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Effects of the tax on retail sales of some fuels on a regional economy: a computable general equilibrium approach

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Abstract This study simulates the effects on the economy of Extremadura that are produced by a new tax on retail sales of some fuels. A computable general equilibrium model involving various labour market scenarios is employed as a modelling framework. Model parameters are obtained by calibration, using a social accounting matrix for Extremadura updated to the year 2000. Further, we also include an additional simulation in which a hypothetical regional tax rate, to finance environmental policies, is considered. This second simulation assumes constant fiscal revenues. The results of the first simulation show that the effects of this tax are modest. The simulation shows household welfare losses, decreasing activity levels and generalised price reductions, except in production sectors more directly linked to the oil products sector. In addition, we also observe that this hypothetical additional regional fuel tax rate would reinforce the effects produced by the national tax rate.

JEL Classification C68 · D58 · R13

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1 Introduction

The "Tax on Retail Sales of Some Fuels" (Impuesto sobre las Ventas Minoristas de determinados Hidrocarburos), created in 2002, is a relatively recent tax in the Spanish fiscal system. It is defined as an indirect tax on the retail sales and own consumption of automotive fuels (petrol, gas-oil, fuel oil and kerosene), liquid fuels for heating and some additives. The application of this tax is theoretically supported by its capacity to collect tax revenues and for the correction of negative externalities (Labandeira and López 2002). Thus, it serves a dual purpose: controlling demand and collecting tax revenue.

Although it is a national tax, in the decentralized Spanish fiscal system revenue generated by this fuel tax in each region is completely transferred by the central government to the corresponding regional government. Further, regional governments are able to augment the national tax rate with an additional regional tax rate and, therefore, the current tax rate in each region is the sum of both rates. The national tax revenue can only be applied to finance the health system, although revenue from the regional tax rate can also be used to finance environmental policies.

The main objective of this study is to analyse the effects that have been caused by the introduction of this tax on retail sales of some fuels in a regional economy, specifically the economy of Extremadura.[1] Romero and Sanz (2003) have already studied its effects on the overall Spanish economy, by using microsimulations to determine the impact on tax collection and households' expenditure distribution. At a regional level, Cansino et al. 2007 developed a simple input–output price model to calculate the cumulative impact of the new tax on the Andalusian regional economy, determining its effects on the price indices and on remaining tax collections.

However, these studies mainly deal with welfare indicators and/or income inequality indices, thus ignoring the overall economic impact that a fiscal reform, or any other economy-wide alteration of the tax structure for that matter, will have on resource allocation and the derived major macromagnitudes of the regional economy.

This limitation can be overcome by using one of the most suitable tools for studying the effects of a wide-range fiscal reform, namely, computable general equilibrium models. In the past 25 years, these models have been profusely used to analyse government economic policies, both in developed and developing countries (Shoven and Whalley 1992). In general terms, these models translate the theoretical Walrasian general equilibrium system into fully operative tools, including an endogenous output and price system, substitutability in production and demands, and the optimization behaviour of individual agents. A computable general equilibrium analysis permits to capture the changes in the spheres of production and consumption, as well as in income distribution, in response to changes in a given economic policy, as these models

[1] The region of Extremadura is located in the South-West of Spain next to the Portuguese border. Its GDP is the lowest in Spain and among the lowest in the European Union. In fact, it is an "Objective 1" region because its per capita GDP is below the 75% of the European Union mean. Besides of the high unemployment rate, the relevant shares of agriculture and services sectors in terms of production and workforce structures point out.

explicitly include a representation of the framework of interdependencies among all markets in an economy.

It is important to note that this modelling framework has also been widely used to assess the economic effects of different environmental tax reforms. Among the large number of applications in the literature, one can mention those by Dessus and Bussolo (1998), Bye (2000), Xie and Saltzman (2000), Wender (2001), Conrad and Löschel (2005) and Van Heerden et al. (2006). Besides, Manresa and Sancho (2005) and Andre et al. (2005) develop two models referred to the Spanish economy and the Spanish region of Andalusia, respectively. An important share of this literature has been focused on the double dividend hypothesis, that is, if an environmental tax reform consisting of taxing pollution emissions and recycling the so-obtained revenue by reducing other distorting taxes, in such a way that public revenue remains unchanged, gives rise to environmental and non-environmental improvements (*green dividend* and *blue dividend*, respectively).[2]

Our study introduces two different applications related to tax on retail sales of some fuels. First, we determine the effects that this fuel tax has caused in Extremadura, where its current tax rate consists of the national rate only. In addition, we carry out a second simulation, in which a hypothetical additional regional fuel tax rate is introduced to finance environmental policies. Further, in this second exercise we impose a reduction in income tax, to maintain constant tax revenue.

Given that the Spanish regional governments have some capacity to alter the fuel tax considered, it is important to point out the relevance of this analysis to a given regional economy. Besides, the tax on retail sales of some fuels has achieved greater importance in the Spanish economy because of the discussion about the regional financing system.

The study is structured as follows. In Sect. 2, we present the main features of the CGE model employed. Sect. 3 shows the social accounting matrix (SAM) built for the Extremadurian economy that was used to calibrate the model parameters. A detailed description of the proposed simulations is then presented in Sect. 4, together with the main results obtained. Finally, Sect. 5 presents the main conclusions that can be drawn from the analysis of simulation results.

2 The model

We have developed a static CGE model for the Extremadurian economy. It allows us to determine the effects on resource allocation caused by the introduction of the tax on retail sales of some fuels. This model involves a set of equations that reflect equilibrium conditions and the behaviour of the different economic agents. As such, we can consider the producers, the households, the public sector and the foreign sector in general terms. In this section, we develop a detailed analysis of each sector or agent (Subsects. 2.1 to 2.4 below), including some observations in relation to the labour market (Subsect. 2.5) and the notion of equilibrium used (Subsect. 2.6). In this sense,

[2] Theoretical arguments related to the viability of a double dividend are concisely stated in Goulder (1995), Bovenberg (1999) and De Mooj (1999). An interesting survey can be found in Schoeb (2003).

PRODUCTION SECTORS	**COMMODITIES**
j_1 -Agriculture	h_1 - Food and non-alcoholic drinks
j_2 - Energy	h_2 - Alcoholic drinks and tobacco
j_3 - Oil refining	h_3 - Clothing and footwear
j_4 - Chemical products and minerals	h_4 - Housing, heating and lighting
j_5 - Metal products and electrical material	h_5 - Furnishings and fittings
j_6 - Transport material	h_6 - Medical services
j_7 - Food, beverages, and tobacco industries	h_7 - Transport and communication
j_8 - Textiles, leather, shoes, and clothing	h_8 - Leisure, education and culture
j_9 - Paper and printing	h_9 - Other commodities
j_{10} - Sundry industrial products	
j_{11} - Construction	
j_{12} - Recovery and repair, trade and hostelry	
j_{13} - Transport and communication	
j_{14} - Credit and insurance	
j_{15} - Other sales oriented services	
j_{16} - Non-sales oriented services	

Fig. 1 Production sectors and commodities

this section only includes the main equations of the model, but a full listing is showed in Appendix 1.

