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A multi-country analysis of austerity policies in the European Union

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Abstract

We analyse the global effects from the austerity policies recently implemented in the EU, by developing an extension of the GTAP general equilibrium model. The extended model incorporates a new specification of the trade balance (i.e. endogenous), the labour market (i.e. unemployment under a wage curve framework) and the public sector (i.e. split from the representative national agent, with endogenous expenditure and savings). Three alternative policies aimed to get a one percentage point reduction in the EU's government deficit to GDP ratio are simulated, and their effects on the main macroeconomic variables of seven regions of the world economy are examined. The three policy measures led to contractionary effects on the EU's activity levels, together with changes in income distribution, always detrimental to labour. The effects on the rest of the world, driven by changes in trade flows, were, however, mostly negligible.

KEYWORDS

Austerity policies, European Union, global economy

1 | INTRODUCTION

One of the most relevant after-effects of the global financial crisis that started in 2008 is the appearance of large fiscal imbalances in most advanced countries. As a consequence, a series of fiscal consolidation measures have been pursued in order to reduce the size of government deficits and the

subsequent debt accumulation, so that the confidence of financial markets can be recovered, and the risk of sovereign default avoided.

The economic effects of these fiscal consolidation policies have been the subject of intensive research since the beginning of the crisis. An influential line of research in the first stages of the crisis claimed that, unlike the traditional 'Keynesian' effects of fiscal policy, contractionary fiscal policies would provoke an expansionary effect on output. This result was explained in terms of the increased confidence of the private agents on government's solvency, leading to lower expected taxes in the next future. This is the literature on the so called 'non-Keynesian' effects of fiscal policy, following the pioneering work of Giavazzi and Pagano (1990). The generality of these 'non-Keynesian' effects of fiscal policy, however, has been put recently into question. In particular, some empirical studies using a novel methodology (i.e. identifying changes in fiscal policy motivated by the desire to reduce the budget deficit from historical documents) find that fiscal consolidations have a contractionary effect on economic activity, as expected from standard Keynesian models; see Romer and Romer (2010) and Guajardo et al. (2014). In addition, as shown by Auerbach and Gorodnichenko (2013), fiscal policy multipliers seem to be larger in recessions, which can be explained from several features that characterise depressed economies, such as the absence of supply constraints in the short run, and a binding zero lower bound on interest rates (DeLong & Summers, 2012). As a result, contractionary fiscal policies implemented during the crisis would have led to a permanent decline in output levels, as well as being unable to reduce debt-to-GDP ratios (Fatás & Summers, 2018).

Another relevant issue for the assessment of the effects of fiscal consolidations relates to their composition. Following previous contributions on this topic, Alesina and Ardagna (2010) concluded that, in the case of a fiscal consolidation, spending cuts are more effective than tax increases in order to stabilise the debt and avoiding a recession, whereas, for the case of a fiscal stimulus, the opposite result would hold; that is, tax cuts are more expansionary than spending increases. Empirical support for these results has been provided by Alesina et al. (2015), who simulated the fiscal plans adopted by 16 OECD countries over a 30-year period (1978–2009) and found that spending-based fiscal consolidations were associated with minor and short-lived recessions, unlike tax-based consolidations, which led to deeper and longer recessions. The authors justified these results in terms of the confidence of investors, which recovers much sooner following a spending-based adjustment than a tax-based one. However, using a completely different methodology, Bajo-Rubio and Gómez-Plana (2015) simulated by means of a computable general equilibrium (CGE) model the effects of several alternative policy measures intended to reduce the Spanish government deficits, distinguishing between different types of taxes and expenditures. They found that the strongest negative effects on GDP and employment appeared in the case of an increase in the income tax, followed by spending cuts (especially in public education and, at a smaller extent, public health and public administration); in contrast, for indirect tax increases the negative effects on GDP and employment were milder.

On the other hand, especially in the member countries of the European Union (EU), the preferred way of implementing consolidation plans has been by reducing government spending, rather than increasing revenues. Leaving aside its ideological implications, this fact can be related to the standard result of the literature on fiscal policy and growth, which can be traced back to Barro (1991), of a negative and significant effect of the level of public consumption as a percentage of GDP (which would proxy government size) on the growth rate of a cross section of countries. This is justified on the grounds that a greater government intervention would distort the incentives systems, so that a higher government size would be associated with a lower productivity, and hence a lower growth. However, this effect did not appear robust to changes in the conditioning variables in the influential study of Levine and Renelt (1992). In addition, and even more important, it is not very clear why using government consumption as a proxy for the whole public expenditure. In particular, a

model intended to analyse the effects of fiscal policy on growth should consider instead some other components of public spending more directly linked to growth, such as the government capital stock (directly, as an additional productive factor in the aggregate production function, and through its favourable effects on private capital's productivity), as well as public transfers that encourage accumulation and growth (as an externality in the aggregate production function); see Bajo-Rubio (2000).

