Economic Modelling 45 (2015) 83–92

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

A simulation of impact of withdrawal European funds on Andalusian economy using a dynamic CGE model: 2014–20

Manuel Alejandro Cardenete, M. Carmen Delgado *

Department of Economics, Loyola University Andalusia, Campus Palmas Altas, C/Energía Solar 1, Ed. G, 41014 Seville, Spain

ARTICLE INFO

Article history:
Accepted 19 September 2014
Available online xxxx

Keywords:
Social accounting matrix
Dynamic Applied General Equilibrium Models
Regional economy
European regional policy
Impact analysis

ABSTRACT

This is the first time that European Regional Policy will not consider Andalusia as one of the Objective 1 priority areas. Thus, this paper analyzes the economic impact of the withdrawal of a large amount of European Structural Funds from the Andalusian economy in the 2014–2020 Community Support Framework. A Dynamic Applied General Equilibrium Model is developed to assess the effects of the loss of this funding on the main regional economic indicators and under different simulation scenarios. The model analyzes the effect of economic policy actions on the economy, satisfying the requirements of welfare and technological feasibility when given some restrictions on available resources.

1. Introduction

The main goals of the European Union are to boost economic and social progress and eliminate existing differences between the standards of living of State Members and in regions. Since the adhesion of Spain to the European Union, Andalusia has been cataloged as an Objective 1 region because its Gross Domestic Product (GDP) has been inferior to 75% of the community average.

Objective 1 regions came to be known as Convergence regions in the last septennium 2007–2013. The Spanish communities in this category are Galicia, Castilla-La Mancha, Andalusia and Extremadura, the last being the only one, for the moment, that will still be receiving European Funds during the next period programmed.

The rest of them are falling from the list, forming two different groups.

On the one hand, there are the so-called "phasing-out" or gradual exit communities that, although still under 75% of the EU-15, are no longer poor compared to others in the UE-27. These regions have been affected by statistics that have led to a recalculation of the community average GDP per capita since the adhesions to the UE of new countries with levels of income comparatively inferior to ours in 2004 and 2007. The autonomous regions of Ceuta and Melilla, Asturias or Murcia are in this situation and they are experiencing a transitory period in which structural aids are being rescinded.

On the other hand, there are the "phasing-in" regions or growth-effect regions, which, on taking part in the priority intervention, have registered a dynamism that has allowed them to improve their levels of income independently of the block of countries (UE15 or UE27) for which the calculation was made. These regions will enjoy another transitory period under the second goal of Regional Competitiveness and Employment. Castilla León, Comunidad Valenciana and Canarias find themselves in this case.

The rest of the Spanish regions are direct beneficiaries of this second objective. There is also a third one of a much more residual nature called European Territorial Cooperation. The new regions belonging to countries in Central and Oriental Europe are now in the priority necessity group.

In this way the funds have contributed to generating regional GDP and reducing unemployment during these years. In terms of efficiency, infrastructure investments of a physical type (ERDF) have contributed mostly to regional GDP growth oriented toward employment and human capital formation (ESF), or have led to the financing of agrarian structures (the extinct EAGGF-G). This great performance, added to the above mentioned statistical effect, has caused Andalusia to exit from this last group and record levels over 75% with respect to average GDP per capita in the EU-27, according to the latest data from Eurostat.

With the changes in the region and the threat of an expected withdrawal of funds, this paper proposes an analysis to explain the effects of this withdrawal of European Funds from Andalusian Funds in the seven year period 2014–2020. This will expand on the study of Cardenete et al. (2012). Structural funds are quite a new line of research, although some interesting works can be highlighted therein. At European level, Midelfart-Knarvik and Overman (2002) note that structural fund expenditures have notably promoted the location of industry by attracting industries that are research and development intensive. They study the specific case of Ireland where structural

* Corresponding author. Tel.: +34 954 64 16 00.
E-mail addresses: macardenete@uloyola.es (M.A. Cardenete), mcdelgado@uloyola.es (M.C. Delgado).

http://dx.doi.org/10.1016/j.econmod.2014.09.021
0264-9993/

funds even reinforced comparative advantage. In a similar line of inquiry, Bradley et al. (2003) adapted the HERMIN macroeconomic model for Ireland, Portugal, Greece and Spain, important recipients of regional aids. Beugelsdijk and Eijffinger (2005) analyzed convergence among EU member states for the period 1995–2001 and developed some ideas about the efficiency of structural funding. They pointed out the relation existing between aggregate growth and internal cohesion.

Furthermore, Le Gallo and Dall'Erba (2008) analyzed the evolution of labor productivity disparities in 145 European regions throughout 1975–2000, according to the concepts of sigma and beta-convergence and addressing a sectoral analysis. They detected that inequality persists in productivity levels between core and peripheral regions and emphasized how convergence speeds and the nature of spatial effects vary from one sector to another. Crescenzi and Rodríguez-Pose (2012) revisited the question of the extent to which transport infrastructure endowment contributed to regional growth in the EU between 1990 and 2004. The results indicated that infrastructure endowment should be complemented by other variables related to social patterns, innovation or immigration.

This issue has also been studied with respect to Spanish economy by De la Fuente (2003). This author evaluates the structural funding contribution to output growth and employment in the Objective 1 region group by means of a growth model. His results support the idea that European funds can be considered to be a good contributor to per capita income. Other regional overviews can be found in Sosvilla-Rivero (2003) for the Canary Islands, in Sosvilla-Rivero and Herce (2003) for Madrid, and Sosvilla-Rivero et al. (2006) for Castilla La Mancha-, among others, following the HERMIN model. Focusing on Andalusia, Sosvilla-Rivero et al. (2004) worked with a regionalized HERMIN model from 1989 to 2006 and detected an important contribution to a real convergence of regional policy. In a later study, Sosvilla-Rivero and Murillo (2005) captured supply side effects of the Community Support Framework (CSF) 1994–99 through cointegration techniques and time series. The results confirmed that European facilities had reduced the gap between the Andalusian economy and its more developed neighbors.

The above models were based on econometric techniques. With respect to multisectoral models, our methodological approach (linear as well as non-linear general equilibrium models) can be found regarding this issue. Reviewing the former, Morillas et al. (1999) captured European funding externalities by means of input–output tables for the period 1989–93, and Lima and Cardenete (2005) developed an impact analysis using three Social Accounting Matrices (SAM) for Andalusia, while Cámara (2006) presented a linear multiplier model for Madrid.

Although SAM-type models allow us to capture a wider range of effects than traditional input–output models, we have gone a step further by building a more sophisticated CGE model: specifically, our Dynamic Applied General Equilibrium Model to analyze the effects caused by the above-mentioned withdrawal of European Funds on the main macro magnitudes of Andalusian economy because of its being a region with over 75% GDP per capita for this programmed period.

Thus, a methodological approach consistent with the theoretical foundations of economic analysis is established to find the economic impact of European Fund reduction on regional economy, and at the same time to generate practical recommendations. Therefore, the study proposes the construction of an operational model for regional economy which, once developed, will analyze the estimated impact.

The structure of this paper is as follows: the second section shows the methodology used and the main features of the model. The third presents the database necessary for analysis. The fourth and fifth include the different simulation scenarios raised, with the sharing rule for the Funds established for the analysis in question. The results are presented in the sixth section and, finally, conclusions are drawn in the seventh section.

