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Validating Policy-Induced Economic Change Using Sequential General Equilibrium SAMs

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ABSTRACT
We present a novel sequential approach that explores the capacity of Computable general equilibrium (CGE) models to track down policy-induced economic changes and their ability to generate contrastable data. We use an empirical Social accounting matrix (SAM) of the region of Andalusia, in the south of Spain, to construct an initial CGE model. This model is then perturbed with a set of policy shocks related to EU Structural Funds invested into Andalusia. These shocks are accompanied by some parameter adjustments that pick up the main external changes not explained by the model. We generate a sequence of model-produced virtual SAMs. We then compare the last virtual SAM in the sequence with a new available empirical SAM. This allows us to check relatedness, for the same year, between the model produced and the empirical SAMs. The results show a good fit to the empirical data, providing further support to the CGE modelling tool. Copyright © 2016 John Wiley & Sons, Ltd.

KEY WORDS Social accounting matrices; applied general equilibrium; impact analysis; European regional policy

INTRODUCTION

Computable general equilibrium (CGE) models have become a tool in addition to econometrics-based models for the assessment of the implications of policy decisions, and especially so when the interest rests in obtaining detailed information of a microeconomic and sectoral nature.

CGE models are richer in economic structure but have a less sound statistical foundation compared to econometric models (Whalley, 1985). Thus the typical disaggregated implementation characteristic of CGE models allows researchers to study sectoral interdependence and general equilibrium repercussions in depth, but results cannot be statistically tested given the usual nature of the CGE approach. Nevertheless, CGE models might be connected, in a way, to econometrics since elasticities are usually imported from the empirical literature. Moreover, the availability of larger and better elasticities databases for a specific region or time period would definitely help in achieving more conclusive model results.

The present work falls within the context of ex post validation of CGE models. In general, by validation we mean the ability of CGE models to track down policy changes and external shocks, once these have actually taken place. If this line of inquiry turns out to be successful, simulation results can signal directions to improve model structure and to produce better simulation fits. This would provide a further empirical backing of CGE models, in addition to their being based on sound and generally accepted micro theory.

There have not been many contributions in the literature checking the empirical validity of CGE models. Thus any efforts to fill this gap could no doubt provide some new indications of the analytical power of the CGE methodology. Following a chronological approach, we find the initial point of Johansen (1960), who outlined a relevant question: How well do multisectoral models perform? Focusing on this idea, Polo and Sancho (1993) checked the macroeconomic performance of a CGE calibrated to a SAM of Spain for 1988. After updating a group of exogenous variables, they found that their model captured adequately the major macro developments that occurred in the Spanish economy, increasing their confidence in the results derived from their CGE model. Improving on this line of research, Kehoe *et al.* (1995) looked beyond aggregate magnitudes and centred their analysis on detailed microeconomic results—the essence, after all, of what CGE models are about. They compared their model resource allocation results with empirical data for a 10-year period. They also updated a few external major shocks affecting the Spanish economy and found their model was a good enough conditional predictor for actual changes in sectoral activity levels and relative prices under a variety of model scenarios (i.e. closure rules and labour market characteristics).

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Inspired by similar ideas, Fox (1999) worked on Brown and Stern's CGE model of the Canada–US Free Trade Agreement (Brown and Stern, 1989). He found that the model performed well for changes in trade flows, whereas additions of appropriate macroeconomic shocks were necessary to improve the simulation results for output and employment. A more technical review on validation techniques was addressed by Kleijnen (1995). This author surveys verification and validation of models, focusing especially on simulation models in operational research.

Some years later and examining in more depth what may be called the predictive ability of models, Kehoe (2005, ch. 13) reinforced the idea of the need and relevance of some type of ex post model checking as an indirect indicator of the accuracy of results produced by CGE modelling tools. Kehoe used three static CGE models to evaluate the effects of the North American Free Trade Agreement and undertook a comparison of model results with actual data. From this comparison some model weaknesses were revealed—in particular, an underestimation of sectoral impacts—and their identification helped in 'fine tuning' the initial models with the aim, of course, of improving their predictive ability. In similar research, Domingues *et al.* (2008) studied the welfare results of alternative free trade areas in MERCOSUR countries, dealing with the sensitivity to shocks under different degrees of intra-blocs trade liberalization. This paper showed that trade elasticities were important parameters driving the model's results and, for example, welfare gains for Argentina and Uruguay were found to be very sensitive to these parameters.

Moving to other policies, a research study for agriculture markets was undertaken by Valenzuela *et al.* (2007) that focused on the ability of a CGE model to reproduce observed price volatility. They concluded again that patterns in the deviations between model predictions and validation criteria could be used to identify the weak points of a model in order to improve its specifications with firmer empirical foundations.

Energy-oriented CGE models have also paid attention to this issue. Beckman *et al*. (2011) recently worked on the validation of a widely utilized global CGE model: GTAP-E. By comparing model-generated petroleum price distributions with observed 5-year data, they come to the conclusion that energy demand in GTAP-E is far too price elastic over this time framework. After incorporating the latest econometric estimates of energy demand and supply elasticities, they found the model to perform more satisfactorily. Partridge and Rickman (2010) expressed a similar concern in relation to regional development policies. They provided government authorities with a reliable and complementary analytical tool, which is especially suited to the evaluation of economy-wide policies.

In the context of regional policy evaluation and the role to be played by CGE models, Giesecke and Madden (2013) highlighted a number of challenges that should be faced by modellers in the near future, such as interregional factor mobility, trade and transport, government impact on regional economies, or regional migration and investment, that would provide models with interesting tools for an in-depth policy-relevant regional economic analysis. They are also quite aware of the limitations that might be found under such an ambitious approach, requiring a huge and complex database, including a multiregional input–output table or detailed social accounting information. A wide range of new elasticity coefficients might be estimated as well. Moreover, they point out that recent econometric research yields that regional Armington and labour-capital substitution elasticities might not differ significantly from the corresponding ones in a national or international framework when a fine industrial disaggregation is considered.