In fact, over a long-term viewpoint, consolidation strategies based on cutting public expenditure items such as education, health care, R&D or public investments might harm future growth prospects (European Commission, 2012). For all these reasons, and even more in the current context of credit supply restrictions, fiscal adjustments should be gradual and rely also on increases in government revenues in addition to spending cuts, in order not to dampen future growth (Baldacci et al., 2015). And all this would be particularly relevant since, as emphasised by Reinhart and Rogoff (2009), the decrease in public revenues due to the subsequent recession is the main reason behind the higher government deficits associated with financial crises.

Turning to the case of the EU, it is well known that, faced with the increase in government deficits in most countries following the financial crisis that started in 2008, the EU authorities have endorsed the implementation of fiscal consolidation strategies, known as austerity policies. While only partially successful in reducing government deficits, such austerity policies have resulted in deepening the recession in most EU countries (De Grauwe & Ji, 2013). Our aim in this paper will be to analyse the global effects, i.e. the effects on both the EU and the world economy, from the austerity policies implemented in the EU over the last years. Specifically, we will simulate the effects of three alternative policies aimed to get a one percentage point reduction in the EU's government deficit to GDP ratio, through a decrease in the level of public spending, an increase in consumption taxes and an increase in labour taxes, and examine their effects on the main macroeconomic variables of seven regions of the world economy, that is the EU, the United States, Japan, China, Asia-Pacific, Latin America and Rest of the World. The empirical methodology will make use of a CGE model, through an extension of the Global Trade Analysis Project (GTAP) model. This methodology allows obtaining the consequences of changes in a particular variable on the whole economy under analysis, as well as the specific effects across the different productive sectors. CGE models have been widely used for policy analysis in fields such as fiscal policies, trade policies and environmental policies. While not including a financial sector, international capital movements or the role of expectations, the potential of CGE models lies in their ability to integrate micro and macro elements (Devarajan & Robinson, 2005).

The rest of the paper is organised as follows. A summary description of the model is provided in Section 2. The data and calibration process are discussed in Section 3. The results from the simulations are presented in Section 4. Section 5 concludes.

2 | THE MODEL

The model is an extension of Lanz and Rutherford (2016), based on GTAP9inGAMS (where GAMS stands for General Algebraic Modeling System, i.e. a high-level modelling system for mathematical programming and optimisation), and is a static, multi-region CGE model. The centrepiece of GTAP is the GTAP Data Base, a global database representing the world economy, which contains complete bilateral trade information, transport and protection linkages. We have used the GTAP 9 Data Base (Narayanan et al., 2015), which includes 140 regions and 57 sectors, taking 2004, 2007 and 2011 as reference years.

The extension of the model performed in this paper is as follows:

1. The original version of GTAP9inGAMS has one representative agent for each country or region. The model developed here splits the representative agent into public and private agents, extending the equations, and using National Accounts and other data sources to assign the corresponding micro and macro variables.
2. Public expenditure and public savings are modelled as independent and endogenous variables, unlike the original GTAP9inGAMS, which assumes exogenous public expenditure and national savings, where public and private savings are aggregated.
3. There is unemployment at regional level. It must be noted that due to the high unemployment rate in some regions, instead of using the common assumption of full employment in labour markets, the model includes unemployment in a way derived from the wage curve models.
4. The trade balance is endogenous at regional level, unlike GTAP9inGAMS where it is assumed to be exogenous.

Our version of the model draws on seven open economies (regions), disaggregated in fifteen productive sectors, one private representative consumer and a public sector for each region, and three primary factors (i.e. labour, capital and natural resources); the listing of the world regions and sectors appears in Table 1. In the rest of this section, we will present a short description of the model; a more detailed account can be found in the working paper version of this article (Bajo-Rubio & Gómez-Plana, 2018). The correspondence of the above regions and sectors with the GTAP 9 Data Base and the full set of equations are shown in Appendix 1 and Appendix 2, respectively.