2. Applied general equilibrium model

Applied General Equilibrium Models (AGE) analyze the effect of policy actions on the economy in particular, meeting welfare requirements and technological feasibility even when given some restrictions on available resources. In this way, they are able to capture the chain of relationships that generates certain exogenous shocks on agents and markets, and on the whole economy in general.

AGE models are built upon the general equilibrium theories developed by Walras (1874) who expressed the simplest problem of general equilibrium in an exchange economy as a set of mathematical equations. Wald (1951) made a model without joint production, the most important hypothesis being that the demand functions satisfy the so-called “weak preference axiom reveals”. Later these models were improved by Arrow and Debreu (1954) who demonstrated the existence of equilibrium. In a further step, McKenzie (1959) formalized the Walrasian theory and worked on a linear production model, proving the existence of this equilibrium for a model that made assumptions about demand functions, rather than directly on preferences. Given the important mathematical foundations of these theories, potent algorithms capable of obtaining equilibrium solutions were required to develop models such as those of Shoven and Whalley (1972) and Whalley (1975, 1977) or Shoven (1976), among others, that presented AGEM as a tool allowing the assessment of public policies and the implementation of comparative statics exercises. Scarf (1984) made possible much of the computational development.

General equilibrium models have traditionally been used to analyze the effects of changes in economic policy. According to the case study, model parameters are required to reach levels of prices and outputs that provide solutions for the general equilibrium model, resulting in an initial equilibrium. Next, a new calculation is made based on a specific behavior hypothesis and using any of the available algorithms. The impact of the exercise on the most significant economic variables (prices, output level, government revenues and the new distribution of income among consumers) is thus predicted.

The choice of the functional forms that will reflect the behavior of economic agents usually depends on the use given to model elasticities. Most frequently, the functional form chosen is that which will best allow the incorporation of key parameter values (for instance, price and income elasticities), while trying to avoid damaging the treatment of the model. This is the main reason why “convenient” functional forms like the Cobb–Douglas, the Constant Elasticity of Substitution (CES), the Linear Expenditure System (LES), Translog, Generalized Leontief or other flexible forms are those most often used.

Another hurdle to overcome is calculating the values of those parameters that define functional relationships. There are two main ways of obtaining these values: a deterministic calibration process and econometric estimation. We opted for the first, the most commonly used. It is assumed that the economy studied, represented by an empirical database, is in equilibrium under the existing tax policy, and is what is called a “balance of reference” (free translation for the term “benchmark equilibrium”). The model parameters are then calculated to reproduce empirical data as an equilibrium solution for the model. There is no statistical test that contrasts resulting model specification. The procedure in this type of model makes the confection of an economic model more perfect and does not prioritize the statistical properties of the model. In practice, the data used in the calibration that represents the reference equilibrium account are obtained from national accounting and other data provided by government institutions. These data (flows of goods, services and income for a specified period or reference period) must be collected and sorted so that they are operational. One of the most consistent ways to do this is through the database called the Social Accounting Matrix (SAM). A SAM includes data for transactions between businesses, the initial endowments of individual consumers and the quantities demanded by them for consumer goods and services, the sector breakdown of value for production sectors, taxes and transfers between government and private partakers in economic transactions with the foreign sector, etc… The compatibility of information sources is achieved by classifying them in a hierarchy. Input–output tables and national accounting are usually found at the apex of this hierarchy.

Having explained what an AGE model is, we shall discuss some of our model's features. It is a model that includes economic interactions that take place between consumers and families, producers or companies, and the government and the foreign sector.

2.1. Static model

A static general equilibrium model, like the one proposed by Cardenete and Sancho (2003), is taken as the basis for this work. The static model consists of five blocks as follows:

1. Producers

The model used here consists of production sectors obtained from an aggregation of input–output tables in Andalusia in 2013, where the domestic production Xdj in each sector is used as a factor, the production of the other sectors:

$$\mathrm{Xd}j = \min\left(\mathrm{X}_{1j}/\mathrm{a}_{1j},\ \mathrm{X}_{2j}/\mathrm{a}_{2j}, \ldots,\ \mathrm{X}_{nj}/\mathrm{a}_{nj},\ \mathrm{VA}_j/\mathrm{v}_j\right) j = \text{ production sectors} \quad (1)$$

X_{ij} being the corresponding quantities of goods i required for the domestic production of goods j; aij are equivalent to the coefficients within the technical analysis input–output; VA_j represents the value added by the sector j and V_j the minimum amount of value added that is required to produce one unit of goods j.

At the next level of nesting, the regional value added for each sector j (VA_j) is the result of combining the primary factors (labor L and capital K), combined by a Leontief technology of fixed coefficients:

$$\mathrm{VA}_j = \min\left(\mathrm{K}_j/\mathrm{k}_j, \mathrm{L}_j/\mathrm{l}_j\right) \quad j = \text{production sectors} \quad (2)$$

Total production Q_j is the result of combining domestic production Xd_j with equivalent imports $Xrow_j$, which are considered imperfect substitutes for domestic production, as discussed above following Leontief technology. Specifically we assume that the production of sector j is given by:

$$\mathrm{Q}_j = \min\left(\mathrm{Xd}_j, \mathrm{Xrow}_j\right) \quad j = \text{production sectors} \quad (3)$$

2. The public sector

The government is an agent that taxes transactions between other economic agents to obtain public revenue (R), has an influence on consumers' disposable income (DPI), makes transfers to the private sector (TPS) updated by a consumer price index (cpi), and demands goods and services, GD_j, at sectoral prices (P_j). The difference between revenues and payments represents the deficit or surplus of their administration.

In our model there is a constant activity level of public spending and the deficit is endogenously determined, so PD is given by:

$$PD = R - TSPcpi - \sum_{j=1}^{n} GD_j P_j \quad (4)$$

3. The foreign sector

Since our analysis is based on regional Andalusian economy, the foreign sector is modeled in a simple, aggregated way, namely as a single foreign sector that includes the three trading partners. The level of export activity in the foreign sector is fixed exogenously, whereas the trade deficit is endogenously determined, given that imports are also endogenous. Following Armington's hypothesis,[1] the closing rule of this sector is given by the following Commercial Deficit expression (PDROW):

$$PDROW = prow \sum_{j=1}^{n} IMP\, P_j - TROW - prow \sum_{j=1}^{n} EXP\, P_j \quad (5)$$

where IMP_j represent imports from the foreign goods sector j, EXP_j exports from sector j TROW transfers from abroad to consumers.

4. Consumers

Final demand includes several sectors: on the one hand, unconsumed demand sectors, investment and exports and, on the other hand, the demand for consumer goods for families. Consumers demand goods, and the rest of their disposable income is their savings. Representative consumer purchases are funded primarily with revenue from the sale of their factor endowments.

$$\begin{aligned} \mathrm{YDISP} &= \text{Gross income – Total direct taxes} \\ \mathrm{YDISP} &= \mathrm{w\,L + r\,K + cpi\,TPS + TROW – DT\,(r\,K + cpi\,TPS + TROW)} \\ &\quad \mathrm{–DT\,(w\,L–CO\,w\,L)–CO\,w\,L} \end{aligned} \quad (6)$$

where w and r are the prices of labor and capital respectively, and CPI is an index of consumer prices. Therefore, each consumer maximizes the utility that reports consumer goods CD_i and savings SAVD, subject to budget constraint of disposable income.

$$\begin{aligned} &\mathrm{Max} \quad \mathrm{U\,(CD_i,\ SAVD)} = \prod_{j=1}^{n} \mathrm{CD}^{\alpha}{}_i + \mathrm{SAVD}^{\beta} \\ &\mathrm{s.t.\ YDISP} = \mathrm{(1–DT)\,(r\,K + cpi\,TPS + TROW) – (1–DT + DT\,CO–CO)\,w\,L} \end{aligned} \quad (7)$$

where α and β are the coefficients of participation for different consumer goods and savings, respectively.