2.1 Production

The model for the Extremadurian economy incorporates 16 production sectors (see Fig. 1). It is assumed that each production sector obtains a homogeneous product, according to a nested production function. At the first nesting level, the total production of each sector (Q_j) is obtained as a Cobb–Douglas aggregate of domestic output (Qd_j) and imports (Qm_j), following the Armington hypothesis (1969).[3] At the second level, the domestic production for each sector is obtained with a fixed-coefficients technology between intermediate inputs (X_{ij}) and value added (VA_j). Finally, at the third nesting level, the value added of each sector is obtained by combining the primary factors of capital (K_j) and labour (L_j), according to a Cobb–Douglas technology function. The expressions used at these three levels are given in (1), (2) and (3) respectively:

$$Q_j = \beta_{Aj}\, Qd_j^{\delta dj}\; Qm_j^{1-\delta dj} \tag{1}$$

$$Qd_j = \min\left\{{}^{X_{1j}}\!/_{a_{1j}}, {}^{X_{2j}}\!/_{a_{2j}}, \ldots, {}^{X_{16j}}\!/_{a_{16j}}, {}^{VA_j}\!/_{v_j}\right\} \tag{2}$$

$$VA_j = \beta_j K_j^{\alpha_j} L_j^{1-\alpha_j}, \quad j = 1, 2, \ldots, 16 \tag{3}$$

[3] This specification assumes that domestic production and imports are imperfect substitutes. Thus, the empirical evidence that real economies simultaneously import and export similar products is considered.

In these expressions, β_{Aj} and β_j are scale parameters; δd_j are parameters which reflect the share of domestic output of j in $j's$ total production; parameters a_{zj} express the minimum amount of z needed to obtain a unit of j; v_j is the technical coefficient of value added; and, finally, α_j and $(1-\alpha_j)$ are parameters which represent the participation of the primary factors, capital and labour, with regard to value added.

One could note that the functional form used for domestic production in Eq. (2), although widely used in the computable general equilibrium literature, implies there is no substitution between different intermediate inputs and the value added when their relative prices change. For resolving this constraint, a sensitivity analysis has been performed by using an alternative Cobb–Douglas specification (see Eqs. 38–40 in Appendix 1). The results obtained in both cases are very similar—qualitative and quantitatively—and, therefore, those from the Cobb–Douglas specification have not been included.[4]

Finally, it is assumed that firms obtain their demand functions for inputs and supplies of outputs by maximising profits under these technological constraints (see Appendix 1).

2.2 Consumption

The model assumes only one consumer. We consider the following Cobb–Douglas utility function (U), defined in terms of saving and consumption:

$$U = \sum_{h=1}^{9} \gamma_h \ln C_h + \gamma_s \ln S \tag{4}$$

In (4), the parameters γ_h and γ_s reflect the share of disposable income for commodities h and private savings. S represents the saving and C_h expresses the private consumption of commodity h.[5]

Inequality (5) shows the budget constraint for this representative household group:[6]

$$\sum_{h=1}^{9} p_h(1+\text{vat}_h)C_h + p_i S = \sum_{h=1}^{9} p_h^F C_h + p_i S \leq YD \tag{5}$$

The sum on the left-hand side is the expenditure on final consumption. The parameter vat_h is the value added tax rate for the commodity h, and p_h^F is its final consumption

[4] The results obtained with the Cobb–Douglas specification for the domestic production are available upon request.

[5] The nine commodities considered in Eq. (4) are also shown in Fig. 1. Production goods and commodities match different disaggregations of the economic activity, the former from a productive point of view and the latter from the private consumption approach.

[6] Due to the features of consumer's utility function—increasingly monotone—this weak inequality must be satisfied as an equality in the equilibrium. The same comments are valid for expression (8)—government budget constraint.

price inclusive of taxes. Private saving is also included in the expression, being valued at the saving/investment price, p_i.

The right-hand side of inequality (5) shows disposable income, *YD*. This income comes from the sale of its endowments of capital (K) and labour (L), at the prices r and w, respectively. In addition, households receive transfers from the public sector, (TPS), indexed by the consumption price index (cpi), and receive transfers from the foreign sector (TFS), although their total quantitative importance is minimal. Finally, households have to pay employees' social contributions and income tax, whose rates are ess and τ, respectively.

Thus, the disposable income of the only household group[7] is given by (6):

$$YD = (1 - \tau)\left[rK + wL(1 - u) + \text{cpi TPS} + \text{TFS} - \text{ess } wL(1 - u)\right] \tag{6}$$

The representative consumer derives the consumption demand functions by maximising the utility function subject to the budget restriction shown in (5) (see Appendix 1).

2.3 Government

The activity of the government consists, on the one hand, of producing public services, by using the technology of "Non-sales oriented services" (j_{16}, see Fig. 1), while, on the other, of demanding public services (public consumption, C^G_{j16}) and investment goods (C^G_i). In this sense, this agent can be considered to maximise a Leontief utility function (U^G), defined by (7):

$$U^G = \min\left\{C^G_{j16},\ \gamma^G C^G_i\right\}, \tag{7}$$

where γ^G is an economic policy parameter reflecting the existence of a fixed proportion between public consumption and public investment.

The budget constraint that the government confronts can be expressed by inequality (8):

$$p_{j16}C^G_{j16} + p_i C^G_i \le R^G + p_i w^G_i - \text{cpi TPS} \tag{8}$$

The left-hand side of this inequality reflects government spending on consumption and investment. On the right-hand side, tax revenues are R^G, from which transfers paid to households have to be subtracted. w^G_i represents the stock of debt that the government issues when it is in budgetary deficit. The rest of the sectors could buy this debt at the same price as saving/investment, p_i.

With respect to the total tax revenues R^G, the model includes net taxes on production, employers' social contributions, import taxes and the previously mentioned value added tax as indirect taxes. As direct taxes, employees' social contributions and income tax are considered. The tax revenue components (a) to (f) are specified in Eqs. (9) to (14) respectively:

[7] As will be commented later, u is an endogenous variable that reflects the unemployment rate.

a) Taxes on production (Rt):

$$Rt = \sum_{j=1}^{16} t_j \left[\sum_{z=1}^{16} p_z X_{zj} + w(1 + \mathrm{esc}_j)L_j + rK_j \right] \quad (9)$$

That is, the domestic output of each sector is subject to a tax at a rate t_j. The production price for sector z is p_z. Finally, esc_j stands for the employers' social contributions rate.

b) Employers' social contributions (Resc):

$$R\mathrm{esc} = \sum_{j=1}^{16} \mathrm{esc}_j \, w \, L_j \quad (10)$$

c) Import taxes (Rtarif):

$$R\mathrm{tarif} = \sum_{j=1}^{16} \mathrm{tarif}_j \, p_m \, Qm_j \quad (11)$$

tarif_j is the import tariff rate for sector j, while p_m is the weighted price index of imported products.

