibly, higher levels of per capita income.

3.2 SF evaluation tools: a review

An evaluation of the macroeconomic impact of SF investments can be done in three ways: case studies, econometric analysis and macroeconomic models (Ederveen, Gorter and de Mooij and Nahuis, 2002). The first two have characteristics which stand in the way of a conclusive macroeconomic impact analysis of focused investments in specific sectors by financial instruments like SF.

Most analyses using case studies[10], while drawing qualitative conclusions, do not seem to reach any significant quantitative ones. This tool is used in the analysis of individual projects made within a given territory, from which it seeks to draw conclusions regarding the effectiveness of macroeconomic structural interventions on the whole area under examination. It is mostly used for the valuation of investments carried out under Objective 2 (Ederveen et al., 2002). However, the distribution of Structural Funds under Objective 2 does not cover the whole territory of a NUTS II regions[11] but only a part of them.

Econometric analysis have been used in many studies[12], following the work of Barro and Sala-i-Martin (1991,1992), based on the estimation of b-convergence but they do not seem to be the most appropriate for a macroeconomic evaluation of SF since, as pointed out by Garnier (2003), these are primarily financial instruments focused on contributing to the development of specific sectors. Thus, any assessment of SF on a macroeconomic level requires the use of tools that enable interaction between the largest number of possible variables to permit a description of the impact at a sectoral level.

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[10] See for example Huggind (1998).

[11] In the case of Italy, the NUTS II classification corresponds to the Italian administrative regions.

[12] See Boldrin and Canova (2001).

From the above, it is apparent that these two techniques have critical shortcomings. In addition, as mentioned, in this chapter we analyse the impact of SF in the Objective 1 regions and the same European Commission (EC) has stated that macroeconomic models appear to be the most appropriate. Hence, this literature review focuses on the latters.

Amongst the various models available, Hermin, Quest II, Beutel and Pereira models are the most popular for the impact analysis of structural funds. The choice of these models is significant to this review, since each belongs to a different type, which allows a comparative analysis (Moretti, 2004).

The Hermin model is a macro-econometric model with four sectors: manufacturing, services, agriculture and the public sector. Among these, only manufacturing sector produces goods tradable with foreign countries while services are restricted to the domestic market. Both agriculture and the public sector are assumed not to have a market at all, since both are strongly influenced by exogenous policies; Agricultural Policy and Public Policy respectively. The monetary sector is excluded since most analyses are conducted for economies of the European periphery which do not have a well-developed financial sector.

The model structure is divided into three blocks: supply, absorption and accounting identities. On the supply side, output equations for the manufacturing sector are formulated differently for each economy based on the extent of influence from international competition. It is assumed that open economies with a high presence of multinational companies, such as Ireland, are more influenced by international competition than those where the output equation depends to a greater extent on domestic demand, such as Greece and Portugal (Bradley et al. 1995b). Conversely, the output of the service sector is influenced only by domestic demand, since it is assumed not to have a market abroad.

Wages are modelled with an equation reflecting wage bargaining in which both the interests of employees and employers are expressed. On the demand side, the household consumption equation is based on the assumption that households evaluate their choices based on disposable income while government spending is assumed to be exogenous.

Assuming three types of investments (infrastructure, human capital and business aid) SF investments enter into the model using the output and production functions. It is assumed that these investments increase capacity, workforce productivity and the stock of private capital, influencing prices and consequently, the competitiveness of the economy. The production function is changed under the hypothesis that an increase in the stock of physical capital (infrastructure and private capital) will increase production and also human capital above their baseline level, i.e. the level without the infusion of ESF. Also, the production function is changed to make the scale parameter (which is used as an indicator of the technology in the production function) endogenous, such that productivity increases in response to a disturbance.
Increasing productivity of the factors of production has an ambiguous effect on the labour market, since an increase in labour productivity implies that a lower level of employment will be needed to maintain a constant output: "[…] a given output can now be produced by less workers or where any increased level of sectoral output can become more skill intensive but less employment intensive" (Bradley et al., 2000b). However, this effect on the labour market is not certain since "employment can, however, actually increase after an externality creating shock if income and output effects are sufficiently large to offset labour shedding effects" (Bradley et al., 1995b).

The Quest II model has been used over the years for analysis of Maastricht policies like harmonization and implementation of Value Added Tax (VAT). Therefore, unlike Hermin, it was not constructed with the intent of applying it to impact evaluation of SF.

Lolos (2001) defines it as a modern version of the neo-Keynesian theory as the transmissions of policies on income in the short term follow Keynesian mechanisms reflecting imperfect flexibility of wages and prices, while the long-run supply curve is based on the neoclassical production function.
The long-term behaviour is very similar to that of a typical growth model à la Solow: "The steady state growth rate is essentially determined by the rate of (exogenous) technical progress and the growth rate of the population" (Roeger, 1996). In addition, economic policies influence only output level but not the growth rate of the economy, unless it fails to attain a new steady state in the long run (Roeger, 1996).

However, it differs from the neoclassical model in two critical ways: firms are not in competition and in the steady state there is a situation of less-than-full employment due to involuntary unemployment and wage rigidity (Roeger, 1996). A key aspect of the Quest II model structure is that economic agents are assumed to be forward-looking, unlike the Hermin model. This has an important influence on the transmission mechanisms of structural policy within the economy, resulting in less optimistic impacts in comparison to those obtained with the other models (for example in comparison to the Hermin).

In fact, since capital expenditure financed by SF is announced in advance, forward-looking private investors anticipate an increase in interest rates due to an increased demand for funds. This results in a scenario where in the short-term, investments financed by SF are accompanied by private investment, while in the medium term private investments are crowded out (Roeger. 1996).

The Beutel Model was developed in the mid-nineties at the instance of the EC which specifically requested a model which was equipped to capture supply side effects over the long run. Two versions of the model were built: a static model (Beutel, 1993) and a dynamic model (Beutel, 1995).

There are two key differences between the Beutel Model and the two already presented. The Beutel model has greater sectoral breakdown and a common method of constructing databases of the economies concerned. The first is made possible by the nature of the model that has the characteristics of a typical input-output model: "it is only one of the techniques applicable to the sectoral impacts of structural interventions, because it allows for the detailed division of an economy's productive structure" (Tavistock Institute, 2003). Since it is based on IO tables, sectorally disaggregated into 25 production sectors, it permits an analysis of the intersectoral linkages and the production structure of the economy. Consequently, it is capable of detecting the direct, indirect and induced effects of a policy. Common database structures are achieved through collaboration between the author and Eurostat in the preparation of the input-output tables.

The model assumes that SF investments are intended for public infrastructure, private productive capital and human capital enhancement. The static model estimates the effects of a reduction in the stock of capital (omitting SF) in the economy and in value added components. For example, if investments in training are omitted, it is expected that wages in the sectors concerned decrease, thereby decreasing the economy’s absorption capacity.

The dynamic model (Beutel, 1995), on the other hand, is focused on ascertaining the impact on the supply side in the long run. The underlying assumption here is that if there is an expectation of increase in final demand, investments increase as well. Given the rate of growth in final demand attributable to SF (calculated with the static model), investments are expected to increase (or decrease) because of an increase (or decrease) in autonomous demand components. Beutel (1995 and 2003) binds investments to consumption and exports, in particular.

As a result, the model is able to capture the links between structural fund infusion and investments induced by such infusions to quantify its direct and indirect impact on gross fixed capital formation in the long-run (Beutel, 2003).

However, IO models are not supply-side model but demand-driven model that has a passive (permissive) supply side. Thus, the supply-side stimuli that the SF aim to produce has to be converted to a demand side shock.

The model developed by Pereira is a CGE model. It is an inter-temporal endogenous growth model. Three kind of capital are considered: human, public and private. The stock of physical capital (both public and private) and human capital do not adjust instantaneously to their optimal level since private capital is not perfectly mobile (neither internationally nor sectorally) and public and human capital are considered public property and are, therefore, indivisible.

The stickiness of the adjustment process towards the optimal accumulation level is captured by adjustment costs that are specific for each investment (Gaspar and Pereira, 1999). The production functions for each sector are of the Cobb-Douglas type.

The optimal path of the economy towards its long-run equilibrium is obtained from the maximization of an indicator of social utility, calculated as the discounted value of a per capita utility function which includes both private and public consumption. SF enters the model through various channels: increasing productivity of inputs directly in the production function and acting on the equations of balance of payments and public debt (Gaspar and Pereira, 1999).

4. The Sardinian model

To perform our analysis we use a modified version[13] of the Sardinia General Equilibrium Model (SGEM) developed in Garau and Lecca (2013). SGEM is a single-region dynamic CGE model calibrated on the Sardinia SAM developed by Garau et al. (2006).

Since Sardinia is an open economy and too small to affect prices in international and interregional markets, the Rest of Italy (ROI) and the Rest of the World (ROW) prices are fixed to base year values. Moreover, Sardinia belongs to a common currency area so that the model assumes fixed exchange rate.

As for Households' and firms' behaviour, the model incorporate optimization process with myopic expectations. The rate of savings is exogenous and the optimal path of investments (tangibles and intangibles) is derived through the accelerator mechanism (Jorgenson, 1963), according to which investment equals depreciation plus some fraction of the gap between the desired and actual level of the capital stock. This means that investment and saving decisions are separated (Garau and Lecca, 2013)[14].

The Armington assumption is used to mix the domestic intermediate goods and imported goods so that they are considered as imperfect substitutes. With regard to

[13] See section 4.1 and 4.2.

[14] Note that this is a typical regional macroeconomic closure where balance of payment equilibrium is not imposed by the modeller. If instead we were to assume that saving is investment driven (or the opposite) as in many neoclassical model (or national model) this would be a mistake given that households are not liable for the financial needs of the regional system (see Lecca et al., 2013).

export modelling, an export demand function by which foreign demand for Sardinian goods depends on the terms of trade effect and on export price elasticity closes the model. Note that this specification is used in order to consider domestic and exported goods as perfect substitutes, reflecting the very high degree of openness of Sardinia[15]. Moreover, using this formulation, for any demand side shock (given full adjustment of production factors) Leontief/Input Output results are obtained[16] (see, Section 5).

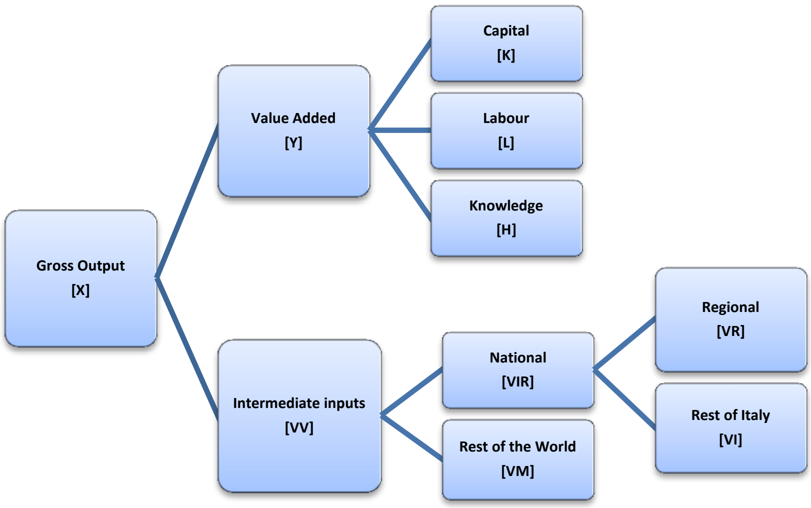
4.1 Production structure

Basically there are five economics activities: primary sector, heavy and light industry, energy and services sector. Capital (tangible and intangible) and Labour are the primary factors of production. There are four institutional sectors: firms, households, government (a consolidated sector representing both central and local government) and the external sectors, rest of Italy and rest of the world. The production inputs of the model are constituted by the labour, capital and the intermediate inputs. In Figure 5, the original SGEM production structure is shown.

[15] Note that, by and large, in many CGE applications the relationship between exports and domestic goods is modelled by using a constant elasticity of transformation (CET) function where domestic and exported goods and services are treated as imperfect substitute

[16] See McGregor et al. (1996).

Figure 5. The model's production structure.

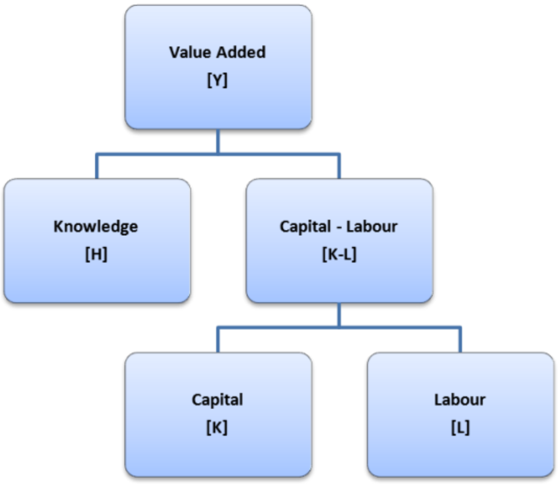


The value added (Y) is produced by the production factors: capital (K), labour (L) and Knowledge (H). They are combined in a CES production function so that substitution between K, L and H is allowed. The demand function of K, L and H are derived from first order condition of profit maximisation. Gross output (X) is obtained from Y and the intermediate inputs (VV) combined in a Leontief technology production.

However, from Figure 5, is clear that knowledge is treated as one of the three inputs in a CES function. This means that knowledge substitutes other inputs but, indeed, in a CES production function we have only one elasticity of substitution so that with this specification it is assumed that knowledge substitutes labour just as easily as capital does.

Thus, we modify the value added composition by assuming separability between inputs that, in turn, allows us to use a nested CES production function reported in Figure 6.

Figure 6. The modified Value Added specification.



The figure above implies that:

$$KLH(VV)_i = \left[\alpha_{(KL)H(VV),i} KLH_i^{\frac{\sigma_{(KL)H(VV),i}-1}{\sigma_{(KL)H(VV),i}}} + (1-\alpha_{(KL)H(VV),i})(VV)_i^{\frac{\sigma_{(KL)H(VV),i}-1}{\sigma_{(KL)H(VV),i}}} \right]^{\frac{\sigma_{KLH(VV),i}}{\sigma_{(KL)H(VV),i}-1}} \quad (1)$$

$$KLH_i = \left[\alpha_{(KL)H,i} KL_i^{\frac{\sigma_{(KL)H,i}-1}{\sigma_{(KL)H,i}}} + (1-\alpha_{(KL)H,i})H_i^{\frac{\sigma_{(KL)H,i}-1}{\sigma_{(KL)H,i}}} \right]^{\frac{\sigma_{KLH,i}}{\sigma_{(KL)H,i}-1}} \quad (2)$$

$$KL_i = \left[\alpha_{KL,i} K_i^{\frac{\sigma_{KL,i}-1}{\sigma_{KL,i}}} + (1-\alpha_{KL,i})L_i^{\frac{\sigma_{KL,i}-1}{\sigma_{KL,i}}} \right]^{\frac{\sigma_{KL,i}}{\sigma_{KL,i}-1}} \quad (3)$$

Where KL is a capital labour composite and KLH represents capital-labour knowledge composite. σ is the elasticity of substitution and it assumes different values at each nest. Thus, in this way we are able to overtake the problem of the same elasticity of substitution and we can test the results of the analysis for different degree of substitution between H and the K-L composite (see Section 6).

4.2 Knowledge in the model

The model incorporates knowledge (intangible capital) so that its creation defines the source of the Induced Technical Change (ITC). From above, knowledge is considered as a primary factor like physical capital and labour in the value added production function[17] and substitution between K-L composite and H is allowed and determined by relative price changes. Thus, the substitution elasticity defines the shape of the production function. ITC is endogenous in the model since, when there is an increase in the quantity of knowledge, technical change arises. Indeed, technical change is due to a greater knowledge quantity. The knowledge stock (HS) accumulation is defined by the equation:

$$HS_{i,t} = (1-\delta^H)HS_{t-1} + R_{i,t-1} \quad (4)$$

Where, δ^H is the rate of depreciation of the stock of knowledge and R_i represents the R&D investment by sector of destination. From equation (4) it is clear that the level of HS depends on the level in the previous period plus R&D investment. Since knowledge is embodied in the value added production function, an increase in R&D investment leads to a rise in a HS which in turn implies a higher level of value added production. In this sense the creation of knowledge is the source of the ITC (Garau and Lecca, 2013).

[17] This is in line with one of the main changes of the new System of National Account 2008 (SNA 2008 Rev 1) that treated assets created throughout R&D investments as part of value added. This approach is quite similar to those used by Bovenberger and Smulders (1995), Goulder and Schneider (1999) and Sue Wing (2003) for ITC in climate policy analysis.

Furthermore, in SGEM, spill-over effect of the no-excludable knowledge are modelled[18] but, we are analysing the SF impact using a single country model so we believe that, the incorporation of external spillover would probably require the use of a bi-regional model (Sardinia-Rest of Italy). On the other hand, given that Sardinia is a small country where its contribution to the national GDP is around 2.2% and the local population constitutes only 2.9% of the national population, the use of a single country model can be justified, in the sense that the effect of a policy implemented in Sardinia would not dramatically impact the rest of the national (and world) economy.

In addition, the literature on R&D[19], essentially, has reached two major conclusions: i) the effect of spillovers is strongly local, i.e., spillovers do not travel over long distances, and ii) the effect of spillovers depends on domestic absorptive capability. Since we have not knowledge about the latter and considering that Sardinia is an island in middle of the Mediterranean Sea, we prefer to not include in the model spillovers effect[20].

4.3 Labour market: wage setting.

The empirical evidence of wage responsiveness on unemployment, wedge and labour productivity is rather unsatisfactory for Italy (and its regions) because of the lack of data (Chiarini Piselli, 1997).

Several estimates regarding Italy have denied the existence of the wage curve up to the early '90s (1999 and Devicienti et al., 2008). However, as it has been confirmed by the work of Devicienti et al., after national labour market reform (Income Policy

[18] Cfr. Garau and Lecca (2013).
[19] See for instance Paci et al. (2001).
[20] Note that even if spillovers effects are included, their contribution to the overall impact of the policy could be negligible as pointed out in the work of Garau and Lecca (2013).

Agreement, July 1993[21]) wages became more responsive to local unemployment but, contrasting evidence is found in Ammermuller et al., (2010) who rejects the hypothesis of wage flexibility.

Thus, labour market is assumed to be imperfect and two labour markets are incorporated in the model: national and regional bargaining. In the first case the nominal wage is fixed. The basic idea is that the wage is determined by bargaining at the level of the nation as a whole (Harrigan et al., 1991). The resultant nominal wage is then effectively exogenous to any small region economy, as Sardinia is.

Instead, in the case of regional bargaining regime, according to Blanchflower and Oswald (1994) regional consumption wage is inversely related to the regional unemployment rate and positively related to workers' bargaining power. Hence, regional labour market in the model is defined by the wage curve (McGregor, Swales and Yin, 1996):

$$\ln(W_t) = \beta_u - \mu * \ln(u_t) \tag{5}$$

Where W_t is the consumption wage defined by the ratio w/cpi (cpi is the price consumer index), β is a parameter calibrated to the steady state, μ is the elasticity (of wages) and it is related with regional unemployment rate (u). Note that this closure implies local wages flexibility so that they respond to the local excess demand for labour.

[21] Before the reform wages were set within a centralized bargaining with automatic indexation of wage to the real inflation and the top up component was not linked to the firm and regional performance. After the reform a new bargaining system has been introduced. Centralized bargaining process still remains in order to set the industry wide national wage but with indexation to the Government's target inflation. The top up component which is instead the additional wage distributed to the workers is now set according to the firm and regional condition.

4.4 Migration.

The interregional migration in Italy was considerable during the 1960's and 1970's when people used to migrate from the south to the north. The migration wave instead became negligible from 1980 up to 1990. In this period, the immobility of workers contrasts with high regional disparities. (Etzo, 2011). The end of this empirical puzzle came in 1996 when internal migration rates started to grow again. Etzo (2011) investigates the main economic determinant of migration. He identifies income and unemployment as the major variables that govern interregional migration in Italy. Income plays a strong role both in the sending and destination region while unemployment seems to be stronger in the sending region than the region of destination.

