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Simulating the Impact of Sectorial Productivity Gains on Two Regional Economies: Key Sectors from a Supply Side Perspective

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Document de treball nº -12- 2011

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ROVIRA I VIRGILI
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Edita:

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Adreçar comentaris al Departament d'Economia / CREIP

Dipòsit Legal: T -1210- 2011

ISSN 1988 - 0812

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Simulating the Impact of Sectorial Productivity Gains on Two Regional Economies: Key Sectors from a Supply Side Perspective

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Abstract

In this paper we simulate and analyse the economic impact that sectorial productivity gains have on two regional Spanish economies (Catalonia and Extremadura). In particular we study the quantitative effect that each sector's productivity gain has on household welfare (real disposable income and equivalent variation), on the consumption price indices and factor relative prices, on real production (GDP) and on the government's net income (net taxation revenues of social transfers to households). The analytical approach consists of a computable general equilibrium model, in which we assume perfect competition and cleared markets, including factor markets. All the parameters and exogenous variables of the model are calibrated by means of two social accounting matrices, one for each region under study. The results allow us to identify those sectors with the greatest impact on consumer welfare as the key sectors in the regional economies.

Keywords: Productivity gains, key sectors, computable general equilibrium

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* We acknowledge the financial support of the Spanish Ministry of Culture (grant ECO2010-17728 and ECON2009-06953) and of the Catalan Government (grant SGR2009-322). Useful comments and suggestions by Erik Dietzenbacher and Ferran Sancho have substantially improved an earlier draft.

1. INTRODUCTION

The purpose of this paper is to simulate and analyse the quantitative effects that sectorial productivity gains have on two regional Spanish economies: Catalonia and Extremadura. Specifically, we provide an elasticity measure of the impact that the productivity gains in each sector have on important economic variables in these economies. These variables are prices (the consumer price index (CPI), an additional extended CPI, and the relative prices of factors), production (real GDP), consumer welfare (real disposable income and equivalent variation), and government net income. Solow (1956) and many other studies in this field have put forward the idea that productivity gains are an important component that affects the growth of an economy, raises household purchasing power, and increases GDP per capita. We focus on sectorial productivity gains because of the empirical evidence provided by, among others, Jorgenson et al (2007) and Mas and Robledo (2010).[1] An important finding of these contributions is the disparity between sectorial contributions and aggregate productivity gains in an economy.[2]

Identifying which sectors' productivity gains contribute most to increasing consumer welfare (or any other relevant economic variable) is important because it help us to better understand the economic consequences of these gains and the ways that such a complex economic phenomenon can be propagated throughout the economy. Also, our analysis may lead, for instance, to strategic R+D investment in those sectors or to other policies which may eventually give a maximum payoff to the economy. Once we identify these sectors we can call them key sectors. Previous literature in the field has often used techniques such as multiplier analysis to focus on a demand side perspective. The novelty of our approach is that we develop the analysis from a supply side perspective and we use consumer welfare as the main indicator for classifying sectors.

Since the pioneering contributions of Rasmussen (1956) and Chenery and Watanabe (1958), much of the related literature has focused on defining and identifying key sectors. We will not attempt to review this literature (the interested reader can refer to, among others, Dietzenbacher (1992) and García, Morillas and Ramos (2008)).

[1] The first study analyses the productivity gains of 85 sectors in the US economy during the period 1960-2005. The second quantifies the productivity gains of 27 sectors in Spain, Germany, France, Italy, the United Kingdom, the European Union and the US between 1995 and 2007.

[2] In particular, the communications technology sector and those other sectors that have bought into this technological sector have made a large contribution to total productivity gains during the last decade.

However, we may refer here to two fundamental criteria that have been used very often in the key sector analysis of many economies: conventional multiplier analysis (Dietzenbacher, 2005) and the hypothetical extraction method (Strassert, 1968). The main framework in which these two criteria have been applied is the classic Input-Output model, although this analysis has also been applied to the Social Accounting Matrices (SAMs).[3] More recently, Cardenete and Sancho (2010, 2011) have studied the extraction method and multiplier analysis, respectively, within the framework of an applied general equilibrium model. The main conclusion of these studies is that, from a methodological point of view, the linear models (Input-Output and SAM) assume a very restrictive hypothesis (i. e. linear technologies of production with fixed coefficients, full availability of resources, fixed prices). This significantly affects the quantitative results of the analysis and led those authors to question the validity of these classic criteria under a general equilibrium framework.

In our case, we think that the computable general equilibrium model is an appropriate starting framework for answering the types of question that we consider to be relevant to our analysis. Following the Shoven-Whalley model (1992), we consider, for each of the two regional economies, a multisector production side, a representative consumer (or household), a public government and a foreign sector. We use the traditional Walrasian equilibrium concept for the economy. We calibrate our model with a SAM data set for each regional economy. Finally, we compute the equilibrium and perform all the simulations needed to obtain the results.

The effects caused by productivity gains on an economy have been analysed in several contributions to the literature. González-Calvet and Manresa (2007) used the Leontief price model to analyse how the productivity gains in each sector of production affected regional prices in the Catalan economy.[4] Hanson and Rose (1997) analysed income inequality in the US by simulating productivity gains in the labour and capital of each sector with a computable general equilibrium model. More recently, Cutler and Davies

[3] See Pyatt and Round (1979) for the conventional multiplier analysis and Cardenete and Sancho (2006) for the extraction method. Additionally, Los (2004) used the hypothetical extraction approach in a dynamic multisectorial model to analyse the impact caused by the disappearance of a sector of the economy.