The equilibrium of the model is a set of prices and an allocation of goods and factors involving the simultaneous solution of three sets of equations, that is zero-profit conditions for firms; market clearing in goods, natural resources and capital markets; and constraints on income balance, labour market and macroeconomic closure of the model.

TABLE 1 Regions and sectors

Regions	Sectors
European Union	Agricultural products
United States	Chemical industry
Japan	Motor vehicles
China	Other transport equipment
Latin America	Machinery and equipment
Asia-Pacific	Electronic equipment
Rest of the World	Other industry
	Construction
	Trade
	Transport and communications
	Financial intermediation
	Business services
	Recreational services
	Government services
	Other services

Production is based on a technology characterised by a nested CES-Leontief structure of intermediate inputs and factors. Firms maximise profits under constant returns to scale and follow a competitive pricing rule with free entry and exit of firms. Two sectors (i.e. Agricultural products and Other industries) use a specific factor, so their technologies show decreasing returns to scale. On the other hand, there is a representative private household who maximises a nested Cobb–Douglas utility function subject to a budget constraint that includes the rents from endowments of factors and exogenous savings.

The GTAP Data Base and GTAP9inGAMS include a single representative agent, so it has been necessary to split it into a private representative household and the public sector. The role of the public sector in the model is twofold; that is, it is an owner of resources and a purchaser of certain goods. Its income includes net tax revenues, where net taxes consist of tax rates on primary factors and commodities, domestic tax rates on firms, tariff rates, subsidy rates on output and subsidy rates on exports. In turn, the most relevant part in quantitative terms of the goods purchased by the public sector are those included in the sector Government services (i.e. public administration, defence, education, health).

There is trade balance at global level, although trade imbalances are allowed at national or regional level. These aggregate trade balances are endogenous, and sectoral exports and imports are also allowed to change endogenously. We assume that goods are differentiated according to their origin (i.e. domestic or foreign), following Armington's assumption (Armington, 1969), which allows for the possibility of intra-industry trade. Consumers (both private and public) perceive domestic and imported goods as differentiated.

The representative private household owns fixed endowments of natural resources (i.e. agricultural land and other natural resources), capital and labour, which are internationally immobile. The natural resources' and capital rents adjust to clear domestic markets. Natural resources are sector-specific. Labour employment (i.e. the labour endowment minus unemployment) is elastic up to the fixed endowment of labour, and the unemployment rate is determined through a wage equation (Blanchflower & Oswald, 1990) such as

$$\frac{W}{P} = \left(\frac{u}{u0}\right)^{\beta}$$

where W is the nominal wage, P is the consumer price index, u is the unemployment rate, $u0$ is the unemployment rate in the benchmark, and $\beta < 0$. Notice that, as long as $\beta \to 0$, the wage equation approaches a downward-rigid real wage.

Finally, the model embodies a macroeconomic closure equation stating that investment and savings (private, public and foreign) are equal, and is solved as explained in Rutherford (1999), with the general equilibrium model defined as a mixed complementarity problem. The software used in the empirical application is GAMS/MPSGE.

3 | CALIBRATION AND DATA

The model has been calibrated using the GTAP 9 Data Base (Narayanan et al., 2015) with data for 2011. Most of the data for the public sector have been taken from GTAP (i.e. regional public savings have been estimated as the difference between tax revenue and public expenditure). The calibration method is based on a benchmark equilibrium corresponding to the National Accounts and a set of exogenous parameters; a detailed explanation of the calibration method can be found in Dawkins et al. (2001). The benchmark values for the elasticities appearing in the different equations of the model are those of the GTAP 9 Data Base (Narayanan et al., 2015). The elasticity β (i.e. the elasticity of the real

wage with respect to the unemployment rate) has been fixed as −0.1, a standard value from the wage curve literature (e.g. Blanchflower & Oswald, 1995).

Finally, data for some regional variables, taken from other sources, were also needed (see Bajo-Rubio & Gómez-Plana, 2018, for more details). In particular, regional unemployment rates have been estimated using the labour force and the total unemployment for each country or region, with the data coming from World Bank (2015). In turn, the shares of public gross capital formation on total gross capital formation have been estimated with data from European Commission (2015) and United Nations (2014), together with the exchange rates taken from International Monetary Fund (2015) (at 30 December 2011). The figures for the EU, United States and Japan have been taken from European Commission (2015) and those for the rest of the regions from United Nations (2014). Latin America has been proxied using data from Brazil (2009) and Mexico, the Republic of Korea is the proxy for Asia-Pacific, and Rest of the World has been estimated as the average of the other six regions.