Thus, assuming no natural growth rate in the population, a migration model developed by Layard et al. (1991) and Treyz et al. (1993)[22] is used:

$$nim_t = \varsigma - v^u \cdot \left[\ln(u_t) - \ln(u^N)\right] + v^w \cdot \left[\ln\left(\frac{w_t}{cpi_t}\right) - \ln\left(\frac{w^N}{cpi^N}\right)\right] \qquad (6)$$

Where *nim* is the net migration's rate and the elasticities v^u and v^W defined the impact of the gap between unemployment and real wages rate respectively.

Thus, migration is positively related to the regional and national wages (w^N / cpi^N) gap and negatively related to the unemployment rate (u) differential. Moreover, regional economy is initially assumed to have zero net migration and long-run population equilibrium is achieved by net migration flows.

[22] This migration function is commonly employed in AMOS, a micro macro model of Scotland (AMOS) developed by Harrigan et al. (1991) and McGregor at al. (1996).

4.5 Dataset and model parameterization

The model is calibrated using the Social Accounting Matrix (SAM) for Sardinia for 2001 (Garau and Lecca, 2009). Some selected benchmark values are reported in Table 1. Since the Sardinian SAM does not explicitly incorporate a knowledge sector, the authors extend the SAM to include information on this intangible component. Basically[23], a vector of Sardinia R&D investment expenditure by sectors is derived from the National Account System. Furthermore, an aggregated version of the Yale Technology Matrix (YTM) developed by Evenson et al., (1989) is used in order to determine a vector of investment by sector of origin[24].

The model is calibrated in a steady-state. Some behavioural parameters come from the literature.. The unemployment elasticity is set at 0.03. In fact, according to Devicienti et al. (2008), this is the estimated value for the South of Italy. The coefficients in the migration function (ν^u and ν^W in the equation (6)) are set at -0.117 and 0.076 respectively, as estimated in Bonasia and Napolitano (2010).
The value of the adjustment cost parameter in the investment equation is 1.5 and the elasticity of substitution, in the value added equation, between the capital-labour composite and knowledge is set to 0.588[25] and between capital and labour to 0.3 (default value).

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[23] For a fully and detailed explanation of the R&D inclusion in the Sardinian SAM see Garau and Lecca (2013).

[24] The Sardinian SAM with knowledge is reported in the Appendix B

[25] This is the value of elasticity of output with respect to the intangible capital estimated in Bontempi and Mairesse (2008) using a CES production function.

Table 1. Selected benchmark values

Tangible Investment/GDP	0.290
Intangible Investment/GDP	0.009
Physical Capital-Labour ratio	0.532
Physical capital-Knowledge Capital ratio	0.268
Consumption/GDP	0.767
Export/Output	0.135
R&D Investment by sector of Destination -*Millions of Euros*-	
Primary	17.65
Heavy Industry	78.96
Light Industry	49.17
Energy	12.36
Services	44.62
Ratio of Knowledge Stock to Value added	
Primary	0.13
Heavy Industry	0.33
Light Industry	0.18
Energy	0.14
Services	0.06

5 Simulation strategies

As mentioned in Section 1, the paper seeks to determine the magnitude of the effect arising from the implementation of R&D financed by SF during the period 1994-2006. The expenditure was distributed over different Ateco sectors and types of expenditure including: operating expenses; incentives to businesses, and real services offered.

In order to analyse the impact of these programs we construct a vector of expenditure, reported in Table 2[26], which follows the disaggregation level of the data-set used as base-run scenario.

Note that periods are divided into 1994-2001 and 2002-2008 corresponding to the real time payments made by the Regional Government so that for the OP 94-99 the last payment was made in 2001 and the first and last for the POR 00-06 was made in 2002 and 2008 respectively.

Table 2.Sardinia's investments in R&D (values in million euros)

Years 1994-2001	
primary	€ 9,73815
heavy industry	€ 40,52076
light industry	€ 42,24000
energy	€ 0,14847
services	€ 71,49095
TOT	€ 164,13833

Years 2002-2008	
primary	€ 0,00000
heavy industry	€ 0,00000
light industry	€ 22,20312
energy	€ 0,79708
services	€ 241,43145
TOT	€ 264,43165

The figures above are converted into a shock to the model. These are considered as subsidies to investment in R&D.

We shock the system by increasing exogenously the base year value of the knowledge investment (the amount of investments by destination, see Table 1) in every period for all the years of the program.

The model is run using a myopic dynamic structure[27] so that the equations for each period of the model are solved simultaneously for a given finite time horizon

[26] A brief discussion on the final vector construction is given in Appendix B.

although this version of the model could be solved recursively as well. The model is used for the analysis of the short and long run, and it is able to track period-by-period results.

In the short run, which corresponds to the first period of the model, labour supply and capital stock are fixed. However, accumulation starts in the second period and continues up to the attainment of the long-run period. In long-run equilibria, the rental rates and the user cost of capital are equal (in each sector) due to the fact that the capital stock is at its optimum level. Also, since labour supply is fully adjusted, the system exhibits zero net migration (see Section 4.4).

As already noted, our aim is to analyse the impact of the Sardinian executive program by using the best tool available since, often, impact analysis of SF are made using demand driven models such us IO model or its extension: the SAM multiplier approach. The analysis conducted by these models ignores the fact that these expenses are capital expenses and model them as an increase in current expenditure.

Furthermore, we have to note that the breakdown between these two kinds of government spending is very important, especially for the long run impact estimate. Indeed, capital expenditures have a lasting impact on the regional production structure by making it more efficient and consequently more productive. Current expenditures, however, do not have such a lasting impact and their impact on the economy is simply a short-term one. In other words these investments have to be treated and modelled as a supply-side shock.

We show how the model works by performing two illustrative simulations. Firstly, we simulate an increase in government expenditures, and treat this as a pure

[27] However, in a regional context, the myopic version generates identical long-run results to the forward looking specification although the adjustment paths differ as demonstrated in Lecca et al., 2011.

demand shock, as it is appropriate for public current (but not capital) expenditures. Secondly, we simulate an increase in R&D investments, which is, clearly, a supply-side shock.

Both simulations are performed for the two labour market regimes (NB and RB). In order to compare the shocks, the stimulus imposed is of the same magnitude in both simulations. These are: an increase of 0.07% of current public expenditure and a 5% increase in R&D investment[28].

5.1 Increase in government expenditure.

As pointed out in section 4, given the specification used, the increase in government expenditure (demand side shock) should lead to Leontief-type (input-output) results in the long-run. This is a situation where prices in the new equilibrium remain unchanged. However quantities vary. Results are reported in Table 3. These are expressed in percentage change from base year values.

[28] Clearly, and as reported in the SAM used, Government current expenditures are higher than those in capital investment.

Table 3. Percentage changes from base year values

	GOVERNMENT EXPENDITURE			
	National Bargaining		*Regional Bargaining*	
	SR	LR	SR	LR
GRP	0,019	0,037	0,003	0,037
Consumer price index	0,034	0,000	0,034	0,000
Unemployment rate	-0,284	0,000	-0,040	0,000
Total employment	0,032	0,037	0,004	0,037
Nominal gross wage	0,000	0,000	0,035	0,000
Real gross wage	-0,034	0,000	0,001	0,000
Government deficit	0,104	0,054	0,118	0,054
Current account	0,227	0,067	0,152	0,067
Labour supply	0,000	0,037	0,000	0,037
Households Cons	0,020	0,030	0,008	0,030
Total Exports	-0,059	0,000	-0,055	0,000

We start our analysis comparing the short run results (SR) in the case of RB and NB. The 0.07% increase in government expenditure generates an increase in gross regional output (GRP) employment and households' consumption.

Note that changes in employment are greater than the changes in GRP because of fixed capital stock. Conversely, where capacity constraint are relaxed in the long run, capital, labour and GRP increase by the same amount reflecting the absence of price changes and substitution possibilities; that is the reason why such a result is called Leontief-type Outcome (McGregor et al 1996) .

Differences between columns 1 and 3 reflect the different wage behaviour implied by the NB and RB closures. In the case of NB, where nominal wage is fixed, the real wage after the shock is below its initial equilibrium (-0.03%). This reflects the fact that in this model the wage is bargained at the national level, with the nominal wage being dictated to peripheral regions. The increase in aggregate demand leads to an

increase in prices (see for example the cpi which increase by 0.03%) that in turn reduces the real wage, and stimulates employment.
In the case of RB the real wage is above its initial equilibrium (0.001%); the increase of the labour demand caused by the demand shock reduces the unemployment rate by 0.04% which in turn increases the bargaining power of workers and, as a consequence, the real wage (0.001%). Accordingly, the stimulus to employment in the RB case is lower than in the NB case, where the real wage actually falls in response to a local demand stimulus.

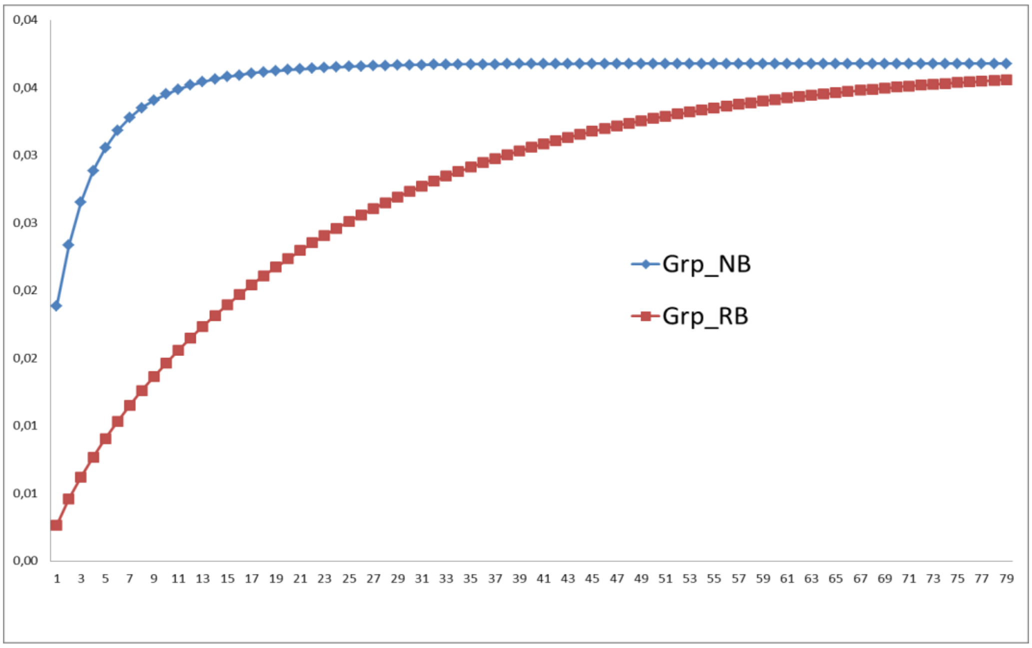
For both labour market closures we can see that there is a fall in total exports; the economic system loses competitiveness due to the increase in prices. In other words, the increase in prices crowds out exports to some degree. Moreover, the decrease in total exports is high if compared with the size of the shock since our analysis is conducted in a regional context where a small regional economy is typically more prone to international competition than a large nation.

If we look at the long run (LR) we see that prices and wages return to their base year values: the percentage change relative to base is zero. As we shall see, this reflects the fact that, over the long-run migration ties down the real wage & unemployment rate and rental rates eventually fall to their initial levels as capital stocks expand. The new steady-state equilibrium is reached by adjustments in the factors of production, notably the expansion of capital and labour. There is a rise in capital stock due to the investment which is affected by the real return to capital. Since there is a rise of aggregate demand, commodity prices increase creating profits for the firms; this means that capital rental rates are higher than the user cost of capital, stimulating an increase in investment that will increase capital stocks until rental rates are driven down towards their initial levels.

The increase in real wage and the fall in unemployment rate generate an increase in migration raising labour supply which limits and ultimately reverses the rise in wages until the labour market is in equilibrium. Here the change in employment is equal to the change in labour supply. At the sectoral level, value-added, capital and labour all expand equi-proportionately. Although factor substitution is, of course, possible, and occurs in the short-run, over the longer-term there are no changes in factor prices and so no change in factor proportions.

To sum up, in Figure 7, the time paths of adjustment for the GRP are shown. Even if the adjustments are different in NB and RB: in the LR, the same level of GRP is achieved.

Figure 7. Gross Regional Product (Percentage change from base year value).



5.2 Increase in R&D.

In order to understand how this simulation is conducted it is useful to recall how R&D enters the model. Knowledge (intangible capital) is considered a primary factor and substitution with the other production factors composite (tangible capital and labour) is allowed and embodied in the value added production function. An increase in R&D investment leads to a rise in knowledge stock which in turn implies a higher level of value added. Thus, the creation of knowledge is the source of ITC (Induced Technical Change).

We start our analysis by looking at the SR results. The impact is a demand side shock due to capacity constraint, as in the previous case and, in fact, the results are qualitatively similar to those reported in Table 3. Thus, comments on SR figures are omitted since are similar to the previous.

Conversely, looking to the LR results, the importance of the distinction between current and capital expenditures is clear.

Table 4. Percentage changes from base year values

	R&D INVESTMENT			
	National Bargaining		*Regional Bargaining*	
	SR	LR	SR	LR
GRP	0,011	1,058	0,001	2,647
Consumer price index	0,023	-0,732	0,023	-1,965
Unemployment rate	-0,169	0,476	-0,010	-0,052
Total employment	0,019	0,662	0,001	2,486
Nominal gross wage	0,000	0,000	0,023	-1,964
Real gross wage	-0,023	0,738	0,000	0,002
Government deficit	0,004	-1,463	0,013	-3,888
Current account	0,276	-2,040	0,229	-4,907
Labour supply	0,000	0,715	0,000	2,480
Households Cons	0,010	0,831	0,002	1,944
Total Exports	-0,077	2,103	-0,076	4,636

The LR figures (columns 2 and 4) show evidence of supply side effects. This is reflected in the fact that we do not get Leontief results. In the case of a supply-side shock not only do quantities change, but so do relative prices: the CPI falls permanently below steady-state in the NB case by 0.73% (even with nominal wages fixed), and by 2% in the RB case. The reason is that after an increase in investment there is a price adjustment which generates changes both in aggregate demand and also in production.

The relative price change reflects an increase in system-wide efficiency. As the stock of knowledge increases, the output effect, preceded by substitution effect, raises both the stock of capital and labour. Thus, total exports increase both in NB and RB. Of course, the stimulus under RB is much higher (5% vs. 2%) reflecting the bigger fall in prices under this closure (2% as against 0.7%).

As in the previous simulation the main differences between NB and RB are related to the behaviour of wages and we note that, in the short run, for the RB case, the nominal wage increases by 0.02% but the fall in the real wage is negligible and employment rises by just 0.001%, which is less than the corresponding figure obtained in NB (0.02%).

Finally, these two illustrative simulations highlight essentially two findings: first, the importance of the labour market modelling and, more importantly, if the shock is treated as current expenditure the evaluation design leads to an underestimation of the impact.

5.3 Simulation results: 1994-2008 Sardinian Executive Program analysis.

In this section we begin by reporting simulation results in which the regional population is fixed, that is to say that migration flows are not allowed (we switch off the migration function)

In Table 5, the proportionate changes (percentage values) from base-year values for a set of key economic variables are shown.

We start by considering the case on National Bargaining reported in column 1, 2 and 3. The figures in the first column reflect only the demand impacts of the investment expenditure associated with the program carried out by the Sardinian government, since we assume that economic activity takes a year[29] to expand its capacity. In other words, in the short run (Period 1 in table 5) we impose capacity constraints (capital, tangible and intangible, and labour are kept fixed) so that, shocking the system by the exogenous increase in R&D investment by destination, there is only a rise in investments by origin: a component of the final demand.
In the first period both gross regional output and total employment rise (0.02% and 0.04%). Moreover, at the sectoral level we can see that the percentage increase in employment in each sector is greater than that in value-added due to capacity constraints. Capital rentals, tangible and intangible, rise in all sectors along with value-added prices.

The increase in total employment together with the rise in commodity prices because of capital fixity lead to an increase in consumer price index (CPI) which, in turn, results in a fall in regional competitiveness, reducing exports; total exports in

[29] We consider one period as one year.

all sectors fall in the first period of the analysis especially in the energy sector (-0.22%).

As capacity constraints are relaxed, supply-side effects generated by the investment comes into play. The positive demand impact, combined with the increased capacity of the economic system implies a higher effect than in the first period of the investment shock. Note that in the second period the impact of the expansion in export demand is in primary, heavy and light industry sectors, whilst the other sectors still suffer from capacity constraints. Moreover, exports in the services sectors start to move above their base year values in period 3. We can explain the different behaviour of the energy sector bearing in mind that the latter has received a smaller investments (table 1).

The decrease of output prices, except for the energy sector, is reflecting an increase in system-wide efficiency, encouraging exports to rise. Foreign demand for regional goods rises as regional prices decrease, resulting in an improvement in the current account.

In other words, there is excess capacity in the industrial, primary and services sector where the rise in output and employment is proportionately less than the increase in the knowledge capital stock.

From columns 4 to 6, results for the same simulation but under the assumption of wages regionally bargained are shown. Compared with the NB closure, the main difference is related to the wages behaviour; both nominal and real wages (NW and RW) are above the base year values.

Labour-market displacement is incorporated due to the substitution effects that arise in the production function: the rise of both NW and RW, due to the increase in bargaining power of workers, leads to the substitution of capital for labour in the production of value-added. Thus, as in the case of NB, total employment is above the base–year value but the figure is significantly lower in the RB case (0.002% vs. 0.04% in NB case). Moreover, at sectoral level, service sector employment falls below its initial value.

Finally, this substitution effect implies, in the short run, a lower expansion in economic activity associated with the investment when compared with the NB closure. The value-added prices rise as a result of increases in both nominal wage and capital rental rates above base-year values.

Simulation results for RB closures with migration are shown in columns 7 and 8. Where migration flows are allowed, the activity increase associated with the Sardinian executive program produces net in- migration that, in turn, enhances the impact of the investment.

In fact, net migration flow increases activity both by generating additional welfare transfers from national government in both labour market closures and, only in the case of RB, by reducing the fall in unemployment rate, which in turn limits the growth of real wages caused by the increase of regional employment.

However, the size of the impact produced by higher welfare national government transfers associated with the introduction of the migration model is quite small and therefore not able to change the regional economic system response significantly. Obviously, there is a change in employment since migration flow are inversely related with the unemployment rate but, with fixed nominal wage, firms labour demand is quite low. Thus, figures related to NB closure with migration are omitted.

On the other hand, simulation results under RB closure with endogenous population differ significantly from those where population is kept fixed especially in the long run as we show below.

As expected, in period 1 we obtain the same figures of the RB case without migration given that in the model, population is updated between periods. However, in the second period, the population level (labour supply) increases by 0,002% compared to the base year as there is an increase in economic activity generated by the investment. Thus the rise of nominal wage is slightly lower (0.04% vs. 0.03%) in period 2 and it falls under its steady-state value (-0.03%) in period 3, confirming smaller labour market pressures.