[4] The analysis showed a sectorial ranking in terms of the impacts caused by each sector on the consumption price index of the regional economy. No other variables were considered in this study.

(2010) studied the impact of sectorial productivity gains in Fort Collins (Colorado) on certain economic variables.[5]

The structure of the paper is as follows. The following section describes the main characteristics of the model used and the types of simulation performed. The third section describes the databases used to calibrate the regional models. The fourth section presents the main results of the simulations, which include price-elasticites and relative prices of factors, production-elasticities, the elasticities concerning private household (income-elasticity and equivalent variation-elasticity) and the elasticity-public revenues. The fourth section also includes a summary of the results which enabled us to identify the key sectors of each economy. The final section contains the paper's conclusions.

2. THE MODEL AND SIMULATIONS

2.1. The Model

Our objective is to simulate the effects of sectorial productivity gains on an economy; therefore, we will use the computable general equilibrium approach because we think that it has advantages over other partial equilibrium models in that it provides a complete representation of the economic agents and their behaviour. It also takes into account all the economic interactions represented by a complete circular flow of income. Specifically, our study is based on a static general equilibrium model that has been calibrated for the Spanish regions of Catalonia and Extremadura.

Our definition of equilibrium follows Walras' law, which has been extended to include not only producers and consumers but also government and foreign agents. Therefore, the equilibrium is determined by a vector of prices, a vector of activity levels and a set of macroeconomic indicators that clear all markets and allow all agents to reach their optimizations plans. Mathematically, the model is represented as a set of equations containing the equilibrium conditions of all the economic agents.

In what follows, we describe the main features of the computable general equilibrium model used for the two Spanish regions.[6] The structure of production shows 15 differentiated sectors and assumes perfect competition in all markets. Each sector

[5] Cutler and Davies used a multisectorial computable general equilibrium model that was adapted to the characteristics of the towns under study. For each sector of production, they simulated increases in factorial productivity, capital and labour.
[6] A complete description of the model, with a list of the equations and the variables involved, can be found in De-Miguel Vélez et al. (2009).

produces a homogeneous good by using a nested technology with constant returns-to-scale. In the first level of the production function, the total output in each sector is obtained with a Cobb-Douglas aggregator of the domestic production and imports from abroad (Armington specification). The second level of the production function shows the domestic production as a Cobb-Douglas combination of intermediate inputs and value added. We use this specification so that we can make a broader interpretation of the types of simulation (productivity gains) that we carry out in the following section. Finally, in the third level of the production function, the value added is obtained by combining labour and capital through a Cobb-Douglas function.

Additionally, the model shows a generic household that has a Cobb-Douglas utility function in logarithms which combines consumption and saving (or future consumption).[7] The budget restriction of consumers establishes that the amount of expenses in final consumption and saving cannot exceed the disposable household income. The private income comes from the endowments of labour and capital and transfers from government and from abroad. To obtain private disposable income we subtract the social security contributions and the direct taxes on income from the private income of workers.

The government or public agent produces public goods and public services and demands public services and investment goods. Our model assumes that the public agent has a Leontief utility function that combines public consumption and public investment in fixed proportions. The budget restriction of government establishes that public consumption and public investment must be equal to the total public revenues that come from taxation once social transfers have been subtracted from government revenues. The model also includes a stock of public borrowing or government bonds that the public agent can emit in case of deficit.

Finally, the model has a generic foreign agent that includes, for each region, the rest of Spain, the European Union and the rest of the world. This agent produces a trade good through regional exports with a fixed coefficients technology. At the same time, each economy can receive transfers from abroad and make transfers to external agents. The model allows a situation of external deficit that must be used as savings of the foreign

[7] The model distinguishes between production goods and consumption goods. Consumption goods are obtained through a conversion matrix of fixed coefficients that defines a direct (and linear) relationship between production prices and consumption prices.

agent. This preserves the macroeconomic equilibrium between the total saving and the total investment of the economy.

2.2. Simulations

The simulation analysis is carried out individually for each activity, thus allowing us to determine the effects on the economy of the productivity gains in each sector j ($\forall\, j = 1, 2, ..., 15$). Since we do not have the required information, we do not contemplate the possibility that the productivity gains in one sector affect the technology of the other sectors.

The equation that defines the third level of the nested production function can be written as:

$$VA_j = \beta_j K_j^{\alpha_j} L_j^{1-\alpha_j}, \tag{1}$$

where j = 1, 2, …, 15, are the sectors of production analysed, VA_j is the value added of sector j, K_j is the capital factor in j and L_j is the use of labour. The parameter β_j in equation (1) is especially important because an increase in this parameter means that, with the same amount of capital and labour, a higher value added is obtained in each sector. This technological change, which is in fact an increase in the total productivity factor, is known in the literature as a Hicks-neutral technological change. Bearing in mind that the value added functions are Cobb-Douglas, this technological change can also be viewed as Solow neutral (where the productivity gains are attributed to capital) or Harrod neutral (where the productivity gains are attributed to labour).[8] Given that we assume a Cobb-Douglas production function that combines value added and intermediate inputs to produce domestic goods, we can also interpret the productivity gains in value added as an increase in the efficiency of the production of total domestic output, or in the efficiency of the use of any intermediate input.