With regard to investment and savings, savings are considered an exogenous component, thus allowing investment to be defined endogenously. In an equilibrium situation, it is necessary to guarantee the macroeconomic equality between savings at the aggregated level and the total investment in the economy:

$$\sum_{j=1}^{n} DI_i pinv = SAVD\ pinv + PD + PDROW. \quad (8)$$

Finally we will consider the full use of both work and capital factors. In addition, the activity levels of government and external sectors will be fixed, allowing relative prices to function as endogenous variables, activity levels of the productive sectors and public and external deficits, as just explained.

Formally, the model reflects a steady state of the regional economy where supply and demand functions of all goods will be obtained as the solution to the problems of utility maximization and profits. The result will be a vector of goods and factor prices along with activity levels of such tax revenues that meet the conditions described above.

The applied general equilibrium model here presented follows traditional Walrasian equilibrium doctrine – Scarf and Shoven (1984),

[1] Armington's hypothesis (1969) considers that the country or economy under analysis must be small enough so as not to influence foreign trade.

Ballard et al. (1985), Shoven and Whalley (1992a,b) –now enlarged to include public and foreign sectors.

2.2. Dynamic model

Reviewing the literature of Applied General Equilibrium Models (AGE), it is seen how most of the models developed over the years are of a static type, i.e., they analyze a single period of time and the analysis is carried out through comparative static exercises. However, in some empirical applications it may be interesting to generate a temporary path to endogenous variables to develop dynamic models or multiple periods.

These models incorporate dynamic aspects of growth through changes in capital stocks. The most common specification in the literature on Dynamic General Equilibrium is characterized by adopting the starting point of the Ramsey growth models (1928) with their infinite lifetime consumer, later on improved by Cass (1965) and Koopmans (1965) and serving Solow (1956) and Swan (1956) for developing the methodological basis of later models, leading the way toward several possibilities for future work. Thus, other types of models can also be found, such as the Solow–Swan model and overlapping generation models.

But it was not until the seventies, with the work of Scarf and Hansen (1973), that Dynamic General Equilibrium Models were strengthened. However, it was Johansen (1974) who, in a very simple way, developed the first model to represent the dynamic economy of Norway. Another of the pioneers in using this dynamic analysis was Harberger (1962) who examined the impact of a tax in a model with two sectors.

Since the nineties, these dynamic AGE models have become more numerous to analyze economic policy issues in various disciplines such as foreign trade policy, price control and optimal taxation, and changes related to climate policies.

Some of these works where steady state dynamics is imposed through exogenous specification of the growth rate have been published by authors like Jorgenson and Wilcoxen (1990) who analyzed the economic impact of the United States economy with and without regulation; Hazilla and Kopp (1990) estimated the social cost of the environmental quality regulations mandated by clear air and clean water acts; Mercenier (1995) provided general equilibrium research on welfare and employment consequences in Europe's move toward a unified market, using a static multicountry–multisector applied general equilibrium model with imperfect competition; Blitzer et al. (1994) built a dynamic general equilibrium model for Egypt to analyze carbon emission restrictions in this country. Vennemo (1997), using a Ramsey type dynamic model, analyzed what happens in the economy if it reduces labor productivity through capital depreciation; Rutherford (1999) constructed a dynamic general equilibrium model to study different policy problems; Bye (2000) discussed tax environmental reform and the possibilities of a double dividend with a dynamic Ramsey-type model for Norway; Jensen (2000) also used a Ramsey-type model in an analysis of carbon taxes in Denmark; Rasmussen (2001) extended the Ramsey model to capture endogenous technological progress; Gerlagh and Van der Zwaan (2003) used a similar approach, specifying multiple technologies; Bergoeing et al. (2001), forging ahead in the use of computational tools, created a dynamic model to analyze trade policies; Dissou et al. (2002) introduced monopolistic competence in a Ramsey-type model for Canada with carbon emissions; Gómez (2005) contained an overview of equational implementation in applied general equilibrium models; Boyd and Ibarrarán (2009) quantified cross-sectoral vulnerability, adaptation and mitigation policies, and climate change to measure the impact of drought on agriculture, forestry and hydroelectric sectors; and Ibarrarán et al. (2008) proposed using a Dynamic General Equilibrium Model to model climate change impacts in Mexico.

There are different approaches to a Dynamic Applied General Equilibrium Model. The most common specification in the literature of AGEMs is Ramsey growth models (1928), which were perfected by Cass (1965) and Koopmans (1965). We limit ourselves to the simple model of Ramsey. The model behaves differently depending on whether or not it is in the so-called stationary state. Steady state is defined as a situation in which different amounts (capital, product, investment, etc.) grow at constant rates. This model is appropriate at this moment in Andalusia[2] because capital accumulation has stagnated; the capitalization of Andalusia is below average when considered as a reference population, occupation or area. Instead, the capital/output ratio is above average, suggesting that not only is capital scarce, but also its productivity is low.

So, in the dynamic version, the representative consumer maximizes the present value of the usefulness of his/her lifetime as follows:

$$Max \sum_{t=0}^{\infty} (1/1 + \rho)^t U(c_t) \tag{9}$$

where t is the time period, p is the intertemporal discount factor, U is the utility function, and ct is consumption in period t. The consumer faces a number of restrictions. First, the total output of the economy is divided into consumption and investment, I_t. Second, capital depreciates at the rate δ. Third, the investment cannot be negative. These constraints can be expressed as follows:

$$c_t \le F(k_t, l_t)\text{-}I_t \tag{10}$$

$$K_{t+1} = K_t(1\text{-}\delta) + I_t \tag{11}$$

$$I_t \ge 0 \tag{12}$$

where K is capital and F represents the production function.

To find first order conditions, consider two periods: t and t + 1. A representative agent makes his decision not only about his consumption today, but rather about consumption today and investment today (which will determine his capital and consumption tomorrow). So there are three decision variables: c_t, K_t, and I_t (I_t means that two constraints on capital need to be considered, one constraint is for K_t, and the other is for K_{t+1}.) Therefore, the Lagrangian is:

$$L = (1/1+\rho)^t U(c_t) + \lambda_1(F(K_t, L_t)\text{-}I_t\text{-}c_t) + \lambda_2(K_{t\text{-}1}(1\text{-}\delta) + I_{t\text{-}1}\text{-}K_t) + \lambda_3(K_t(1\text{-}\delta) + I_t\text{-}K_{t+1}). \tag{13}$$

There are three Largange multipliers: λ_1 is a multiplier on a consumption constraint, λ_2 is a multiplier on a "capital today" constraint, and λ_3 is a multiplier on a "capital tomorrow" constraint.