Dixon and Rimmer (2013) focus on the idea that validation is a keystone for improving the potential of CGE forecasts. They claim that the analysis, besides being computationally sound, should strive to be based on accurate up-to-date data and should try to capture the main institutional characteristics of the corresponding economy. In order to achieve these ambitious goals, modellers should undertake a set of simulations that would reveal model weaknesses, by means of testing, for instance, baseline forecasting against reality.

Our approach here follows the previous line of research. Our thesis statement consists of introducing a novel method—sequential general equilibrium SAMs—that improves estimates compared to those from calibrating single-period CGE models. This is due to the sequential SAM method's ability to control for other shocks over the extended time period under study. We compare our new method using the example of convergence funds given to the Andalusian economy and we evaluate that policy in the light of our improved model estimates.

We use, in other words, a sequence of comparisons based upon the construction of yearly SAMs built from the results generated by a sequence of CGE model implementations. From a baseline regional SAM for Andalusia, a calibrated CGE model is built. A policy shock is introduced and a simulation is run. From the counterfactual equilibrium a virtual SAM reflecting the new equilibrium is built. The virtual SAM is used again in order to introduce a new policy shock. The process is repeated for the number of years the European regional policy is enacted. At the end, a virtual SAM reflecting the sequenced equilibrium is available and a comparison with an actual empirical SAM for the same year, or the previous years if available, is undertaken. From the comparison one should be able to identify and assess the role played in the economy attributable to the yearly injected external shocks, while at the same time checking the predictive ability of the CGE model built to represent the region's economy.

The types of policy shocks we consider are related to European Structural Funds commonly known as 'Cohesion Funds'. These funds respond to EU aid earmarked for promoting capital improvements, both in physical infrastructures and human capital. In the last 25 years the region of Andalusia has been the recipient of about 40,000 million euros in EU aid. This amount has been distributed through the implementation of several Multiannual Financial

Frameworks (MFF), in the policy jargon. The most recent ones are the 2000–06 and 2007–13 MFF, already finished, whereas the current one started in 2014 and will finish in 2020. The previous two will presumably be the last ones in which the region will be receiving significant financial aid since Andalusia will stop being priority convergence, or Objective 1 Region, in the near future. The fact that Andalusia's gross domestic product (GDP) is expected to be above the 75% lower bound for average EU GDP will considerably restrict access to further regional convergence funds in subsequent periods.

We examine, because of data availability, the distribution of funds into the region in the 2000–05 sub-period of the 2000–06 MFF. For the initial year 2000 and the terminal year 2005, two empirical regional SAMs for Andalusia are available (SAMAND2000, SAMAND2005). From the initial empirical SAM, we construct a chained sequence of virtual SAMs ($VSAM_t$, $t = 2000, \ldots, 2005$) using the counterfactuals of a CGE model. The first sequence of virtual SAMs incorporates exclusively the policy changes associated to the disbursement of funds. Since in the actual economy other changes will also take place, we will introduce their feedbacks as well so that they play a role in the production of virtual SAMs. We can see this complementary procedure as a robustness check that gives us a way to contextualize and appraise the results beyond the strict static nature of the CGE model.

When tracking economic variables over time using an economic model, CGE or otherwise, we should consider and decide which assumptions are needed regarding relevant modelling issues such as the behaviour of capital accumulation or technical progress, among other factors.

For this purpose, the paper is organized as follows. The next section describes the nature and level of structural funding in Andalusia, promoting different types of investments. In the third section we discuss the characteristics of the regional CGE facility representing the economy of Andalusia. The fourth section presents the battery of simulations and illustrates the way additional feedbacks are introduced into the model, focusing on providing updates in the behaviour of capital accumulation and dealing with thoroughly selected elasticities. In the fifth section we present and discuss the derived empirical results. We conclude in the sixth section.

THE EUROPEAN CONVERGENCE FUNDS

When Spain became a fully fledged member of the then called European Economic Community, back in the mid 1980s, Andalusia was classified as an Objective 1 Region as far as European regional policies were concerned. The fact that Andalusia's GDP per capita was below the 75% lower bound (in terms of the Community's average GDP per capita) gave rise to a large and sustained financial disbursement of regional convergence funds. In broad terms, these funds were aimed at correcting the structural disparities in physical infrastructures and human capital levels between developing Andalusia and the developed European areas. Thus several Regional Development Plans were devised so that funds would be earmarked to improve the underprovided regional physical infrastructure, which were in fact a hindrance to a more fluid set of intersectoral productive relationships and an obstacle to a more dynamic economic interconnection with other areas and trade partners. Likewise, the low qualification of the labour force was also an impediment for reaching productivity improvements and creating a better trained and hence more cost-efficient labour force.

The *Integrated Operational Programme for Andalusia 2000–06* (IOPA), managed by the regional economic authorities, describes the financial plan regarding the European convergence funds and indicates the distinct action priorities and the corresponding distribution of funds for each priority and each year. The programme stipulates the endowment granted by the executive branch of the European Commission and specifies the required Spanish co-financing by both the national and regional governments. All these funds have been classified into two categories. The first one includes the *European Regional Development Fund* (ERDF) and the *European Agricultural Guidance and Guarantee Fund* (EAGGF), since in both cases these funds are used to promote investment in physical capital goods. The second category of funds groups all those being transferred from the *European Social Fund* (ESF) and that relate to improvements in the skills of human capital in the region. The quantification of IOPA for the period 2000–06 shows the level of executed expenditures to reach a grand total of 11,708.90 million euros. Of these, nearly 70% correspond to financial aid directly disbursed by the European authorities. From a detailed analysis of the nature of these funds and their time instalment, they have been distributed to the two above-mentioned categories for the corresponding periods. The level of resources assigned to the improvement of physical and human capital can be seen to be, respectively, 88.9% and 11.1% of the grand total aggregate. Further quantitative details regarding recipient sectors and period adscription can, of course, be requested from the authors.