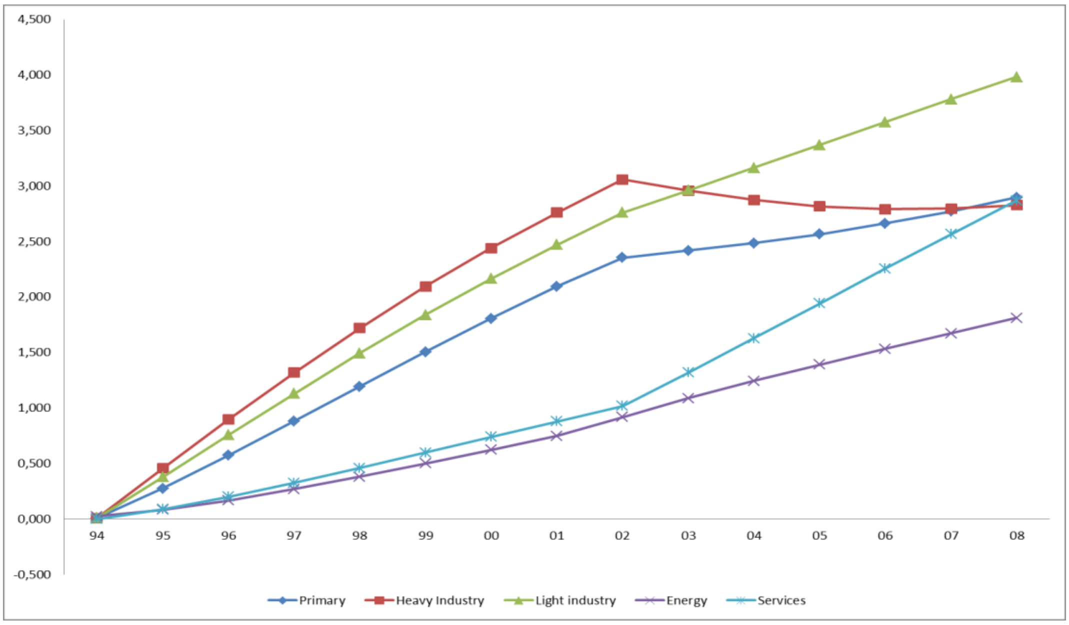
Table 5. Proportionate changes (percentage values) from base-year values for a set of key economic variables.

		NATIONAL BARGAINING			REGIONAL BARGAINING				
		Population Fixed			Population Fixed			Population Endogenous	
		P. 1	P. 2	P. 3	P. 1	P. 2	P. 3	P. 2	P. 3
Grp		0,022	0,174	0,327	0,001	0,152	0,319	0,152	0,332
CPI		0,045	0,000	-0,077	0,046	0,010	-0,064	0,010	-0,064
Un. rate		-0,339	-1,270	-2,164	-0,018	-0,986	-2,134	-0,970	-1,255
Total employment		0,038	0,141	0,240	0,002	0,110	0,237	0,110	0,258
Nominal wage		0,000	0,000	0,000	0,047	0,040	0,001	0,039	-0,026
Real wage		-0,045	0,000	0,077	0,001	0,030	0,065	0,029	0,038
Current account		0,551	0,836	0,857	0,455	0,805	0,930	0,806	0,985
Labour supply		0,000	0,000	0,000	0,000	0,000	0,000	0,002	0,118
H. Cons		0,020	0,153	0,282	0,004	0,137	0,278	0,137	0,287
Knowledge stock	Primary	0,000	1,096	2,018	0,000	1,096	2,018	1,096	2,018
	Heavy Industry	0,000	1,187	2,154	0,000	1,187	2,154	1,187	2,154
	Light industry	0,000	1,452	2,708	0,000	1,452	2,708	1,452	2,708
	Energy	0,000	0,030	0,055	0,000	0,030	0,055	0,030	0,055
	Services	0,000	0,839	1,643	0,000	0,839	1,643	0,839	1,643
Total output	Primary	0,035	0,306	0,583	0,007	0,276	0,572	0,276	0,589
	Heavy Industry	0,029	0,479	0,906	0,008	0,455	0,896	0,456	0,909
	Light industry	0,043	0,411	0,765	0,012	0,379	0,756	0,379	0,774
	Energy	0,037	0,099	0,175	0,024	0,084	0,168	0,084	0,175
	Services	0,018	0,110	0,206	-0,002	0,089	0,199	0,089	0,211
Value added	Primary	0,035	0,306	0,583	0,007	0,276	0,572	0,276	0,589
	Heavy Industry	0,029	0,479	0,906	0,008	0,455	0,896	0,456	0,909
	Light industry	0,043	0,411	0,765	0,012	0,379	0,756	0,379	0,774
	Energy	0,037	0,099	0,175	0,024	0,084	0,168	0,084	0,175
	Services	0,018	0,110	0,206	-0,002	0,089	0,199	0,089	0,211
Employment	Primary	0,050	0,256	0,473	0,010	0,216	0,463	0,217	0,487
	Heavy Industry	0,056	0,345	0,637	0,015	0,306	0,629	0,306	0,653
	Light industry	0,068	0,294	0,514	0,018	0,250	0,510	0,251	0,539
	Energy	0,086	0,184	0,280	0,057	0,158	0,277	0,158	0,294
	Services	0,030	0,096	0,156	-0,003	0,067	0,154	0,067	0,173
Total Export	Primary	-0,073	0,002	0,111	-0,091	-0,021	0,098	-0,021	0,109
	Heavy Industry	-0,191	0,170	0,592	-0,172	0,168	0,564	0,168	0,553
	Light industry	-0,171	0,194	0,641	-0,156	0,178	0,597	0,177	0,588
	Energy	-0,222	-0,379	-0,455	-0,212	-0,386	-0,478	-0,386	-0,483
	Services	-0,076	-0,056	0,043	-0,085	-0,084	0,011	-0,084	0,017
ROE Knowledge	Primary	0,103	-1,327	-2,446	0,066	-1,363	-2,456	-1,363	-2,436
	Heavy Industry	0,123	-1,251	-2,290	0,079	-1,290	-2,295	-1,289	-2,270
	Light industry	0,146	-1,821	-3,459	0,086	-1,867	-3,456	-1,867	-3,423
	Energy	0,219	0,385	0,527	0,191	0,365	0,531	0,365	0,548
	Services	0,069	-1,199	-2,414	0,040	-1,220	-2,409	-1,220	-2,393
Commodity price	Primary	0,019	-0,001	-0,028	0,023	0,005	-0,025	0,005	-0,028
	Heavy Industry	0,066	-0,058	-0,202	0,059	-0,057	-0,192	-0,057	-0,188
	Light industry	0,071	-0,080	-0,265	0,065	-0,074	-0,247	-0,074	-0,243
	Energy	0,083	0,141	0,169	0,079	0,144	0,178	0,144	0,180
	Services	0,033	0,025	-0,019	0,038	0,037	-0,005	0,037	-0,008
Output price	Primary	0,026	-0,001	-0,039	0,033	0,008	-0,035	0,007	-0,039
	Heavy Industry	0,066	-0,058	-0,204	0,059	-0,058	-0,194	-0,058	-0,190
	Light industry	0,071	-0,081	-0,266	0,065	-0,074	-0,248	-0,074	-0,244
	Energy	0,109	0,186	0,223	0,104	0,190	0,235	0,190	0,237
	Services	0,036	0,027	-0,020	0,041	0,040	-0,005	0,040	-0,008
Value added price	Primary	0,044	-0,001	-0,067	0,055	0,013	-0,059	0,013	-0,066
	Heavy Industry	0,074	-0,065	-0,225	0,066	-0,064	-0,215	-0,064	-0,211
	Light industry	0,073	-0,083	-0,271	0,066	-0,076	-0,253	-0,076	-0,249
	Energy	0,156	0,268	0,322	0,149	0,273	0,338	0,273	0,342
	Services	0,038	0,028	-0,022	0,043	0,043	-0,006	0,043	-0,009

Before analysing the long run investment impact, it is informative to analyse the effect of the change in the Sardinian executive strategies in the two periods examined (1994 - 2001 and 2002 - 2008). In fact, as shown in table 2, while in the POP 94-99 large investments (50 million Euros) were made in the primary and heavy industry sectors, in the POR 2000-2006, R&D investments in these sectors was zero. Conversely, a total of 241 million Euros was invested in public administration, education and health ("services" in the table 2) in the later period.

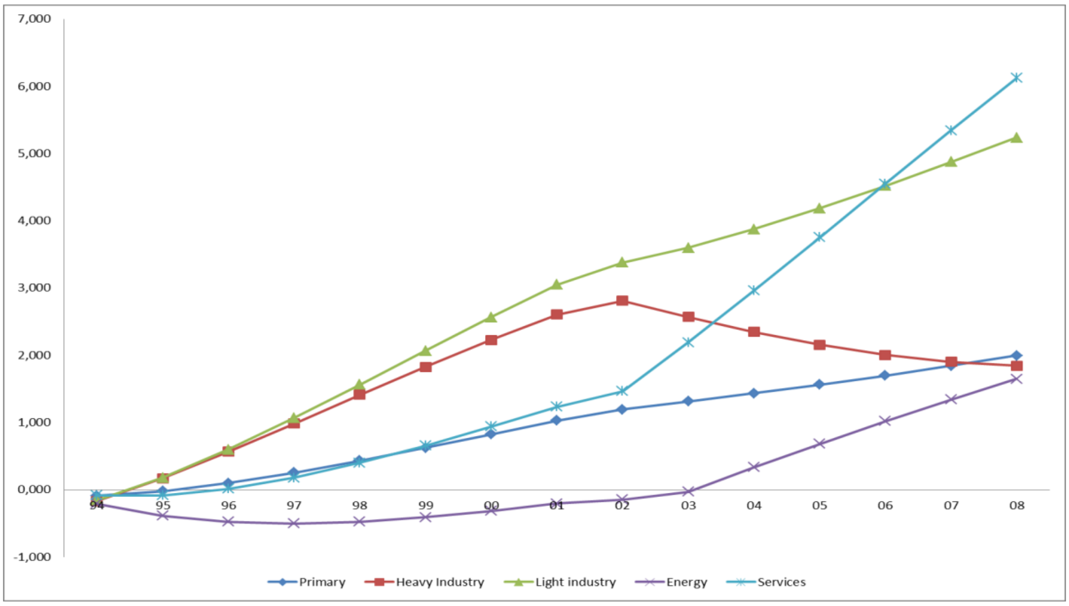
It seems therefore not only appropriate, but essential, to understand how the change in strategy may have led to different results. Thus, we have analysed, in terms of production (value added) and competitiveness (exports) what happened in the 15 years (1994-2008) of investments. The figures below show the impact of the investment under the assumption of RB closure without migration flows[30]

Figure 8. Impact on production (value added). Percentage changes from base year value



[30] Results for the other labour market closures are omitted as they are qualitatively similar to those reported.

Figure 9. Impact on competitiveness (exports). Percentage changes from base year value



The impact on Primary and Heavy Industry sectors of the change in regional strategy is clearly apparent from the chart of sectoral value-added and, with regard to Heavy industry, from the exports side as well. From 1994 to 2002 there is an increase both in production and in competitiveness. In contrast, from 2002 when the Government stopped investments in these sectors, both production and competitiveness have grown at a slower pace in the Primary sector and actually fallen in the Heavy industry sector. Conversely, both production and competitiveness in the Services sector has increased sharply after 2002 primarily due to higher government investment in this sector.

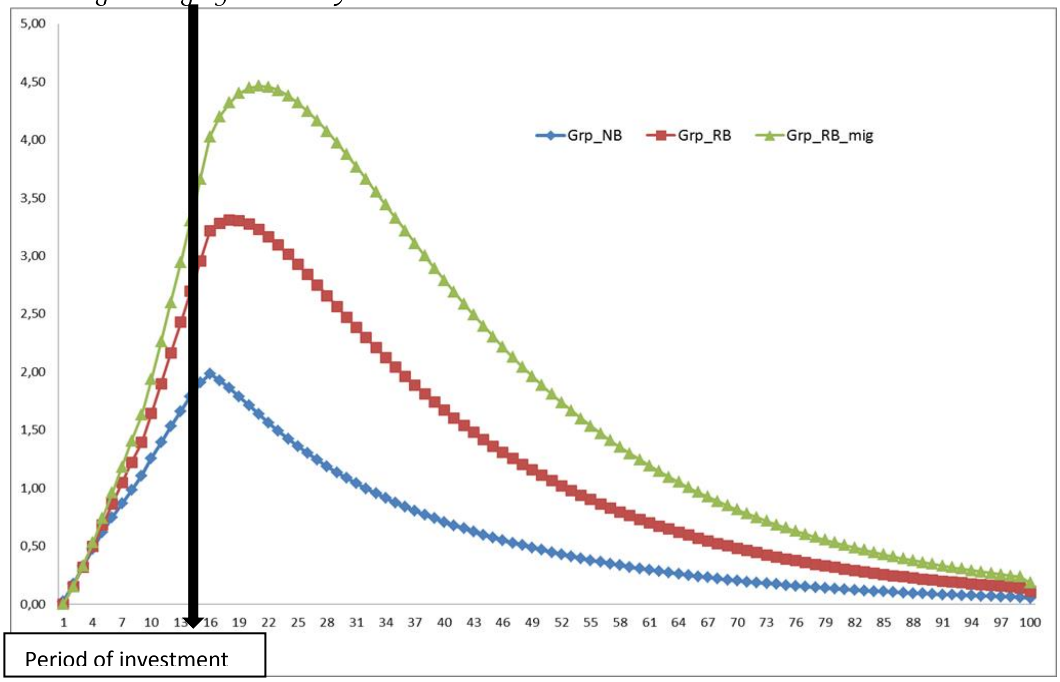
Moreover, we note that the effect both on production and competitiveness of the change in investment strategy is very marked in heavy industry reflecting the knowledge capital intensity (see table 1) in this sector: the highest amongst the sectors analysed. Furthermore, even with the services sector receiving almost double that of the industrial sector, the trajectory of increase in production and competitiveness was low. It is only after these investments were tripled in the later period that a steep rise in exports was visible. Again, this finding is confirmed by the sector's low ratio of knowledge capital stock to value added (lowest amongst analysed sectors). With regard to other sectors we see that in Light Industry (essentially construction) there is a continuous increase; in fact there were investments for all the years considered in this analysis.

Long run results confirm the Sardinian executive investments program as a supply-side shock since not only the quantities change, but so do relative prices underlining a variation in the Sardinian economic system.

Moreover the dynamic model structure allows us both to discuss the investments legacy effects and the time path adjustment to the LR of the economic variables considered.

Figure 10 shows the dynamic of GRP, for all three model set-ups considered. We run the model for 100 periods in order to show the legacy impacts which may continue long beyond the ending of the policy and, as illustrated in this case, they are much extended. As mentioned above, in this analysis we are assuming myopic transactors. However, we would not expect the legacy effects to be significantly less extended in the perfect foresight case (forward-looking transactors) since the shock is temporary and not permanent. Moreover, as in the previous section, in the case of regional models the long run equilibrium is equal both in the case of myopic and forward looking.

Figure 10. Time path adjustment of Gross Regional Product for all model set-ups considered. Percentage changes from base-year value.



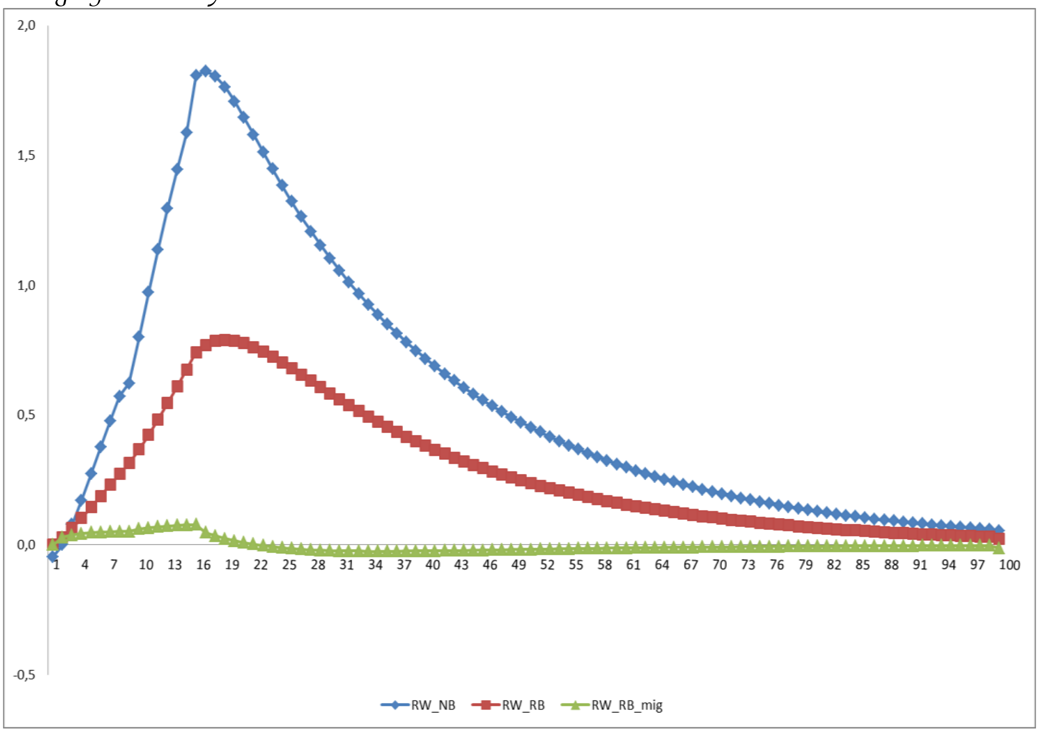
With regard to the GRP, LR results seems to confirm, as pointed out by existing literature on R&D-driven growth models, that public R&D investments induce domestic economic growth by increasing R&D capital. Since R&D products require a certain period of time to mature in the market these results cannot be achieved in a very short time (Bor, 2009). In fact the results suggest that supply-side impacts can take some time to build up, since price impacts are felt only gradually and it takes time for capacity to adjust. After GRP attains its maximum value with respect to the steady-state, it gradually diminishes (maintaining a positive trend) and converges to the origin.

More importantly, from figure 10, it is clear that the role played by labour market structure in determining the response of the regional economic system to an exogenous stimulus is significant.

Our results are qualitatively similar to those achieved in Lecca et al (2013) where the most important conclusion is that to achieve a determinate level of GRP, the required R&D subsidy is much smaller in the RB case. In fact, our results confirm that where wages are bargained locally the economic expansion associated with the investment program is higher than when compared with the NB case.

Once again, these differences are essentially related to the behaviour of real wages as shown in Figure 11. Where population update is allowed, the real wages increase is offset and partially reversed by the increase of labour supply that, in turns, reduces the bargaining power of workers. Indeed, even if there is no migration, the increase of the real wages is smaller as nominal wages decrease.

Figure 11. Time path adjustment of real wages for all model set-ups considered. Percentage changes from base-year value.



In terms of changes in employment, due to the stimulus to demand and labour productivity, employment increases in all scenarios in the mid-term and then gradually decreases as the stimulus is removed.

While in the case of a permanent supply-side shock we will get the effects identified in the previous section, we are not surprised by these results as we would expect that the variables return to their base year values since the policy shock in this analysis is prolonged but nevertheless temporary. Consequently, we would expect it to have only a temporary impact – at least in the absence of permanent hysteresis effects. The positive results we note simply reflect the fact that a new steady state equilibrium has not yet been attained.

6. Sensitivity

As mentioned in the model production structure description[31], we modify the production structure of the SGEM model so that we can test the results of the analysis for different degree of substitution between H and the K-L composite.
In fact, in the preceding simulations we set the value of elasticity of substitution[32] between capital-labour composite equal to 0.588 according to the estimation of Bontempi and Mairesse (2008) and, the value of 0.3 as default case for the degree of substitution between capital and labour.
Thus, in order to measure the sensitivity of our results in terms of productivity (GRP) we run the model setting different values of the above elasticities (σ) since, variation in the factor substitutions can be seen as key determinants of our results.
We perform the analysis for the case of regional bargaining labour market closure without migration.