4 | SIMULATION RESULTS

Three different simulations, representative of the fiscal consolidation strategies followed by the EU governments, have been performed. In all three cases, the objective is getting a fall of one percentage point in the EU's government deficit to GDP ratio:

A A decrease in public expenditure, holding all tax rates fixed.
B An increase in ad valorem final consumption tax rates, holding public expenditure fixed.
C An increase in ad valorem labour tax rates, holding public expenditure fixed.

Notice that the two taxes we have chosen are by far the most relevant in terms of receipts for the EU (Narayanan et al., 2015). Labour taxes include social security contributions.

The results of these simulations on the main macroeconomic variables are shown in Table 2 as percentage changes from benchmark, except for the unemployment rate and the trade balance to GDP ratio, where changes are expressed as percentage points; the numeraire used is the US consumer price index. In particular, we present the results of the simulations on the levels of GDP and employment, the unemployment rate, real wage rate (in terms of the consumer price index, i.e. the real wage relevant for workers), compensation of employees, gross operating surplus, the trade balance as a ratio to GDP and the levels of public expenditure and public revenue. When discussing the results, we will make a particular emphasis on the variables compensation of employees and gross operating surplus, which proxy the shares of labour and capital on total income, that is the functional distribution of income. The analysis of distributional issues is usually neglected in empirical assessments of austerity policies; an exception is Ball et al. (2013).

Starting with the results for the EU's economy, we can see that GDP falls in all scenarios. The negative effects on GDP range from −0.24% for the decrease in government expenditure, to −0.36% for the increase in consumption taxes and −1.02% for the increase in labour taxes. Employment also falls, and the rate of unemployment rises, in all scenarios, corresponding again the worst results to the rise in labour taxes, followed by the rise in consumption taxes, being milder when cutting government spending. On the other hand, real wages fall in the first and third scenarios, unlike the second scenario, where they experience a small increase.[1]

[1]Notice that in this case an increase in consumption taxes lowers the real wage net of taxes, which decreases labour supply, so the resulting excess demand for labour should lead to a rise in wages.

TABLE 2 Simulation results: effect on macroeconomic variables (% change from benchmark)

	European Union	United States	Japan	China	Latin America	Asia-Pacific	Rest of the World
A. Decrease in public expenditure							
GDP	−0.239	0.011	−0.007	−0.012	−0.020	−0.009	−0.018
Employment	−0.227	0.007	0.002	0.002	0.000	0.002	0.002
Unemployment rate (p.p.)	0.205	−0.007	−0.002	−0.002	0.000	−0.002	−0.002
Real wage rate	−0.317	0.006	−0.008	−0.013	−0.022	−0.013	−0.023
Compensation of employees	−0.543	0.013	−0.006	−0.011	−0.022	−0.011	−0.022
Gross operating surplus	0.044	0.006	−0.008	−0.011	−0.021	−0.005	−0.018
Trade balance/GDP (p.p.)	−4.492	0.461	0.216	−0.181	−0.364	−0.925	−0.655
Public expenditure	−4.542	0.003	−0.010	−0.015	−0.023	−0.014	−0.027
Public revenue	−0.135	0.012	−0.010	−0.024	−0.021	−0.021	−0.034
B. Increase in ad valorem final consumption tax rates							
GDP	−0.361	0.003	0.023	0.017	−0.009	0.020	−0.015
Employment	−0.626	0.003	0.002	0.003	0.001	0.005	0.001
Unemployment rate (p.p.)	0.566	−0.003	−0.002	−0.003	−0.001	−0.005	−0.001
Real wage rate	0.076	0.002	0.022	0.018	−0.008	0.020	−0.013
Compensation of employees	−0.550	0.005	0.025	0.021	−0.008	0.024	−0.012
Gross operating surplus	−0.172	0.000	0.022	0.020	−0.008	0.023	−0.015
Trade balance/GDP (p.p.)	−4.710	0.486	0.219	−0.197	−0.365	−0.939	−0.656
Public expenditure	0.000	0.001	0.020	0.015	−0.008	0.017	−0.013
Public revenue	0.854	0.002	0.018	0.038	−0.009	0.015	−0.007
C. Increase in ad valorem labour tax rates							
GDP	−1.022	0.003	0.027	0.022	−0.008	0.024	−0.012
Employment	−0.912	0.003	0.003	0.004	0.001	0.005	0.001
Unemployment rate (p.p.)	0.825	−0.003	−0.003	−0.004	−0.001	−0.005	−0.001
Real wage rate	−0.885	0.003	0.026	0.023	−0.007	0.023	−0.011
Compensation of employees	−1.788	0.006	0.029	0.026	−0.007	0.028	−0.010
Gross operating surplus	−0.264	0.000	0.026	0.024	−0.007	0.028	−0.011
Trade balance/GDP (p.p.)	−4.454	0.486	0.219	−0.198	−0.365	−0.939	−0.658
Public expenditure	0.000	0.001	0.024	0.019	−0.008	0.020	−0.011
Public revenue	0.579	0.003	0.022	0.042	−0.008	0.018	−0.007