In each simulation, we introduce an arbitrary productivity gain of 25% .This means that, following expression (1), in the simulations the parameter β_j is increased by 25% (with respect to the benchmark value) in each sector of production, and this implies 15 different simulations for each region. This percentage might be viewed as unrealistically high given that an economy with a value added productivity growth rate of 2% per year

[8] Acemoglu (2009) contains a formal analysis of these possibilities.

would take 11 years to reach that figure. Nevertheless we use this figure to get sharper results from the simulations.

3. DATABASES

All of the model's parameters and exogenous variables have been obtained by using a SAM for each regional economy and by applying the standard calibration procedure. This exercise allows us to reproduce the values of the endogenous variables of the SAM as an initial equilibrium of the model (*benchmark situation*).

As is well known, a SAM is a double-entry square matrix in which each agent is represented in a row and a column of the matrix. This database contains not only the economic transactions concerning the production system (as in an input-output table) but also other transactions corresponding to the circular flow of income (factorial and personal distribution of income). By agreement, the rows of a SAM show the revenues of each economic agent and the columns show the corresponding expenditures. To preserve the accounting equilibrium, the value of income must be equal to the value of expenditure in each agent, that is, the total of a row must be equal to the total of the corresponding column.

The empirical simulations rely on two social accounting matrices, one for each region (SAMCAT for Catalonia and SAMEXT for Extremadura).[9] Given that these databases have a homogeneous structure and show the same desegregation of accounts, the same definition of economic agents is found in both regional models.[10]

The structure of the social accounting matrices is simple because there are information deficiencies at regional level. In the case of Catalonia, the official sources do not provide a symmetric input-output table of intermediate consumptions. To fill this statistical gap, we have used indirect information to estimate the symmetric table. In the case of Extremadura, the main limitation is that the production relations are not covered by recent statistics. For this reason, the SAMEXT is the result of an indirect update procedure that takes the year 1990 as a reference.

[9] Llop (2011) describes the construction and characteristics of the social accounting matrix of Catalonia. De Miguel-Vélez et al. (2009) describe the structure of the social accounting matrix of Extremadura.
[10] The SAMEXT is for 2000 and the SAMCAT is for 2001. Given that the statistical availabilities in each region concern different years we were unable to use the same temporal reference. However, our results can be directly compared given that there is only one year's difference between the two SAMs and that the patterns of revenues and expenditures have practically no variation over short periods of time.

Table 1. List of accounts in the SAMCAT and in the SAMEXT

Production sectors	1. Agriculture
	2. Energy
	3. Chemistry
	4. Metals and electrical equipment
	5. Automobiles
	6. Food production
	7. Textiles
	8. Paper
	9. Other industries
	10. Construction
	11. Commerce
	12. Transport and communications
	13. Finance
	14. Private services
	15. Public services
Consumption goods	16. Food
	17. Tobacco and alcohol
	18. Clothes and shoes
	19. Housing
	20. Furniture
	21. Medical assistance
	22. Transports and communications
	23. Culture and education
	24. Other consumption goods
Factors of production	25. Labour
	26. Capital
Consumers	27. Consumers
Saving-investment	28. Capital account
Public sector	29. Production taxes
	30. Product taxes
	31. Social Security taxes on employers
	32. Direct taxes on income
	33. Consumption taxes
	34. Social Security taxes on employees
	35. Government
Foreign sector	36. Foreign sector

Table 1 shows the accounts of the SAMCAT and the SAMEXT, which coincide with those used in the regional models. The production system is divided into 15 sectors:

agriculture, eight industrial activities, construction and five service sectors. Additionally, the social accounting matrices show nine consumption goods, which are different from the goods obtained in the production system. The regional SAMs reflect two factors of production, labour and capital, and a generic account containing the revenues and expenditures of the households in the economy. The capital account shows all the sources of saving and investment of all the economic agents. The government account contains the revenues and expenditures of the public administration and six accounts for the different taxes reflected in the model.[11] The regional databases are completed with an account for the foreign agent that shows the imports, exports and income transactions from abroad.

4. RESULTS

As we have described above, the simulation analysis consists of separately introducing a 25% increase in the total factor productivity to each productive sector.[12] During the first stage, the computation of the two regional models involved calculating the initial reference equilibriums (the *benchmark situation*), in which all the prices and activity levels are unitary and the model reproduces the numerical information of the social accounting matrix.

After the benchmark computation, the simulation analysis consisted of calculating 30 new equilibriums as a result of combining 15 productivity increases (one for each sector) and the two regions under study. The computation of these new equilibriums and a comparison with the benchmark will show, for each region, which sectors have the greatest impact on the economy when there are productivity gains and which sectors have the least impact. This information is useful to see how this complex phenomenon propagates throughout the economy, and also to identify the most important activities in each region. As a result of this, local and territorial planning strategies could be defined and focused on the most influential sectors.

[11] There are minimal differences in the taxes of the two social accounting matrices. The SAMEXT only shows a tariff tax on the imported goods, whereas the SAMCAT shows both these tariffs and the other taxes levied on products. On the other hand, the SAMCAT does not include the Social Security of the employee because there is no information regarding this tax in Catalonia. These differences reflect the impossibility of obtaining homogeneous information; however, their effect on the simulations and in the results obtained is irrelevant.

[12] We have also simulated improvements in sectorial productivity that affect both primary factors and intermediate inputs. The results obtained from this analysis do not differ from those shown here and so have not been included in the text for the sake of brevity.