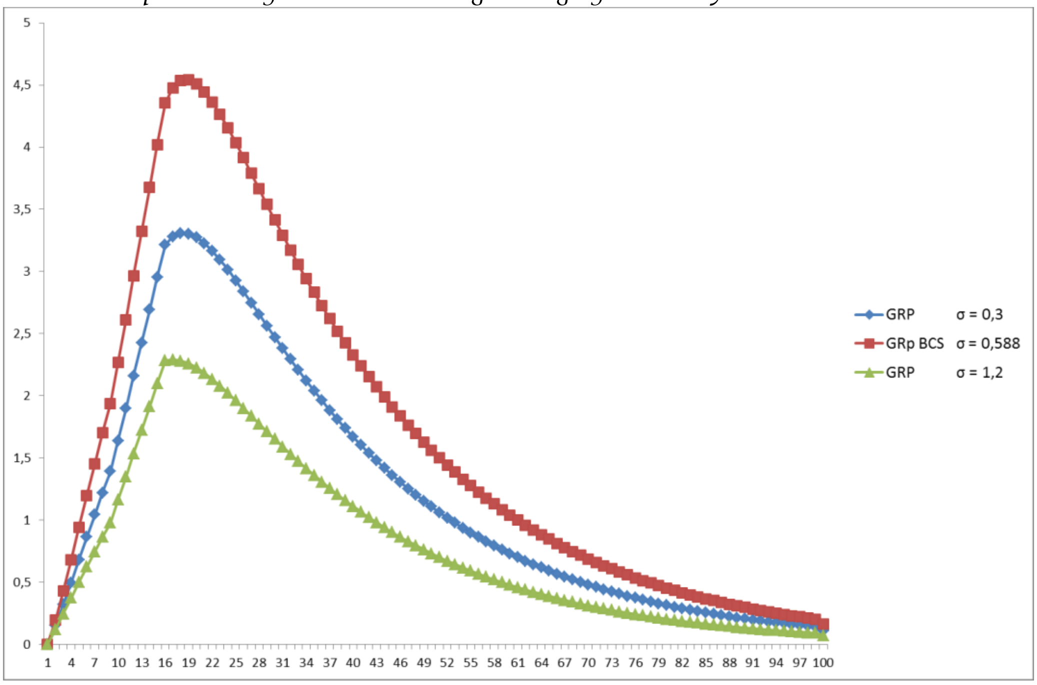
[31] See Section 4.
[32] In the value added function (see eq (1) to (3)).

We start by analyse the case in which different values for σ between capital-labour composite and knowledge (see equation (2)) are set at 0.3 and 1.2. In figure 12, the R&D investments impacts on GRP are shown.

With a high elasticity of substitution we would expect more substitution in favour of knowledge since its rental rate fall after the shock. However what we can see is that with a high elasticity of substitution (1.2) the impact on GRP is lower because the shock on knowledge investment is exogenous[33] thus preventing the intangible capital stock to increase further.

On the other hand if we reduce the elasticity of substitution (0.3) there will be relatively more substitution in favour of capital and labour with an additional activity expansion due to the output effect.

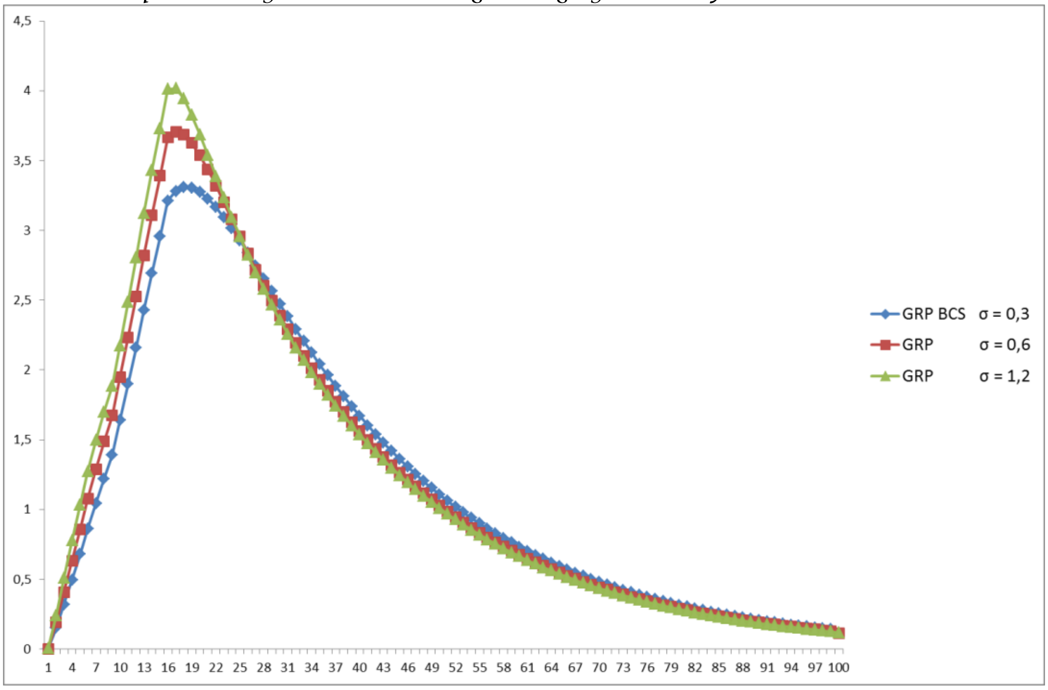
Figure 12. R&D Investment impact on GRP for different elasticity of substitution values in the value added production function. Percentage changes from base-year value.



[33] R&D investments are the policy variable.

Conversely, when we increase the σ values in the lower nest of the production function (see equation (3)) at 0.6 and 1.2 we obtain the expected results (Figure 13): with higher elasticity of substitution and, thus, higher substitution between capital and labour, the policy has a stronger impact on the economic system.

Figure 13. R&D Investment impact on GRP for different elasticity of substitution values in the value added production function. Percentage changes from base-year value.



7. Final comments

The aim of this chapter is to provide the first quantitative analysis of the effects of investments in R&D undertaken by the Region of Sardinia; this provides an analysis of the role of public investment in R&D with particular reference to its impact on long-term performance and interaction with other factors of production.

The evaluation is performed by using a CGE since R&D investments are intrinsically supply-side policies so that these models seem to be the best choice given that they explicitly incorporates a full specification of the supply side of the host region.

Furthermore, this modelling framework allows for greater flexibility related especially to the labour market closures, allowing for Regional and National bargaining

Our analysis indicates that public R&D investments induce domestic economic growth by increasing in R&D capital. The results suggest that supply-side impacts can take a time to build up, since price impacts are felt only gradually and it takes time for capacity to adjust.

Finally, these results suggest the Importance of CGE models when we have to consider a supply side policy. It is made clear the importance to consider extended lifetime of the investment to analyse the legacy impacts and the potential benefits derived by the implementation of these kinds of policies. , demonstrating that there are evidences of economic and social benefit, GDP and employment, from R&D investments. The latter confirms that this kind of analysis is an important guide to the policy makers who can have different scenarios on which they can base their decisions.

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Chapter 3

1. Introduction

By 2030 energy efficiency gains will reduce global energy consumption to approximately 30% below where it would otherwise be (Intergovernmental Panel on Climate Change of the United Nations, IPCC, 2007). The International Energy Agency (IEA, 2009) details the importance of efficiency improvement to reduce energy use and, within the European Union, one of the targets for member states is to reduce energy consumption by 20% through increased energy efficiency (European Commission, 2009).

The importance of energy efficiency policies is made clear by the European Economic and Social Committee (EESC) which states that "the increase in energy demand despite energy efficiency policies and measures will be one of the biggest challenges facing EU energy policy". However, the relation between increased energy efficiency and reduced energy consumption has been questioned due to the rebound effect.

From a simple engineering perspective, a given increase in energy efficiency would generate a reduction of energy consumption by the same amount. However from an economic perspective, an increase in efficiency will also reduce the price of energy in efficiency units with consequent substitution and income effects. Thus in the energy economic literature it is now widely accepted that the response to the introduction of new technologies aimed to save energy consumption is likely to be partially (or totally) offset by the demand response to a reduction in the effective price of energy services (or by the reduction of the price of energy in efficiency units). This is what is known as the rebound effect, initially identified[1] by Jevons (1865) and subsequently by Khazzoom (1980).

The improvement in energy efficiency stimulates demand for energy in production and/or consumption by reducing the price of effective energy services for each physical unit of energy used. The price reduction leads to different but related macroeconomic effects (such as positive substitution, output, competitiveness, etc.) that act to offset the decreases in energy consumption derived from the pure sufficiency effect.

According to Greening et al. (2000) and Barker et al. (2007), the rebound effect can be further classified as direct, indirect and wide general equilibrium rebound effects. Direct rebound effects are generally associated with substitution effects while indirect rebound effects are related to income/output effects. The economy-wide rebound effects correspond to new technologies that create new production possibilities and increased economic growth.

In this chapter we focus primarily on the economy-wide or general equilibrium rebound effects. According to the definition proposed by Sorrel (2007):

"economy-wide rebound effects represent the net effect of a number of mechanisms that are individually complex and mutually interdependent".

It is clear that the rebound effect appears to be general rather than partial equilibrium in nature and its magnitude depends on the price response of direct and indirect energy demands. For this reason, computable general equilibrium models (CGE) have been used to analyse the economy-wide impact of energy efficiency

[1] See also, Jevons,1865; Khazzoom, 1980; Brookes, 1990; Saunders,1992, 2000; Schipper, 2000

improvements. Also, since an efficiency improvement leads to a change in the production structure of the economy, any analysis of the impact will be incomplete without a thorough analysis of the supply-side effects.

Economy-wide rebound effects have been extensively analysed for energy efficiency improvements that occur within production especially using computable general equilibrium (CGE) modelling frameworks (see Dimitropoulos, 2007, for a review). However, to the best of our knowledge there are no studies that attempt to measure the economy-wide impacts of increased energy efficiency for the Italian economy.

Thus, we investigate and quantify the general equilibrium rebound effects using an inter-temporal, dynamic, multi-sectoral general equilibrium model developed for the Italian economy where dynamics arise from consumption and investment decision of forward looking economic agents; households and firms respectively. The model allows for labour market imperfections through a bargaining real wage equation (Blanchflower and Oswald, 1994). Furthermore the decisions of savings are separated from investment decision following the skeletal neoclassical growth model of Abel and Blanchard (1983). We consider four energy sectors in the model: coal, oil, gas and electricity. Thus we can analyse total energy rebound and energy rebound related to different type of energy source.

The remainder of the chapter is structured as follows. In Section 2 we present the economic concept of the rebound effect and how it is calculated. Section 3 reviews the relevant works on rebound effect analysed in a general equilibrium context and in Section 4 the model developed for Italy is described. In Section 5 we present and discuss the results of the simulations. In Section 6, a sensitivity analysis of the size of the rebound effect under different production function specification is carried out. Finally, we summarize the main conclusion and possible directions for future research in Section 7.

2. Defining rebound effect

We introduce the economic concept of the rebound effect providing its definition in terms of price elasticity[2] (Khazzoom, 1980; Berkhout et al., 2000 and Greene et al., 1999). According to the analytical approach used in Hanley (2006) and Turner (2009), firstly, we make a distinction between energy measured in physical units, E, and energy measured in units of efficiency, ε[3]. Secondly, we assume that factors augmenting technical progress increase at the rate ρ. The relation between the percentage change in the use of physical energy, $\dot{E}$, and the percentage change in the use of energy measured in units of efficiency, $\dot{\varepsilon}$, takes the following form:

$$\dot{\varepsilon} = \rho + \dot{E} \qquad (1)$$

The implication is that, an increase of energy efficiency of X% has an impact on the output (associated with a given amount of physical energy used) which is equivalent to an X% increase in the input energy, without the improvement of efficiency.

Any energy efficiency improvement has a corresponding impact on energy prices that, where energy is measured in efficiency units takes the form:

$$\dot{P}_{\varepsilon} = \dot{P}_E - \rho \qquad (2)$$

Where $\dot{P}_{\varepsilon}$ and $\dot{P}_E$ are the percentage change in energy price measured in efficiency and natural units respectively. Assuming $\dot{P}_E$ as constant, if efficiency increases, the

[2] See Sorrell and Dimitropoulos (2008) for a description of the different definitions of rebound and their implications.

[3] The measure in physical units can be any measure of the energy, for example kWh (kilowatt hours), while the efficiency units are a measure of real energy service.

$\dot{P}_{\varepsilon}$ reduction stimulates a rise in energy services demand: this is the source of rebound. In a general equilibrium context:

$$\dot{\varepsilon} = -\eta \dot{p}_{\varepsilon} \qquad (3)$$

Where η is the (positive) general equilibrium price elasticity of demand for energy (Turner, 2009) and, substituting (2) and (3) in (1) we obtain the energy (in natural units) demand change relation:

$$\dot{E} = (\eta - 1)\rho \qquad (4)$$

Rebound effect (R) expressed in percentage change, is calculated as (see Hanley et al., 2006):

$$R = \left[1 + \frac{\dot{E}}{\rho}\right] \times 100 \; or \; R = \eta \times 100 \qquad (5) - (6)$$

Thus, rebound effect identifies the extent to which the energy demand cannot be reduced in line with the increase of energy efficiency. In other words, when R is equal to 0 means that the use of energy is reduced in proportion to the increase of efficiency; when R is equal to 100, there is no change in the use of energy despite the improvement of efficiency; values between 0 and 100 mean that there is energy saving as a result of the improvements in energy efficiency but, it is lower than the efficiency improvement.

3. Review of evidence for rebound effect.

By and large we can identify seven general equilibrium effects following an improvement in efficiency in the use of energy: i) an engineering or pure efficiency effect; ii) a substitution effect; iii) an output/competitiveness effect (positive supply-side effect); iv) a compositional effect and v) an income effect on households (UKERC[4], 2007). Recent works (Allan et al., 2007 and Turner, 2009) identify two more, supply-side, effects: a negative multiplier effect (energy demand falls) and, finally, a disinvestment effect.

The two supply side effects play an important role in determining the magnitude of the rebound in the short and long-run. Saunders (2007) argues that long run rebound has to be greater than that in the short run because fixed supply in the short-run constrains the rebound in this period. However Turner (2009) show that the long run rebound can be lower than the short run.

Turner (2009) points out that in the in the work of Saunders the fixed capital rental rate prevent negative multiplier effects in the energy sector to arise. According to Turner (2009) with endogenous capital rental rate disinvestment effects may occur in the long run putting downward pressure on the rebound in this period. Thus, potential disinvestment effects might cause short-run rebound to be greater than the long run although the presence of economic growth.

The rebound effects estimated using numerical dynamic general equilibrium models vary widely in the literature. The reason for this rests on the structure of the KLEM production function, the price elasticity of energy demand in production, wage settings and treatment of capital market.

[4] United Kingdom Economic Research Centre.

For instance in Semboja (1994), a study applied to Kenya, electricity, other fuels, capital and labour are combined together in a composite that in turns substitutes with material inputs. The productions functions used are Cobb-Douglas and Leontief. As for the capital market, investment demand is treated as a fixed proportion of aggregate investment, allocated to the expansion of capital stock by sector. In the paper there is no discussion of labour market features. Disturbances take the form of an improvement in energy production efficiency (an increase in TFP in the energy sector) and an improvement in efficiency in the use of energy, which lead to an estimated rebound effect greater than 100% (backfire effects).

Glomsrød and Taoyuan (2005) study the rebound effect in China. Value added is the result of energy, capital and labour combine together using a Cobb-Douglas function. Total investments are savings driven and their sectoral allocation is based on sectoral share of total capital in the base year. Labour market is modelled with exogenous real wage with fixed labour supply. The energy efficiency improvement enters in the model by comparing business-as-usual dynamic scenario and a case where costless investments generate increased investments and productivity in coal sector, lowering price and increasing supply of cleaned coal. As with Semboja's work, the rebound in this case is more than 100% as well. A characteristic of this work is that the paper examines also the case in which the use of coal is subject to emission tax.

Vikstrom (2004) analyses rebound in Sweden adopting a nested CES production function approach where capital and energy combine together at the lower nest and then, this composite is combined with labour. The values range used for the elasticity of substitution is from 0.07 to 0.87. Accumulation of capital is not explicitly treated in this model. Savings are allocated to investments and their sectoral composition is allocated in line with a benchmark data set. Labour supply is fixed. The disturbance is a single simulation with 15% increase in efficiency of use of energy of non-energy sectors and 12% increase in efficiency of use of energy in energy sectors. Rebound values range from 50% to 60%.

Grepperud and Rasmussen (2004) in their analysis of the rebound effect for the Norwegian economy use a nested CES production function as in Vikstrom (2004). The elasticity of substitution between energy and capital differ between sectors. The model is shocked by doubling annual average growth rates of energy productivity at the sectoral level. In particular, the model considers six sectors, four where the electricity efficiency doubles and two where the oil efficiency doubles. With regard to rebound estimates, Oil sectors generally show small rebound, while rebound and backfire effects are found in electricity efficiency improving sectors.

In his study for Japan, Washida (2004) used a multi-level CES function in which value added is obtained by capital-labour composite combined with energy and the constant elasticity of substitution between energy and value added is set to 0.5. With regard to the capital closure, investment demand is included with government expenditure, firms demand for capital depends on cost of capital and the aggregate capital stock is kept fixed. The labour market is modelled with fixed aggregate supply of labour. The shock consists of a 1% change in the efficiency factor for use of energy in production in all modelled sectors. In the central simulation the rebound effect estimated is around 53%. Furthermore the paper shows that rebound effect increases as energy/capital-labour, labour/capital and level of energy composite substitution elasticities increase.

Finally, Allan et al. (2006), Hanley et al. (2005) and Turner (2009) use a similar model, which is a variant of the AMOSENVI and UKENVI[5] model to investigate the rebound effect in Scotland and UK respectively. The production of gross output is

[5] A micro macro model for Scotland plus environment and UK environmental model.

obtained by combining value added (capital and labour) and intermediate inputs which in turn are a CES combination between Energy and Material. The elasticity of substitution between energy and material is set to 0.3. The capital closure consists of a period-by-period capital stock updating in line with difference between actual and desired capital stocks; when desired and actual capital stocks are equal to those required by the economy for long run equilibrium. Labour market imperfections are modelled via a bargained real wage equation (Blanchflower and Oswald, 1994). They simulate a 5% improvement in efficiency of energy use across all production sectors (including energy sectors). The magnitude of the rebound is greater than 100% for Scotland and 37% for the UK.

4. The Model for Italy[6]

4.1. General model features

As mentioned above, In this work we analyse and quantify the impact of an efficiency improvement in the industrial use of energy in Italy. The analysis is performed by using a numerical general equilibrium model.

The model's dynamic structure allows us to model agents with either forward looking or myopic expectations. In the second case, the structure and the dynamics of the model are recursive (or can be solved simultaneously maintaining the absence of forward-looking agents' behaviour) and agents use adaptive expectation abstracting from future periods. In the rational expectation case, where all periods of the model have to be solved simultaneously, firms and consumers have perfect foresight and react to anticipated future events.

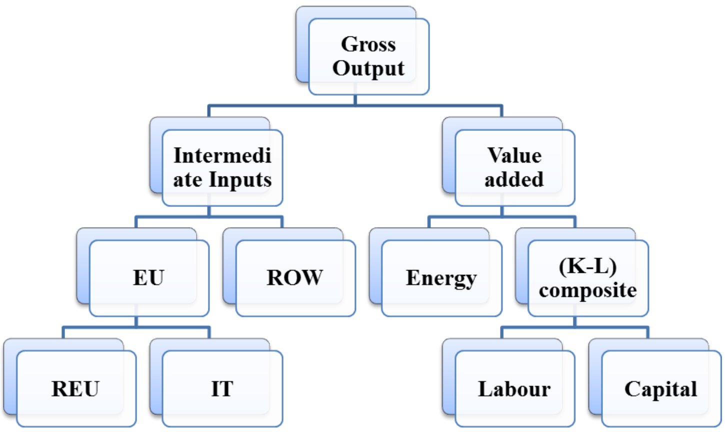
[6] The mathematical presentation of the model is provided in Appendix A

The model incorporates 21 industries, 4 of which are energy sectors (Coal, Oil, Gas and Electricity)[7]. With regard to the production side, it is characterized by cost minimization with standard production functions. Firms sell output in competitive markets. In the simulations carried out throughout, the work wage setting follows a bargaining procedure where the real wage is inversely related to the unemployment rate.

4.2. Production structure

The production structure of the model is represented by a nested production function reported in Figure 1[8]. Three institutional sectors (firms, households and government) and two external sectors (rest of Europe, ROE and rest of the World, ROW) are considered.

Figure1. The model's production structure



Value added is given by a CES combination of energy and capital and labour composite. First order conditions of profit maximisation provide the demand

[7] The structural breakdown is reported in Table 1.
[8] Figure 1, refers to the production structure specification used in the Central Case Scenario.

equations for these inputs. The gross output is obtained by value added and the intermediate inputs combined in a Leontief technology production function. Intermediate inputs can be purchased in the domestic market or imported from the Rest of Europe (ROE) and from the Rest of the World (ROW). Regional and imported goods are combined under the so called Armington assumption through a CES function with intermediate goods produced locally or imported considered as imperfect substitutes.