Some interesting distributive effects appear, too, detrimental to labour in all cases. The compensation of employees clearly falls in all scenarios due to the decrease in both real wages and employment, especially when labour taxes are risen. In turn, the gross operating surplus falls in the two scenarios of tax increases although much less than the compensation of employees and rises slightly in the scenario of cuts in spending. As a result, income distribution clearly worsens for labour in all scenarios, especially in the case of an increase in labour taxes, followed by the case of a cut in government spending.

These results on the distributional effects of fiscal consolidations, on the other hand, are in line with those found in Ball et al. (2013).

Regarding the trade balance, a worsening of around 4.5 points of GDP appears in all scenarios, which can be related to the reallocation of resources from the government sector towards exporting manufacturing sectors that are more intensive in imports than Government services in the EU (see Table 3 below). However, since such resources should be more suitable for public expenditure, they should lose efficiency, and hence the competitiveness of those sectors be reduced.

Notice, finally, that, in order to reduce the ratio government deficit/GDP by one percentage point, total government expenditure should fall by 4.54% when cutting government spending, at the same time that government revenues would be reduced by 0.14% due to the fall in the level of activity. On the other hand, in the scenarios of tax increases government expenditure would not change, and total government revenue should rise by 0.85% and 0.58% in the cases of increasing consumption taxes and labour taxes, respectively.

Regarding the effects on the other world regions, trade flows are the transmission mechanism of the effects of the simulated policies on the rest of the world. As shown in Table 2, in the first scenario of a decrease in government expenditure GDP falls in all regions (with the only exception of the United States), although the effects on employment and unemployment tend to be favourable; in all cases, however, the figures are very small. Notice that Government services is a non-traded sector and that world regions are linked through trade. In any case, the contraction in the EU demand should be behind the negative output effect in the rest of the world, although the non-EU regions also experience some positive effects through the cheaper EU goods. Indeed, the lower demand in the EU decreases the price of EU's goods, generating a small substitution effect with respect to domestic goods in the rest of regions. On the other hand, in the two scenarios of tax increases GDP only falls in Latin America and Rest of the World, and the results on employment and unemployment are always positive, even though the effects are again quantitatively very small. Although the contraction in EU's demand is still present, now the higher indirect taxes (especially those on labour) make EU's goods relatively more expensive, so the substitution effect works in the opposite sense. Finally, the results for both the distributive variables and the public expenditures and revenues, in all three scenarios, are mostly negligible, with very small changes that roughly cancel out.

Next, we present in Table 3 the percentage changes in employment across sectors, following from the above three scenarios; the results for other variables are available from the authors upon request. The last row of every part of the table shows, for the sake of comparison, the overall change in employment, as it appears in the second row of each part of Table 2.

Focusing on the results for the EU, in the first scenario of a decrease in government expenditure employment falls markedly in the Government services sector. However, employment rises in the rest of sectors due to the fall in the wage rate; additionally, since the model assumes full capital employment, the capital expelled out from the Government services sector must be employed in other sectors. The overall effect on employment is negative, though. On the other hand, when raising consumption taxes in the second scenario, the prices of all final goods increase. For that reason, those sectors more involved in the production of intermediate inputs are less affected in terms of lower employment; some examples are the positive changes in employment found in Construction, Machinery and equipment or Electronic equipment. In turn, in the third scenario of an increase in labour taxes, those sectors more burdened with labour taxes attract more capital for substitution purposes. Due to the technological requirements of the model, the sectors losing capital are those that are also losing workers, as is the case of Government services, Other services or Recreational services. Additionally, the large decrease in employment in Government services in this third scenario is due to the fact that that this sector is the most labour intensive of all in the EU, and so is the most affected by an increase