One of this paper's contributions is that it provides a new supply-side view for identifying key sectors that is different from traditional approaches based on linear multipliers (demand-side view) or the hypothetical extraction method (demand and supply view). Moreover, the use of a computable general equilibrium framework has advantages over other models that have traditionally been used in this context, in particular the input-output and SAM based linear models. Two advantages that the general equilibrium setting has over those models is that 1) it fully represents the circular flow of income by extending the production transactions to include both private and factorial income distribution, and 2) it shows the nonlinearity of the equilibrium equations that results from the interaction of agents' behaviour in equilibrium. Additionally, the general equilibrium allows us to analyse a wider set of variables that involve both micro-indicators and macro-indicators such as the simultaneous impacts on prices, quantities, and consumer welfare.

Among the set of results, we show the effects of sectorial productivity gains on four macroeconomic variables. First, we analyse the changes in regional prices by using a consumption price index (CPI), an extended CPI, and the relative prices of factors. Second, we analyse the effects of sectorial productivity gains on regional production (regional real GDP). Third, we use two indicators to calculate the impact of sectorial productivity gains on consumer welfare: the real disposable income of households and the equivalent variation. Finally, we analyse the effects of sectorial productivity gains on the public agent (net taxation revenues of social transfers). To conclude, we summarize and compare the results of the two regions, which in turn allows us to identify some key sectors for each economy.

Before examining the effects of the productivity gains, we should bear in mind some additional aspects of the analysis. First, given that Walras' law states that one of the equilibrium equations in the model is redundant and that prices should be interpreted as relative prices, we have taken the wage as *numéraire*. Consequently, the price of labour is unitary in all the simulations undertaken. In this way, the equilibrium prices are in fact relative prices with respect to the *numéraire*. Second, we have used the same macroeconomic closure rules for the government and the foreign sector. These consist of an endogenous activity level of government and of the foreign agent and a fixed deficit for both agents. Finally, the results correspond to a scenario in which the labour market clears in equilibrium given that the model does not allow for any unemployment.[13]

In all the simulations performed we assume that all the initial aggregate resources of the economy are fully used. We only consider the basic idea that productivity gains in an economy mean that more output is generated from the same number of inputs. We ignore, whilst recognizing them as an important issue beyond the scope of this paper, the causes that may lead to such productivity gains and their consequences in terms of the resources used by the economy. We also assume that labour and capital flow from one sector to another to meet the equilibrium conditions.

4.1. Price Effects

The increases in sectorial productivity will have a direct effect on the production prices, which in turn will affect the final consumption prices. Table 2 shows an index measure of the price changes for both regions. This measure shows price-elasticity of the CPI and is calculated by dividing the percentage variation in the CPI and the percentage variation in sectorial productivity. We also show (in parenthesis) another price index that includes the price of the saving/investment good in the CPI. In addition, Table 2 shows the price of capital relative to labour (r). We order elasticities according to their value (starting with the most negative number). It should be remembered that a change in equilibrium prices means a change in relative prices, and that our *numéraire* is the price of labour which is set equal to one in all the simulations.

[13] We are aware that our analysis is a simplification of the complex relationship between unemployment and productivity gains, which certainly deserves greater attention than it is possible to give within the scope of this paper. Consequently, we have also used a labour supply as in Oswald (1982) to analyse a situation with rigidities in a labour market with endogenous unemployment. The fact that the results obtained in this way do not differ substantially from the ones showed here is proof of the robustness of our conclusions.

Table 2. Price-elasticity and price of capital (*r*) of the sectorial productivity gains

	Extremadura			Catalonia		
	Elasticity	***r***	**Order**	**Elasticity**	***r***	**Order**
1. Agriculture	-0.1808 (-0.1724)	1.019	3 (1)	-0.0216 (-0.0202)	0.995	10 (11)
2. Energy	-0.0400 (-0.0456)	1.009	4 (4)	-0.0192 (-0.0196)	0.997	13 (13)
3. Chemistry	-0.0020 (-0.0019)	1.000	12 (13)	-0.0300 (-0.0305)	1.000	6 (8)
4. Metals and electrical equipment	-0.0048 (-0.0097)	1.001	10 (9)	-0.0464 (-0.0574)	1.001	5 (3)
5. Automobiles	-0.0016 (-0.0014)	0.999	13 (14)	-0.0224 (-0.0237)	1.000	8 (10)
6. Food production	-0.0324 (-0.0267)	1.000	6 (7)	-0.0224 (-0.0305)	0.999	9 (9)
7. Textiles	-0.0088 (-0.0069)	0.999	8 (10)	-0.0212 (-0.0202)	1.001	11 (12)
8. Paper	-0.0024 (-0.0020)	0.999	11 (12)	-0.0196 (-0.0194)	1.000	12 (14)
9. Other industries	-0.0060 (-0.0020)	1.001	9 (11)	-0.0284 (-0.0321)	1.000	7 (7)
10. Construction	0.0704 (-0.0213)	1.033	15 (8)	-0.0184 (-0.0514)	1.001	14 (4)
11. Commerce	-0.2024 (-0.1659)	0.995	2 (3)	-0.2228 (-0.2004)	0.998	2 (2)
12.Transport and communications	-0.0352 (-0.0354)	1.004	5 (5)	-0.0756 (-0.0496)	0.998	3 (5)
13. Finance	-0.0320 (-0.0344)	1.005	7 (6)	-0.0544 (-0.0496)	1.000	4 (6)
14. Private services	-0.2072 (-0.1715)	0.985	1 (2)	-0.2424 (-0.2313)	0.990	1 (1)
15. Public services	0.0444 (0.04429)	1.021	14 (15)	0.0000 (0.0000)	0.999	15 (15)

Practically all the CPI values in Table 2 are negative, showing that productivity gains cause relative prices of consumption to fall with respect to wages. In almost all cases the fall in the CPI can be explained as follows. Efficiency gains in the production processes of goods in a given a sector result in a cheaper cost per unit of production, and since technologies show constant returns-to-scale and there is perfect competition, there is a reduction in the price of the goods produced by that sector. As other sectors buy intermediate goods at cheaper prices we can also expect a reduction in prices, and so on. In general we expect a generalized reduction in the consumption price indexes. For instance, a 1 percent increase in the productivity gains in the agricultural sector in Extremadura causes a 0.1808 percent reduction in the CPI of Extremadura. Since wages are constant, this also means that wages have increased compared to consumption prices.