Finally, each economic sector considered produces goods and services that can be sold in the national market ore exported. Thus, an export demand function closes the model where the foreign demand for Italian goods depends on the terms of trade effect and on the export price elasticity.

4.2.1 Introducing Energy to KLEM nested production function

We use the well-known KLEM approach and Energy is treated as a component of the Value Added. As pointed out in Lecca et al. (2011), the use of nested CES production function is common in studies that use KLEM production function (Chang, 1994; Kemfert, 1998; Kemfert and Welsch, 2000; Kuper and Van Soest, 2002; Prywes, 1986). Figure 1 implies that:

$$KLEM_i = \left[\alpha_{(KL)EM,i} KLE_i^{\frac{\sigma_{(KL)EM,i}-1}{\sigma_{(KL)EM,i}}} + (1-\alpha_{(KL)EM,i}) M_i^{\frac{\sigma_{(KL)EM,i}-1}{\sigma_{(KL)EM,i}}} \right]^{\frac{\sigma_{KLEM,i}}{\sigma_{(KL)EM,i}-1}} \qquad (7)$$

$$KLE_i = \left[\alpha_{(KL)E,i} KL_i^{\frac{\sigma_{(KL)E,i}-1}{\sigma_{(KL)E,i}}} + (1-\alpha_{(KL)E,i}) E_i^{\frac{\sigma_{(KL)E,i}-1}{\sigma_{(KL)E,i}}} \right]^{\frac{\sigma_{KLE,i}}{\sigma_{(KL)E,i}-1}} \qquad (8)$$

$$KL_i = \left[\alpha_{KL,i} K_i^{\frac{\sigma_{KL,i}-1}{\sigma_{KL,i}}} + (1-\alpha_{KL,i}) L_i^{\frac{\sigma_{KL,i}-1}{\sigma_{KL,i}}} \right]^{\frac{\sigma_{KL,i}}{\sigma_{KL,i}-1}} \tag{9}$$

Where K, L, E, M are capital, labour, energy composite goods (Coal, Oil Gas, Electricity) and intermediate inputs respectively. KL and KLE are capital labour composite and capital-labour energy composite. σ is the elasticity of substitution and it assumes different values at each nest[9].

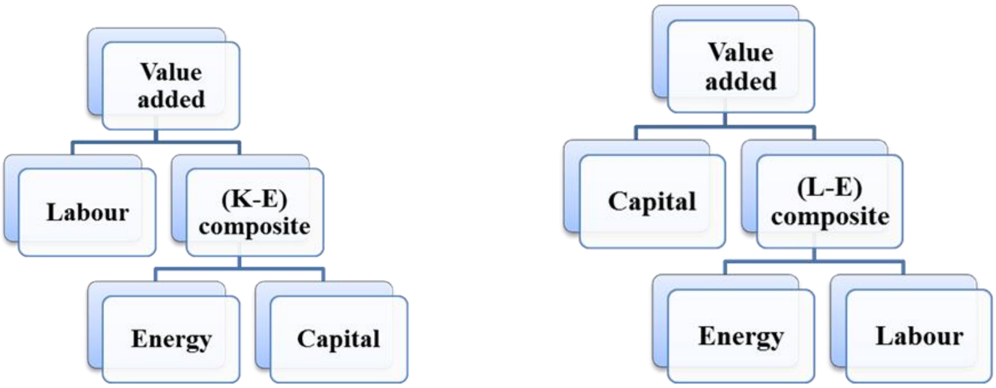
There is still a debate on the appropriate specification of the KLEM production function, in particular on how energy should combine with other inputs since, as demonstrated in Lecca et al. (2011), different combinations of the KLEM production function specification can lead to different estimates of the size of rebound. Thus, in order to show the importance of the separability assumption, we perform a sensitivity analysis by changing the structure of the production function itself and calculating (under the same disturbance) the size of the rebound in the case of Energy combined with Capital (Case A) or Labour (Case B), as shown in Figure 2.

Essentially, we modify the way in which value added is obtained: KL composite and E in the central case, KE composite and L in case A and, finally, LE and K in the last case (B).

[9] See paragraph 4.6

Figure 2. Alternatives KLEM production function specification.

Case A. Energy in Value-Added – (KE) +L *Case B. Energy in Value-Added – (LE)+K*



4.3. Consumers[10]

Following Go, 1994 and Devarajan et al., 1998, the representative consumer maximizes his discounted Utility (U) of aggregate consumption, as summarized by the lifetime utility function which takes the following form:

$$Max\sum_{t=0}^{\infty}(1+\rho)^{-t}\frac{C_t^{1-\nu}-1}{1-\nu} \qquad (10)$$

Where C is the consumption at time period t, ν is the constant elasticity of marginal utility[11] and ρ is the constant rate of time preference. It is a homogeneous utility function, additively separable and U is discounted by the consumer's constant and positive rate of time preference. The dynamic budget constraint takes the form:

[10] See Chapter 1.

[11] In the model its value is set to 1.2. Note that we do not test the sensitivity of our results to different constant elasticity of marginal utility since in the long run (steady state) the consumption rate is constant. Indeed, the time path of consumption to the long run equilibrium would be different for different elasticity values.

$$\dot{W} = Y_t + r_t W_t - Pc_t C_t \tag{11}$$

Where

$$\mathrm{W}_t = FW_t + NFW \tag{12}$$

Y is the current income, W is wealth, financial (FW) and non-financial (NFW) wealth[12]. In particular, FW is defined as the present value of the future capital income and NFW as the discounted labour income after tax plus net transfers from government.

The budget constraint ensures that the discounted present value of consumption must not exceed total household wealth (W). Once the optimal path of consumption is obtained from the solution of the inter-temporal problem, the aggregate consumption is allocated between sectors through a constant elasticity of substitution (CES) function. Household demand for regional and imported goods is the result of the intra-temporal cost minimization problem and similar to the production side, domestic and imported commodities are imperfect substitutes.

4.4. Investment[13]

Investment decision is modelled following the works of Abel (1980) and Hayashy (1982). The rate of investment is a function of marginal q (or average q) defined as the ratio of the value of firms (VF) to the replacement cost of capital (Pk·K). The path of investment is obtained by maximizing the present value of the firm's cash flow given by profit (π) less private investment expenditure, subject to the presence of adjustment cost g where:

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[12] See appendix A.

[13] See Chapter 1

$$\text{Max} \sum_{t=0}^{\infty} \frac{1}{(1+r)^t} [\pi_t - I_t(1+g(x_t))] \qquad \text{subject to } \dot{K}_t = I_t - \delta K_t \qquad (13)-(14)$$

The solution of the dynamic problem gives us the law of motion of the shadow price of capital, and the time path of investment related to the tax-adjusted Tobin's q (Tobin, 1969). Moreover, since adjustment cost g is quadratic, the direct implication is that firms are unable to achieve the desired stock of capital immediately.

4.5 Labour Market

The labour market is characterized by imperfect competition, the wage rate is not obtained by the first order condition but it is determined through a wage bargaining function (wage curve) as in Blanchflower and Oswald (1994) according to which real wages and unemployment are negatively related:

$$\ln(W_t) = \beta_u - \mu * \ln(u_t) \qquad (15)$$

Where W is the consumption wage defined by the ratio w/cpi (cpi is the price consumer index), β is the value at the steady state, μ is the elasticity (of wages) and it is related with regional unemployment rate (u). The wage-unemployment elasticity is -0.03 as estimate in Devicienti et al., 2008. Indeed, this closure implies wages flexibility so that they respond to the local excess demand for labour. There is no change in natural population.

4.6 Dataset and model parameterization

The benchmark data set is the Italian Social Accounting Matrix (SAM) for the year 2006 developed by us through the make and use tables provided by ISTAT (2010)[14]. Data related on energy consumption by industries and final consumers were provided by ISTAT (2011). The Table below reports energy use for four types of fuels in million tons of Oil Equivalent (TOE).

Table1. Energy consumptions for four types of fuels. Millions of Tons of Oil Equivalent (TOE).

	COAL	OIL	GAS	ELECTRICITY
Agriculture, forestry and logging	0,000	2,378	0,140	0,396
See fishing and See firming	0,000	0,225	0,000	0,033
Mining and extraction	0,000	0,234	0,068	0,147
Mfr food, drink and tobacco	0,210	0,488	2,334	1,040
Mfr textiles and clothing	0,043	0,425	1,619	0,652
Mfr chemicals etc	0,873	4,624	7,066	3,430
Mfr metal and non-metal goods	7,260	4,105	7,293	3,202
Mfr transport and other machinery, electrical and inst eng	0,041	0,932	1,572	2,222
Other manufacturing	0,003	0,167	0,145	0,249
Water	0,000	0,015	0,000	0,506
Construction	0,001	4,611	0,120	0,137
Distribution	0,004	5,746	0,783	2,627
Transport and Communications	0,011	15,041	0,165	1,236
finance and business	0,000	0,250	0,066	0,201
R&D	0,001	1,994	0,257	1,177
Education	0,000	0,138	0,337	0,128
Public and other services	0,975	1,795	1,214	1,329
COAL (EXTRACTION)	0,000	0,000	0,000	0,000
OIL (REFINING & DISTR OIL AND NUCLEAR)	0,845	99,797	2,557	0,489
GAS	0,000	0,039	0,001	0,000
Electricity	9,460	9,182	25,660	3,520

Source: our elaboration on data provided by ISTAT, 2011

With regard to the parameters of the model, most of them are obtained from the SAM by the well-known calibration method. However some behavioural and structural parameters are based on econometric estimation or best guesses.

For all the simulations carried out in section 5 and for all sectors considered, the elasticity of substitution between primary factors of production (KLE) are taken

[14] The SAM for Italy related to 2006 is reported in Appendix B

from the work of Van Der Werf (2008) who estimates these values also for Italy[15] and where the test for common elasticity over the two nests leads to the result that the production function for ITALY could not have a single elasticity of substitution and hence it has to be nested.

Furthermore, following Sorrel (2008), one of the most important criticism moved to the CGE models results is that, often, they are very sensitive to the best guess estimations of elasticity of substitution that, in turn, are estimated using different production function specification, trans-log or Cobb-Douglas for example. Instead, Van Der Werf elasticity are estimated using all the three nested KLE-CES production functions specification we used in this work so that we can overtake the problem above. In Table 2 elasticity values are shown[16].

Table2. Elasticity of substitution used in the value added nested CES production function.

Central Case	*Case A*	*Case B*
$\sigma_{(KL)E} = 0.2417$	$\sigma_{(KE)L} = 0.9218$	$\sigma_{(LE)K} = 0.4651$
$\sigma_{KL} = 0.5216$	$\sigma_{KE} = 0.9799$	$\sigma_{LE} = 0.8037$

[15] To the best of our knowledge, there are no other econometric estimations of these elasticity for Italy.

[16] In table 2 we named Central Case the value added specification depicted in Figure 1 and formalized in equation (7) – (9). (KL)E form appears to be more popular and is used, between others, in Bosetti et al. (2006) (the WITCH model), Manne et al. (1995) (the MERGE model), Paltsev et al. (2005) (the EPPA model). Moreover, In Van der Werf (2008), the goodness of fit of the nesting structures (KL)E, (KE)L and (LE)K) was investigated and, based on the R-squared, Van der Werf concluded that the (KL)E structure mostly fits the data.
Moreover, the work of Medina and Cervera (2001), where a trans-log cost function is estimate for Italy and Spain, concludes that only for Italy, there is an higher substitution of labour in favor of energy (confirmed also by the values estimated in Van Der Werf, Table 2.). Thus, the reason to include also this specification

5. Simulation set up and results discussion.

The disturbance simulated is an exogenous and costless improvement of 1.014% in the efficiency of energy inputs used by all production sectors (use-efficiency shock). The size of the shock is determined according to the rates of factor-specific technological change for Italy estimated by Van Der Werf (2008) for the production structure we used.

We perform the shock as one-off step change in energy efficiency use[17]. Thus, a positive supply-side disturbance is introduced which would be expected to reduce the price of energy measured in efficiency units, the price of outputs and, in turn, stimulating economic activity. In other words, for each sector, there is a 1.014% increase in the efficiency with which energy combines (for the Central Case) with the KL composite to produce value added.

The resulting changes in key energy and economic variables due to the shock are reported, unless otherwise specified, in terms of the percentage change from the base year values given by the 2006 Italian SAM. Moreover, the economy is calibrated to be in long-run equilibrium so that we are able to run the model forward in the absence of any disturbance in order to replicate the base year dataset in each period. We refer to percentage changes in the endogenous variables relative to the initial steady state equilibrium; hence all the effects detected can be directly attributed to the stimulus to energy efficiency use.

[17] Note that in our analysis, we apply the efficiency shock not only to the use of domestically supply energy (as in the Turner (2007), Allan et al. (2006)), but also on imported energy inputs. Thus, we can expect that simultaneous efficiency improvements in imported energy might lead to even higher economy-wide rebound impacts because there will be a stronger decline in the actual prices of energy than that when productivity improvements occur only in domestic production.

Two time frames are considered: short run and long run. We refer to the short run as the first period (year) after the efficiency policy implementation and supply constraints (capital stocks are fixed at their base year values) are imposed. Conversely, in the long run, constraints are removed and capital stocks adjust fully to their desired sectoral values, given the efficiency shock and a fixed interest rate. In the next paragraph, results for the central case scenario are discussed and, in the subsequent paragraph, a comparison of the estimated rebound size obtained with the alternative KLEM production function (Figure 5) is made.

5.1. Central Case Scenario results

We present the results for the central case scenario (CCS). The characteristic of this shock is such that the increase in efficiency introduces a positive supply-side disturbance, whose primary effect is to raise production efficiency, particularly in energy intensive sectors. The efficiency gains stimulate economic activity through downward pressure on the prices, including the price of energy output since the energy supply sector itself is typically energy intensive.

The percentage changes from the initial steady state are shown in Table 3[18]. The energy efficiency improvements increases generate an increase in economic activity from the outset. GDP increases by 0.06% and 0.19% in the short and long-run respectively. Employment rises in both time frames by 0.06% and 0.13%. In the long run, changes in employment are lower than the GDP reflecting an increase in the capital-labour ratio. As regard to GDP and employment short run values and, considering the assumption made for this time frame, one would expect to find changes in employment larger than those in GDP. However, in this case the combined effects of the large fall in energy suppliers sector output and those

[18] The first column in Table 3 reports the "labels"used in the model.

induced in all the other sectors by the efficiency shock, lead to changes in GDP values slightly higher than those in employment (this cannot be seen in the Table since we are reporting two digits figures).

The increase in efficiency in the industrial use of energy reduces the price of energy, measured in efficiency units, which in turn tend to lower the price of output (and commodities) not only in the energy sector (see Figure 3). This stimulates competitiveness with additional effect on economic activity. From Table 3 we see that total exports increase in all sectors, especially in the energy intensive sectors through a reduction in their relative price.

In the short and long run total import of goods and services are below their steady-state values. This drop in imports can be explained by the fall in the price of locally produced goods relative to the price of goods and services imported from the ROE and ROW. This also means that the relative price effect dominates the positive stimulus that arises from the expansionary effect on the economic activity. Both in the short and long-run, real wages rise since the increase in energy efficiency stimulates labour demand, increasing the bargaining power of workers that now can claim for more real income.

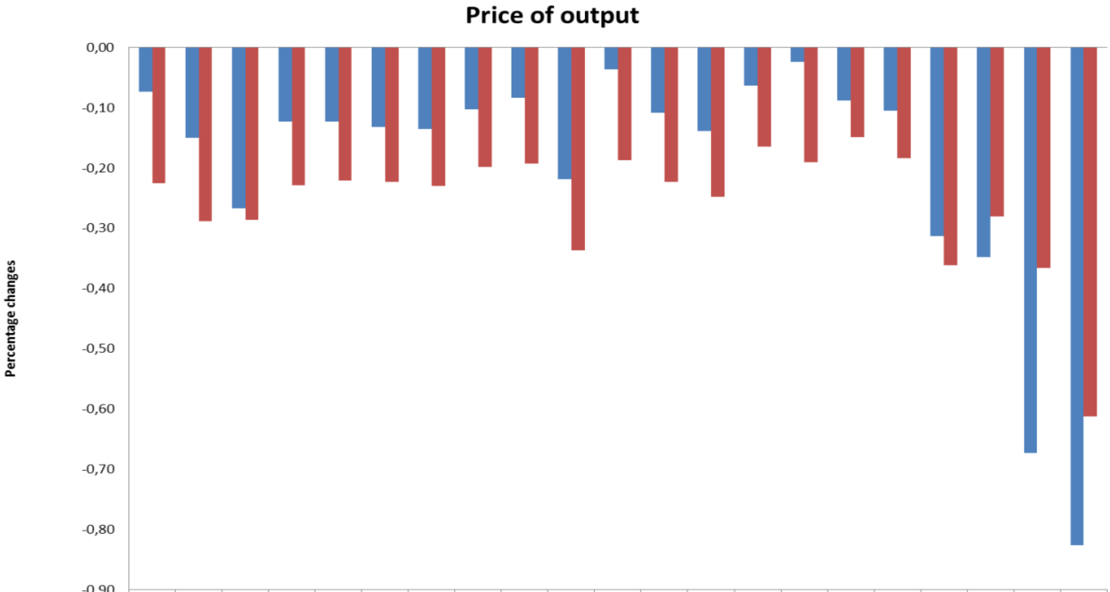
From Figure 3, where the impact on output price is shown, sectoral differences that generally reflect the energy intensity of the sector are immediately clear. In the long run, prices in the manufacturing (no chemicals or metals) and essentially service sectors show a smaller decrease, reflecting the relatively low use of energy inputs in these sectors; the largest impact on the price of output, generally, comes in the four energy sectors themselves both in the short and long run. This is the result of the production techniques in these sectors. The largest reductions in price occur in electricity and gas sectors. In these sectors together with oil sector, the fall in the long run price is smaller than the short run one; coal sector, however show the opposite due to demand effect, i.e. the exports increase.

In order to clarify the short run behaviour of prices illustrated above, we need to consider that the marginal cost of production of value added is upward sloping due to supply constraints (Allan et al., 2007). Thus, if the demand for a sector's value added increase, ceteris paribus, we would expect an increase in the price of value added, with a corresponding rise in the capital rental rate in that sector. Conversely, where the demand for a sector's value added falls, the price will fall and so does capital rental rate and investments. In our analysis, however, after the disturbance, in short run value added and capital rental rate rise in all non-energy sectors but value added price fall due to the fall in the energy price composite.

In Figure 4, we show the short and long run sectoral changes in output. As one would expect, the increased efficiency in energy use has increased the output of all non-energy sectors with the exception of mining sector. In the education and public services sectors, output increase is smaller than the other non-energy sectors reflecting their lower energy intensities.