TABLE 3 Simulation results: effects on sectoral employment (% change from benchmark)

	European Union	United States	Japan	China	Latin America	Asia-Pacific	Rest of the World
A. Decrease in public expenditure							
Agricultural products	0.491	−0.009	−0.005	−0.003	0.022	−0.002	0.017
Chemical industry	0.579	−0.105	−0.052	−0.025	−0.025	−0.061	−0.071
Motor vehicles	1.288	−0.008	−0.037	−0.048	0.007	−0.027	0.022
Other transport equipment	1.554	0.070	0.003	−0.020	0.041	0.084	0.039
Machinery and equipment	2.181	0.005	0.007	0.016	−0.006	0.026	0.078
Electronic equipment	2.230	0.071	0.063	0.255	0.070	0.221	0.099
Other industry	0.846	−0.018	−0.011	−0.005	0.006	−0.013	0.017
Construction	4.370	0.096	0.028	−0.033	−0.012	−0.023	−0.035
Trade	0.296	0.016	0.000	−0.006	0.001	0.005	0.004
Transport and communications	0.376	−0.008	0.007	0.001	−0.004	0.012	−0.001
Financial intermediation	0.422	0.003	−0.003	0.010	−0.001	−0.002	−0.002
Business services	1.097	0.010	0.001	−0.003	0.002	0.002	0.007
Recreational services	0.012	0.004	0.002	0.000	−0.006	−0.014	−0.013
Government services	−3.376	−0.003	0.000	0.001	−0.002	−0.013	−0.004
Other services	0.241	0.006	0.004	0.007	0.004	0.012	0.010
Total	−0.227	0.007	0.002	0.002	0.000	0.002	0.002
B. Increase in ad valorem final consumption tax rates							
Agricultural products	−0.176	−0.025	−0.024	−0.023	−0.018	−0.024	−0.011
Chemical industry	−0.289	−0.048	−0.051	−0.025	−0.007	−0.063	−0.032
Motor vehicles	0.375	0.008	−0.025	−0.005	0.030	−0.003	0.057
Other transport equipment	0.789	0.229	0.089	0.053	0.177	0.224	0.209
Machinery and equipment	1.365	0.112	0.078	0.075	0.093	0.126	0.248
Electronic equipment	1.214	0.114	0.063	0.221	0.104	0.198	0.179
Other industry	−0.223	−0.015	−0.024	−0.027	−0.003	−0.041	−0.010
Construction	3.805	0.004	0.025	0.007	0.005	0.039	0.011
Trade	−0.410	0.005	0.000	−0.001	0.001	0.010	0.000
Transport and communications	−0.466	−0.017	−0.006	−0.005	−0.011	−0.030	−0.018
Financial intermediation	−0.439	−0.009	−0.005	0.004	−0.003	−0.014	−0.011
Business services	0.382	0.004	−0.001	0.004	0.004	−0.004	0.015
Recreational services	−0.916	−0.007	0.001	−0.004	−0.013	−0.026	−0.028
Government services	−2.773	−0.004	0.000	0.000	−0.003	−0.004	−0.011
Other services	−1.137	−0.008	0.002	−0.001	−0.009	−0.005	−0.026
Total	−0.626	0.003	0.002	0.003	0.001	0.005	0.001

(Continues)

TABLE 3 (Continued)