Despite being a quite new line of research, some multisectoral models have already been developed in order to assess the impact of European Structural Funds at a regional level. Sharify and Batey (2006), for instance, use linear programming models under a SAM database to evaluate the impact of expenditure policies. At the Spanish level, Lima and Cardenete (2006) identify satisfactory results regarding the structural funds management for the 1990s in the region of Andalusia. For the period 2000–2006, these funds contributed considerably to the generation of regional GDP, while showing that the investment in physical infrastructures turned out to be more efficient than that devoted to foster employment and human capital formation. Monrobel *et al*. (2013) find similar results for the region of Madrid. Recently, Cardenete *et al*. (2013) made a first attempt to introduce elements of dynamics in the regional modelling setup in order to explore further possible conclusions.

THE CGE MODEL

In this section, we build a CGE model based on a SAM as the main database. SAMs are a tabular representation of all bilateral value flows for a given period and a given sectoral classification within an economy. They improve the data available in an inter-industry table since a SAM, in addition to capturing these relations, closes the circular flow of income circuit by way of integrating the links between primary factors' income, households' income and the demand for final goods and services.

Stone (1962) was the precursor in promoting the use of this type of data when he published the first SAM for the UK. Numerous analytical applications of SAM databases have been used in the literature, and selecting any sample for citation would most likely be unfair to the many non-cited ones. An enumeration of some of the typical applications, which include issues related to developing economies, poverty eradication, multiplier analysis in its most general meaning, economic influence, cost and price analysis, CGE model calibration, and many more, should therefore suffice.

All of the SAMs that will be used in this paper have the same account structure. This is required since a sequence of virtual SAMs will be generated using the results of the CGE model that represents the regional economy, and these virtual SAMs will in turn be used for posterior model calibration. The initial-regional SAM for 2000 is based on work by Cardenete *et al*. (2010). It was used for studying some environmental issues and it therefore contemplated a wider disaggregation of the energy subsector—an aspect that is not required here. Its structure has therefore been adapted by way of aggregating the energy sectors. The final empirical SAM available for 2005 follows the same account structure and is due to Cardenete and Fuentes (2009). Both of these SAMs will distinguish 29 different accounts and, of these, 21 correspond to production units, while the rest represent the typical accounts for a representative household: two non-produced inputs—labour and capital—a capital account for savings and investment flows, a government account, two tax accounts that aggregate indirect and income tax figures, and a foreign sector account.

Our analysis relies in the use of a static CGE model of the region that incorporates rules of behaviour for the standard economic agents—households and production units—as well as for the government and the foreign sector. Optimizing behaviour that follows competitive rules translates into a set of equations that describe the way demand and supply functions operate in the economy. Any empirical model—and CGE models are of course no different—reflects always a trade-off between tractability and technical complexity. In our case, the size of the model depends directly upon the size of the base SAM for 2000 in Andalusia. Using the base regional SAM for 2000, a first CGE model is calibrated. Its most representative characteristics are succinctly described below.

Production

Similar firms are grouped into sectors and each one produces a homogeneous good that is used to satisfy intermediate and final demand by all agents. Each productive sector is assumed to behave competitively and thus they maximize after-tax profits subject to their technological constraints while taking prices for goods and factors as given. Production functions are assumed to be nested. At the first level, total output X_j for each of the 21 production sectors is a constant elasticity of substitution (CES) aggregate that combines two inputs: domestic production, XD_j, and imports, IMPO_j:

$$X_j = \beta_j \cdot \left(\alpha_{j1} \cdot \mathrm{XD}_j^{\rho_j} + \alpha_{j2} \cdot \mathrm{IMPO}_j^{\rho_j} \right)^{\frac{1}{\rho_j}} \tag{1}$$

with β_j being an efficiency parameter and α_{ji} productivity parameters. The substitution parameter ρ_j is related to the substitution elasticity through the relationship $\rho_j = 1 - 1/\sigma_j$. At this level of nesting, the substitution elasticity σ_j corresponds to the so-called Armington (1969) elasticity between domestic and imported goods. This elasticity has been calculated using empirical values for three European countries provided by Welsh (2008) that have been weighted using the shares between sectoral imports and sectoral output. We can rewrite expression 1 in a somewhat easier format:

$$X_j = \left(\left(\theta_{j1} \cdot \mathrm{XD}_j \right)^{\rho_j} + \left(\theta_{j2} \cdot \mathrm{IMPO}_j \right)^{\rho_j} \right)^{\frac{1}{\rho_j}} \tag{2}$$

simply by taking $\theta_{ji} = \left(\beta_j \cdot \alpha_{ji} \right)^{1/\rho_j}$. The adopted values of σ_j for each production sector are shown in Table 3 in the Appendix at the end of the paper.

The second level of nesting provides domestic production XD_j as a result of combining intermediate inputs X_{ij} with a composite factor called value added, VA_j, following the fixed proportions typical of a Leontief technology:

$$XDj = \min\left(\frac{X_{1j}}{a_{1j}}, \frac{X_{2j}}{a_{2j}}, \ldots \frac{Xnj}{anj}, \frac{VAj}{vj}\right) \tag{3}$$

where X_{ij} is the quantity of good i necessary for the domestic production of good j at level XD_j, a_{ij} are the technical coefficients that measure the minimum quantity of this factor necessary to produce one unit of good j, and v_j are the technical coefficients that represent the minimum quantity of value added necessary to produce one unit of good j.