We should point out, however, two exceptions in the case of Extremadura that have positive price-elasticities: construction (sector 10) and public services (sector 15). These two activities have weak connections with the others sectors through intermediate sales and most of their production takes the form of investment and public expenditure respectively. Thus, the productivity gains in these sectors reduce prices in these sectors, although this is hardly transmitted to other prices. Furthermore, the prices of the goods produced by these sectors are not considered in the calculation of the CPI. Note that the price elasticity of construction in the parentheses is negative, since we include here the saving/investment good. A similar explanation applies to the public sector in Extremadura.

The mechanism operating for these two sectors in Extremadura is not as important as it is in Catalonia, where construction (sector 10) and public services (sector 15) have a negative and a close to zero price-elasticity respectively. This suggests that the improvement in productivity in these activities does not have a significant effect on regional consumption prices.

Another important result in Table 2 is that, in general, price-elasticities in Catalonia are greater (in absolute value) than in Extremadura. That is, Catalan prices are more sensible to productivity gains, except for in the following sectors: agriculture (sector 1), energy (sector 2), food production (sector 6), construction (sector 11) and public services (sector 15). This may be because there are more economic interconnections in the Catalan economy, especially regarding inter-industry relationships, as was found by Llop et al. (2002), who compared Catalonia and Extremadura using the linear SAM model of multipliers.

Table 2 also shows several similarities between the two economies. Specifically, the two sectors that have the greatest effect on prices in both regions are, in this order, private services (sector 14) and commerce (sector 11), which have price-elasticies that surpass 0.2 in both economies.

However, there are also important differences between the two regions. In Catalonia, transport and communications (sector 12), finance (sector 13), and metals and electrical equipment (sector 4) are the most influential activities, presenting price-elasticities of between 0.04 and 0.08 (in absolute value). Of particular note in Extremadura are the negative elasticity in agriculture (sector 1), which is the highest in the region at -0.1808, and to a lesser extent, the positive elasticities of construction (sector 10), at 0.0704, and public services (sector 15), at 0.0444. In contrast, Table 2 shows that in Catalonia public services and construction had the smallest effect. Finally, special attention should be paid to industrial activities (sectors 3 to 9) which, despite having moderate price-elasticity in Catalonia, in Extremadura show very small effects on prices, with the exception of food production (sector 6).

A final comment should be made regarding the value for the price of capital services. Because the aggregate factors have fixed supply in all the simulations performed, a value for price of capital services that is greater (lower) than 1 means that (with respect to the initial equilibrium) the owners of this capital factor are better (worse) off than workers. It also means that aggregate capital services are relatively more (less) demanded than labour services, with respect to the initial equilibrium. Thus, by looking at this price we have an aggregate indicator of how sectorial productivity gains affect income distribution between factors, and the relative aggregate demand of those factors.

4.2. Production Effects

One traditional criterion used in the literature to measure the importance of a sector has been to measure the effects that changes in a particular sector cause to the total production of an economy. In this section, we use the real GDP to show the effects that the productivity gains cause to the net production of each region. As before, we show the elasticity values that have been calculated by dividing the percentage changes in real GDP by the percentage change increase in sectorial productivity (first column of each region in Table 3).

As Table 3 shows, all the production-elasticities are positive, which demonstrates that the productivity gains in each sector increase the real GDP. Another result is that, for most sectors, the Catalan values are greater than the corresponding values for Extremadura. The exceptions to this result are agriculture (sector 1), energy (sector 2), construction (sector 10) and public services (sector 15).

Table 3. Production-Elasticity of the sectorial productivity gains

	Extremadura		Catalonia	
	Elasticity	**Order**	**Elasticity**	**Order**
1. Agriculture	0.1087 (0.1253)	5	0.0168 (0.0220)	14
2. Energy	0.0413 (0.0474)	7	0.0162 (0.0182)	15
3. Chemistry	0.0015 (0.0017)	14	0.0328 (0.0372)	8
4. Metals and electrical equipment	0.0121 (0.0133)	10	0.0639 (0.0721)	4
5. Automobiles	0.0010 (0.0010)	15	0.0243 (0.0273)	11
6. Food production	0.0200 (0.0228)	9	0.0273 (0.0310)	10
7. Textiles	0.0051 (0.0055)	12	0.0207 (0.0232)	12
8. Paper	0.0022 (0.0024)	13	0.0202 (0.0225)	13
9. Other industries	0.0072 (0.0081)	11	0.0338 (0.0379)	7
10. Construction	0.1136 (0.1135)	4	0.0659 (0.0769)	3
11. Commerce	0.1460 (0.1675)	3	0.1768 (0.1979)	2
12. Transport and communications	0.0439 (0.4986)	6	0.0631 (0.0717)	5
13. Finance	0.0410 (0.0463)	8	0.0441 (0.0479)	6
14. Private services	0.1495 (0.1710)	2	0.2609 (0.2857)	1
15. Public services	0.2091 (0.2242)	1	0.0303 (0.0285)	9

The values in parenthesis in Table 3 are the share of value added that each sector has with respect to the total value added in each economy at the benchmark equilibrium. These figures can also be interpreted as the percentage change in total value added in a region when the corresponding sectorial value added is increased by 1 percent. Since a 1 percent increase in the productivity parameter of each sector increases the value added of that sector by 1 percent, we may refer to these numbers as value-added elasticities.