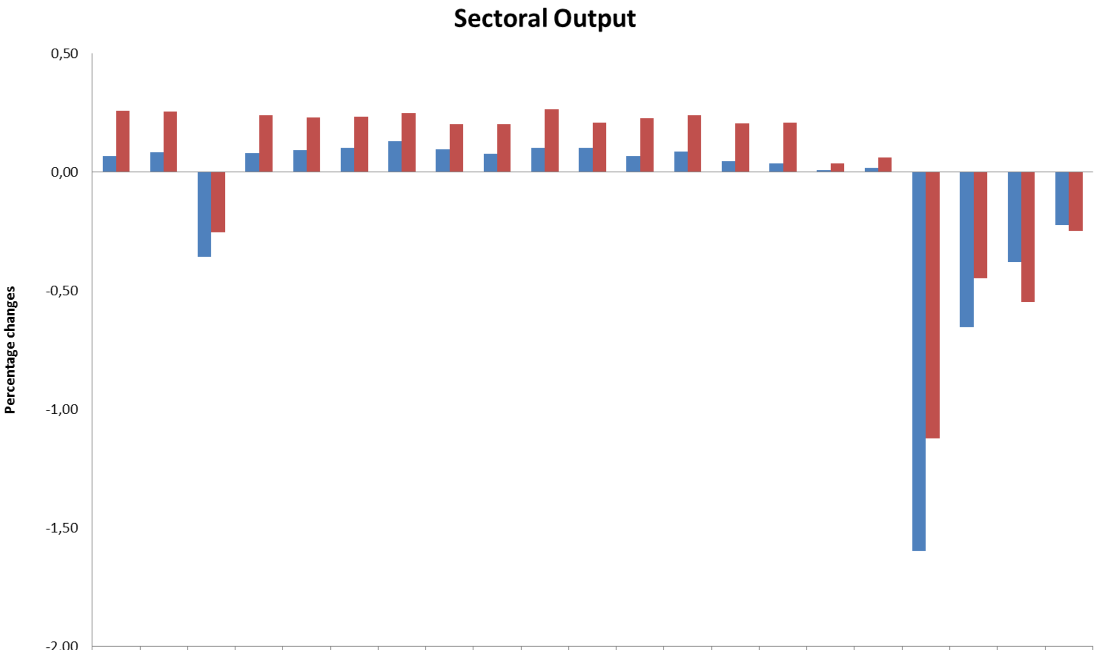
On the other hand, the output of the four energy sectors falls in both the short and long run, and, long run reduction is greater for Electricity and Gas sectors. As regard to the Coal and Oil the large reduction in price in the short run go to offsetting the fall in demand that occurs in the short run. However note that in both the short and long run, the reduction in output is less than the 1.014% improvement in energy efficiency use. Coal is the exception and it can be explained looking at the very low industrial demand for coal (See table1) where the efficiency improvement has a stronger impact on this sector. In the next section, the rebound effect raised from the disturbance is described.

Figure3. Percentage changes in price of output in Italian production sectors in response to a 1,014% increase in energy efficiency in all sectors



	AFL	SFF	MAE	FDT	TEX	CHE	MNM	MTR	OTM	WAT	CON	DIS	TRA	CFB	ENE	EDU	POS	COAL	OIL	GAS	ELE
Output price SR	-0,07	-0,15	-0,27	-0,12	-0,12	-0,13	-0,14	-0,10	-0,08	-0,22	-0,04	-0,11	-0,14	-0,06	-0,02	-0,09	-0,10	-0,31	-0,35	-0,67	-0,83
Output price LR	-0,23	-0,29	-0,29	-0,23	-0,22	-0,22	-0,23	-0,20	-0,19	-0,34	-0,19	-0,22	-0,25	-0,16	-0,19	-0,15	-0,18	-0,36	-0,28	-0,37	-0,61

Figure4. Percentage change in output in Italian production sectors in response to a 1,014% increase in energy efficiency in all sectors



	AFL	SFF	MAE	FDT	TEX	CHE	MNM	MTR	OTM	WAT	CON	DIS	TRA	CFB	ENE	EDU	POS	COAL	OIL	GAS	ELE
Output SR	0,07	0,08	-0,36	0,08	0,09	0,10	0,13	0,10	0,08	0,10	0,10	0,07	0,09	0,05	0,04	0,01	0,02	-1,60	-0,65	-0,38	-0,22
Output LR	0,26	0,25	-0,26	0,24	0,23	0,23	0,25	0,20	0,20	0,26	0,21	0,23	0,24	0,20	0,21	0,04	0,06	-1,12	-0,45	-0,55	-0,25

Table 3. Summary impacts in percentage changes from the initial steady state.

		SR	LR
	GDP	0,06	0,19
	Consumer Price Index	-0,11	-0,22
	Unemployment Rate	-0,54	-1,17
	Total Employment	0,06	0,13
	Nominal Gross Wage	-0,07	-0,11
	Real Gross Wage	0,05	0,11
	Total Import	-0,17	-0,14
	Energy output	-0,49	-0,49
	Non Energy output	0,06	0,19
Investiment			
AFL	Agriculture, forestry and logging	0,25	0,26
SFF	See fishing and See firming	0,22	0,24
MAE	Mining and extraction	-1,34	-0,22
FDT	Mfr food, drink and tobacco	0,22	0,25
TEX	Mfr textiles and clothing	0,24	0,25
CHE	Mfr chemicals etc	0,30	0,25
MNM	Mfr metal and non-metal goods	0,40	0,27
MTR	Mfr transport and other machinery, electrical and inst e	0,27	0,22
OTM	Other manufacturing	0,22	0,22
WAT	Water	0,26	0,25
CON	Construction	0,39	0,22
DIS	Distribution	0,20	0,24
TRA	Transport and Communications	0,23	0,24
CFB	finance and business	0,13	0,23
ENE	R&D	0,17	0,22
EDU	Education	-0,07	0,07
POS	Public and other services	-0,05	0,08
COAL	COAL (EXTRACTION)	-4,91	-1,08
OIL	OIL (REFINING & DISTR OIL AND NUCLEAR)	-2,23	-0,43
GAS	GAS	-2,31	-0,57
ELE	Electricity	-1,63	-0,32
Export			
AFL	Agriculture, forestry and logging	0,07	0,20
SFF	See fishing and See firming	0,13	0,26
MAE	Mining and extraction	0,24	0,26
FDT	Mfr food, drink and tobacco	0,11	0,21
TEX	Mfr textiles and clothing	0,11	0,20
CHE	Mfr chemicals etc	0,12	0,20
MNM	Mfr metal and non-metal goods	0,12	0,21
MTR	Mfr transport and other machinery, electrical and inst e	0,09	0,18
OTM	Other manufacturing	0,08	0,17
WAT	Water	0,20	0,30
CON	Construction	0,03	0,17
DIS	Distribution	0,10	0,20
TRA	Transport and Communications	0,12	0,22
CFB	finance and business	0,06	0,15
ENE	R&D	0,02	0,17
EDU	Education	0,00	0,00
POS	Public and other services	0,09	0,17
COAL	COAL (EXTRACTION)	0,28	0,33
OIL	OIL (REFINING & DISTR OIL AND NUCLEAR)	0,31	0,25
GAS	GAS	0,61	0,33
ELE	Electricity	0,75	0,55

5.1.1 Italian Economic wide-rebound effect

As shown in Table 3, there is evidence of economy-wide rebound effects[19] after the improvement in efficiency in the energy use: 20.6% in the short run and 26% in the long run. In other words, after the disturbance simulated, from a general equilibrium perspective, does not correspond a reduction of energy consumption of the same size (the pure engineering effect).

However, for this production function specification the magnitude of the rebound for Italy is quite small when compared with those found in other empirical works (Section 3). However, sensitivity analysis is required to test the robustness of the findings.

As pointed out in section 3, rebound effects may arise from the more efficient use of energy and they are determined by different and related effects. Firstly the efficiency effect takes place since energy demand falls because a lower amount of energy input is necessary to produce a given level of output. Secondly, the price of using energy relative to other inputs falls, inducing a positive substitution effect in favour of energy. Thirdly, there is a change in the composition of output at the aggregate level since the more energy-intensive products benefit most from the fall in energy prices (actual and/or current): composition effect.

Figure 4, in fact, shows that in the more energy intensive sectors there are larger increases in output in the long run. Also, as in the previous section, output price falls in all sectors directly involved by the disturbance, (all sectors here) so that there is an increase in economic activity and associated energy use that leads to increase exports (competitiveness effect). Finally, the income effect: incomes

[19] Note that in in this analysis we divided the economy wide rebound effect in sectoral specific rebound: coal, oil, gas and electricity (Table 4).

increase and have a further positive impact on production and consumption activity levels, including energy use.

Moreover, where energy is locally produced and is an input to energy production itself, as in the case of Italy, there are two additional effects (supply side response to the disturbances that take place). We discuss them in turn; a negative multiplier effect (Turner, 2009) and the disinvestment effect (Allan et al., 2007). The former arises from the reduction in energy demand, -0.95% in the short run and -0.91% in the long run (Table 3), caused by the improvement in energy efficiency and, if it is strong enough to "entirely offset increased energy demand at the macro-level", there is a negative economy-wide rebound effect (Turner, 2009. We find such a result in the case of Coal and Oil in the short run, -39% and -20% respectively.

The second effect arises from the initial reduction in demand for the output of energy suppliers sectors which causes a contraction in the market price as confirmed by the fall of output shown in Figure4. Thus, if disinvestment effect is large enough, short run rebound may be greater than long run rebound as pointed out in the analysis carried out for the UK economy (Allan et al., 2007 and Turner, 2009).

Such a result is the opposite of what we have obtained but in line with the theoretical provision of Saunders (2007) who argues that where supply side constraints are removed long run rebound is larger because of economic growth. Looking at the sectoral rebounds (Table 4), in the case of gas there is evidence of a long run rebound (26.6%) smaller than the short run (39.5%) one, so that the long run disinvestment effect in this case is large enough to constrain the related long-run rebound effect. As regard to the Electricity we obtain the same size of rebound for both time periods (around 60%) and the fall in output is almost the same for both time frames; hence, the explanation of our results arise from Coal (-40% in short run and 2% in long run) and Oil (-19% and 15% in long run) sectors behaviour;

firstly, the very high negative multiplier effect in Coal and Oil sector. Thus, the explanation of these results can be found in the export orientation of Italian energy suppliers.

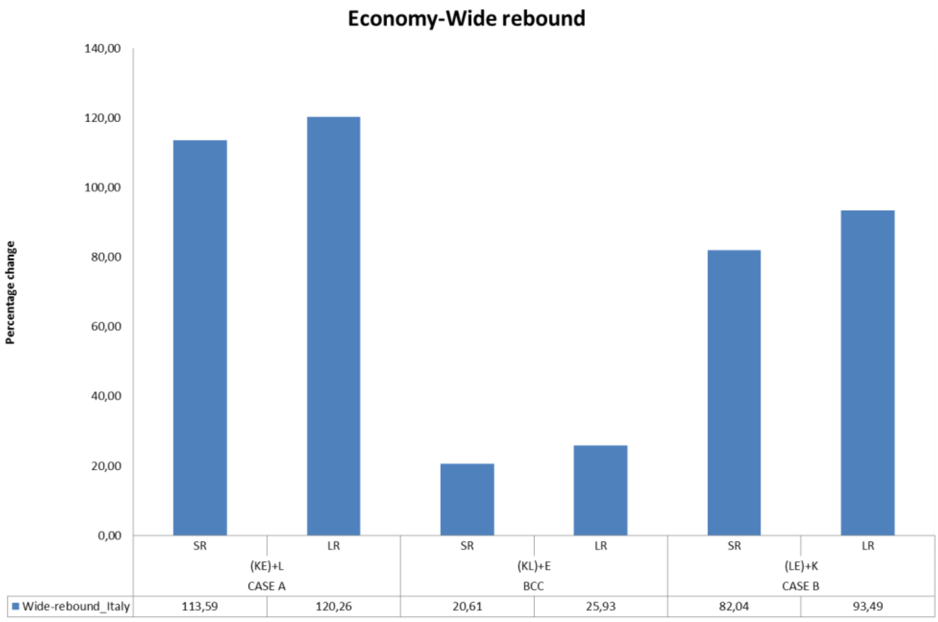
Table 4. Economy-Wide Rebound. Base Case Scenario percentage changes.

	SR	LR
Economy-wide rebound	20,61	25,93
Coal	-39,6	1,773
Oil	-19,2	15,32
Gas	39,53	26,64
Electricity	59,33	60,84
Energy output	-0,49	-0,49
Total Energy demand by industries	-0,95	-0,91

5.2. Alternative KLEM specification, Case A and Case B.

We start considering the estimated size of the rebound effect obtained modifying the way in which valued added composite is obtained, bearing in mind that the disturbance simulated is the same as in the CCS. In Figure 5, we see that, compared to the CCS, Case A and Case B show a very high rebound effects. For case A the rebound effects is above 100% (backfire effect): 114% and 120% in the SR and LR respectively. The reason why for Case A we obtain such a huge rebound effect is the positive change in domestic energy consumption and total energy demanded by industry as we show in Table 5. Consequently, also energy and non-energy output increase (0.26% and 0.21% in the LR, respectively).

Figure 5. Economy-Wide Rebound. Central Case Scenario, Case A and Case B percentage changes.



On the other hand, if we look at the Case B, we find LR rebound effects very close to 100%, situation in which the efficiency gains are completely offset by the increased demand for energy and, in fact, domestic energy consumption in the LR in quite similar to steady-state, only 0.05% above (Table 5).

In terms of economic growth (GDP), in the LR, we have the lower value (0.19%) in the CCS and the higher in Case A and B, 0.22% and 0.23% respectively.

Clearly, one has to be very carefully in analysing these figures since we are comparing not only results derived from different Value added specification but, more important, at each nest, we set the elasticity of substitution estimated in Van Der Werf (2008) for the corresponding KLE combination and their values range are from 0.24 to 0.98[20]. In fact, as pointed out in the conclusions drawn by previous theoretical analysis (Sorrell, 2007, and Sounders, 2008) the role played by these elasticities is the most important in determining the size of rebound effects.

Thus, in the next paragraph we conduct a sensitivity analysis on CCS, Case A and Case B in order to discuss the role played by both the elasticity of substitution between factors and, also, if the different KLE specification can lead to different results.

Table 5. Summary impacts in percentage changes from the initial steady state.

	CASE A (KE)+L		CCS (KL)+E		CASE B (LE)+K	
	SR	LR	SR	LR	SR	LR
GDP	0,14	0,22	0,06	0,19	0,09	0,23
Consumer Price Index	-0,20	-0,27	-0,11	-0,22	-0,16	-0,27
Unemployment Rate	-0,27	-0,66	-0,54	-1,17	0,10	-0,67
Total Employment	0,03	0,07	0,06	0,13	-0,01	0,07
Nominal Gross Wage	-0,18	-0,21	-0,07	-0,11	-0,17	-0,21
Real Gross Wage	0,02	0,06	0,05	0,11	-0,01	0,06
Total Import	-0,07	-0,05	-0,17	-0,14	-0,10	-0,07
Energy output	0,21	0,26	-0,49	-0,49	-0,04	0,05
Non Energy output	0,12	0,21	0,06	0,19	0,09	0,22
Domestic Energy consumption	0,22	0,27	-0,54	-0,54	-0,05	0,05
T.Energy demand by industries	0,12	0,17	-0,95	-0,91	-0,23	-0,14

6. Sensitivity analysis.

We perform the sensitivity analysis comparing the effects of the simulated energy efficiency gains when the degree of factor substitution in the KLEM - CES function are set to σ =0.01, σ =0.9, σ = 0.5 and a scenario where technology is more flexible, σ =1.5.

We select the elasticities of substitution subject to sensitivity analysis considering those that affect the upper nest in which energy is combined with another input, and the lower nest where the KLEM composite or domestic production is obtained.

[20] See Table 2 in Section 4.

Additionally, this simulation strategy allows comparing and drawing conclusions about the relevance that KLEM separability assumptions might have over the evaluation of energy and environmental policies in general and, particularly, over the economy-wide rebound effects.

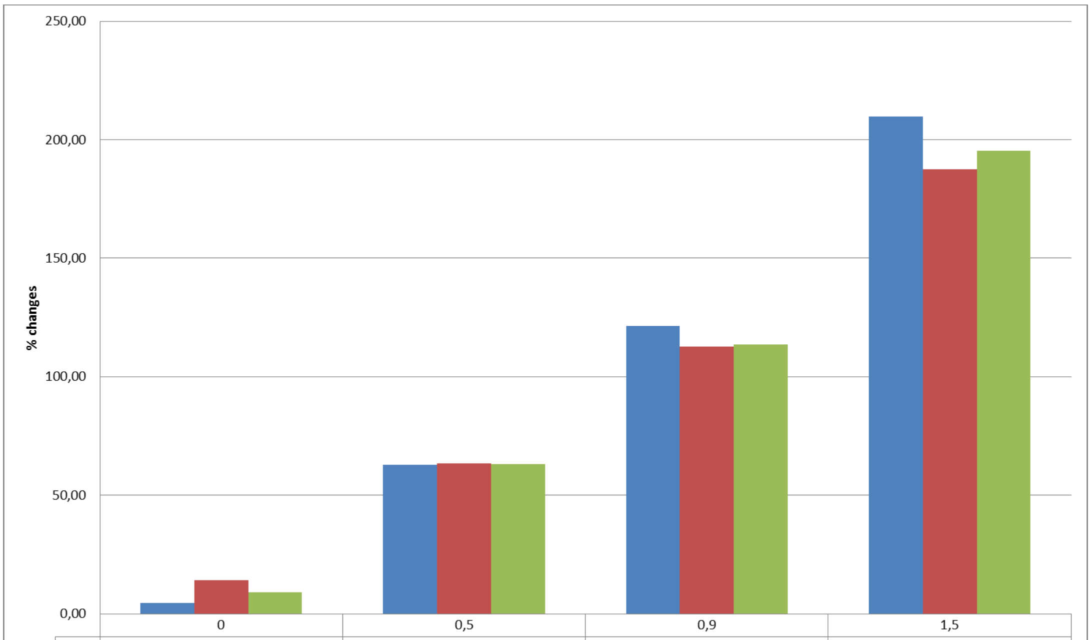
6.1. Comparing Economy-Wide Rebound Effects among different KLEM specifications.

The results of the LR economy-wide rebound effect are presented in Tables 6. According to these results the size of the economy-wide rebound/backfire effect is more sensitive to the variations of the elasticity of substitution between energy and the other composite than to the changes of the lower bound elasticity. These empirical results are consistent with those found by previous theoretical work of Sorrell (2007) and Sounders (2008).

Looking at Figure 6 we can easily compare the sensitivity of the LR economy-wide rebound effects under the different KLEM separability assumptions, i.e. specifications CSS, Case A and Case B. In this Figure we present economy-wide rebound effects for each KLEM specification only considering the evaluated economy-wide rebound impacts reported in the main diagonal of Table 6, i.e. when the values of the elasticity of substitution in the upper and lower nest coincide.
As can be asserted, the production function specification is not very determinant in the size of the rebound in the case of Italy. However, when the elasticity is very low, Case A exibits an higher rebound (14%) than the others. When elasticity is very high (1.5), we find the higher rebound effect is the CCS specification.

Finally, for all specification considered, with high elasticities values there is evidence of backfire effect.

Figure 6. Sensitivity of LR Economy-Wide Rebound to different KLEM specification. Percentage changes



	0	0,5	0,9	1,5
BCC	4,62	62,92	121,43	209,64
A	14,12	63,38	112,83	187,43
B	9,10	63,17	113,48	195,21

Table 6. Sensitivity of LR Economy-Wide Rebound to different KLEM specification. Percentage changes with respect to the steady state.

(KL) E KLE+M	**0**	**0,5**	**0,9**	**1,5**
0	***4,62***	*56,40*	*107,41*	*182,52*
0,5	*10,57*	***62,92***	*114,58*	*190,76*
0,9	*16,32*	*69,19*	***121,43***	*198,57*
1,5	*24,65*	*78,21*	*131,21*	***209,64***

(KE)L KLE+M	**0**	**0,5**	**0,9**	**1,5**
0	***14,12***	*56,83*	*99,66*	*164,12*
0,5	*20,49*	***63,38***	*106,38*	*171,12*
0,9	*26,63*	*69,67*	***112,83***	*177,83*
1,5	*35,46*	*78,71*	*122,10*	***187,43***

(LE)K KLE+M	**0**	**0,5**	**0,9**	**1,5**
0	***9,10***	*56,66*	*101,78*	*165,28*
0,5	*14,75*	***63,17***	*109,27*	*174,43*
0,9	*20,25*	*69,42*	***113,48***	*183,06*
1,5	*28,25*	*78,42*	*126,57*	***195,21***

7. Final comments.

The main contribution of this work is to study the impact of energy efficiency improvement in the use of energy in industrial sectors and to show the resulting economy-wide rebound figures for Italy.

We investigate and quantify the general equilibrium rebound effects using an inter-temporal, dynamic, multi-sectoral general equilibrium model developed for the Italian economy where dynamics arise from consumption and investment decision of forward looking economic agents. In doing this, we consider all the value added specification and for each of them we test our result. We can confirm both that in the case of Italy there is evidence of rebound effect (and backfire effect) and that long run rebound is higher than the short run according with the earlier cited theoretical works of Sounders and Sorrel. Moreover, we stress the determinant role played by the elasticity of substitution in determining the magnitude of the rebound effect so that specific estimation for Italy are needed.