Finally, at the third level of nesting, value-added VA_j is produced by combining the two primary factors, labour L_j and capital K_j, using a CES function as well:

$$VA_j = \beta_j \cdot \left(\alpha_{j1} \cdot K_j^{\rho_j} + \alpha_{j2} \cdot L_j^{\rho_j}\right)^{\frac{1}{\rho_j}} \tag{4}$$

For simplicity of notation, the same parameter symbols are kept and the same interpretation holds here in equation 4 as in equation 1 but, needless to say, in the actual model implementation the adopted and calibrated parameter values will of course be different. The values taken for the sectoral elasticities σ_j are shown in Table 4 of the Appendix. In short, for the Spanish economy the 21 production sectors have been classified into three large categories—with small, medium and high elasticities of substitution—following the suggestion of Fæhn *et al.* (2009).

Consumption

The model includes a representative consumer whose gross income Y is the result of the sale of the endowments of productive factors labour L_j and capital K_j to the different j production units. From this sale households receive a salary w and a capital remuneration r. In addition, the representative consumer also receives transfers from the public sector (TPS; pensions, social benefits, unemployment compensation, etc.) and from the rest of the world (TROW). In order to calculate disposable income, YDISP, the initial amount of income is reduced by the effective direct tax rate DT on total income:

$$Y = \sum_j K_j \cdot r + \sum_j L_j \cdot w + \mathrm{TPS} + \mathrm{TROW} \tag{5}$$

$$\mathrm{YDISP} = (1 - \mathrm{DT}) \cdot Y \tag{6}$$

Savings, S, are a fraction of households' net income calculated using the marginal propensity to save (mps). The budget devoted to consumption is what remains once savings have been detracted from the level of disposable income. It is assumed that the representative consumer maximizes a Cobb–Douglas utility function, defined for consumption goods C_j subject to a budget constraint:

$$\begin{aligned} &\max U(C_j) = \prod_j C_j^{\alpha_j} \\ &\text{s. t. } \mathrm{YDISP} - S = \sum_j P_j \cdot C_j \end{aligned} \tag{7}$$

The public sector

The government collects direct and indirect taxes. Using its income the government demands goods and services from the production units, DG_j, and it also pays unemployment compensation to the idle labour endowment as well as other social transfers. The difference between government revenues and expenditures results in the public deficit (PD), if negative, or government surplus, if positive. There is a part of these government transfers, which is endogenously, determined (namely, unemployment compensation) depending on the level of the unemployment rate, an endogenous variable in the model. The rest of transfers are considered to be fixed in volume but they are updated in value according to the evolution of a consumer price index. In the macroeconomic closure rule, public purchases of goods and services and unemployment subsidies are taken to be endogenous, while keeping the public deficit at a given level.

The foreign sector

The model of the regional economy needs to be completed with the inclusion of a 'foreign' sector whose base import and export flows correspond to the empirical registered data in the initial SAM. The approach here is very simple given the characteristics of our database and the foreign sector is modelled as an aggregated single sector with no distinctions in terms of trade areas and no analysis of migration flows. We consider the Andalusian economy as a small economy and we incorporate a single foreign sector account as representative of the rest of the world. All the European flows are channelled through in the model outside the foreign sector and thus there is no actual need for a disaggregation. Domestic output and imported output are considered to be partial substitutes using the Armington (1969) assumption.

The activity levels for foreign demand, or exports of good j, are fixed exogenously, EXPO_j. On the other hand imports, IMPO_j, are endogenously determined through the cost minimization of the first nesting of the production function as in equation 1 above, i.e. the Armington assumption. As a result, the trade deficit ROWD is an endogenous magnitude in the model. The macroeconomic closure function for the foreign sector can therefore be written as follows:

$$\mathrm{ROWD} = \sum_j \mathrm{IMPO}_j \times \mathrm{rowp} - \sum_j \mathrm{EXPO}_j \times \mathrm{rowp} - \mathrm{TROW} \tag{8}$$

Here TROW is the level of net transfers from the rest of the world, and rowp is an aggregated 'world' price index for the good traded with the rest of the world.

Savings and investment

There is an investment commodity in the model that behaves as a Cobb–Douglas function following the restriction

$$\begin{aligned} &\max\ U(\mathrm{INV}_1, \ldots, , \mathrm{INV}_{21}) = \prod_j \mathrm{INV}_j^{\theta_j} \\ &\text{s.t.}\ \sum_j \mathrm{INV}_j \cdot P_j = S + \mathrm{PD} + \mathrm{ROWD} \end{aligned} \tag{9}$$

with P_j being the price in sector j, S private savings, PD the public deficit and ROWD the rest of the world deficit. Note that this is an extension (allowing for some price effects and substitution) of the analysis developed by Kehoe *et al.* (1988) to deal with investment.

The investment level in sector j, INV_j, is therefore price responsive whereas the aggregate level is endogenously determined by the addition of all sources of savings, i.e. private, public and foreign. The value of aggregate investment demand is therefore given in equilibrium by

$$I = \sum_j \mathrm{INV}_j \cdot P_j \tag{10}$$

The labour market

The model contemplates the possibility of labour not being fully utilized in equilibrium. The reason can be found in the presence of some rigidity in the labour market that does not allow for a full flexibility in the way the real wage reacts to the presence of less than optimal labour requirements. The stylized way that Kehoe *et al.* (1995) propose as a proxy for labour market adjustments between the real wage and the unemployment rate is adopted here. It takes the form

$$\frac{w}{\mathrm{cpi}} = \left(\frac{1-u}{1-u*}\right)^{\frac{1}{\varphi}} \tag{11}$$

In expression 11 u is the (endogenous) unemployment rate and $u*$ is the benchmark unemployment rate. On the left-hand side w/cpi is the real wage, i.e. the nominal wage rate corrected by the consumer price index (cpi). The parameter φ is an elasticity that measures the degree of flexibility in the adaption of the real wage to the unemployment rate. In the simulations we will use the empirical value of 1.25 estimated by Andrés *et al.* (1990).