	European Union	United States	Japan	China	Latin America	Asia-Pacific	Rest of the World
C. Increase in ad valorem labour tax rates							
Agricultural products	−0.240	−0.031	−0.027	−0.025	−0.031	−0.027	−0.017
Chemical industry	−0.344	−0.054	−0.059	−0.030	−0.011	−0.072	−0.048
Motor vehicles	0.398	0.014	−0.020	−0.005	0.038	0.004	0.068
Other transport equipment	0.799	0.261	0.102	0.059	0.199	0.254	0.230
Machinery and equipment	1.488	0.134	0.094	0.086	0.107	0.150	0.278
Electronic equipment	1.354	0.135	0.075	0.252	0.117	0.231	0.196
Other industry	−0.114	−0.009	−0.023	−0.024	0.007	−0.036	0.001
Construction	4.132	0.004	0.028	0.008	0.006	0.043	0.013
Trade	−0.945	0.004	−0.004	−0.015	0.000	0.004	−0.003
Transport and communications	−0.704	−0.024	−0.007	−0.007	−0.016	−0.038	−0.027
Financial intermediation	−0.636	−0.012	−0.006	0.004	−0.003	−0.018	−0.013
Business services	0.244	0.001	−0.002	0.001	0.002	−0.015	0.008
Recreational services	−1.092	−0.008	0.001	−0.005	−0.015	−0.033	−0.034
Government services	−3.541	−0.006	0.000	0.002	−0.003	−0.005	−0.010
Other services	−1.264	−0.007	0.002	0.001	−0.007	−0.001	−0.020
Total	−0.912	0.003	0.003	0.004	0.001	0.005	0.001

in labour taxes. Lastly, the effects on sectoral employment in the other world regions are asymmetric across sectors and mostly negligible.

Finally, we have performed a sensitivity analysis of the previous results, by changing the different elasticities appearing in the model (i.e. the elasticities of substitution among productive factors, between domestic and imported components and among imported components; and the elasticity of the real wage with respect to the unemployment rate), which were alternatively halved and doubled. The main results can be seen in Table 6 of Bajo-Rubio and Gómez-Plana (2018) and are robust in sign, except in two cases for the gross operating surplus in the EU, in the scenario of reducing government spending (recall that the change in this variable was close to zero in the benchmark equilibrium). In particular, changes in the elasticity of the real wage with respect to the unemployment rate lead to small changes in some variables for the EU. For instance, in the first two scenarios the decrease in labour demand under more rigid real wages reduces the fall in the compensation of employees relative to the gross operating surplus, since the sector Government services is labour intensive. Note that this effect is not present in the third scenario, where the increase in labour taxes tends to compensate it.

The elasticities of substitution related to trade are those more influencing the results, but the changes are not particularly significant; see Bajo-Rubio and Gómez-Plana (2018) for details.

5 | CONCLUSIONS

Following the world financial crisis, the EU authorities have endorsed the implementation of fiscal consolidation strategies, known as austerity policies, addressed to cope with the high government deficits that appeared in most EU countries. In this paper, we have simulated the effects of three alternative austerity policies, through a decrease in the level of public spending, an increase in consumption

taxes, and an increase in labour taxes; and examined their effects on the main macroeconomic variables of the EU as well as six other regions of the world economy, that is the United States, Japan, China, Asia-Pacific, Latin America and Rest of the World. The objective of the three simulations was getting a one percentage point reduction in the EU's government deficit to GDP ratio. The empirical methodology made use of a CGE model, through an extension of the GTAP model.

We found that the GDP of the EU fell in all the simulated scenarios, with the negative effects ranging from −0.24% for the decrease in government expenditure, to −0.36% for the increase in consumption taxes and −1.02% for the increase in labour taxes. In addition, employment also fell and the rate of unemployment rose, being again the least harmful results those from a decrease in government expenditure, followed by an increase in consumption taxes and an increase in labour taxes; these effects came in all cases accompanied by a change in income distribution that was detrimental to labour. In other words, contrary to the predictions of the 'non-Keynesian' effects of fiscal policy, all these three policy measures led to contractionary effects on the EU's levels of activity. Furthermore, the economic contraction was accompanied with a worsening of income distribution for labour, an aspect usually neglected in empirical assessments of austerity policies. Finally, regarding the effects on the other world regions, the contraction in EU's demand was transmitted to most regions with the same sign in the first scenario of a decrease in government expenditure, which was not the case in the other two scenarios of an increase in either consumption or labour taxes; in all cases, however, the effects were quantitatively very small.