Solving the utility maximization problem results in the following first order conditions:

$$\partial L/\partial ct = (1/1+\rho)^t(\partial U(ct)/\partial ct)–\lambda_1 = 0 \tag{14}$$

$$\partial L/\partial Kt = \lambda_1(\partial F/\partial Kt)–\lambda_2 + \lambda_3(1–\delta) = 0 \tag{15}$$

$$\partial L/\partial It = -\lambda_1 + \lambda_3 = 0. \tag{16}$$

Now one must recall that the Lagrange multiplier shows sensitivity to changes in the constraint. In economic terms, it measures the value of scarce resources in the problem under consideration. In a common utility maximization problem (the maximization of the utility subject to a budget constraint), the Lagrange multiplier can be interpreted as the marginal utility of (budget) money. In a usual cost minimization problem, the Lagrange multiplier can be interpreted as a marginal cost of production (or the internal value, or imputed value, or more frequently, the shadow price). Mathematically, all these problems are

[2] For additional information see Mas et al. (2013).

identical; what changes is our interpretation. So in our Lagrange optimization, the multiplier shows the shadow price (or marginal cost). Under constant returns to scale and perfect competition assumptions, price equals marginal cost. Therefore, we can rewrite the first order conditions as:

$$P_t = (1/1+\rho)^t \partial U(c_t)/\partial c_t \quad (17)$$

$$PK_t = (1\text{–}\delta)PK_{t+1} + 1 + P_t \partial F\left(K_t, L_t\right)/\partial K_t \quad (18)$$

$$P_t = PK_{t+1}. \quad (19)$$

where Pt, PKt and PK_{t+1} are the values of the corresponding Lagrange multipliers. These can be interpreted as the product price, the price capital today and the price of capital tomorrow, respectively. Let RK_t and W_t represent the rental rate of capital and the wage rate in period t. Denote a unit cost function as $C(RK_t, W_t)$ (unit cost function is a solution of the problem min $(W_t L_t + RK_t K_t)$ s.t. $F(K_t, L_t)=1$), and a demand function as $D(P_t,M)$ (demand function is a solution of the problem max $\sum (1/(1+\rho))^t U(c_t)$ s.t. $\sum P_t c_t = M$), where M is the consumer's income. This can be formulated as follows:

Zero profit conditions:

$$P_t \geq PK_{t+1},\ I_t \geq 0,\ I_t(P_t - PK_{t+1}) = 0 \quad (20)$$

$$PK_t \geq RK_t + (1-\delta)\,PK_{t+1},\ K_t \geq 0,\ K_t(PK_t - RK_t + (1-\delta)\,PK_{t+1}) = 0 \quad (21)$$

$$C\,(RK_t, W_t) \geq P_t,\ Y_t \geq 0,\ Y_t(C(RK_t, W_t) - P_t) = 0. \quad (22)$$

Market clearance conditions:

$$Y_t \geq D(P_t, M) + I_t,\ P_t \geq 0,\ P_t(Y_t - D(P_t, M) + I_t) = 0 \quad (23)$$

$$L_t \geq Y_t \partial C(RK_t, W_t)/\partial W_t,\ W_t \geq 0,\ W_t(L_t - Y_t \partial C(RK_t, W_t)/\partial W_t) = 0 \quad (24)$$

$$K_t \geq Y_t \partial C(RK_t, W_t)/\partial RK_t,\ RK_t \geq 0,\ RK_t(K_t - Y_t \partial C(RK_t, W_t)/\partial RK_t) = 0. \quad (25)$$

In order to quantify the value of investment in a stationary state growth path, the evolution of capital and labor throughout time must be described. This requires assumptions about the growth rate, g, the rate of capital depreciation, δ, and the interest rate, r. As the initial work force L_0, employment at time t is:

$$L_t = L_0(1+g) \quad (26)$$

or, equivalently,

$$L_t = (1+g)\,L_{t-1} \quad (27)$$

The evolution of capital is given by the Eq. (11). If in the base period an economy is on a steady state growth path, all amounts (capital, labor, production, consumption) grow at the same constant rate g. As such, the equation for capital growth can be represented as follows:

$$K_{t+1} = (1+g)\,K_t. \quad (28)$$

A constant interest rate r is also assumed, so that all future prices (including labor and capital) will be, at present value:

$$P_{t+1} = P_t/1+r \quad (29)$$

Capital can be purchased or rented. Therefore implementation of the dynamic involves two prices for capital: the purchase price, PK, and the price of its tenure, RK.

$$VK_t = K_t RK_t \quad (30)$$

We now need to consider first order conditions for capital and investment:

$$PK_t = (1\text{-}\delta)PK_{t+1} + RK_t \quad (31)$$

and

$$PK_{t+1} = P_t. \quad (32)$$

Eq. (32) can be rearranged using Eq. (29) for PK:

$$PK_t = (1+r)P_t. \quad (33)$$

Substituting Eq. (33) for PKt and Eq. (32) for PK_{t+1}in (31), we get:

$$(1+r)P_t = (1\text{-}\delta)P_t + RK_t. \quad (34)$$

As such, the equation of the rental price of capital is:

$$RK_t = (\delta - g)\,P_t \quad (35)$$

Eqs. (11) and (28) derive the following rule for the investment of the stationary state:

$$I_t = (\delta + g)\,K_t \quad (36)$$

Presented below are the changes which must be made in the code of the static model to make it dynamic[3]: firstly, it introduces time sets; it declares the assumed interest rate, growth rate and depreciation rate; it declares four more scalars: rental rate of capital in a base period, RK0, initial capital stock, K0, initial investment, I0, and initial capital earnings, VK; it declares two parameters which represent the growth rate of quantities (i.e., an index of economic activity over the model horizon in the steady-state equilibrium), and the growth rate of prices (i.e., an index of present value prices over the model horizon in a steady state equilibrium); it introduces two more production blocks: capital accumulation, K, and investment, I; it changes the reference quantities to represent an adjustment for the level of consumption in a base period and the reference quantities in the demand block: labor endowment and consumption are adjusted for growth rates; it introduces terminal capital in blocks and, finally, it makes initial value assignments.

3. Database: social accounting matrix for Andalusia 2013

Social Accounting Matrices (Social Accounting Matrix or SAM in Anglo terminology) represent all transactions that have transpired in an economy over a certain period of time. It is an important database table organized as a double entrance, with economic and social information on the transactions occurring between all economic agents.

The use of Social Accounting Matrices was initiated by Stone (1962) who published a SAM for the UK. However, given its usefulness for intersectoral relations in the economy and the distribution of income, the first SAM was developed for use in developing countries in order to establish programs leading to poverty reduction.

A SAM collects economic and social information relevant to all the economic agents, manifested in all the transactions between these

[3] See Paltsev (1999) and Diao et al. (1998).

agents during a period of time: transactions that describe operations of production, distribution and the use of income and accumulation, all within the economy itself as well as those transpiring with the rest of the world. A SAM extends information contained in an input–output table and also includes all flows between added value and final demand. Therefore, a SAM reflects the circular flow of income in an economy.