Equilibrium

The model follows the standard Walrasian concept of equilibrium enlarged to include the tax and expenditure activities of the public sector and the import–export activity of the foreign sector (for further details relating to actual implementation, see Scarf and Shoven, 1984; Ballard *et al.*, 1985; Shoven and Whalley, 1992). An equilibrium is a price vector for goods and for primary factors, an allocation represented by a vector of activity levels for all involved sectors, a level of the unemployment rate, and a level of tax revenues such that consumers maximize their utility for current and future consumption, producers maximize after-tax profits, the unemployment rate weighs down labour supply so that it is equal to the labour demand by all productive units, capital demand equals capital supply, all demands for final and intermediate goods equal the respective supply of goods, and government tax revenues are equal to the amount of taxes paid by all economic agents. Because of Walras' law, one of the equilibrium equations is redundant. It is therefore needed to select and exogenously fix one of the variables to make the equilibrium system conformal between the number of independent equations and the number of variables. The price of the capital good, r, is used as the model's *numéraire*.

The model has been coded using algebraic GAMS (General Algebraic Modeling System) and equilibrium is achieved as the solution of running a fictitious nonlinear optimization program. In the software code all the equilibrium conditions appear as restrictions of the nonlinear program, while the objective function picks up the maximization of regional GDP. These types of model are well behaved regarding their functional forms, they have unique solutions and the equilibrium solutions enjoy the property of parameter continuity (Kehoe and Whalley, 1985), and thus comparisons of alternative equilibriums are justified and well founded.

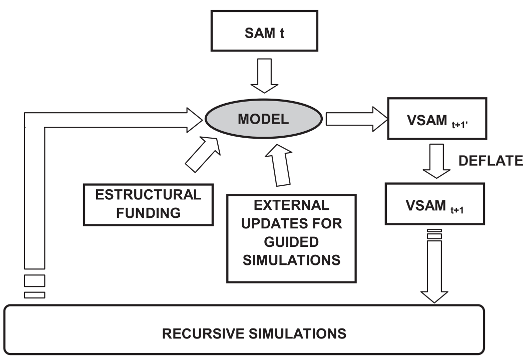
Database and calibration

The simulation strategy requires the numerical specification of a first CGE model for the initial 2000 period. The empirical regional SAM of Andalusia for the year 2000 is used along with sensible literature values for some of the model elasticities to calibrate the initial model. Calibration consists, as is well known, in using the available data to determine a set of parameters, which, under the conditions derived from the optimization problems of agents, allows the model to exactly replicate the empirical database as the benchmark equilibrium for the regional economy. After the model is calibrated, the whole set of literature elasticities in the consumption and production sides of the economy are taken as fixed for subsequent simulations runs.

Once the initial model has been calibrated, it is subjected to policy shocks that reflect the yearly disbursement of the European cohesion funds. As a result of the policy shock incorporated in say period t the CGE model provides a counterfactual and from it, a virtual SAM for $t+1$ is reconstructed. This virtual SAM, $\text{VSAM}_{t+1}\left(e_t^*\right)$, where e_t^* is a symbolic representation of the counterfactual equilibrium variables in t, is then used to calibrate a second-stage CGE model for period $t+1$. Again, the new policy shock for $t+1$ is injected into the system and the procedure is repeated for $t+2$, and so on until the last policy shock corresponding to 2005 is injected. To compensate for nominal price increases all the virtual SAMs are correspondingly deflated to the year 2000. The same deflation is applied to the last period empirical SAM for 2005. This way all values are expressed in year 2000 prices. See Figure 1, where the sequence of equilibrium and SAMs are depicted in a graphical way.

SIMULATIONS

The total European funds received in the region have been classified, as mentioned before, into two broad categories depending on whether they are used as investment in physical capital or in promoting human capital through formation and labour training. These funds are also distributed over the reference 2000–2005 period. Table 1 shows the time and type distribution of these funds. The external policy-induced shocks will be incorporated into the model as a yearly increase in the available supply of primary factors—labour and capital, which are expressed in normalized euros in the model. If K_t and L_t represent the available stocks of capital and labour in period t and $F_{K,t}$ and $F_{L,t}$ represent the annual additions, as indicated in Table 1, the following sequence for primary factors will ensue:



Source: Own elaboration

Figure 1. Recursive equilibrium procedure. *Source*: own elaboration

Table I. Distribution of European structural funds in Andalucía, 2000–05 (in thousands of euros, and percentage over empirical GDP)

Funds for simulation	2001		2002		2003		2004		2005	
F_K	1,456,453.6	88.6%	1,580,185.2	89.2%	1,607,296.8	89.2%	1,535,091.1	89.5%	1,445,798.5	88.8%
F_L	187,244.1	11.4%	190,386.3	10.8%	194,002.6	10.8%	179,410.7	10.5%	182,896.9	11.2%
Total amount	1,643,697.7		1,770,571.6		1,801,299.3		1,714,501.8		1,628,695.3	
Percentage over empirical GDP	1.91%		1.90%		1.80%		1.58%		1.39%	

Source: Own elaboration using data from the *Integrated Operational Programme for Andalucía 2000–06* (IOPA), Consejería de Economía y Hacienda (2001), Andalusian regional government.

$$\begin{aligned} K_{t+1} &= F_{K,t} + K_t \\ L_{t+1} &= F_{L,t} + L_t \end{aligned} \tag{12}$$

In the model, we use the standard normalization that equates 1 euro with one (implicit and redefined) unit of good. This responds to the need to have index numbers to measure equilibrium changes when initial values are expressed in standard units. Labour and capital are then expressed in euros in the database and model; i.e. the value of the structural funds and the labour or capital supply can be summed up. For example, when we shock the model with structural funds devoted to labour (F_{L}), we increase the amount of money available for labour supply in order to enlarge the labour force in the regional economy. This injection (in addition to that of funds devoted to capital investment) produces a new equilibrium in the economy.