d) Value Added Tax (Rvat):

$$R\mathrm{vat} = \sum_{h=1}^{9} \mathrm{vat}_h \, p_h \, C_h \quad (12)$$

e) Employees' social contributions ($Ress$):

$$R\mathrm{ess} = \mathrm{ess} \; w \, L \, (1 - u) \quad (13)$$

f) Income tax ($R\tau$):

$$R\tau = \tau \left[rK + wL(1-u) + \mathrm{cpi \; TPS} + \mathrm{TFS} - \mathrm{ess} \; wL(1-u) \right] \quad (14)$$

Equations (9) to (14) show the taxes included in the benchmark equilibrium of the model. In addition, the tax on retail sales of some fuels has been included as a new indirect tax in the two proposed simulations. Regarding its modelling, this tax has been incorporated into the cost structure of "Oil Refining" sector (j_3), without modifying any other production sector. The domestic production of "Oil Refining" in Extremadura is nil and, therefore, its cost structure is very simple because it only shows imports from the rest of Spain.

More specifically, the introduction of the Tax on Retail Sales of some Fuels implies a slight modification of the equation that shows the formation of the "Oil Refining" production price, specified in (15):

$$p_{j3} Q_{j3} = (p_m + trsf_{j3})\, Qm_{j3}, \tag{15}$$

where $trsf_{j3}$ is the unitary rate of the new tax.[8] The expression (16) gives the tax revenues:

$$Rtrsf = trsf_{j3}\, Qm_{j3} \tag{16}$$

Given the special characteristics of the "Oil Refining" sector in Extremadura, the new indirect fuel tax is levied directly on imports, a treatment allowed by Spanish law. On the other hand, in the inner workings of the model, the new tax acts as a compound tax along with the value-added tax on the consumption side. In this case, there is a distribution of the tax according to the transformation that maps the 16 production goods into the nine consumption goods, which is done by means of a conversion parameters matrix.

2.4 Foreign sector

The model considers only one foreign sector, being the rest of Spain, the European Union and the rest of the world. Because of the import/export trade and the transfers between this foreign sector and the domestic agents, the regional Extremadurian economy has a deficit with the foreign sector. This deficit must be considered as saving for this sector, to achieve the macroeconomic consistency between saving and investment.

2.5 Labour market

Capital and labour demands are obtained from conditional factor demand functions, thus minimizing the cost of obtaining value added. For the capital factor, we assume perfectly inelastic supply and therefore this factor is always fully employed. However, the model allows possible rigidities in the labour market, so the unemployment rate may be positive. More precisely, we consider the relationship (17) between the real wage and the unemployment rate:

$$\left(\frac{w}{\text{cpi}}\right) = \left(\frac{1-u}{1-u_0}\right)^{1/\beta_d} \tag{17}$$

This formulation of the labour market in CGE modelling is due to Kehoe et al. (1995), following the precepts established in Oswald (1982). The variable (*w/cpi*) represents the real wage; u is the unemployment rate; u_0 is a parameter that reflects the unemployment rate in the benchmark equilibrium; and β_d is a parameter that expresses the sensitivity of the real wage to the unemployment rate. This formulation

[8] In the benchmark equilibrium of the model it is considered that $trsf_{j3} = 0$

is consistent with an institutional setting where the workers, or unions, decide real wage taking into account the unemployment rate—according to Eq. (17)—and employers decide the amount of labour to take on.

The parameter β_d can have values between zero and infinity. If $\beta_d = 0$, the real wage will adjust sufficiently so that the unemployment rate remains constant and equal to the benchmark equilibrium rate. If $\beta_d = \infty$, the situation is exactly the opposite, that is to say, the real wage remains constant and the unemployment rate varies. For intermediate values, higher values of this parameter represent greater salary rigidity. In other words, the sensitivity of the real wage to the unemployment rate diminishes.

In the simulations we shall show later, calculations are carried out for different values of this parameter. Specifically, the extreme values $\beta_d = 0$ and $\beta_d = \infty$ are used, as well as a value from the econometric literature ($\beta_d = 1.25$, see Andrés et al. 1990).

2.6 Equilibrium

The notion of equilibrium that is used in the model is that of the Walrasian competitive equilibrium, extended to include not only producers and households, but also the government and foreign sectors (see, for instance, Shoven and Whalley 1992). Specifically, economic equilibrium is determined by a prices vector, an activity-levels vector, and a set of macro variables such that supply equals demand in all markets, with the sole exception being the labour market, as previously mentioned. Further, each one of the economic agents included in the model attains its corresponding optimal choices under the respective budget constraint, *i.e.*, the agents implement their optimal equilibrium solutions.

3 Database and calibration

The values of the model parameters are obtained by the usual procedure known as calibration. First it is necessary to obtain a social accounting matrix (SAM) for the Extremadura economy to calibrate the parameters. The last available SAM for this region is for the year 1990, so this was updated to 2000. For this, we applied the cross-entropy method (Robinson et al. 2001).

The resulting SAM includes 37 accounts. As this matrix has been built to calibrate our CGE model, there is a perfect concordance between the SAM and the model. Thus, the SAM-Extremadura-2000 incorporates the 16 production sectors and the nine commodities shown in Fig. 1. This matrix also contains two accounts for labour and capital factors, an account for households, an aggregate capital account or saving/investment account, an account for the government, six accounts for the taxes considered in the model and, finally, an account for the foreign sector.

The calibration process assumes that the SAM (the base period) represents an initial equilibrium of the economy. That is to say, it determines the parameter values that verify this property. Furthermore, in the benchmark equilibrium, measurement units are normalised so that all the price and activity levels are unitary. For the proposed model, all the parameters can be obtained by calibration, except the unemployment rate for the benchmark equilibrium.[9]

4 Simulations and results

Once the parameters and the initial values of the variables are computed, we can consider the desired simulations. The first goal of this study is to quantify the effects on the Extremadurian economy that have been caused by the introduction of the new tax on retail sales of some fuels. In Extremadura, the tax rate applied up to now has been just the national component without any additional regional component.

After simulating the introduction of the tax with only the national tax rate, we consider a distinct second simulation to determine the effects caused by a hypothetical additional regional tax rate, aimed at financing environmental policies. Further, in this second simulation, we impose a reduction in income tax to keep total tax revenue constant.

Regarding the macroeconomic model closure, a mixed rule has been used. Firstly, because the simulations done involve the introduction of a new tax, we consider adequate for the government that the public deficit was endogenously determined by the model while its activity level remains fixed. For the foreign sector, the commercial deficit remains fixed at the benchmark equilibrium level, while its activity level is a variable and so, it may change in the simulations. This type of closing rule could be considered, in computable general equilibrium methodology, a way to approach the differences between short run and long run (Cardenete and Sancho 2003), allowing a certain flexibility degree to the model.