This study works with an updated 2013 SAM for Andalusia by Cardenete (2010), using these matrix projections for simulations of longer time ranges, all from the 2005 SAM with a methodology for updating the cross-entropy method which needs to use the information available in the GDP, GVA and the production sector. Table 1 presents the SAM structure of accounts, divided into 25 productive sectors with 12 more for institutional sector accounts.

Table 1
Structure of the SAM of Andalusia 2013.

Productive sectors		Institutional sectors	
1	Agriculture	26	Labor
2	Stockbreeding	27	Capital
3	Fishing	28	Consumption
4	Extractive industries	29	Gross capital formation
5	Oil refining and nuclear waste treatment	30	Social security contributions paid by employers
6	Production and distribution of electric energy	31	Indirect taxes
7	Production and distribution of gas, water steam and water	32	Tariffs
8	Water capture and treatment	33	VAT
9	Mining and iron and steel industry	34	Direct taxes
10	Construction materials	35	Social Security contributions paid by employees
11	Chemical industries	36	Public sector
12	Metal manufactures	37	Foreign sector
13	Machinery		
14	Vehicles		
15	Other transport elements		
16	Food		
17	Textiles and leather		
18	Wood manufactures		
19	Other manufactures		
20	Construction		
21	Trade		
22	Transport and communication		
23	Other Services		
24	Sale-oriented services		
25	Non-sale oriented services		

Source: Authors.

4. Alternative scenarios

The future of European Funds in Spain is now under debate. As noted in the introduction regarding work in Spain, the four regions in the Convergence Objective were Andalusia, Galicia, Castilla-La Mancha and Extremadura; the first three will lose some of these funds for the next seven-year period because their income exceeds 75% of the community average. Only Extremadura continues receiving in 2014 the European Funds destined to the poorest regions. Thus, Spain will go from receiving EU funds to becoming a net contributor.

With this scenario, the European Parliament strongly opposes freezing the EU budget after 2013, setting a 5% growth allowance for initiatives such as the 2020 strategy, new tasks under the Treaty of Lisbon or the consolidation of regional convergence. Moreover, by focusing on a cohesion policy, the European Parliament proposed that the European Commission establish an intermediate category (called transition regions) for regions that have exceeded the threshold of 75% of Community GDP per capita but that, at the same time, are below 90% of that indicator. With this, it is trying to provide, in the words of the report "more clarity and confidence in their development". The region of Andalusia is precisely in this situation, so it could benefit from this category if the European executive council were to support this proposal.

Since it is still too early for information about how much the region of Andalusia could receive for the upcoming 2014–2020 multiannual programming period, and due to the scarcity of available information, this analysis will use data from the 2007–2013 period. Three scenarios have been designed, based on some of the initial positions of the European Parliament for the upcoming programming period.

- Conservative scenario: loss of the total amount of current resources.
- Progressive scenario: structural funding remains at the same level as in the current period.
- Effective/realistic scenario: loss of a third of the resources available at the present time.

As its name suggests, the most likely scenario is called effective/realistic because, as discussed above, Andalusia has exceeded the GDP per capita threshold and therefore stops receiving funds and becomes a net contributor. However, the Spanish Government is trying to avoid this scenario with a proposal that has been made to maintain an allocation corresponding to 2/3 of what was received in the period 2007–2013. The other two scenarios are presented in order to compare all possible alternatives in order to deduce the consequences of decisions that might finally be adopted by the corresponding agencies.

5. Simulations

As already discussed in this paper, the fundamental objectives of the Union are to promote European economic and social progress and eliminate differences existing between Member States and regions.

On this premise, we proceed to amplify on the results of the work of Cardenete et al. (2012), analyzing the three scenarios with their simulation as introduced in the previous section and based on information available for the seven year period 2007–2013. This is done by establishing a distribution of these funds among the productive sectors of the model, which are affected by receiving this aid. In addition, this model includes a constant GDP growth rate for each year under study, although it must be noted that it is particularly difficult to make assumptions about behavior and predictions with respect to evolution of not only the Andalusian but also the Spanish and European economies in the coming years. This is due to the situation of current economic instability, with its highly volatile financial markets, strict rules of fiscal discipline, and significant uncertainties in the evolution of the real economy. On this basis, a constant growth rate of 0.8% has been established according to economic forecasts afforded by The Economist–Economist Intelligence Unit.[4]

Thus, following the necessary steps to make an impact on Andalusian economy, a sharing rule is established to describe the proposal to be made with regard to the different branches of the model:

Following Monrobel et al. (2012) and taking into account the synthesis of the interventions of Community Funds in Andalusia 2007–2013 and its endowment budget, this budget will be divided up among the branches of the model taking into account the specific objectives of each of the axes and their priority issues, determining the amounts according to the weight of each sector's productive output.

In addition, a corrective index is constructed which will apply to the variable of public sector demand in the Model. This index reflects the fall in demand in the appropriate sector, which is derived from the total withdrawal of funds or the withdrawal of one third of the funds, depending on the scenario in question, setting alternative scenarios to seek a new balance to meet all the most optimal conditions of the model.

[4] The Economist, n.d www.eiu.com.

Before starting with the distribution of each of the priorities, there is a summary of Community Fund activities for the years 2007–2013 presented in Table 2.

Table 2
Summary of community fund interventions 2007–2013 (thousands of Euros).

Intervention	Total aid (€)
European Regional Development Fund (ERDF)	9,451,160
European Social Funds (ESF)	2,875,850
Cohesion Fund (CF)	200,040
European Agricultural Fund for Rural Development (EAFRD)	1,881,740
European Fisheries Fund (EFF)	176,700
Total	14,585,490

Source: Compiled from Ministerio de Política Territorial (2009).

Following submission of the table showing the expenditure programmed for each major fund, we now proceed to distribute it among different branches of the activity model. Table 3 collects each priority axe of ERDF resources allocated to the various branches of the production model.

Table 3
ERDF Aid 2007–2013 (thousands of Euros).

Priority axes	Productive sectors	Resources (€)
1. Development of the economy of knowledge (R&D and social information)	25. Services not intended for sale	2,050,940
2. Development and business innovation	23. Other services	1,171,270
	24. Services intended for sale	
3. Water resources and risk prevention	8. Uptake and depuration of water	1,744,260
	36. Public sector	
4. Transport and energy	6. Production and distribution of electric power	3,163,600
	22. Transports and communications	
5. Local and urban development	36. Public sector	708,130
6. Social infrastructure	25. Services not intended for sale	529,970
7. Technical assistance	36. Public sector	83,000

Source: Compiled from Consejería de Economía y Hacienda, Programa Operativo del Fondo Europeo de Desarrollo Regional de Andalucía 2007–2013.

According to this distribution, Table 4 indicates the total allocations of the budget for each one of the sectors that are direct beneficiaries of ERDF aid, according to the weight of productive output in the Social Accounting Matrix of Andalusia in 2013.

Table 4
ERDF allocation 2007–2013 to productive sectors (thousands of Euros).

Productive sectors	Resources (€)
6. Production and distribution of electric power	606,791
8. Uptake and depuration of water	45,323
22. Transport and communications	2,556,809
23. Other services	559,715
24. Services intended for sale	611,555
25. Services not intended for sale	2,580,910
36. Public sector	2,490,067

Source: Authors.

Table 5 presents the resources assigned to the different branches of the production model by each ESF funding.

Table 5
ESF aid 2007–2013 (thousands of Euros).