Different scenarios are explored and two distinct types of simulation are considered. The first one will be termed 'unguided' and the sequence of chained simulations runs will incorporate exclusively the distribution of funds as indicated in expression 12. With the help of these simulations, one can obtain an estimation of the role played by the distributed funds from the EU in the evolution of the regional GDP over the studied period. The additional effects of a set of simulations that will be referred to as 'guided' are also explored. These are aimed at capturing the role played by other economic changes affecting the economy in addition to those of the European funds. For instance, the capital stock in period t goes through a process of depreciation, while at the same time capital goods in the form of investment are added to the capital stock. We adopt the econometric estimate of Denia *et al.* (2002) for the Spanish economy, which is based on a novel approach that estimates the depreciation rate of capital as an additional parameter in the production function. Hence a depreciation rate, Dep$K$, of 4.5% in the evolution of the capital stock is introduced in the CGE model. The new sequence for the capital stock in this 'guided' case will be given by

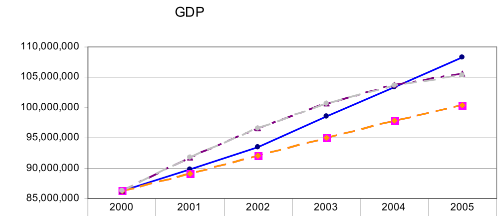
$$K_{t+1} = F_{K,t} + K_t \cdot (1 - \mathrm{Dep}K) + I_t \tag{13}$$

A second 'guided' simulation run contemplates the substitution of the unemployment rate that the model yields by the actual rate taken from official statistics. This is an attempt to control for the deviations in this leading indicator, which, incidentally, is reaching outrageously high values lately (see Usabiaga, 2004, for a discussion on the rigidities of the labour market in the region). Apart from updating unemployment rates, the model is also updated introducing the empirical data on unemployment compensation disbursed by the government. Finally, these two 'guided' simulations are combined into a third 'guided' simulation run, which incorporates all these major data updates.

RESULTS

We present two sets of results. The first one shows the evolution of GDP, whereas the second one illustrates the trends in the unemployment rate. The results summarized in Figure 2 depict the actual and CGE-simulated evolution of real GDP in the region for the 2000–05 period, under the above-described simulation scenarios. A first observation is that regional GDP has increased about 25% in the 5-year period, with growth rates picking up some speed as the economy approached the latter years. Reading the results of the 'unguided' simulation, the recursive CGE-SAM approach explains about 93% of the actual 2005 real GDP. The results, however, deviate more from the empirical data as time progresses, with initial deviations close to 1% and final figures being around 7%.

When the updates are refined and the capital endowments incorporate the additional data, as laid out in expression 13, the recursive model results under this first 'guided' simulation become considerably closer to the actual data. In this case, the model-projected real GDP reaches almost 98% of the actually observed 2005 empirical GDP. This



	2000	2001	2002	2003	2004	2005
EMPIRICAL DATA	86,215,965	89,828,112	93,498,616	98,555,929	103,372,427	108,310,046
UNGUIDED SIM.	86,215,965	89,081,691	92,084,449	95,052,925	97,805,857	100,325,270
GUIDED SIM. (UPDATES IN K)	86,215,965	91,760,555	96,615,877	100,706,887	103,809,286	105,569,177
GUIDED SIM. (UPDATES IN u)	86,215,965	89,081,691	92,096,608	95,072,536	97,835,925	100,374,783
GUIDED SIM. (UPDATES IN K & u)	86,215,965	91,760,555	96,632,225	100,674,532	103,693,378	105,338,899

Source: Official Regional Accounts for Andalusia and recursive CGE model projections

Figure 2. Evolution of real GDP in Andalusia for 2000–05: empirical and model projected values (in thousands of euros, deflated to the 2000 base year). *Source*: Official regional accounts for Andalusia and recursive CGE model projections

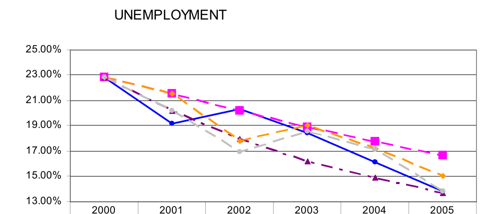
closeness between the recursive model results and actual end-of-period data strongly suggests that growth in the capital endowments, physical and human, when incorporated into a recursive CGE model is a good proxy for explaining aggregate changes in the regional GDP. The help attributable to the second ‘guided’ simulations that relate to updates in unemployment data, however, seems to have very small, almost negligible, effects. Given this very minor effect, it is no surprise that the cumulative effects in the third ‘guided’ simulations are quite similar to the first one.