If we compare both figures, we find, as expected, that they are very much alike for each sector in each economy and that they also give rise to the same order; which means that the sectorial differences in production elasticities can be explained by the share in the total value added of each sector. This is no surprise because total value added is equal to GDP minus net indirect taxes.

In Catalonia, the most influential activities are private services (sector 14) and commerce (sector 11), with production-elasticities of 0.2609 and 0.1768 respectively. The industrial sector with the highest value in Catalonia is metals and electrical equipment (sector 4), which has a similar value to construction.

In Extremadura, the highest value corresponds to public services (sector 15), with a production-elasticity of 0.2091, followed by private services (sector 14), with a value 0.1495, commerce (sector 11), with a value of 0.1460, construction (sector 10), with a value of 0.1136, and agriculture (sector 1), with a value of 0.1087. Again, the industrial sectors present smaller elasticities, with chemistry (sector 3) and automobiles (sector 5) having the least impact.

4.3. Effects on Household Welfare (Real Disposable Income and Equivalent Variation)

One of the most important aspects in a new economic scenario is to analyse its effects on the welfare of private agents in the economy. Table 4 presents the household income-elasticity with respect to each sector's productivity gains. This has been calculated by dividing the percentage variation in the real disposable income of households by the percentage increase in sectorial productivity. The real income is defined as the ratio between nominal income and a price index, which includes consumption good prices and the price of the saving-investment good. This way of calculating the income deflation index is based on the idea that consumers allocate income to both consumption and savings-investment (or future consumption). Also, by introducing this feature to the index, we are capturing information regarding the importance of house prices (as a consumption-investment good) in the budget of Spanish households.[14]

In our opinion, the effects of productivity gains on household welfare are particularly useful for establishing the relative importance of a sector in an economy, and they represent a new area of study in key sector literature. Moreover, to analyze the effects of

[14] According to the Banco de España (2006), in the year 2000 a typical Spanish home set aside 32% of its disposable income to purchase a house.

productivity gains on households in greater depth, we have defined a new elasticity based on the equivalent variation (EV). Specifically, the expression of this elasticity is:

$$\text{EV-elasticity} = \frac{\frac{EV}{m_0}\times 100}{VSP},$$

where m_0 is the initial disposable income of households, EV is the equivalent variation resulting from the simulations, and VSP is the **percentage** variation in sectorial productivity. The results of this new elasticity are shown in parentheses in Table 4.

Table 4. Private Income-Elasticity (Equivalent Variation-Elasticity) of the sectorial productivity gains

	Extremadura		**Catalonia**	
	Elasticity	**Order**	**Elasticity**	**Order**
1. Agriculture	0.1759 (0.1774)	1 (1)	0.0187 (0.0186)	14 (13)
2. Energy	0.0536 (0.0536)	5 (5)	0.0189 (0.0174)	13 (14)
3. Chemistry	0.0015 (0.0015)	14 (14)	0.0306 (0.0306)	8 (8)
4. Metals and electrical equipment	0.0117 (0.0117)	9 (9)	0.0592 (0.0591)	4 (4)
5. Automobiles	0.0007 (0.0007)	15 (15)	0.0243 (0.0243)	10 (10)
6. Food production	0.0212 (0.0213)	8 (8)	0.0297 (0.0298)	9 (9)
7. Textiles	0.0038 (0.0038)	12 (12)	0.0216 (0.0215)	11 (11)
8. Paper	0.0015 (0.0015)	13 (13)	0.0200 (0.0200)	12 (12)
9. Other industries	0.0082 (0.0082)	10 (10)	0.0329 (0.0329)	7 (7)
10. Construction	0.0965 (0.0999)	4 (4)	0.0530 (0.0536)	5 (5)
11. Commerce	0.1217 (0.1225)	2 (2)	0.2045 (0.2064)	2 (2)
12. Transport and communications	0.0370 (0.0373)	7 (7)	0.0674 (0.0679)	3 (3)
13. Finance	0.0379 (0.0379)	6 (6)	0.0497 (0.0499)	6 (6)
14. Private services	0.1092 (0.1123)	3 (3)	0.2414 (0.2431)	1 (1)
15. Public services	0.0047 (0.0048)	11 (11)	0.0000 (0.0000)	15 (15)

The two elasticity measures provide not only the same ranking in sectorial effects but also very similar quantitative values. These similarities suggest that our conclusions about the effects of productivity gains on consumer welfare are robust.

Table 4 shows that all the elasticities are positive, which means that the productivity gains always increase the real disposable income and welfare of households. Second, the sectorial elasticities corresponding to Catalonia are clearly higher than those of Extremadura, with the exceptions of agriculture (sector 1), energy (sector 2), construction (sector 10) and public services (sector 15).

In fact, the sectors with the highest elasticities in Catalonia are private services (sector 14) and commerce (sector 11), with values of between 0.24 and 0.20 respectively. Still important, but well behind of these two sectors, are transport and communications (sector 12), with an elasticity of 0.067; metals and electrical equipment (sector 4), with a value of 0.059, and construction (sector 10), with a value of around 0.053. In contrast, public services (sector 15) show practically no elasticity and are in last position in the ranking. The Catalan results can be easily explained as follows. In all the simulations the household nominal income remains very much at its initial value, and it is the relative fall in the price index which allows consumers to buy more goods with the same income.