Priority axes	Productive sector	Resources (€)
1. Promoting the business spirit and improvement of the adaptability of workers and entrepreneurs	23. Other services	729,289
	24. Services intended for sale	
2. Promoting employability, social inclusion and equality between men and women	36. Public sector	1,609,578
3. Increase and improvement of human capital	25. Services not intended for sale	446,283
4. Promoting transnational and interregional cooperation	36. Public sector	55,700
Technical assistance	36. Public Sector	35,008

Source: Compiled from Consejería de Economía y Hacienda, Programa Operativo del Fondo Social Europeo de Andalucía 2007–2013.

According to this distribution, the ESF allocation to each sector is set forth in the table below (Table 6). It indicates the total allocations of the budget for each sector that is a direct beneficiary of ESF aid, according to the weight of productive output in the Social Accounting Matrix of Andalusia in 2013.

Table 6
Assignment ESF 2007–2013 to productive sectors (thousands of Euros).

Productive sectors	Resources (€)
23. Other services	348,505
24. Services intended for sale	380,784
25. Services not intended for sale	446,283
36. Public sector	1,700,286

Source: Authors.

Table 7 presents the resources allocated to the different subsectors of the model from the Cohesion Fund (CF):

Structural Funds (ERDF, ESF and CF) finance activities that are complementary to the European Agricultural Fund for Rural Development (EAFRD) and the European Fisheries Fund (EFF) in order to encourage diversification in rural economy and areas dependent on fisheries.

Table 7
CF aid 2007–2013 (thousands of Euros).

Priority axes	Productive sectors	Resources (€)
0	22. Transport and communications	189,683
2. Environment and sustainable development	8. Uptake and depuration of water	10,357

Source: Compiled from Consejería de Economía y Hacienda, Programa Operativo del Fondo de Cohesión de Andalucía 2007–2013.

Although the European Fisheries Fund (EFF) and European Agricultural Fund for Rural Development (EAFRD) are no longer strictly

Structural Funds in the programming period, they are included in the analysis as part of Communitarian Aid in Andalusia.

Below is the allocation of EAFRD and EFF to beneficiary sectors presented in table 8:

Table 8
AFRD and EFF aid 2007–2013 (thousands of Euros).

Productive sectors	Resources (€)
1. Agriculture (EAFRD)	1,881,740
2. Fishing (EFF)	176,7

Source: Compiled from Ministerio de Política Territorial (2009).

After presenting the breakdown by type of fund, a summary table can be found in table 9 which includes the sum of all the funds in each productive sector established as a beneficiary.

Table 9
European funds in Andalusia 2007–2013 (thousands of Euros).

Productive sectors	Resources (€)
1. Agriculture	1,881,740
2. Fishing	176,7
6. Production and distribution of electricity	606,791
8. Water collection and treatment	55,68
22. Transport and communications	2,746,491
23. Other services	908,22
24. Services intended for sale	992,339
25. Services not intended for sale	3,027,193
36. Public sector	4,190,353
Total	14,585,508

Source: Authors.

6. Main results

Next to be presented are the results obtained in the simulations made for a number of macromagnitudes, which are based on the scenarios previously mentioned and where an annual growth described in the above section is applied to the economy. Two comparisons of the conservative scenario are developed: one of them with the continuity scenario and the other with the effective/realistic scenario, for GDP expenditure and its components. Remember that the optimistic scenario assumes that the amount of funds received in the 2007–2013 period will be maintained in the upcoming programming period while in the realistic scenario a reduction of one-third is applied to the amount of funds allocated to Andalusia in the period 2007–2013.

Table 10 shows the growth rates obtained when comparing the conservative scenario and the continuity scenario and effective/realistic scenario. This analysis was performed on each of the components of GDP expenditure. The model shows that GDP increases throughout the whole period in both cases and on calculating the variation rate between scenarios, the average change in the seven years in the GDP reaches 1.2% when comparing the conservative scenario with the continuity scenario, and 0,8% comparing the conservative scenario with the effective/realistic scenario, the highest rate of variation being the variable public expenditure (5.6% and 3.7% average change in seven years respectively) because it is this variable which receives the impact of the funds in the model constructed; the public sector receives the funds from the European Union and is responsible for distributing them depending on where the regional government needs improvement, investing in infrastructure of a physical type which has contributed for years to regional GDP growth, or orienting employment and human capital formation. In contrast, the investment variable is that with the lowest rate of

Table 10
Conservative scenario vs. continuity and effective/realistic Scenario. Variation rates 2014–2020 (thousands of Euros).

Year	Macromagnitudes	Consumption (€)	Investment (€)	Public expenditure (€)	NX (€)	GDP expenditure (€)
2014	No funds	116,262,180	43,759,802	31,787,846	−40,403,129	151,406,699
	Total funds	117,542,794	42,848,995	33,224,646	−40,709,723	152,906,712
	VR (%)	1.101%	−2.081%	4.520%	0.759%	0.991%
	33% reduction	117,112,207	43,154,559	32,742,208	−40,606,611	152,402,363
	VR (%)	0.731%	−1.383%	3.002%	0.504%	0.658%
2015	No funds	117,192,278	44,109,880	32,042,149	−40,726,354	152,617,953
	Total funds	118,873,807	42,915,140	33,927,583	−41,128,976	154,587,554
	VR (%)	1.435%	−2.709%	5.884%	0.989%	1.291%
	33% reduction	118,306,952	43,316,737	33,293,120	−40,993,208	153,923,601
	VR (%)	0.951%	−1.798%	3.904%	0.655%	0.856%
2016	No funds	118,129,816	44,462,759	32,298,486	−41,052,165	153,838,896
	Total funds	119,823,956	43,259,052	34,198,067	−41,457,806	155,823,269
	VR (%)	1.434%	−2.707%	5.881%	0.988%	1.290%
	33% reduction	119,252,853	43,663,659	33,558,848	−41,321,020	155,154,340
	VR (%)	0.951%	−1.797%	3.902%	0.655%	0.855%
2017	No funds	119,074,854	44,818,461	32,556,874	−41,380,582	155,069,607
	Total funds	120,796,879	43,595,001	34,487,665	−41,792,903	157,086,642
	VR (%)	1.446%	−2.730%	5.931%	0.996%	1.301%
	33% reduction	120,216,306	44,006,271	33,837,889	−41,653,846	156,406,620
	VR (%)	0.959%	−1.812%	3.935%	0.660%	0.862%
2018	No funds	120,027,453	45,177,009	32,817,329	−41,711,627	156,310,164
	Total funds	121,690,298	43,995,367	34,681,986	−42,109,769	158,257,882
	VR (%)	1.385%	−2.616%	5.682%	0.955%	1.246%
	33% reduction	121,129,945	44,392,441	34,054,717	−41,975,560	157,601,543
	VR (%)	0.919%	−1.737%	3.771%	0.633%	0.826%
2019	No funds	120,987,673	45,538,425	33,079,867	−42,045,320	157,560,645
	Total funds	122,679,433	44,336,282	34,976,903	−42,450,387	159,542,231
	VR (%)	1.398%	−2.640%	5.735%	0.963%	1.258%
	33% reduction	122,109,378	44,740,312	34,338,716	−42,313,868	158,874,538
	VR (%)	0.927%	−1.753%	3.805%	0.639%	0.834%
2020	No funds	121,955,574	45,902,733	33,344,507	−42,381,683	158,821,131
	Total funds	123,675,985	44,680,267	35,273,632	−42,793,609	160,836,275
	VR (%)	1.411%	−2.663%	5.785%	0.972%	1.269%
	33% reduction	123.096.137	45.091.125	34.624.574	−42.654.732	160.157.104
	VR (%)	0.935%	−1.768%	3.839%	0.644%	0.841%

Source: Authors.

variation (−2.5% and 1.1% average change in seven years respectively); this can be attributed to a crowding-out effect that justifies an investment downgrade in the regional economy by increasing public expenditure. The rate of change of the GDP grows or falls from one year to the next depending on the funds injected into the regional economy each year under study.