A comparison between actual and model-projected values for the unemployment rates appears in Figure 3. Once again, we verify that the closest approximation comes from the capital endowments ‘guided’ simulation runs. The ‘unguided’ simulation projects a 16.67% unemployment rate, almost 3 percentage points above the 13.8% official rate in 2005. When updates in the labour data are introduced, the projected ‘guided’ rate of 15.02% is closer to the empirical rate but still more than 1 percentage point above it. When the simulations are ‘guided’ using the updates in the capital endowments, the recursive projected rates become very close and almost indistinguishable, i.e. 13.68% and 13.78%, to the empirical end-of-period rate of 13.8%. The recursive model works better to track down the empirically observed values when updating relies on the adjustment of the pools of primary factors, physical and human capital.

We consider that the reception of structural funding has been the most important shock affecting the Andalusian economy during the period of study. Moreover, we have complemented this initial shock, improving the capital factor behaviour. This guided simulation has finally contributed to getting our results closer to the empirical ones. We have also learnt about the accuracy of our model, being able to discard those updates that do not provide a better approximation to empirical data.

We perform a final validation check comparing actual gross and sectoral output of the region with projected levels according to the ‘unguided’ and ‘guided’ simulation runs in Table 2. Results for gross output tend to coincide with the previous observations for GDP and unemployment. In the ‘unguided’ simulations, the level of approximation between the simulation result and the empirical data is 89%, whereas the ‘guided’ one with capital factor updates improves the score considerably, reaching 93% of the overall output level. Once again, updating some of the labour data has little if any impact. We can conclude that our CGE model slightly underestimates sectoral output growth, but a much better approximation is addressed with factor capital updates.

As one of the utilities of CGE models is their capacity to capture information from a sectoral point of view, we have analysed sectoral output behaviour. Looking at specific sectors, we focus on simulations with refinements in *K*, where we obtain the closest results in comparison with reality. The model produces almost the same values as the empirical figures in Livestock (2), Chemical industry (10), Machinery, vehicles and transportation equipment



	2000	2001	2002	2003	2004	2005
EMPIRICAL DATA	22.80%	19.20%	20.30%	18.40%	16.10%	13.8%
UNGUIDED SIM.	22.80%	21.51%	20.18%	18.89%	17.72%	16.67%
GUIDED SIM. (UPDATES IN K)	22.80%	20.17%	17.96%	16.17%	14.87%	13.68%
GUIDED SIM. (UPDATES IN u)	22.80%	21.51%	17.82%	19.00%	17.20%	15.02%
GUIDED SIM. (UPDATES IN K & u)	22.80%	20.17%	16.94%	18.57%	17.16%	13.78%

Source: Official Regional Accounts for Andalusia and recursive CGE model projections.

Figure 3. Evolution of unemployment in Andalusia for 2000–05: empirical and model projected values (in percentage rates). *Source*: Official regional accounts for Andalusia and recursive CGE model projections

Table II. Gross and sectoral output in Andalucía for 2000–05: empirical data and model projections (in thousands of euros and percentage over empirical output)

			2005							
		2005 Empirical	Unguided simulation	% over empirical	Guided SIM (updates in K)	% over empirical	Guided SIM (updates in u)	% over empirical	Guided SIM (updates in K and u)	% over empirical
1	Agriculture	8,874,254	9,715,757	1.09	9,916,038	1.12	9,707,561	1.09	9,897,117	1.12
2	Livestock	2,108,407	2,112,047	1.00	2,162,749	1.03	2,110,505	1.00	2,158,480	1.02
3	Fishing	1,190,229	996,591	0.84	1,032,760	0.87	995,359	0.84	1,029,601	0.87
4	Extractives	5,420,487	5,829,951	1.08	6,036,166	1.11	5,825,370	1.07	6,020,566	1.11
5	Non-energy extractives	2,456,180	2,070,734	0.84	2,182,244	0.89	2,067,861	0.84	2,173,418	0.88
6	Energy production	19,883,356	14,473,824	0.73	14,977,012	0.75	14,461,909	0.73	14,938,110	0.75
7	Food	25,665,215	21,873,755	0.85	22,486,630	0.88	21,849,823	0.85	22,430,146	0.87
8	Textiles and leather	6,399,375	6,839,222	1.07	7,092,681	1.11	6,829,038	1.07	7,069,044	1.10
9	Wood manufactures	3,689,219	4,509,077	1.22	4,719,035	1.28	4,503,363	1.22	4,702,106	1.27
10	Chemical industry	10,338,667	9,994,963	0.97	10,393,143	1.01	10,006,740	0.97	10,383,482	1.00
11	Mining and iron and steel industry	5,352,703	4,399,325	0.82	4,520,700	0.84	4,395,480	0.82	4,510,340	0.84
12	Metal manufactures	4,103,341	2,964,412	0.72	3,151,574	0.77	2,959,143	0.72	3,136,342	0.76
13	Machinery, vehicles and transportation equipment	20,650,990	19,582,943	0.95	20,633,434	1.00	19,554,374	0.95	20,548,846	1.00
14	Building materials	6,084,944	5,697,173	0.94	6,081,867	1.00	5,685,597	0.93	6,049,753	0.99
15	Other manufacturing	8,334,871	7,621,181	0.91	7,960,976	0.96	7,611,545	0.91	7,933,249	0.95
16	Construction	40,950,897	29,401,148	0.72	31,872,590	0.78	29,332,228	0.72	31,672,040	0.77
17	Commerce	32,870,750	29,427,183	0.90	30,552,635	0.93	29,388,574	0.89	30,454,182	0.93
18	Transports and Communications	14,265,350	14,632,656	1.03	15,260,654	1.07	14,617,148	1.02	15,211,675	1.07
19	Other trades	38,129,322	20,710,251	0.54	21785044	0.57	20,697,914	0.54	21,715,308	0.57
20	Sale-oriented services	19,774,439	22,302,335	1.13	23,329,791	1.18	22,286,595	1.13	23,258,969	1.18
21	Non sale-oriented services	11,117,577	20,202,499	1.82	21,664,134	1.95	20,379,698	1.83	21,762,287	1.96
	Total output and % over empirical output	287,660,574	255,357,029	0.89	267,811,855	0.93	255,265,824	0.89	267,055,060	0.93

Source: Regional accounts for Andalucía and recursive CGE model projections.