Before analysing the results, it is important to note that three versions of the model are considered, because we have employed three different values of the β_d parameter (0, 1.25 and infinite). Therefore, each version corresponds to a different scenario for the labour market.

4.1 Introduction of the tax on retail sales of some fuels

In this first exercise, we determine the main effects on the Extremadurian economy that have been caused by the introduction of the tax on retail sales of some fuels, only composed of the national component in this region. The results analysed in the following Tables 1, 2, 3 and 4 show the variations in prices, activity levels, macroeconomic indicators, welfare measures and tax revenues. It is noteworthy, besides, that the equations related to the tax on retail sales of some fuels, (15) and (16), constitute the only changes in the model with respect to the benchmark equilibrium.

It is important to note that the new tax rate, $trsf_{j3}$, is not a model parameter. On the contrary, this tax rate is endogenously determined by the model so that *Rtrsf* was the

[9] The tax rates introduced in the model are also obtained by calibration, using data of tax revenues included in the Extremadurian SAM. Therefore, they are effective rates instead of nominal rates.

Table 1 Introduction of the tax on retail sales of fuels. Percentage changes in prices

		Labour market scenarios		
		$\beta_d = 0$	$\beta_d = 1.25$	$\beta_d = \infty$
Production (p_j)				
j_1	Agriculture	0.009	−0.087	−0.158
j_2	Energy	0.018	−0.063	−0.124
j_3	Oil refining	8.187	8.100	8.036
j_4	Chemistry and minerals	0.072	−0.014	−0.078
j_5	Metal and electrical material	0.026	−0.053	−0.112
j_6	Transport material	0.019	−0.065	−0.127
j_7	Food, drinks and tobacco	0.026	−0.057	−0.118
j_8	Textiles and clothing	0.022	−0.057	−0.116
j_9	Paper and printing	0.028	−0.046	−0.100
j_{10}	Other industries	0.047	−0.026	−0.080
j_{11}	Construction	0.052	−0.002	−0.042
j_{12}	Trade	0.002	−0.075	−0.132
j_{13}	Transport and communication	0.368	0.303	0.255
j_{14}	Credit and insurance	−0.002	−0.050	−0.086
j_{15}	Other sales-oriented services	−0.025	−0.107	−0.168
j_{16}	Non-sales-oriented services	0.019	−0.006	−0.024
Commodities (p_h^F)				
h_1	Food and non-alcoholic drinks	0.015	−0.069	−0.131
h_2	Alcoholic drinks and tobacco	0.018	−0.063	−0.123
h_3	Clothing and footwear	0.011	−0.066	−0.124
h_4	Housing, heating and lighting	0.165	0.087	0.030
h_5	Furnishings and fittings	0.013	−0.051	−0.099
h_6	Medical services	0.025	−0.050	−0.105
h_7	Transport and communication	0.608	0.533	0.478
h_8	Leisure, education and culture	0.010	−0.067	−0.124
h_9	Other commodities	0.004	−0.073	−0.131
cpi	Consumption price index	0.136	0.058	0.000
p_i	Saving/investment price	0.046	−0.014	−0.059
p_m	Average weighted price of imported products	0.023	−0.066	−0.132
Production factors				
r	Capital factor	−0.058	−0.179	−0.268
w	Labour factor	Numeraire	Numeraire	Numeraire

Source: Own elaboration. All the numbers included in the tables have been rounded up to three decimals. Therefore, some numbers that are actually close to zero may appear as zero

value of the actual tax revenue obtained with this tax. Therefore, *Rtrsf* is an exogenous variable in the model. Using 2002 official data, the first year of this tax's application, this tax revenue in Extremadura was 13,863,648 euros. As our database—the updated

Table 2 Introduction of the tax on retail sales of fuels. Percentage changes in activity levels

		Labour market scenarios		
		$\beta_d = 0$	$\beta_d = 1.25$	$\beta_d = \infty$
Production				
j_1	Agriculture	0.035	−0.028	−0.075
j_2	Energy	0.030	−0.041	−0.094
j_3	Oil refining	−0.306	−0.339	−0.364
j_4	Chemistry and minerals	−0.015	−0.055	−0.085
j_5	Metal and electrical material	0.148	0.079	0.027
j_6	Transport material	−0.407	−0.429	−0.445
j_7	Food, drinks and tobacco	−0.015	−0.042	−0.062
j_8	Textiles and clothing	−0.008	−0.027	−0.043
j_9	Paper and printing	−0.012	−0.038	−0.057
j_{10}	Other industries	0.073	0.013	−0.032
j_{11}	Construction	0.330	0.231	0.158
j_{12}	Trade	−0.105	−0.130	−0.149
j_{13}	Transport and communication	−0.159	−0.201	−0.232
j_{14}	Credit and insurance	−0.023	−0.074	−0.111
j_{15}	Other sales-oriented services	−0.089	−0.112	−0.129
j_{16}	Non-sales-oriented services	0	0	0
Commodities				
h_1	Food and non-alcoholic drinks	−0.014	−0.025	−0.034
h_2	Alcoholic drinks and tobacco	−0.017	−0.031	−0.042
h_3	Clothing and footwear	−0.011	−0.028	−0.041
h_4	Housing, heating and lighting	−0.164	−0.182	−0.195
h_5	Furnishings and fittings	−0.012	−0.043	−0.066
h_6	Medical services	−0.024	−0.045	−0.060
h_7	Transport and communication	−0.603	−0.624	−0.639
h_8	Leisure, education and culture	−0.009	−0.028	−0.041
h_9	Other commodities	−0.003	−0.021	−0.034
i	Saving/investment activity level	0.396	0.286	0.204

Source: Own elaboration. The activity level for "Non-sales oriented services" (j_{16}) remains constant due to the closure rule the authors use in the model

SAM for Extremadura—refers to 2000, this amount has been deflated to obtain the 2000 figure of 12,980,944 euros.

Generally, the results of this first simulation show diminished variations in the variables and therefore, the distortions caused by the new tax are not very important. The analysis begins by considering the percentage changes that occur for each price category (see Table 1). It is important to note that, in all the simulations that have been done, wage (w) remains constant because it is used as numeraire of the model. In this sense, all the price variations commented on in the study actually represent relative variations, expressed in relation to this numeraire.