However, we have analyzed a costless efficiency improvement so that the research should be enriched by the inclusion of the costs of such efficiency improvement. In addition, not only the rebound effects on the industrial sectors should be analyzed but also those related to the households consumption of energy.

Finally, since efficiency improvements are strictly related with environmental issues; an analysis of the consequences on the CO_2 emissions would be essential in order to provide a complete picture to the policy makers, considering the 20-20 20 European Union Program that aims to reduce not only energy consumption but also emissions in the environment.

Conclusions

This thesis has been very useful to better understand my interest research. Below, as a conclusion, a brief description of our new work (the end of a work and the beginning of another one) is presented.

Starting from the evidence that in the next 50 years the Italian population will fall dramatically, the economy will experience a pronounced ageing process in the coming decades with a strong decline in the growth rate of the labour force. Since old people has different consumption pattern than young people. Thus, our aim is to evaluate the likely effects of demographic change on energy use. Old people might use more heat energy than young people, whilst we would expect young people to consume more gasoline than older people.

Using a regional overlapping general equilibrium model calibrated on a social accounting matrix for Italy, we will investigate how demographic change affect the consumption patterns and especially we try to identify the size of the impact on energy use and greenhouse gas (GHG).

Dalton et al. (2008) and Kronenberg (2009) investigate the relationship between demographic change and GHG. The former uses a growth model that assumes a closed economy, with fixed labour supply. The latter instead uses a fixed income, fixed price model with not substitution between goods and services.

Our approach will be some extent different from other applications as far as the modelling behaviour is concerned. It is an open economy model with endogenous migration and imperfect labour market.

APPENDIX A

The mathematical presentation of the model

Prices

$$PM_{i,t} = \varepsilon_t \cdot PWM_i \cdot (1 + MTAX_i) \quad \textbf{(A.1)}$$

$$PE_{i,t} = \varepsilon_t \cdot PWE_i \cdot (1 - TE_i) \quad \textbf{(A.2)}$$

$$PX_{i,t} = \frac{PR_{i,t} \cdot R_{i,t} + PE_{i,t} \cdot E_{i,t}}{R_{i,t} + E_{i,t}} \quad \textbf{(A.3)}$$

$$PQ_{i,t} = \frac{PR_{i,t} \cdot R_{i,t} + PM_{i,t} \cdot M_{i,t}}{R_{i,t} + M_{i,t}} \quad \textbf{(A.4)}$$

$$PIR_{j,t} = \frac{\sum_i VR_{i,j,t} \cdot PR_{j,t} + \sum_i VI_{i,j,t} \cdot \overline{PI}_j}{\sum_i VIR_{i,j,t}} \quad \textbf{(A.5)}$$

$$PY_{j,t} \cdot a_j^Y = \left(PX_{j,t} \cdot \left(1 - btax_j - sub_j - dep_j\right) - \sum_i a_{i,j}^V PQ_{j,t} \right) \quad \textbf{(A.6)}$$

$$UCK_t = Pk_t \cdot (ir + \delta) \quad \textbf{(A.7)}$$

$$PC_t^{1-\sigma^c} = \sum_j \sum_h \delta_{j,h}^f \cdot PQ_{j,t}^{1-\sigma^c} \quad \textbf{(A.8)}$$

$$Pgov_t^{1-\sigma^g} = \sum_j \delta_j^g \cdot PQ_{j,t}^{1-\sigma^g} \quad \textbf{(A.9)}$$

$$w_t^b = \frac{w_t}{(1 + sscee + sscer) \cdot (1 + ire)} \quad \textbf{(A.10)}$$

$$\text{Wage setting} \begin{cases} ln\left[\dfrac{w_t}{cpi_t}\right] = \beta - \varepsilon \ln(u_t) & \text{(Regional Bargaining)} \\ w_t = w_{t=0} & \text{(National Bargaining)} \end{cases} \quad \textbf{(A.11)}$$

$$rk_{j,t} = PY_{j,t} \cdot \delta_j^k \cdot A(\xi_{j,t})^{\varrho_j} \cdot \left(\frac{Y_{j,t}}{K_{j,t}}\right)^{1-\varrho_j} \tag{A.12}$$

$$Pk_t = \frac{\sum_j PQ_{j,t} \cdot \sum_i KM_{i,j}}{\sum_i \sum_j KM_{i,j}} \tag{A.13}$$

Production technology

$$X_{i,t} = min\left(\frac{Y_{i,t}}{a_i^Y}; \frac{V_{i,j,t}}{a_{i,j}^V}\right) \tag{A.14}$$

$$Y_{i,t} = a_i^Y \cdot X_{i,t} \tag{A.15}$$

$$V_{i,t} = a_{i,j}^V \cdot X_{i,t} \tag{A.16}$$

$$Y_{i,t} = A(\xi_{i,t}) \cdot \left[\delta_i^k \cdot K_{i,t}^{\rho_i} + \delta_i^l \cdot L_{i,t}^{\rho_i}\right]^{\frac{1}{\varrho_i}} \tag{A.17}$$

$$L_{j,t} = \left(A(\xi_{j,t})^{\rho_i} \cdot \delta_j^l \cdot \frac{PY_{j,t}}{w_t}\right)^{\frac{1}{1-\rho_j}} \cdot Y_{j,t} \tag{A.18}$$

Trade

$$VV_{i,j,t} = \gamma_{i,j}^{vv} \cdot \left[\delta_{i,j}^{vm} VM_{i,t}^{\rho_i^A} + \delta_{i,j}^{vir} VIR_{i,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \tag{A.19}$$

$$\frac{VM_{i,j,t}}{VIR_{i,j,t}} = \left[\left(\frac{\delta_{i,j}^{vm}}{\delta_{i,j}^{vir}}\right) \cdot \left(\frac{PIR_{i,t}}{PM_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \tag{A.20}$$

$$VIR_{i,j,t} = \gamma_{i,j}^{vir} \cdot \left[\delta_{i,j}^{vi} VI_{i,t}^{\rho_i^A} + \delta_{i,j}^{vr} VR_{i,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \tag{A.21}$$

$$\frac{VR_{i,j,t}}{VI_{i,j,t}} = \left[\left(\frac{\delta_{i,j}^{vr}}{\delta_{i,j}^{vi}}\right) \cdot \left(\frac{PI_{i,t}}{PR_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \tag{A.22}$$

$$E_{i,t} = \bar{E}_i \cdot \left(\frac{PE_{i,t}}{PR_{i,t}}\right)^{\sigma_i^x} \tag{A.23}$$

Regional Demand

$$R_{i,t} = \sum_j VR_{i,j,t} + \sum_h QHR_{i,h,t} + QVR_{i,t} + QGR_{i,t} + QHK_{i,t} \tag{A.24}$$

Total Production

$$X_{i,t} = R_{i,t} + E_{i,t} \tag{A.25}$$

Households and other Domestic Institutions

$$U = \sum_{t=0}^{\infty} (1+\rho)^{-t} \frac{C_t^{1-\sigma} - 1}{1-\sigma} \tag{A.26}$$

$$\frac{C_t}{C_{t+1}} = \left[\frac{PC_t \cdot (1+\rho)}{PC_{t+1} \cdot (1+r)}\right]^{-\left(\frac{1}{\sigma}\right)} \tag{A.27}$$

$$W_t = NFW_t + FW_t \tag{A.28}$$

$$\begin{aligned} NFW_t(1+r_t) = {} & NFW_{t+1} + \sum_h dtr_h \cdot (ssce + ire) \cdot \sum_j L_{j,t} \cdot w_t \\ & + \sum_h \sum_{dnginsp} TRSF_{h,dnginsp,t} + \sum_h TRG_h \cdot PC_t \\ & + \sum_h REM_h \cdot \varepsilon_t - \sum_{dnginsp} \sum_h TRSF_{dnginsp,h,t} \end{aligned} \tag{A.29}$$

$$\begin{aligned} & FW_t(1+r_t) \\ & = FW_{t+1} + d_{dngins}^K \cdot rk_{i,t} \cdot \sum_i K_i - \sum_h SAV_h \end{aligned} \tag{A.30}$$

$$\begin{aligned} YNG_{dngins,t} = {} & d_{dngins}^L \cdot w_t \cdot \sum_i L_i + d_{dngins}^K \cdot rk_{i,t} \cdot \sum_i K_i + d_{dngins}^h \cdot rh_{i,t} \sum_i H_i \\ & + \sum_{dnginsp} TRSF_{dngins,dnginsp,t} + PC_t \cdot TRG_{dngins} + \varepsilon_t \cdot REM_{dngins} \end{aligned} \tag{A.31}$$

$$TRSF_{dngins,dnginsp,t} = PC_t \cdot \overline{TRSF}_{dngins,dnginsp} \tag{A.32}$$

$$SAV_{dngins,t} = mps_{dngins} \cdot YNG_{dngins,t} \quad \textbf{(A.33)}$$

$$QH_{i,h,t} = \delta_{i,h}^{f\ \rho_i^c} \cdot \left(\frac{PC_{i,t}}{PQ_{i,t}}\right)^{\rho_i^c} \cdot C_t \quad \textbf{(A.34)}$$

$$QH_{i,h,t} = \gamma_{i,h}^{f} \cdot \left[\delta_{i,h}^{hr} \cdot QHR_{i,h,t}^{\rho_i^A} + \delta_{i,h}^{hm} \cdot QHM_{i,h,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \quad \textbf{(A.35)}$$

$$\frac{QHR_{i,h,t}}{QHM_{i,h,t}} = \left[\left(\frac{\delta_{i,h}^{hr}}{\delta_{i,h}^{hm}}\right) \cdot \left(\frac{PM_{i,t}}{PR_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \quad \textbf{(A.36)}$$

Government

$$\begin{aligned} FD_t = {} & (G_t + I_{(g),t}) \cdot Pgov_t + \overline{GSAV} + \sum_{dngins} TRG_{dngins,t} \cdot PC_t \\ & - \Bigg(d_g^k \cdot \sum_i rk_{i,t} \cdot K_{i,t} + d_g^h \cdot \sum_i rh_{i,t} \cdot H_{i,t} + \sum_i IMT_{i,t} + \sum_h dtr_h \\ & \cdot (ssce + ire_t) \cdot \sum_j L_{j,t} \cdot w_t \ + \overline{FE} \cdot \varepsilon_t\Bigg) \end{aligned} \quad \textbf{(A.37)}$$

$$G_t = \sum_i QG_{i,t} \cdot PQ_{i,t} + \overline{GSAV} \quad \textbf{(A.38)}$$

$$QG_{i,t} = \gamma_i^g \cdot \left[\delta_i^{gr} \cdot QGR_{i,t}^{\rho_i^A} + \delta_i^{gm} \cdot QGM_{i,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \quad \textbf{(A.39)}$$

$$\frac{QGR_{i,t}}{QGM_{i,t}} = \left[\left(\frac{\delta_i^{gr}}{\delta_i^{gm}}\right) \cdot \left(\frac{PM_{i,t}}{PR_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \quad \textbf{(A.40)}$$

Investment Demand

$$QV_{i,t} = \sum_j KM_{i,j} \cdot J_{j,t} \tag{A.41}$$

$$QV_{i,t} = \gamma_i^v \cdot \left[\delta_i^{qvm} \cdot QVM_{i,t}^{\rho_i^A} + \delta_i^{qvir} \cdot QVIR_{i,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \tag{A.42}$$

$$\frac{QVM_{i,t}}{QVIR_{i,t}} = \left[\left(\frac{\delta_i^{qvm}}{\delta_i^{qvir}}\right) \cdot \left(\frac{PIR_{i,t}}{PM_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \tag{A.43}$$

$$QVIR_{i,t} = \gamma_i^{vir} \cdot \left[\delta_i^{qvi} \cdot QVI_{i,t}^{\rho_i^A} + \delta_i^{qvr} \cdot QVR_{i,t}^{\rho_i^A}\right]^{\frac{1}{\rho_i^A}} \tag{A.44}$$

$$\frac{QVR_{i,t}}{QVI_{i,t}} = \left[\left(\frac{\delta_i^{qvr}}{\delta_i^{qvi}}\right) \cdot \left(\frac{PI_{i,t}}{PR_{i,t}}\right)\right]^{\frac{1}{1-\rho_i^A}} \tag{A.45}$$

Time path of investment

$$J_{i,t} = I_{i,t}\left(1 - bb - tk + \frac{\beta}{2}\,\frac{\left(\frac{I_{i,t}}{K_{i,t}} - \alpha\right)^2}{\frac{I_{i,t}}{K_{i,t}}}\right) \tag{A.46}$$

$$\frac{I_t}{K_t} = \alpha + \frac{1}{\beta} \cdot \left[\frac{\lambda_{i,t}}{Pk_t} - (1 - bb - tk)\right] \tag{A.47}$$

$$\dot{\lambda}_{i,t} = \lambda_{i,t}(r_t + \delta) - R_{i,t}^k \tag{A.48}$$

$$\theta(x_t) = \frac{\beta}{2}\,\frac{(x_t - \alpha)^2}{x_t};\ \text{and}\ \ x_t = \frac{I_t}{K_t} \tag{A.49}$$

$$R_{i,t}^k = rk_t - Pk_t\left[\frac{I_{i,t}}{K_{i,t}}\right]^2 \theta'_t(I/K) \tag{A.50}$$

Factors accumulation

$$KS_{i,t+1} = (1-\delta) \cdot KS_{i,t} + I_{i,t} \tag{A.51}$$

$$LS_{i,t+1} = \left(1 + \left(\varsigma - \nu^{u}[ln(u_t) - ln(\bar{u}^N)] + \nu^{w}\left[ln\left(\frac{w_t}{cpi_t}\right) - ln\left(\frac{w^N}{cpi^N}\right)\right]\right)\right) \cdot LS_{i,t} \tag{A.52}$$

$$K_{i,t} = KS_{i,t} \tag{A.53}$$

$$LS_t \cdot (1-u_t) = \sum_j L_{j,t} \tag{A.54}$$

Indirect taxes and subsidies

$$IBT_{i,t} = btax_i \cdot X_{i,t} \cdot PX_{i,t} \tag{A.55}$$

$$IMT_{j,t} = \sum_i MTAX_j \cdot VM_{i,j,t} \cdot PM_{i,t} \tag{A.56}$$

$$SUBSY_{i,t} = SUB_i \cdot X_{i,t} \cdot PX_{i,t} \tag{A.57}$$

Total demand for import and current account

$$M_{i,t} = \sum_j VI_{i,j,t} + \sum_j VM_{i,j,t} + \sum_h QHM_{i,h,t} + QGM_{i,t} + QVI_{i,t} + QVM_{i,t} \tag{A.58}$$

$$TB_t = \sum_i M_{i,t} \cdot PM_{i,t} - \sum_i E_{i,t} \cdot PE_{i,t} + \varepsilon_t \cdot \left(\sum_{dngins} \overline{REM}_{dngins} + \overline{FE}\right) \tag{A.59}$$

Assets

$$VF_{i,t} = \lambda_{i,t} \cdot K_{i,t} \tag{A.60}$$

$$D_{t+1} = (1 + r - \tau) \cdot D_t + TB_t \tag{A.61}$$

$$Pgov_{t+1} \cdot GD_{t+1} = \left[1 + r - \tau g + \left(\frac{Pc_{t+1}}{Pc_t} - 1\right)\right] \cdot GD_t \cdot Pgov_t + FD_t \quad \textbf{(A.62)}$$

Steady-state conditions

$$KS_{i,T}\delta = I_{i,T} \quad \textbf{(A.63)}$$

$$R_{i,T}^k = \lambda_{i,T}(r_T + \delta) \quad \textbf{(A.64)}$$

$$FD_T = -\left[r - \tau g + \left(\frac{Pc_{t+1}}{Pc_t} - 1\right)\right] \cdot Pgov_T \cdot GD_T \quad \textbf{(A.65)}$$

$$TB_T = -(r - \tau) \cdot D_T \quad \textbf{(A.66)}$$

$$NFW_T \cdot r_T = \sum_h dtr_h \cdot (ssce + ire) \cdot \sum_j L_{j,T} \cdot w_T + \sum_h \sum_{dnginsp} TRSF_{h,dnginsp,T} + \sum_h TRG_h \cdot PC_T + \sum_h REM_h \cdot \varepsilon_T - \sum_{dnginsp} \sum_h TRSF_{dnginsp,h,T} \quad \textbf{(A.67)}$$

$$FW_t \cdot r_T = d_{dngins}^K \cdot rk_{i,t} \cdot \sum_i K_i - \sum_h SAV_{h,T} \quad \textbf{(A.68)}$$

In order to produce short-run results, we have that

$$KS_{i,t=1} = KS_{i,t=0} \quad \textbf{(A.69)}$$

$$LS_{=1} = LS_{t=0} \quad \textbf{(A.70)}$$

$$GD_{t=1} = GD_{t=0} \quad \textbf{(A.71)}$$

$$D_{t=1} = D_{t=0} \quad \textbf{(A.72)}$$

For Energy Model (Chapter 2) equation (A.33) disappear if *dngins*=*h*. *We* also add:

$$FW_t = \sum_i VF_{i,t} + Pgov_{t+1} \cdot GD_t + D_t \quad \textbf{(A.73)}$$

$$FW_t(1 + r_t) = FW_{t+1} + \Pi_t - \left(\sum_i J_{i,t} + FD_t - TB_t\right) \quad \textbf{(A.74)}$$

In order to run the myopic model (Chapter 2) from the consumption side, equations (A.26) and (A.27) are substitute with the following:

$$C_t = \sum_{dngins \in \langle H \rangle} YNG_{dngins,t} - \sum_{dngins \in \langle HH \rangle} SAV_{dngins,t} - HTAX_t - \sum_{dngins} \sum_h TRSF_{dngins,h,t} \quad \textbf{(A.75)}$$

To obtain the path of investment equations (A.46 – A.49) disappear and we introduce:

$$I_{i,t} = v \cdot \left[KS^*_{i,t} - KS_{i,t}\right] + \delta \quad \cdot KS_{i,t} \quad \textbf{(A.76)}$$

$$KS^*_{i,j} = \left(A\left(\xi_{j,t}\right)^{\rho_i} \cdot \delta^k_j \cdot \frac{PY_{j,t}}{uck_t}\right)^{\frac{1}{1-\rho_j}} \cdot Y_{j,t} \quad \textbf{(A.77)}$$

Alternatively we can use the following:

$$\frac{I_{i,t}}{KS_{i,t}} = \delta \quad \cdot \left[\frac{rk_{i,t}}{uck_t}\right]^v \quad \textbf{(A.78)}$$

Where v equal 0.5 in (A.75) and 2 in (A.77)

Glossary

i,j	the set of goods or industries
ins	the set of institutions
dins $(\subset ins)$	the set of domestic institutions
dngins $(\subset dins)$	the set of non government institutions
h $(\subset dngins)$	the set of households

Prices

$PX_{i,t}$	output price
$PY_{i,t}$	value added price
$PR_{i,t}$	regional price
$PM_{i,t}$	import price
$PWM_{i,t}$	world price of import
$PE_{i,t}$	price of export
$PWE_{i,t}$	world price of export
$PQ_{i,t}$	commodity price
$PIR_{i,t}$	national commodity price (regional + ROI)
$PI_{i,t}$	ROI price
$rk_{i,t}$	rate of return to capital
w_t	unified nominal wage
w_t^b	after tax wage
Pk_t	capital good price
UCK_t	user cost of capital
$\lambda_{i,t}$	shadow price of capital
PC_t	aggregate consumption price
$PGov_t$	aggregate price of Government consumption goods
ε_t	exchange rate [fixed]