7. Conclusions

To complete this analysis, we conclude by emphasizing that the results obtained with the dynamic AGE model in this study on regional economy in the seven-year span 2014–2020 reveal the positive contribution of European Funds to the main macroeconomic indicators, which will give rise to regional development in the seven years under study.

In the results presented, we have observed how the GDP would increase after receiving European Funds in Andalusia. In the case of a continuity scenario (which means continuing to receive the total amount of funds as in the current seven-year period, as mentioned previously), the results show how the GDP would increase by an average of 1.2%, in the seven years; the public expenditure variable would include a higher rate of change, while investment would evidence less variation. In the case of a scenario of more moderate funding (involving two thirds of the amount of funds approved in the current seven year period), the GDP would also increase, although to a lesser extent (in this case by an average of 0.8% in the seven years), thus obtaining different yearly growth rates due to growth and the funds injected into Andalusian economy during each of the years under study, as mentioned above.

All these results point to a boost in the economy in the region thanks to Community aid, but this effect is just one on one (or less than one) in GDP increase and lacks multiplier effects to boost Andalusian economic development, maybe because Andalusia has stopped being poor compared to the UE-27 thanks to the fact that European Funds in Andalusia have contributed for years to the convergence of the region. To illustrate the importance of this funding in the region since 1986, we can list some of the infrastructures that have been financed. Some of these physical infrastructures covered a specific deficit that limited regional growth and deeply contributed to regional articulation like, for example: the high-speed train, some infrastructures of the universal exposition –EXPO'92–, freeways and new roads, new accesses to Seville city as capital of the region, investments in the construction of seaports in the province of Cádiz, reforms in the airports of Seville, Málaga and Almería, the Technological Park of Málaga, the International Center of Tourist Services in Marbella, water and energy infrastructures for near-by towns in Seville, the Sea Sciences College in Cadiz University, new industrial lands in most of the capitals, and water infrastructures (for more information about this regional economy and its convergence experience, see Lima et al. (2010)). Therefore, this work deems it necessary to maintain the financial distribution of the funds provided by the European Regional Policy that, although requested in relation to expected results, allows the recovery of regional economy to be consolidated while avoiding economic turbulences that could endanger the important progress made during the region's long process of convergence. Consequently, this study is based on the assumption that the third scenario suggested could represent an adequate combination to supplement the objectives already achieved in Andalusia in terms of convergence.

References

Armington, P.S., 1969. A theory of demand for products distinguished by place of production. Int. Monet. Fund Staff Pap. 16, 159–178.

Arrow, K.J., Debreu, G., 1954. Existence of an equilibrium for a competitive economy. Econometrica 22 (3), 265–290.

Ballard, C.L., Fullerton, D., Shoven, J.B., Whalley, J., 1985. A General Equilibrium Model for Tax Policy Evaluation. University Chicago Press, Chicago.

Bergoeing, R., Kehoe, P.J., Kehoe, T.J., Soto, R., 2001. A decade lost and found: Mexico and Chile in the 1980s. Rev. Econ. Dyn. 5, 166–205.

Beugelsdijk, M., Eijffinger, S., 2005. The effectiveness of structural policy in the European Union: an empirical analysis for the EU-15 in 1995–2001. J. Common Mark. Stud. 43 (1), 37–51.

Blitzer, C.R., Eckaus, R.S., Lahiri, S., Meeraus, A., 1994. A general equilibrium analysis of the effects of carbon emission restrictions on economic growth in a developing country: Egypt. In: Mercenier, J., Srinivasan, T.N. (Eds.), Applied General Equilibrium and Economic Development. University of Michigan Press, Ann Arbor.

Boyd, R., Ibarrarán, M.E., 2009. Extreme climate events and adaptation: an exploratory analysis of drought in Mexico. Environmental and Development Economics 14. Cambridge University Press, pp. 371–395.

Bradley, J., Morgenroth, E., Untiedt, G., 2003. Macro-regional evaluation of the structural funds using the HERMIN modeling framework. Sci. Reg. 3, 5–28.

Bye, B., 2000. Environmental tax reform and producer foresight: an intertemporal computable general equilibrium. J. Policy Model 22, 719–752.

Cámara, A., 2006. Estimación de la Matriz de Contabilidad Social de la Comunidad de Madrid para el año 2000: Análisis de impacto de los fondos europeos 2000–2006 en la región aplicando la metodología de multiplicadores lineales. Universidad Rey Juan Carlos, (Doctoral Dissertation).

Cardenete, M.A., 2010. Una Estimación de las Matrices de Contabilidad Social de Andalucía 2005-2013. Mimeo.

Cardenete, M.A., Sancho, F., 2003. An applied general equilibrium model to assess the impact of national tax changes on a regional economy. Rev. Urban Reg. Dev. Stud. 15 (1), 55–65.

Cardenete, M.A., Delgado, M.C., Lima, C., 2014. The structural funds in Andalusia for the programming period 2014–20: time for tightening belts. Eur. Plan. Stud. 22 (3), 563–586.

Cass, D., 1965. Optimum growth in an aggregative model of capital accumulation. Rev. Econ. Stud. 32, 233–240.

Consejería de Economía y Hacienda, 2007a. Programa Operativo del Fondo de Cohesión de Andalucía 2007–2013. Junta de Andalucía.

Consejería de Economía y Hacienda, 2007b. Programa Operativo del Fondo Europeo de Desarrollo Regional de Andalucía 2007–2013. Junta de Andalucía.

Consejería de Economía y Hacienda, 2007c. Programa Operativo del Fondo Social Europeo de Andalucía 2007–2013. Junta de Andalucía.

Crescenzi, R., Rodríguez-Pose, A., 2012. Infrastructure and regional growth in the European Union. Pap. Reg. Sci. 91 (3), 487–513.

De la Fuente, A., 2003. El impacto de los Fondos Estructurales: Convergencia regional y cohesión interna. Hacienda Pública Española/Revista de Economía Pública 165 (2/2003), 129–148.

Diao, X., Yeldam, E., Roe, T.L., 1998. A simple dynamic applied general equilibrium model of a small open economy: transitional dynamics and trade policy. J. Econ. Dev. 23 (1), 77–101.

Dissou, Y., MacLeod, C., Souissi, M., 2002. Compliance costs of the Kyoto protocol and market structure in Canada: a dynamic general equilibrium analysis. J. Policy Model 24, 751–779.

Gerlagh, R., Van der Zwaan, B.C.C., 2003. Gross world product and consumption in a global warming model with endogenous technological change. Resour. Energy Econ. 25, 35–57.