Table 3 Introduction of the tax on retail sales of fuels. Macroeconomic indicators and household welfare measures

	Benchmark equilibrium	New equilibrium Labour market scenarios			Variation Labour market scenarios		
		$\beta_d = 0$	$\beta_d = 1.25$	$\beta_d = \infty$	$\beta_d = 0$	$\beta_d = 1.25$	$\beta_d = \infty$
Unemployment rate (%)	23.62	23.62	23.675	23,716	0	0.055	0.096
Real GDP (millions of euros)	9,658.886	9,658.721	9,654.983	9,652.209	−0.002	−0.040	−0.069
Real disposable income (millions of euros)	9,396.293	9,383.606	9,381.993	9,380.796	−0.135	−0.152	−0.165
Equivalent variation (millions of euros)	–	−10.535	−12.561	−14.063	–	–	–
Compensating variation (millions of euros)	–	−10.547	−12.566	−14.061	–	–	–

Source: Own elaboration

Table 4 Introduction of the tax on retail sales of some fuels. Tax revenues

	Benchmark equilibrium (millions of euros)	New equilibrium (millions of euros) Labour market scenarios			Percentage variation Labour market scenarios		
		$\beta_d = 0$	$\beta_d = 1.25$	$\beta_d = \infty$	$\beta_d = 0$	$\beta_d = 1.25$	$\beta_d = \infty$
Taxes on production *(Rt)*	−27.941	−27.893	−27.821	−27.768	−0.173	−0.428	−0.618
Employers social contributions (*R*esc)	892.164	892.185	891.447	890.900	0.002	−0.080	−0.142
Import taxes (*R*tarif)	0.078	0.078	0.078	0.078	0.024	−0.112	−0.213
Value Added Tax (*R*vat)	135.697	135.698	135.569	135.473	0.001	−0.094	−0.165
Employees social contributions (*R*ess)	713.574	713.574	713.057	712.673	0	−0.073	−0.126
Income tax ($R\tau$)	620.665	620.671	620.080	619.642	0.001	−0.094	−0.165
Tax on retail sales of some fuels (*Rtrsf*)	–	12.981	12.981	12.981	–	–	–
Total tax revenues (R^G)	2,334.237	2,347.293	2,345.391	2,343.980	0.559	0.478	0.417

Source: Own elaboration

In relation to production prices, they are directly affected by the simulation because the new tax fuel is modelled by including it in the "Oil refining" (j_3) cost structure (see Eq. 15). As a result of this, in every labour market scenario, production prices show significant increases of greater than 8% in this production sector. The high increases in "Transport and communication" (j_{13}) also point out, because of this sector's dependence on "Oil refining" through intermediate inputs.

It is important to note that there is a fall in the price of the capital factor in all the scenarios. That fall is jointly determined by a reduction in the activity levels of production sectors (see Table 2) and the full employment of this factor. In this sense, one can observe that, the higher the wage rigidity (i.e., larger the value of β_d), greater is the reduction in the price of the capital factor, decisively bringing about lower production prices. More specifically, in the scenario with fully flexible wage ($\beta_d = 0$) almost all production prices show small increases, while the other two scenarios present generalised reductions.

This final result is also observed for the final consumption prices. In general, the behaviours of the consumption and production prices are directly correlated because the commodities are obtained by applying a conversion matrix on the production goods. Besides, one can observe that the commodities "Housing, heating and lighting" (h_4) and "Transport and communication" (h_7), directly linked to "Oil refining" sector (j_3) through the mentioned conversion matrix, show increases in their prices in all scenarios. Because of this, the consumption price index, *cpi*, a variable that summarizes the behaviour of these prices, shows a slight increase in each scenario, again higher for wage flexibility and almost zero for fully flexible unemployment.

Finally, the saving/investment price and the average weighted price of imported products also behave differently depending on the labour market scenario, showing increases in the scenario with fully flexible wage ($\beta_d = 0$) and reductions in the others.

Another set of results shows the changes in activity levels (Table 2). For the production sectors, the inclusion of the tax on retail sales of some fuels generally causes small reductions in their activity levels, again higher for "Oil refining" (j_3) and "Transport and communication" (j_{13}), as well as "Transport material" (j_6). Therefore, the slowing down of the productive activity caused by the introduction of the new tax is evident.

However, there are some exceptions to this result, because "Metal and electrical material" (j_5) and "Construction" (j_{11}) experience increases in their activity levels in all scenarios. To explain this result, we note that production in both these sectors is generally aimed at investment. Since investment is determined by savings in the model, the introduction of the new fuel tax causes a reduction in the public deficit and an increase in aggregate saving, leading to an increase in the investment activity level between 0.396 and 0.204% that *pulls* the two activity sectors up.

On the other side, the activity levels for commodities show little decreases in every commodity and scenario by reflecting reductions in the private consumption. These decreases in consumption come from a lower disposable income (in two of the scenarios, see Table 6) and the aforementioned behaviour of consumption prices. In this sense, one can observe that the commodities with higher increases in final prices, that is, "Housing, heating and lighting" (h_4) and "Transport and communication" (h_7), are just those that experience the greatest reductions in terms of consumption.

On the other hand, it is possible to observe again clear differences among the three versions of the model. Considering the fully flexible wage scenario, the activity levels are clearly higher and so, the slowing down of economic activity seems to be lower.[10]

To clarify this result, we employ some macroeconomic indicators (see Table 3), starting with the unemployment rate variations. In the case of a fully flexible wage, labour market adjustment occurs via the real wage and not via unemployment. In fact, given our specification for the labour market—Eq. (17), unemployment rate u remains constant at the benchmark equilibrium level (23.62%). In the other two versions of the model, the general reduction in production activity levels causes reduced increases in the unemployment rate, between 0.055 percentage points for $\beta_d = 1.25$ and 0.096 points for $\beta_d = \infty$. In terms of real GDP, the introduction of the tax on retail sales of some fuels causes a small decrease in all scenarios, which again becomes smaller as wage flexibility increases (0.002% for $\beta_d = 0$ compared with 0.069% for $\beta_d = \infty$).

Table 3 also shows the changes in household welfare. This table includes the percentage variation of real disposable income, a variable that is computed as the rate between the disposable income and the consumption price index. As is usual, we also present the equivalent variation and the compensating variation, computed by the corresponding expenditure functions.

The three considered indicators show that the new fuel tax determines welfare reductions for all cases. Real disposable income experiences a reduction of between 0.135 and 0.165%, mainly due to the reduction in capital incomes and the increase in variable *cpi*. On the other hand, equivalent and compensating variations show approximate welfare losses of between 10.5 and 14.1 millions of euros, because of the generalized reductions in consumption and private savings.

Moreover, one can observe that the decreases are directly related to increases in wage rigidity, that is, greater wage rigidity causes a greater welfare reduction. Therefore, the scenario of a fully flexible wage is once again the scenario with fewer distortions. In the case of $\beta_d = 0$, although households face up to higher saving/investment and consumption prices than in the other two scenarios, their disposable income is also higher and the reductions in saving and consumption are smaller.

To conclude the first application, we should note that the introduction of the new tax on fuels obviously modifies total tax revenue, R^G, which increases slightly in all scenarios (see Table 4). The fully flexible wage scenario is emphasized again, because it shows the greatest increase in total tax revenues (0.559%). In this labour market scenario, there is a reduction in production subsidies, as well as a slight increase in the revenues from most of the remaining taxes. This result clearly contrasts with the situation in the other two scenarios, in which all tax revenues decrease.

[10] Table 2 shows that, for $\beta_d = 0$, "Agriculture" (j_1), "Energy" (j_2) and "Other industries" (j_{10}) also experience increases in their activity levels. The reductions in the commodities activity levels are clearly lower than those in the other two scenarios, while the increase in the saving/investment activity level is higher.