In Extremadura, it is interesting to note that the greatest impact on the real private income of households is caused by the agriculture sector, with an elasticity of 0.1759. It is also interesting to point out that this activity has an opposite effect in each region. Important effects are presented by commerce (sector 11), with a value of 0.1217, private services (sector 14), with a value 0.1092, and construction (sector 10), with a value 0.0965. It is should also be noted that the value of the energy sector (sector 2) is 0.0536. In contrast, industrial activities have the smallest impacts, with paper (sector 8), chemistry (sector 3) and automobiles (sector 5) occupying the last three positions. In order to explain the higher values in previous results we have to distinguish between two types of sectors in this economy. Agriculture, commerce and services are sectors which, when they increase their productivity, have a very large impact on the fall in consumer prices because they are big suppliers to other sectors. For these sectors, consumers experience big welfare gains because their nominal income stays the same while relative consumption prices fall. In the case of a sector such as construction, productivity gains mostly affect only the savings-investment price, with agents substantially increasing their investment demands. Since this sector makes larges demands on other sectors, but is not a supplier, the relative prices of consumption goods rise. Consumers are better off because they have much more nominal income than in the initial equilibrium. A similar explanation can be given regarding the public sector services.

4.4. Effects on Government

This section analyses the effects of sectorial productivity gains on the government's real income and completes the information regarding the effects of these gains on the circular flow of domestic agents' incomes. This new elasticity is based on the percentage variation of public revenues divided by the same percentage variation in the previously analyzed sectorial productivity.

Two comments should be made regarding this indicator. First, we define government income as the sum of all income sources of the public agent (including all collected taxes and the stock of public debt, as has been described in section 2.1) minus all social income transfers to consumers. To obtain the government's real income we use the same deflation index as that used for private income, which allows us to compare the public and private incomes in real terms and which is an analogous criterion to that used for consumer welfare.

Table 5 shows that in Catalonia, productivity gains in each sector have positive effects on government income. However, in Extremadura, the negative impacts associated with construction (sector 10), public services (sector 15), and metals and electrical equipment (sector 4) should be noted. Again, we can observe greater values in Catalonia than in Extremadura, with practically the same exceptions as in the previous section, plus food production (sector 6) which has a higher elasticity in Extremadura. This means that, for almost all sectors, both private and public agents are better off when productivity increases.

Table 5. Government Income-Elasticity of sectorial productivity gains

	Extremadura		**Catalonia**	
	Elasticity	**Order**	**Elasticity**	**Order**
1. Agriculture	0.1401	3	0.0213	12
2. Energy	0.0115	7	0.0197	14
3. Chemistry	0.0018	11	0.0322	9
4. Metals and electrical equipment	-0.0079	13	0.0617	4
5. Automobiles	0.0020	10	0.0255	10
6. Food production	0.0342	4	0.0334	8
7. Textiles	0.0101	8	0.0232	11
8. Paper	0.0026	9	0.0209	13
9. Other industries	0.0016	12	0.0342	7
10. Construction	-0.2634	15	0.0536	5
11. Commerce	0.2143	2	0.2188	2
12. Transport and communications	0.0226	5	0.0718	3
13. Finance	0.0148	6	0.0491	6
14. Private services	0.2224	1	0.2528	1
15. Public services	-0.0109	14	0.0001	15

These results show that in Catalonia there are also similarities with the previously analysed variables. If we compare the elasticities of government with the private income-elasticities (and equivalent variation), it can be seen that the rankings are the same for the first seven sectors, once again highlighting the role of the private services (sector 14) and commerce (sector 11), which have elasticities of 0.2528 and 0.2188 respectively. In contrast, public services (sector 15) have the lowest impact, with an elasticity that is now practically zero. This information tells us that both agents may agree to use specific policies to promote productivity increases in the same sectors.

In Extremadura, the sectors whose productivity gains have the highest impact on real public income are: private services (sector 14), commerce (sector 11), agriculture (sector 1), and food production (sector 6). This last sector is the only industrial sector in Extremadura that has a significant impact on all the variables analysed. The negative effect of the construction sector in Extremadura can be explained by a big fall in the government's nominal income. Because the price of government debt (a source of government income) is the savings-investment price, and this price drastically falls when productivity increases in the construction sector, there is a fall in the government's nominal income.

4.5. Summary of Results and Key Sectors

This section summarises the results presented above and identifies some important sectors for each economy that we may call key sectors from a supply side perspective. Table 6 shows those activities with elasticities greater than the average value for each regional economy and for each indicator analysed.

In Catalonia, the key sectors are private services and commerce which, in that order, show by far the highest values in all the elasticities analysed for this region. Transport and communications also have higher elasticities than the average, and metals and electrical equipment, together with construction, follow with a significant value. Note that all five sectors are the same when the production and welfare criteria are applied. Furthermore, they all (with the exception of construction) provide the most benefit to public sector real income. This means that private consumers and public agents may agree to promote policies to improve the productivity of these sectors.