Endogenous Variables

$X_{i,t}$	total output
$R_{i,t}$	Regional supply
$M_{i,t}$	total import
$E_{i,t}$	total export (interregional + international)
$Y_{i,t}$	value added
$L_{i,t}$	labour demand
$K_{i,t}$	physical capital demand
$KS_{i,t}$	capital stock
$LS_{i,t}$	labour supply
$VV_{i,jt}$	Total intermediate inputs
$VR_{i,jt}$	regional intermediate inputs
$VM_{i,jt}$	ROW intermediate inputs
$VIR_{i,jt}$	national intermediate inputs (REG+ROI)
$VI_{i,jt}$	ROI intermediate inputs
$QGR_{i,t}$	regional government expenditure
$QGM_{i,t}$	government expenditure(ROI+ROW)
C_t	aggregated household consumption
$QH_{i,h,t}$	total households consumption in sector *i* for *h*
$QHR_{i,h,t}$	regional consumption in sector *i* for group *h*
$QHM_{i,h,t}$	import consumption in sector *i* for group *h*
$QV_{i,t}$	total investment by sector of origin *i*
$QVR_{i,t}$	regional investment by sector of origin *i*
$QVM_{i,t}$	ROW investment demand
$QVIR_{i,t}$	national investment (REG+ROI)
$QVI_{i,t}$	ROI investment demand
$I_{(g),t}$	Public investment in infrastructure
$I_{j,t}$	investment by sector of destination *j*

$J_{j,t}$	investment by destination *j* with adjustment cost
u_t	regional unemployment rate
$R^k_{i,t}$	marginal net revenue of capital
$SAV_{dngins,t}$	domestic non-government saving
$YNG_{dngins,t}$	domestic non-government income
$TRSF_{dngins,dngins}$	transfer among *dngins*
$HTAX_t$	total household tax
TB_t	current account balance
U	utility function
$SUBSY_t$	production subsidies

Exogenous variables

$\overline{REM}_t$	remittance for *dngins*
$\overline{FE}_t$	remittance for the Government
$QG_{i,t}$	government expenditure
$GSAV_t$	government saving
$A(\xi_{i,t})$	exogenous technical change
r_t	interest rate
tk	corporation tax
ire_t	rate of income tax

Elasticities

σ	constant elasticity of marginal utility
ϱ_j	between labour and capital in sector *j*
ρ^A_i	in Armington function
σ^x_i	of export with respect to term of trade
μ	of real wage with respect to unemployment rate

Parameters

$a_{i,j}^{V}$	Input-output coefficients for *i* used in *j*
a_{j}^{Y}	share of value added on production
$\delta_{i,h}^{f}$	share parameter in household demand function
$\delta_{j}^{k,l}$	shares in value added function in sector *j*
$\delta_{i,j}^{vir,vm,vr,vi}$	shares parameters in CES function for intermediate goods
$\delta_{i,j}^{qvir,qvm,qvr,qvi}$	shares parameters in CES function for investment goods
$\delta_{i,h}^{hr,hm}$	shares parameters in CES function for households consumption
$\delta_{i}^{gr,gm}$	shares parameters in CES function for government consumption
$\gamma_{i,j}^{vv,vir}$	shift parameter in CES functions for intermediate goods
γ_{i}^{f}	shift parameter in CES function for households consumption goods
γ_{i}^{g}	shift parameter in CES function for government consumption
$btax_{i}$	business tax
sub_{i}	rate of production subsidy
$MTAX_{i}$	rate of import tax
$KM_{i,j}$	physical capital matrix
mps_{dngins}	rate of saving in institutions *dngins*
ssce	rate of social security paid by employees
sscer	rate of social security paid by employer
ρ	pure rate of consumer time preference
bb	rate of distortion or incentive to investment
α	a parameter in the adjustment cost function
β	a parameter in the adjustment cost function
δ	rate of depreciation

Appendix B

The SAM of Sardinia related to 2001 with Knowledege (Garau and Lecca, 2010)

		Primary	ADV	OTH	ENE	SER	LAB	CAP	KWL	IBT	SOP	HG	FIRMS	GOV	KFOR	HFOR	IIP	ROI	ROW	
Primary Sector	**Primary**	195,06	1096,33	504,65	196,99	73,26	0,00	0,00	0,00	0,00	0,00	364,34	0,00	0,93	16,75	19,65	0,00	983,98	24,69	**3476,62**
Heavy Industry	**ADV**	128,58	1899,20	1224,52	158,86	1665,57	0,00	0,00	0,00	0,00	0,00	1764,52	0,00	0,00	2299,21	107,68	0,00	2284,90	1881,26	**13414,28**
Light Industry	**OTH**	126,78	184,04	1355,77	122,06	1058,37	0,00	0,00	0,00	0,00	0,00	3536,22	0,00	6,20	3058,81	54,22	0,00	1688,08	205,18	**11395,72**
Energy	**ENE**	51,47	264,73	118,09	263,65	447,70	0,00	0,00	0,00	0,00	0,00	696,94	0,00	7,13	0,00	21,22	0,00	39,83	0,00	**1910,76**
Services	**SER**	221,55	1114,29	1168,92	125,94	7835,59	0,00	0,00	0,00	0,00	0,00	11811,96	0,00	7914,51	1028,73	0,00	0,00	725,43	674,81	**32621,73**
Labour Income	**LAB**	667,98	889,03	1482,60	215,38	10950,66	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**14205,65**
Capital Income	**CAP**	185,67	394,00	528,71	227,60	6218,45	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**7554,44**
Knowledge	**KWL**	111,03	426,85	363,52	60,95	1065,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**2027,38**
Indirect business tax	**IBT**	25,32	872,68	799,17	191,17	1333,99	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**3222,32**
Subsidies	**SOP**	-243,10	-210,37	-49,53	-21,29	-2101,41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**-2625,71**
Households	**HG**	0,00	0,00	0,00	0,00	0,00	14205,65	5950,26	1603,93	0,00	0,00	91,93	831,31	4520,91	0,00	0,00	0,00	0,00	63,53	**27267,52**
Firms	**FIRMS**	0,00	0,00	0,00	0,00	0,00	0,00	876,43	239,24	0,00	0,00	718,97	185,21	36,62	0,00	0,00	0,00	0,00	55,41	**2111,89**
Government	**GOV**	0,00	0,00	0,00	0,00	0,00	0,00	727,74	184,21	3222,32	-2625,71	2849,27	942,42	2893,17	7252,18	0,00	123,90	0,00	19,69	**15589,19**
Capital Formation	**KFOR**	387,34	356,11	313,45	319,16	2537,74	0,00	0,00	0,00	0,00	0,00	5206,88	59,29	0,00	0,00	0,00	0,00	1957,21	3018,60	**14155,79**
Knowledge Formation	**HFOR**	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	157,67	25,67	19,43	0,00	0,00	0,00	0,00	0,00	**202,77**
Import tax	**IIP**	3,90	90,89	28,15	0,42	0,54	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**123,90**
Interregional trade	**ROI**	406,35	3218,33	2728,29	32,51	1040,38	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	253,57	0,00	0,00	0,00	0,00	**7679,43**
International trade	**ROW**	1208,69	2818,18	829,42	17,35	495,87	0,00	0,00	0,00	0,00	0,00	68,85	68,00	190,28	246,53	0,00	0,00	0,00	0,00	**5943,17**
		3476,62	**13414,28**	**11395,72**	**1910,76**	**32621,73**	**14205,65**	**7554,44**	**2027,38**	**3222,32**	**-2625,71**	**27267,52**	**2111,89**	**15589,19**	**14155,79**	**202,77**	**123,90**	**7679,43**	**5943,17**	

R&D Investments

R&D investments, financed by SF, carried out by the Sardinia region in the period 1994-2008. In the Tables below, payments from regional government to different economic sectors (where Ateco code is the Italian classification of the economic activities) are listed.

POP 1994-1999

AtEco code 2002	Economic activity description	Payments
A	Agriculture, hunting, forestry	€ 29.540,00
H	Hotels and restaurants	€ 33.360,00
O	Other public and social services	€ 1.122.380,00
K(72 - 73 - 74)	Information technology, R&D activities	€ 67.193.520,00
D	Manufactoring sector	€ 40.520.760,00
G	Wholesale and retail trade	€ 2.171.800,00
F	Constructions	€ 42.240.000,00
C	mining activity	€ 9.302.220,00
B	Fishing and related services	€ 406.390,00
E	Energy	€ 148.470,00
I	Transports and Communications	€ 969.890,00
Total		€ 164.138.330,00

Source: our elaboration on data provided by the Sardinian regional government.

POR 2000-2006

AtEco code 2002	Economic activity description	Payments
E	Energy	€ 797.085
M	Education	€ 46.168.192
L	Public administration	€ 47.913.283
N	Health	€ 17.889.716
I	Transports and communications	€ 51.522.720
72-73.74	Information technology, R&D activities	€ 77.937.539
F	Constructions	€ 22.203.120,53
Total		€ 264.431.655

Source: our elaboration on data provided by the Sardinian regional government.

Since the SAM used is aggregated in five sectors (primary sector, heavy and light industry, energy and services sector), the following aggregation criteria have been used:

POP 1994-1999:

- Primary sector: Ateco code A+B+C
- Heavy industry: Ateco code D
- Light industry: Ateco code F

- Energy: Ateco code E
- Services: Ateco code H+O+K(72-73-74)+G+I

POR 2000-2006:

- Light industry: Ateco code F
- Energy: Ateco code E
- Services: Ateco code M+L+N+I+(72-73-74).

The final vector is:

Years 1994-2001	
primary	€ 9,73815
heavy industry	€ 40,52076
light industry	€ 42,24000
energy	€ 0,14847
services	€ 71,49095
TOT	€ 164,13833

Years 2002-2008	
primary	€ 0,00000
heavy industry	€ 0,00000
light industry	€ 22,20312
energy	€ 0,79708
services	€ 241,43145
TOT	€ 264,43165

The SAM of Italy related to 2006 with Energy sectors.

	Agriculture, forestry and logging	See fishing and See firming	Mining and extraction	Mfr food, drink and tobacco	Mfr textiles and clothing	Mfr chemicals etc	Mfr metal and non-metal goods	Mfr transport and other machinery, electrical and inst eng	Other manufacturing	Water	Construction	Distribution	Transport and Communications	finance and business	R&D	Education	Public and other services	COAL (EXTRACTION)	OIL (REFINING & DISTR OIL AND NUCLEAR)	GAS	Electricity	Labour income	Capital income	Net indirect tax	Household	Corporation	Government	Capital formation	Stock	Turists	IIT	REU	ROW
Agriculture, forestry and logging	5253,0	0,6	1,3	22612,5	913,3	1132,1	310,3	138,9	84,4	2,9	64,8	8458,8	383,1	6,2	502,2	0,9	486,8	0,4	1,1	17,0	2,7	0,0	0,0	0,0	6302,7	0,0	327,5	-1307,5	126,8	0,0	0,0	2902,7	1350,7
See fishing and See firming	3,4	9,3	0,0	201,2	0,3	10,3	1,8	2,2	20,7	0,0	0,4	639,8	80,7	0,0	1,7	0,1	24,4	0,0	0,0	0,1	0,0	0,0	0,0	0,0	1290,0	0,0	0,0	108,8	56,8	0,0	0,0	164,3	76,4
Mining and extraction	5,9	0,0	378,2	36,4	3,7	584,8	5691,5	99,0	45,7	2,2	1234,6	1737,6	15,7	1,0	43,8	0,1	3,7	0,0	20146,2	13974,7	2192,4	0,0	0,0	0,0	4,1	0,0	0,0	0,0	959,9	0,0	0,0	405,5	188,7
Mfr food, drink and tobacco	4043,2	69,0	7,5	18455,9	145,1	3668,2	122,7	85,5	35,2	0,0	23,6	28812,3	841,8	1,5	152,8	13,6	1912,4	0,0	46,2	7,1	1,1	0,0	0,0	0,0	46830,0	0,0	0,0	0,1	-578,0	0,0	0,0	11147,8	5187,3
Mfr textiles and clothing	48,4	49,4	2,0	80,5	19304,8	2367,4	553,1	664,0	474,7	3,0	312,6	11370,0	351,7	7,4	543,5	0,9	920,7	0,0	60,2	41,0	6,4	0,0	0,0	0,0	22991,2	0,0	0,0	160,0	183,8	0,0	0,0	17253,0	8028,1
Mfr chemicals etc	1301,4	33,3	271,6	4623,3	4351,0	69080,9	10551,0	14994,7	7633,6	193,9	7064,0	40244,5	7634,1	904,0	10897,7	107,5	10631,6	0,0	1272,8	1165,9	182,9	0,0	0,0	0,0	24972,8	0,0	5437,6	1117,5	142,4	0,0	0,0	43591,7	20284,0
Mfr metal and non-metal goods	288,4	44,8	523,3	1957,0	351,5	5873,0	65028,3	45349,0	5020,3	114,6	32158,5	19224,2	2074,7	139,8	2331,1	46,0	1866,6	0,5	121,5	1017,2	159,6	0,0	0,0	0,0	1515,6	0,0	0,0	8344,2	1982,1	0,0	0,0	31919,0	14852,5
Mfr transport and other machinery, electrical and inst eng	166,3	79,7	194,4	934,1	654,8	4450,3	10079,0	50740,3	1218,3	105,2	6034,9	32503,6	12767,4	386,2	8429,7	22,7	7560,2	4,1	305,0	1550,9	243,3	0,0	0,0	0,0	6864,7	0,0	0,0	57460,7	1375,0	0,0	0,0	86971,9	40469,6
Other manufacturing	8,7	11,8	8,2	186,5	205,7	1105,7	3879,9	1585,7	2529,4	10,8	1137,8	4787,5	1177,7	198,9	914,8	27,5	772,9	0,0	21,0	232,2	36,4	0,0	0,0	0,0	9880,0	0,0	1,0	7939,7	1252,5	0,0	0,0	10388,2	4833,8
Water	169,8	0,0	20,6	141,9	158,1	259,2	169,1	69,9	10,3	1,7	134,8	907,4	229,3	27,4	86,8	132,5	155,3	0,0	6,4	161,1	25,3	0,0	0,0	0,0	3644,0	0,0	158,6	0,0	0,0	0,0	0,0	3,1	1,4
Construction	202,9	2,0	47,4	429,0	489,1	1103,7	1066,0	1179,7	157,9	2142,7	16013,7	5977,3	6216,4	648,4	5975,9	111,4	3903,9	0,0	4,6	473,4	74,3	0,0	0,0	0,0	6312,0	0,0	542,4	133705,2	0,0	0,0	0,0	267,1	124,3
Distribution	1620,8	66,5	346,8	7249,5	4288,4	14568,7	14167,1	23904,3	3506,9	126,9	8897,9	59245,4	17031,8	1670,9	10735,9	113,1	8457,9	0,0	602,8	1744,0	273,6	0,0	0,0	0,0	252726,8	0,0	4794,8	24170,6	33,1	0,0	0,0	18257,1	8495,4
Transport and Communications	1557,8	64,7	323,4	5757,2	2614,0	10109,9	8643,0	10023,3	2194,7	77,2	9061,2	42498,9	42998,1	4181,7	13478,6	94,7	7826,9	0,3	748,9	1591,8	249,7	0,0	0,0	0,0	62605,6	0,0	3271,0	4051,3	234,0	0,0	0,0	12317,8	5731,7
finance and business	770,0	51,4	563,9	1037,8	763,7	2227,7	3469,5	4204,6	639,5	189,6	3563,3	14715,0	6498,6	30604,9	9926,6	538,6	5678,9	0,1	296,3	652,8	102,4	0,0	0,0	0,0	35304,4	0,0	0,0	0,1	0,0	0,0	0,0	3509,0	1632,8
R&D	509,8	14,8	647,9	5439,4	4140,8	14730,4	15206,4	22636,1	2410,0	282,7	18050,0	98418,0	34456,9	12669,5	58220,5	5841,2	24765,7	0,0	527,6	2278,5	357,5	0,0	0,0	0,0	135587,2	0,0	8107,2	23448,2	0,0	0,0	0,0	12861,5	5984,7
Education	0,4	0,0	3,4	83,0	22,1	167,8	118,8	364,5	23,6	2,6	395,5	783,1	746,3	234,3	758,7	1983,0	211,3	0,0	4,0	67,4	10,6	0,0	0,0	0,0	10201,2	0,0	58883,1	0,0	0,0	0,0	0,0	0,0	0,0
Public and other services	192,2	1,3	39,5	1423,1	595,3	2367,3	1294,9	1367,4	291,2	113,2	2754,3	10625,6	1558,4	409,6	2852,7	79,2	20886,6	0,0	218,3	505,0	79,2	0,0	0,0	0,0	62408,1	0,0	220790,4	844,3	50,2	0,0	0,0	813,8	378,7
COAL (EXTRACTION)	0,0	0,0	0,1	1,2	4,3	95,1	690,9	8,2	0,7	0,0	0,0	45,6	0,2	0,0	0,2	0,0	1,7	0,0	48,1	751,7	117,9	0,0	0,0	0,0	2,3	0,0	0,0	0,0	-15,7	0,0	0,0	3,3	1,5
OIL (REFINING & DISTR OIL AND NUCLEAR)	900,7	82,8	131,2	405,3	239,6	1952,0	2460,7	827,9	117,2	14,9	1673,6	7312,4	10521,7	296,0	1750,8	105,2	1400,4	0,1	1909,2	1181,7	185,4	0,0	0,0	0,0	15419,9	0,0	0,0	0,0	451,4	0,0	0,0	6583,2	3063,3
GAS	785,3	60,2	266,7	2368,1	1615,5	5550,0	6446,0	4243,6	421,2	649,7	602,9	11711,3	2737,3	479,2	3221,7	596,7	3630,7	0,7	292,1	5476,5	1317,4	0,0	0,0	0,0	16219,2	0,0	0,0	0,0	0,0	0,0	0,0	388,0	180,5
Electricity	123,2	9,5	41,8	371,5	253,4	870,7	1011,3	665,8	66,1	101,9	94,6	1837,3	429,4	75,2	505,4	93,6	569,6	0,1	45,8	973,7	2005,2	0,0	0,0	0,0	2544,5	0,0	0,0	0,0	0,0	0,0	0,0	60,9	28,3
Income from employment	8568,2	628,5	1499,5	11784,4	11719,7	30919,8	32081,7	48544,9	6466,6	520,7	33439,5	79404,9	45515,7	33992,0	54784,5	54278,5	147474,8	1,1	1384,7	5060,3	793,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Other Value Added	20863,6	1010,9	3259,5	11113,5	6853,0	20922,1	22743,2	23213,6	5620,8	1616,9	44393,2	117040,1	49332,2	24605,4	229719,1	8387,5	58377,1	4,1	3257,1	15714,3	2465,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Net taxes on products/production	-3212,2	103,5	-14340,1	13059,5	15827,8	33176,9	-9730,3	29779,7	11843,3	398,8	-439,0	-122733,9	-3971,4	9910,5	69412,6	2455,5	23662,8	-85,1	19977,7	12799,9	1348,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Household	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	608863,9	325940,0	0,0	1484,5	50097,5	259966,2	0,0	0,0	0,0	0,0	-5987,3	0,0
Corporate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	319499,0	0,0	51389,6	12875,3	2006,8	0,0	0,0	0,0	0,0	-107454,0	0,0
Government	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	25073,4	89245,2	372637,3	42890,7	0,0	0,0	0,0	0,0	0,0	-6962,7	0,0
Capital	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	24208,5	172453,2	-43150,9	0,0	0,0	0,0	0,0	149766,6	2143,9
Stock	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	7268,6	0,0	0,0	0,0	0,0	0,0
Turists	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
IIT	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
REU	4142,4	209,6	37543,2	7913,1	7199,5	43067,2	32443,5	32886,6	1615,3	1,4	353,6	8088,7	8895,1	3852,5	15675,1	24,3	1232,6	1284,4	5393,7	1278,5	384,1	0,0	0,0	0,0	47014,7	0,0	1226,4	26734,4	711,6	0,0	0,0	0,0	0,0
ROW	1762,5	89,2	15974,0	3366,9	3063,3	18324,4	13804,2	13992,7	687,3	0,6	150,4	3441,6	3784,7	1639,2	6669,5	10,3	524,4	546,5	2294,9	544,0	163,4	0,0	0,0	0,0	20004,0	0,0	521,8	11375,0	302,8	0,0	0,0	0,0	0,0

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