4.2 Introduction of a hypothetical additional regional tax rate compensated by a reduction of the income tax (equivalent tax revenues)

Once the effects caused by the new tax have been determined, in this second simulation we analyse the effects produced by the introduction of a hypothetical regional tax rate. Specifically, the previous national tax rate is increased with a regional tax rate aimed at financing 5% of the Extremadurian environmental expenditure. In terms of modelling, we accordingly increase the tax revenue *Rtrsf* by 3,691,576 euros, obtaining the new figure of 16,672,520 euros. As in the former simulation, *Rtrsf* is a model parameter, while the tax rate $trsf_{j3}$ is an endogenous variable.

Besides, in this second simulation we consider a simultaneous reduction in income tax, to quantify the effects in a scenario involving constant total tax revenues (with respect to the first simulation). This tax is selected to provide the fiscal compensation because the Spanish regional governments have a certain capacity to modify it.

In general, the effects on the different variables are very similar to the ones obtained from the former simulation, although they would be more marked. Given these similarities, in this section, our basic goal is to compare the results of both simulations, rather than to do a detailed analysis of this second application. The tables of results will be presented in a different format in order to fulfil this goal.[11]

A good example of these similarities can be found in the behaviour of prices, because in the second simulation the effects on prices almost reproduce the data presented in Table 1. That is, production and consumption prices increase in respect to the benchmark equilibrium with a fully flexible wage, whilst the opposite behaviour predominates in the other two labour market scenarios.

More specifically, Table 5 shows for both simulations several indicators that summarize the changes with respect to the benchmark equilibrium. For production and consumption prices, including *cpi*, the percentage average variations show how the average effects on prices are clearly higher in the second simulation. [12] In fact, increases and reductions in prices are more marked than in the first simulation, hence giving a higher dispersion and a higher variance of the variations. That is, in the fully flexible wage scenario, the prices from the second simulation are higher than those from the first one, while the opposite behaviour occurs for a significant share of prices in the other two labour market scenarios ($\beta_d = 0$ and $\beta_d = 1.25$). Therefore, in the latter it seems to prevail the effects on prices derived from the regional fuel tax rate, because the reduction in the income tax rate would tend to raise them.

On the other hand, there are relevant differences between the two simulations in terms of consumption, especially for the fully flexible wage case (see Table 6). The proposed reduction in income tax and a higher increase in public transfers determine for this second simulation higher disposable incomes than that in the first simulation

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[11] The complete results obtained in this second simulation are available upon request.

[12] The introduction of the regional tax would determine a higher increase for "Oil refining" (j_3), from around 8% up to 10.4%. These increases in prices would also be clearly higher for those sectors and commodities that are more directly related to refining, namely, "Transport and communication" (j_{13}), "Housing, heating and lighting" (h_4) and "Transport and communication" (h_7). Furthermore, we also notice more variability in the saving/investment price (p_i), the average price of imported products (p_m) and the capital factor price (r).

Table 5 Comparison between first and second simulations. Percentage variations in prices

	Labour market scenarios					
	$\beta_d = 0$		$\beta_d = 1.25$		$\beta_d = \infty$	
	1st Sim.	2nd Sim.	1st Sim.	2nd Sim.	1st Sim.	2nd Sim.
Production (p_j)						
Average percentage variation	0.558	0.729	0.569	0.729	0.610	0.784
Variance of percentage variations	4.150	6.860	4.137	6.837	4.127	6.821
Commodities (p_h^F)						
Average percentage variation	0.097	0.139	0.118	0.148	0.149	0.192
Percentage variation in cpi	0.136	0.190	0.058	0.080	0.000	0.000
Variance of percentage variations	0.039	0.065	0.040	0.065	0.040	0.066
Percentage variation in p_i	0.046	0.071	−0.014	−0.014	−0.059	−0.076
Percentage variation in p_m	0.023	0.046	−0.066	−0.079	−0.132	−0.170
Percentage variation in r	−0.058	−0.052	−0.179	−0.221	−0.268	−0.344

1st Simulation: National tax rate of the new tax on retail sales of some fuels

2nd Simulation: National tax rate + Regional tax rate + Reduction in income tax (equivalent total tax revenues)

Source: Own elaboration. The average percentage variations have been computed by considering the absolute values of the percentage variations respect to the benchmark equilibrium

for two of the three labour market scenarios, $\beta_d = 0$ and $\beta_d = 1.25$. In fact, in these two scenarios the reductions in consumption and savings are smaller than the initial ones,[13] excepting the commodities "Housing, heating and lighting" (h_4) and "Transport and communication" (h_7) whose consumptions decrease more in all the scenarios, due to the higher increase in their respective consumption prices.

In terms of household welfare, the three indicators—variation in real disposable income, equivalent variation and compensating variation—again reflect welfare losses with respect to the benchmark equilibrium. In addition, it is clear that in the second simulation, as well as in the first one, the lower distortions in the economy would happen with a fully flexible wage, not only in terms of household welfare, but also in terms of unemployment rate—no increase for $\beta_d = 0$—and real GDP—a lower reduction.

Considering all the results shown in Tables 5 and 6, that is, jointly observing the behaviour of prices, macroeconomic indicators and welfare levels, it is important to note that for the Extremadurian economy, with the exception of the first wage scenario, the second simulation shows worse economic results and higher distortions than the first one. That is, for the two labour market scenarios that imply higher wage rigidity, the reduction in income tax would not be enough to compensate for the negative effects caused by the incorporation of the regional tax rate.

To conclude the analysis, we show the different tax revenues obtained in the two simulations (see Table 7). Given the nature of this second exercise, total tax revenues

[13] More specifically, for the fully flexible wage scenario, consumption increases in a generalized way.

Table 6 Comparison between first and second simulations. Welfare levels and macroeconomic indicators

		Labour market scenarios					
		$\beta_d = 0$		$\beta_d = 1.25$		$\beta_d = \infty$	
		1st Sim.	2nd Sim.	1st Sim.	2nd Sim.	1st Sim.	2nd Sim.
Consumption And Saving							
Percentage variation in disposable income (YD)		0.001	0.055	−0.094	−0.086	−0.165	−0.188
Percentage variation in consumption (C_h):							
h_1	Food and non-alcoholic drinks	−0.014	0.019	−0.025	−0.003	−0.034	−0.019
h_2	Alcoholic drinks and tobacco	−0.017	0.017	−0.031	−0.010	−0.042	−0.030
h_3	Clothing and footwear	−0.011	0.026	−0.028	−0.006	−0.041	−0.028
h_4	Housing, heating and lighting	−0.164	−0.172	−0.182	−0.203	−0.194	−0.226
h_5	Furnishings and fittings	−0.012	0.026	−0.043	−0.024	−0.066	−0.060
h_6	Medical services	−0.024	0.009	−0.045	−0.027	−0.060	−0.053
h_7	Transport and communication	−0.603	−0.735	−0.624	−0.771	−0.639	−0.797
h_8	Leisure, education and culture	−0.009	0.027	−0.028	−0.005	−0.041	−0.029
h_9	Food and non-alcoholic drinks	−0.003	0.035	−0.021	0.003	−0.034	−0.019
Percentage variation in saving (S)		−0.045	−0.016	−0.080	−0.072	−0.106	−0.111
Welfare levels							
Percentage variation in real disposable income		−0.135	−0.134	−0.152	−0.166	−0.165	−0.188
Equivalent variation (millions of euros)		−10.535	−9.789	−12.561	−13.291	−14.063	−15.794
Compensating variation (millions of euros)		−10.547	−9.804	−12.566	−13.299	−14.061	−15.791
Macroeconomic indicators							
Unemployment rate, u (%)		23.620	23.620	23.675	23.696	23.716	23.751
Percentage variation in real GDP		−0.002	−0.002	−0.040	−0.055	−0.069	−0.094