Table 6. Sectors with high elasticities (key sectors)

	Extremadura	Catalonia
Price-Elasticity (negative)	1. Agriculture (0.1724) 2. Private services (0.1715) 3. Commerce (0.1659) 4. Energy (0.0456) 5. Transport and Communications (0.0354) **Mean = 0.0354** 6. Finance (0.0344)	1. Private services (0.2313) 2. Commerce (0.2004) 3. Transport and communications (0.0756) 4. Metals and electrical equipment (0.0574) **Mean = 0.05572** 5. Construction (0.0514) 6. Finance (0.0496)
Production-Elasticity	1. Public services (0.2091) 2. Private services (0.1495) 3. Commerce (0.1460) 4. Construction (0.1136) 5. Agriculture (0.1087) **Mean = 0.05722** 6. Transport and Communications (0.0439)	1. Private services (0.2609) 2. Commerce (0.1768) 3. Construction (0.0659) 4. Metals and electrical equipment (0.0639) 5. Transport and communications (0.0631) **Mean = 0.0598** 6. Finance (0.0441)
Household-Elasticity (Equivalent Variation-Elasticity)	1. Agriculture (0.1774) 2. Commerce (0.12259) 3. Private services (0.1123) 4. Construction (0.0999) 5. Energy (0.0536) **Mean = 0.04629** 6. Finance (0.0379)	1. Private services (0.2431) 2. Commerce (0.2064) 3. Metals and electrical equipment (0.0591) 4. Transport and communications (0.0679) **Mean = 0.05805** 5. Construction (0.0536) 6. Finance (0.0499)
Government-Income Elasticity	1. Private services (0.2224) 2. Commerce (0.2143) 3. Agriculture (0.1401) 4. Food Production (0.0342) **Mean = 0.02638** 5. Transport and Communications (0.0226) 6. Finance (0.0148)	1. Private services (0.2528) 2. Commerce (0.2188) 3. Transport and communications (0.0718) 4. Metals and electrical equipment (0.0617) **Mean = 0.05967** 5. Construction (0.0536) 6. Finance (0.0491)

In Extremadura, commerce, private services and construction have higher elasticities than the average (as in Catalonia) and, consequently, these activities can be considered key sectors in this region. However, there are important differences between the two regions regarding the agriculture and energy sectors (key sectors in Extremadura) and metals and electrical equipment and transport and communications sectors (key sectors in Catalonia). Another important difference between the two regions concerns the public services sector: in Extremadura this sector has high elasticities of production and is the most influential activity on the GDP of this region, whereas in Catalonia the sector presents elasticities that are practically equal to zero. It is also worth noting that that the public sector does not qualify as a key sector for Extremadura despite its influence on production, and that there are no industrial activities among the key sectors for Extremadura.

We consider a sector to be important (a key sector) for an economy if its productivity gain has higher than the average elasticity regarding consumer welfare. We use consumer welfare rather than other variables such as the real GDP or the CPI because it is the most commonly used variable in micro economic analysis and it accounts for all economic activity. The other indicators are useful for providing a better understanding of the economic impacts of productivity gains on an economy. Also, the behaviour of these indicators increases our understanding of how efficiency gains in one sector have a knock-on effect on the rest of the economy. However, if we keep in mind that the essential objective of economic activity is to increase individual welfare, the best way of capturing these welfare effects is to use income-elasticity and the equivalent variation-elasticity along with the other elasticities defined in this paper.

5. CONCLUSIONS

In this paper we simulate and analyse the economic impact of sectorial productivity gains on the economy of two regional Spanish economies: Catalonia and Extremadura. In particular, we analyse a percentage increase in the total factor productivity of each production sector in these economies. We focus our analysis of each economy on the quantitative behaviour of the following variables: the consumption price index (CPI), a price index related to the CPI, the production of the economy (real GDP), consumer welfare (real disposable income and equivalent variation) and government income (net tax revenues of social transfers). The instrument we use is a standard computable general equilibrium model (following the Shoven-Whalley tradition) in which we assume perfect competition in all markets and production technologies with constant returns-to-scale. In all the simulations performed, we assume that all the factor supplies are fixed and that in equilibrium all the markets clear, including the factors' market. The parameters of the model are obtained through calibration by using two social accounting matrices for the two Spanish regional economies.

The results for both regional economies are presented in the form of elasticitities (price-elasticity, production-elasticity, disposable income-elasticity and equivalent variation-elasticity, and public income-elasticity).

To identify the important sectors in these economies, we study the impact of the productivity gains on consumers (real disposable income and equivalent variation). Using traditional terminology, we may refer to as key sectors those whose welfare and real income elasticities are above the average of all other the sectors. However, in contrast with the classic (demand side) multipliers, we should point out that our criteria follow a novel supply side argument that has not been explored before in the literature. In Catalonia the key sectors are: private services, commerce and transport and communications. In Extremadura the key sectors are: agriculture, construction, commerce, private services.

The results should be interpreted in terms of the hypothesis used in our regional models. These models are also very common in the computable general equilibrium literature. We should point out that the assumptions of perfect competition and constant returns to scale may be an important factor when trying to explain our results. Under both hypothesis, the sectorial productivity gains translate into lower relative prices for the produced goods, and this helps increase the purchasing power of consumers and, therefore, raises their available income and welfare. Analyzing other hypotheses, however, is beyond the scope of the present work. On the other hand, factors markets clear in equilibrium. We have shown that this assumption is not relevant to the conclusions. In fact, possible unemployment in the labour market and different definitions of the labour supply allow us to conclude that our results are robust in the sense that they do not differ substantially from those obtained when relaxing this hypothesis. However, we should point out that this is a complex issue beyond the scope of this paper that requires an analysis of the impact of productivity gains on the degree of factors used in an economy.

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