Gómez, A., 2005. Simulación de Políticas Económicas: Los Modelos de Equilibrio General Aplicado. Cuad. Econ. ICE 69, 197–217.

Harberger, A.C., 1962. The incidence of the corporation income tax. J. Polit. Econ. 70 (3), 215–240.

Hazilla, M., Kopp, R.J., 1990. Social cost of environmental quality regulations: a general equilibrium analysis. J. Polit. Econ. 98, 853–873.

Ibarrarán, M.E., Malone, E.L., Brenkert, A.L., 2008. Climate change vulnerability and resilience: current status and trends for Mexico. PNNL-18136. US Department of Energy and Pacific Northwest National Laboratory, December 2008.

Jensen, J., 2000. How valuable are delayed cutbacks in Danish carbon emissions? In: Harrison, G.W., Hougaard Jensen, S.E., Haagen Pedersen, L., Rutherford, T.F. (Eds.), Using dynamic general equilibrium models for policy analysis. North-Holland, Amsterdam.

Johansen, L., 1974. A multi-sectoral study of economic growth (enlarged edition 1974). North-Holland Publishing Company, Amsterdam.

Jorgenson, D.W., Wilcoxen, P.J., 1990. Intertemporal general equilibrium modeling of U.S. environmental regulation. J. Policy Model 12, 715–744.

Koopmans, T.C., 1965. On the concept of optimal economic growth. The Econometric Approach to Development Planning. North Holland, Amsterdam.

Le Gallo, J., Dall'Erba, S., 2008. Spatial and sectoral productivity convergence between European regions: 1975–2000. Reg. Sci. 87 (4), 505–525.

Lima, M.C., Cardenete, M.A., 2005. Análisis de impacto de los fondos FEDER recibidos por una economía regional: Un enfoque a través de matrices de contabilidad social. Presupuesto y Gasto Públic. 40 (3), 113–131.

Lima, M.C., Cardenete, M.A., Usabiaga, C., 2010. Andalucía y el MAC 2000–2006: Una Evaluación de los Fondos Estructurales Recibidos. Papeles de Econ. Española 123, 102–118.

Mas, M., Pérez, F., Uriel, E., 2013. Inversion y stock de capital en España (1964–2011). Fundación BBVA.

McKenzie, L.W., 1959. On the existence of general equilibrium for a competitive market. Econometrica 27, 54–71.

Mercenier, J., 1995. Can “1992” reduce unemployment in Europe? On welfare and employment effects of Europe's move to a single market. J. Policy Model 17 (1), 1–37.

Midelfart-Knarvik, K.H., Overman, H.G., 2002. Delocation and European integration. Is structural spending justified? Econ. Policy 17, 321–359.
Ministerio de Política Territorial, 2009. Perfil Económico y Financiero de las Comunidades Autónomas 2008, Andalucía. Secretaría de Estado de Cooperación Territorial, Dirección de Cooperación Autonómica, Subdirección General de Análisis de las Comunidades Autónomas, Madrid.
Monrobel, J.R., Cámara, A., Marcos, M.A., 2013. Modeling european regional policy 2007–2013: applied general equilibrium analysis of the economic impact on the Madrid region. Eur. Plan. Stud 21 (2), 264–280.
Morillas, A., Moniche, L., Castro, J.M., 1999. Evaluación de los efectos de los Fondos Estructurales en la economía andaluza. Rev. Estud. Reg. 54, 225–249.
Paltsev, S., 1999. Moving from static to dynamic general equilibrium economic models. Notes for a beginner in MPSGE. Massachusetts Institute of Technology.
Ramsey, F., 1928. A mathematical theory of saving. Econ. J. 38 (152), 543–559.
Rasmussen, T.N., 2001. CO2 abatement policy with learning-by-doing in renewable energy. Resour. Energy Econ. 23, 297–325.
Rutherford, T.F., 1999. Applied general equilibrium modeling with MPSGE as a GAMS subsystem: an overview of the modeling framework and syntax. Comput. Econ. 14, 1–2.
Scarf, H., 1984. The computation of equilibrium prices. In: Scarf, H., Shoven, J.B. (Eds.), Applied General Equilibrium Analysis. Cambridge University Press, Cambridge.
Scarf, H.E., Hansen, T., 1973. Computation of Economic Equilibria. Yale University Press.
Scarf, H., Shoven, J.B., 1984. Applied General Equilibrium Analysis. Cambridge Univ, Press, Cambridge.
Shoven, J.B., 1976. The incidence and efficiency effects of taxes on income from capital. J. Polit. Econ. 86 (6), 1261–1284.
Shoven, J.B., Whalley, J., 1972. A general equilibrium calculation of the effects of differential taxation of income from capital in the U.S. J. Public Econ. 1, 281–321.
Shoven, J.B., Whalley, J., 1992a. Canada–US tax comparisons. A National Bureau of Economic Research Project Report. Univ. Chicago Press, Chicago and London.
Shoven, J.B., Whalley, J., 1992b. Applying general equilibrium. Cambridge Univ. Press, New York.
Solow, R., 1956. A contribution to the theory of economic growth. J. Econ. 70 (1), 65–94.
Sosvilla-Rivero, S., 2003. Canarias y los Fondos Estructurales europeos. Technical Report 2003/28. Fundación de Estudios de Economía Aplicada (FEDEA), Madrid.
Sosvilla-Rivero, S., Herce, J.A., 2003. Efectos de las ayudas europeas sobre la economía madrileña, 1990–2006: Un análisis basado en el modelo HERMIN. Technical Report 2003/29. Fundación de Estudios de Economía Aplicada (FEDEA), Madrid.
Sosvilla-Rivero, S., Murillo, E., 2005. Efectos a largo plazo sobre la economía andaluza de las ayudas procedentes de los fondos estructurales destinadas a infraestructuras: El marco de apoyo comunitario 1994–1999. Invest. Reg. 6, 91–124.
Sosvilla-Rivero, S., Avilés, A., Murillo, E., Ordónez, J.M., Herce, J.A., 2004. Andalucía y la política regional europea. Colección Pablo de Olavide, Sevilla: Consejería de Economía y Hacienda. Junta de Andalucía.
Sosvilla-Rivero, S., Bajo, O., Díaz, C., 2006. Efectividad de la política regional comunitaria: El caso de Castilla-La Mancha. Papeles de Economía Española 107, 243–255.
Stone, R., 1962. A social accounting matrix for 1960 in a programme for growth. Chapman and Hall Ltd. Ed, London.
Swan, T.W., 1956. Economic growth and capital accumulation. Econ. Rec. 32, 334–361.
The Economist, d. Economist Intelligence. Unit.www.eiu.com.
Vennemo, H., 1997. A dynamic applied general equilibrium model with environmental feedbacks. Econ. Model. 14, 99–154.
Wald, A., 1951. On some systems of equations of mathematical economics. Econometrica 19 (4), 368–403.
Walras, L., 1874. Elementos de Economía Política Pura. Alianza Editorial, Madrid (1987).
Whalley, J., 1975. A general equilibrium assessment of the 1973 United Kingdom tax reform. Economica 42, 139–161.
Whalley, J., 1977. The United Kingdom System, 1968–1970: some fixed point indications of its economic impact. Econometrica 45 (8), 1837–1858.