1st Simulation: National tax rate of the new tax on retail sales of some fuels

2nd Simulation: National tax rate + Regional tax rate + Reduction in income tax (equivalent total tax revenues)

Source: Own elaboration

(R^G) for each wage scenario must obviously be the same of the first simulation. The results show that, with the exception of the increase in the tax on retail sales of some fuels and the corresponding reduction in income tax, tax revenues are almost constant. We also highlight the fact that the second simulation shows lower revenues for social contributions, due to the increase in the unemployment rate and the reduction in labour factor contracts.

5 Concluding remarks

In this study, we have measured the effects that the introduction of the Tax on Retail Sales of some Fuels has caused in the Extremadurian economy. Since the competences assumed by the regional governments in Spain have risen in the recent years, including issues as education and health system, their financial capacity turns into a very relevant

Table 7 Comparison between first and second simulations. Tax revenues

Tax revenues (millions of euros)	Labour market scenarios					
	$\beta_d = 0$		$\beta_d = 1.25$		$\beta_d = \infty$	
	1st Sim.	2nd Sim.	1st Sim.	2nd Sim.	1st Sim.	2nd Sim.
Taxes on production (*Rt*)	–27.893	–27.935	–27.821	–27.826	–27.768	–27.748
Employers social contributions (*R*esc)	892.185	892.179	891.447	891.168	890.900	890.436
Import taxes (*R*tarif)	0.078	0.078	0.078	0.078	0.078	0.078
Value added tax (*R*vat)	135.698	135.772	135.569	135.580	135.473	135.443
Employees social contributions (*R*ess)	713.574	713.574	713.057	712.863	712.673	712.349
Income tax ($R\tau$)	620.671	616.954	620.080	616.855	619.642	616.750
Tax on retail sales of some fuels (*Rtrsf*)	12.981	16.673	12.981	16.673	12.981	16.673
Total tax revenues (R^G)	2,347.293	2,347.293	2,345.391	2,345.391	2343.980	2343.980

1st Simulation: National tax rate of the new tax on retail sales of some fuels

2nd Simulation: National tax rate + Regional tax rate + Reduction in income tax (equivalent total tax revenues)

Source: Own elaboration

matter. In this sense, the revenues from this new fuel tax are transferred to the regional governments, which can also optionally increase its rate. Therefore, the analysis of this tax and its different economic effects seem to be significant for any regional government in this country. Besides, the developed analysis could be extrapolated to other countries with a high level of fiscal decentralization.

In order to analyse the effects derived from this tax, we should use a general equilibrium approach, rather than a partial equilibrium one, because it allows us to consider the interdependences among all markets in the economy. In our case, starting from the update of a social accounting matrix for Extremadura, we have developed a computable general equilibrium model that allows one to compute the main microeconomic and macroeconomic effects caused by this new fuel tax.

The results obtained in the analysis show an increase in the oil refining production price and in the prices of those commodities closely related to this sector, as well as a generalized reduction in the activity levels except in those sectors more directly linked to investment. Besides, it is possible to observe an increase in the unemployment rate, a decrease in real GDP and a welfare loss for households. Therefore, the increase in total tax revenues caused by the inclusion of this tax contrasts with the distortions on the main economic variables. Anyway, the results we get show diminished effects, so these distortions are not very pronounced.

It is also important to note that the behaviour of the labour market significantly influences the results. There are evident differences among the three labour market scenarios that we have considered, getting the lowest distortions in the fully flexible wage case.

Furthermore, taking into account that regional governments can increase the new fuel tax rate, we have developed a second simulation to determine the effects caused by a hypothetical regional fuel tax rate. In this case, we have also assumed tax revenue neutrality, achieved by a reduction in the income tax rate. The results of this exercise show that the effects of the regional increase tax rate prevail over the reduction in income tax, reinforcing the effects of the national tax rate. In fact, in two of the three labour market scenarios, the observed distortions in the economy would be clearly higher in this second simulation.

Appendix : Equations

Production

1. $$Q_{dj} = \frac{Q_j Y_j}{\beta_{Aj}} \left(\frac{\delta_{dj}}{1-\delta_{dj}}\right)^{1-\delta_{dj}} \left(\frac{p_m(1+\text{tarif}_j)}{p_{dj}}\right)^{1-\delta_{dj}}$$

2. $$Q_{mj} = \frac{Q_j Y_j}{\beta_{Aj}} \left(\frac{1-\delta_{dj}}{\delta_{dj}}\right)^{\delta_{dj}} \left(\frac{p_{dj}}{p_m(1+\text{tarif}_j)}\right)^{\delta_{dj}}$$

3. $$X_{zj} = a_{zj} Q_{dj}$$

4. $$VA_j = v_j Q_{dj}$$

5. $$K_j = \frac{VA_j}{\beta_j} \left(\frac{w(1+\text{esc}_j)}{r}\right)^{1-\alpha_j} \left(\frac{\alpha_j}{1-\alpha_j}\right)^{1-\alpha_j}$$

6. $$L_j = \frac{VA_j}{\beta_j} \left(\frac{r}{w(1+\text{esc}_j)}\right)^{\alpha_j} \left(\frac{1-\alpha_j}{\alpha_j}\right)^{\alpha_j}$$

Consumption

7. $$YD = (1-\tau)\left[rK + wL(1-u) + \text{cpi TPS} + \text{TFS} - \text{ess } wL(1-u)\right]$$

8. $$C_h = \gamma_h \frac{YD}{p_h^F}$$

9. $$S = \gamma_s \frac{YD}{p_i}$$

10. $$\text{cpi} = \sum_{h=1}^{9} \gamma cpi_h p_h^F$$

Government

11. $$Rt = \sum_{j=1}^{16} t_j \left[\sum_{z=1}^{16} p_z X_{zj} + w(1+\text{esc}_j)L_j + rK_j\right]$$