(13), Building materials (14) and Other manufacturing (15). The approximation is above the real data in Agriculture (1), Extractives (4), Textiles and leather (8), Wood manufactures (9), Transport and communications (18), Sale-oriented services (20) and Non-sale-oriented services. The rest of the sectors register values below the real ones. Fifteen out of 21 sectors register values around an interval of ±15% as a maximum. Again, there are no relevant changes in sectoral output when introducing unemployment rates into the recursive procedure.

CONCLUDING REMARKS

In this paper we have explored the extent of predictive ability of CGE models. To this effect, we have performed an ex post validation check using a recursive general equilibrium model, built upon a chain of yearly SAMs. The first SAM is an empirically available one and it is used for the calibration of the first CGE model. After introducing external policy shocks related to EU regional convergence policies, a sequence of virtual SAMs is built using the counterfactual equilibria that are, in turn, used for the subsequent CGE model calibration of newer periods. This combined SAM-CGE recursive modelling strategy allows the construction of a sequence of projected model results that can be compared, year by year, with empirical data. Using a 5-year period, it has been possible to visualize the predictive ability of the general equilibrium model. In addition, this ability can be partially enhanced by providing supplementary model feedbacks that reflect further changes beyond those directly induced by the injection of European funds. This is the case for adjustments in capital endowment (through depreciation and investment), or the unemployment level and the corresponding compensation transfers.

Using a set of four ‘unguided’ and ‘guided’ simulations, we conclude that the regional recursive model yields quite good approximations to actual empirical data in GDP, labour use and gross output, and specially so when the ‘unguided’ simulation is helped by the ‘guided’ one incorporating refinements in the physical capital endowment. As an example related to GDP, the ‘unguided’ simulation helps to explain nearly 93% of the actual effect of GDP in 2005, whereas this figure rises to close to 98% using the mentioned ‘guided’ simulation. This is quite a good fit, even when, *stricto sensu*, this fit cannot be interpreted in any statistically meaningful sense. Also, yearly GDP deviations between model results and actual data are small and in many cases this value is smaller than 1%. Overall predictive ability therefore goes hand in hand with sufficiently good yearly approximations.

The ‘guided’ simulations that update data on unemployment levels and compensations are not equally good. Thanks to this less successful updating attempt, however, relevant information is learnt that indicates the direction that model improvements should possibly take for increasing its predictive ability. This is a valuable ex post insight that can only arise once a comparison of the model results with the actual empirical data is undertaken.

Although this paper has an obvious methodological focus, it is also pertinent to consider, even if briefly, the socioeconomic role played by the European regional convergence funds. The results here clearly indicate the substantial impact these funds have had in Andalusia’s growth, confirming other evidence presented in Lima *et al.* (2010). Precisely because of the huge impact of these funds, the risk of overdependence of the region on them is quite real. The impending cutbacks of these sizeable European funds that have been accruing in the region will no doubt switch the responsibility to local actors. On the one hand, national and regional governments, subject to the strict austerity policies that will inevitably be enacted in the next few years, will have to lead in prioritizing the way the remaining lower level of funds will be utilized in order to provide the highest possible returns to society. On the other hand, the critical role of private investors in reinforcing growth and employment is still very much unclear given the surrounding economic uncertainties at the regional, Spanish and European levels.

Some final thoughts on the methodological use of the CGE tool are possibly in order now. Their predictive ability, even when loosely defined as the ability to track down actual change, seems to be adequate. The results here using a recursive CGE-SAM approach seem to reinforce those of Kehoe *et al.* (1995), which were focused to ‘test’ the predictive ability of a one-shot static model, giving additional support to their novel message that ex post validation is the surest way to go for this class of general equilibrium model. If CGE modelling turns out to be a sufficiently reliable tool, better and more informed policy making is no doubt possible.

Surely some complementary approaches could be used to further enhance appraisal of the results. We may think, for instance, of sensitivity analysis for the elasticity parameters, or the inclusion of dynamic patterns by way of introducing technological progress, or actualization of the database when available. Undoubtedly, complementary results would indeed arise, and they could turn out to be pertinent in order to provide additional insights to our research. We intend to address these multifaceted and comprehensive extensions in future research.

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APPENDIX

Table A.I Armington elasticities

Sector	Imports/sectoral output	Armington elasticity
1	16.41%	0.288
2	24.42%	0.428
3	38.69%	0.678
4	93.67%	1.642
5	41.93%	0.735
6	5.70%	0.100
7	19.76%	0.346
8	29.42%	0.516
9	45.59%	0.799
10	45.85%	0.804
11	29.59%	0.519
12	21.35%	0.374
13	59.33%	1.040
14	27.32%	0.479
15	24.25%	0.425
16	0.00%	0.000
17	0.33%	0.006
18	13.97%	0.245
19	8.85%	0.155
20	1.34%	0.024
21	0.00%	0.000
Average elasticity		0,877

Source: Own elaboration from data provided by Welsh (2008).

Table A.II Labour–capital substitution elasticities

	Elasticity of substitution		
Sector	Low	Medium	High
1	1		
2	1		
3	1		
4		1	
5		1	
6		1	
7		1	
8		1	
9		1	
10		1	
11		1	
12		1	
13		1	
14		1	
15		1	
16			1
17			1
18			1
19		1	
20		1	
21		1	
	0.56	1.20	1.60

Source: Own elaboration from data provided by Fæhn *et al*. (2005).

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