12. $$Resc = \sum_{j=1}^{16} \mathrm{esc}_j \, w \, L_j$$

13. $$R\mathrm{tarif} = \sum_{j=1}^{16} \mathrm{tarif}_j \, p_m \, Qm_j$$

14. $$R\mathrm{vat} = \sum_{h=1}^{9} \mathrm{vat}_h \, p_h \, C_h$$

15. $$R\mathrm{ess} = \mathrm{ess} \, w \, L \, (1-u)$$

16. $$R\tau = \tau \left[rK + wL(1-u) + \mathrm{cpi\ TPS} + \mathrm{TFS} - \mathrm{ess} \; wL(1-u) \right]$$

17. $$Rtrsf = trsf_{j3} \, Qm_{j3}$$

18. $$R^G = Rt + R\mathrm{esc} + R\mathrm{tarif} + R\mathrm{vat} + R\mathrm{ess} + R\tau + Rtrsf$$

19. $$C^G_{j16} = \gamma^G \frac{R^G + p_i w_i^G - cpi \ \mathrm{TPS}}{\gamma^G p_{j16} + p_i}$$

20. $$C_i^G = \frac{C^G_{j16}}{\gamma^G}$$

Equilibrium

21. $$\sum_{j=1}^{16} K_j = K$$

22. $$\sum_{j=1}^{16} L_j = L(1-u)$$

23. $$\left(\frac{w}{\mathrm{cpi}}\right) = \left(\frac{1-u}{1-u_0}\right)^{1/\beta_d}$$

24. $$Q_j Y_j = \sum_{z=1}^{16} X_{jz} + \sum_{h=1}^{9} TR_{jh} Y_h + TR_{ji} Y_i + TR_{jF} Y_F + C_j^G$$

25. $$Q_h Y_h = C_h$$

26. $$Q_i Y_i + w_i^G = S + S_F + C_i^G$$

27. $$Q_F Y_F + w_F = \sum_{j=1}^{16} Q_{mj}$$

Foreign saving

28. $$p_i S_F = p_m w_F - \text{TFS}$$

Prices

29. $$p_{dj} Q_{dj} = (1 + t_j)\left[\sum_{z=1}^{16} p_z X_{zj} + w(1 + \text{esc}_j) L_j + r K_j\right]$$

30. $$p_j Q_j = p_{dj} Q_{dj} + p_m (1 + \text{tarif}_j) Q_{mj}$$

31. $$p_{j3} Q_{j3} = (p_m + trsf_{j3})\, Qm_{j3}$$

32. $$p_h^F Q_h = (1 + \text{vat}_h) \sum_{j=1}^{16} p_j T R_{jh}$$

33. $$p_i Q_i = \sum_{j=1}^{16} p_j T R_{ji}$$

34. $$pva_j V A_j = w(1 + \text{esc}_j) L_j + r K_j$$

Household welfare

35. $$\text{Real disposable income} = \frac{YD}{\text{cpi}}$$

36. $$EV = e\,(p_0, u_1) - e(p_0, u_0)$$

37. $$CV = e\,(p_1, u_1) - e(p_1, u_0)$$

Sensitivity analysis for domestic production

38. $$Q_{dj} = \beta_{Cj} X_{1j}^{\delta c_{1j}} X_{2j}^{\delta c_{2j}} \cdots X_{16j}^{\delta c_{16j}} V A_j^{\delta va_j}$$

39. $$X_{zj} = \frac{Q_{dj}}{\beta_{Cj}} \left(\frac{\delta c_{zj}}{p_z}\right) \left(\frac{pva_j}{\delta va_j}\right)^{\delta va_j} \prod_{g=1}^{16} \left[\frac{p_g}{\delta c_{gj}}\right]^{\delta c_{gj}}$$

40. $$V\,A_j = \frac{Q_{dj}}{\beta_{Cj}} \left(\frac{\delta va_j}{pva_j}\right)^{1-\delta va_j} \prod_{g=1}^{16} \left[\frac{\delta c_{gj}}{p_g}\right]^{\delta c_{gj}}$$

Endogenous variables

Production

Qd_j Domestic output (sector j)
Qm_j Imported output (sector j)
X_{zj} Intermediate inputs (sector j)
VA_j Value added (sector j)
K_j Capital demand (sector j)
L_j Labour demand (sector j)

Consumption

YD Disposable income
C_h Private Consumption (commodity h)
S Private saving

Government

Rt Taxes on production
Resc Employers'social contributions
Rtarif Import taxes
Rvat Value added tax
Ress Employees' social contributions
$R\tau$ Income tax
$trsf_{j3}$ Tax on retail sales of some fuels rate
R^G Total tax revenues
w_i^G Stock of debt issued by the government
C_{j16}^G Public consumption
C_i^G Public investment

Foreign sector

S_F Foreign saving

Primary factors

u Unemployment rate

Activity levels

Y_j Activity level (sector j)
Y_h Activity level (commodity h)
Y_i Activity level (saving/investment)
Y_F Activity level (foreign sector)

Prices

pd_j Domestic price (sector j)
p_j Total price (sector j)
p_h^F Consumption price, inclusive of taxes (commodity h)
cpi Consumption price index

p_i Saving/investment price
p_m Average weighted price of imported products
r Rent of capital
w Wage
pva_j Aggregate price for value added (sector j) – Alternative Cobb–Douglas function

Household welfare

VE Equivalent variation
VC Compensating variation

Exogenous variables and parameters

Production

Q_j Total production in the benchmark equilibrium (sector j) – Armington aggregate
β_{Aj} Scale parameter (sector j)
δd_j Share parameter (sector j)
a_{zj} Technical coefficients (sector j)
v_j Value added technical coefficient (sector j)
β_{Cj} Scale parameter (sector j) – Alternative Cobb–Douglas function
δc_{zj} Share parameters (sector j) – alternative Cobb–Douglas function
δva_j Share parameter (sector j) – Alternative Cobb–Douglas function
β_j Scale parameter (sector j)
α_j Share parameter (sector j)

Consumption

Q_h Consumption in the benchmark equilibrium (commodity h)
TR_{jh} Conversion matrix from production sectors to commodities (j to h)
γ_h Share parameter (commodity h)
γ_s Share parameter
γcpi_h Share parameter to compute cpi (commodity h)
K Endowment of capital factor
L Endowment of labour factor
TPS Transfers from public sector
TFS Transfers from foreign sector

Government

t_j Tax rate on domestic output (sector j)
esc_j Employers' social contributions rate (sector j)
tarif_j Import tariff rate (sector j)
vat_h Value added tax rate (commodity h)
ess Employees' social contributions rate
τ Income tax rate
Rtrsf Tax on retail sales of some fuels revenues
γ^G Fixed proportion between public consumption and investment

Foreign sector

Q_F Total exports in the benchmark equilibrium
TR_{jF} Exports in the benchmark equilibrium (sector j)
w_F Trade deficit

Investment

Q_i Total investment in the benchmark equilibrium
Tr_{ji} Investment in the benchmark equilibrium (sector j)

Primary factors

u_0 Unemployment rate in the benchmark equilibrium
β_d Sensitivity of real wage to unemployment rate – Sensitivity analysis for labour market

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