Regarding the policy implications of our results, notice first that, in the particular case of reducing public spending, we are analysing a specific type of fiscal policy measures, that is reducing government consumption, but not other components of government spending such as government investment or spending on pension systems. On the other hand, the implementation of austerity policies in the EU has been widely challenged since its inception; see, for example, Blyth (2013) for a thorough discussion of their theoretical underpinnings and their flawed results in practice. Austerity policies were designed as an answer to the very high budget deficits that developed in most EU countries in the aftermath of the financial crisis starting in 2008. However, while the rise in budget deficits, and the subsequent increase in the government debt-to-GDP ratios, was a fact, they were not as much the result of an excessive public spending (other than the amounts devoted to the bailout of the financial system), but rather of the fall in public revenues as a consequence of the recession, which is indeed a stylised fact associated with financial crises (Reinhart & Rogoff, 2009). On the other hand, recall that, according to our results, the least harmful effects in terms of GDP and employment were those from a decrease in government expenditure, rather than those from tax increases. However, it should be also noticed that we are not analysing here any welfare issues, since it may be the case that a lower government consumption (in services such as health or education, not included in their utility functions) could reduce the welfare levels of private households. In short, the results of this paper allow us to quantify the contractionary effects of such policies, in terms of a significant fall in the levels of GDP and employment and a rise in the rate of unemployment.

Notice also that, given that austerity policies were implemented in a recessive context, with interest rates at or near the zero lower bound, fiscal multipliers tend to be higher and the impact of austerity policies is likely to be significantly larger than in 'normal' times, so that, in practice, austerity policies could be self-defeating (Holland & Portes, 2012). In such circumstances, an expansionary fiscal policy would be in order, given the present threat of recession (De Grauwe & Ji, 2019).

The decline of the labour share of income is a recurrent feature of the evolution of both advanced and emergent economies since the early 1980s (Karabarbounis & Neiman, 2014). From a longer term point of view, this fact reflects the decrease in the bargaining power of labour, which is related to the lower mobility of labour compared with capital (Rodrik, 2018). On the one hand, firms can threaten workers with leaving the country or outsourcing certain tasks if they do not accept lower wages. On the other hand, it is increasingly difficult for governments taxing such more and more mobile capital,

so they end up reducing corporate tax rates and taxing what is less mobile, mainly labour and consumption. Our results show how, in the short run, the lower levels of wages and employment associated with austerity policies also led to a fall in the labour share. In addition of being an indicator of the worsening in income distribution, this fact could be an additional source of a lower aggregate demand leading to further contractive effects on GDP.

Notice that our analysis in this paper refers to austerity policies performed in the EU as a whole. An interesting extension would be disaggregating the EU into groups of countries, such as the euro area versus non-euro countries, or those countries the most affected by the crisis versus the more stable ones or even across individual countries.[2] Such an analysis might give some relevant insights into the different evolution of EU countries after the crisis.

Turning to the effects of EU's austerity policies on the rest of the world, the results obtained were quantitatively very small, a result that should not be too surprising. In a recent paper, Latorre et al. (2020) analyse, in terms of the GTAP model, the impact of the withdrawal of the United Kingdom (UK) from the EU (i.e. the so called Brexit). The authors conclude that, while the effects for the EU and, especially, the UK, were significant, the rest of the world remained nearly unaffected. This also can be related to the extent of the home bias in international trade, that is the term used to define the preference that domestic consumers have for domestic, rather than foreign, goods. As stressed by Obstfeld and Rogoff (2000, pp. 341–342), there is 'growing evidence that international goods markets appear to be far more segmented than is commonly supposed'. They explain this fact (the first of their 'six major puzzles in international macroeconomics') in terms of the existence of trade costs, in a broad sense, which include not only transport costs, but also tariffs, non-tariff barriers or exchange rate risk.

Some caveats to the conclusions of the paper are in order. First, recall that the results from a CGE model apply just to the short run. In any case, it is important to stress how austerity policies are associated with a fall in the level of activity in the short run for the economy where they are implemented (the EU, in our case), which might jeopardise future increases in government revenues, further complicating the intended reduction in government deficits. Also, it is important to notice that, although the scenario of a cut in government spending led to the smallest contractionary effect in our simulations, government expenditure in GTAP is just government consumption, since government investment is added up to private investment. However, austerity policies in the EU have frequently consisted of cuts in government investment. Even more, government consumption includes items such as education or health care, which, together with government investment, are potentially growth-enhancing (European Commission, 2012). Finally, the distributive effects found in this paper might also have relevant implications for future macroeconomic prospects, in terms of harming social cohesion and the subsequent recovery of the levels of activity (Paulus et al., 2017).

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DATA AVAILABILITY STATEMENT

Most of the data that support the findings of this study (Narayanan et al., 2015) are not publicly available due to license restrictions, that is GTAP data license. The rest of the data are available from the corresponding author upon reasonable request.

[2]We acknowledge an anonymous referee for suggesting us this possible extension.

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APPENDIX 1

A.1 | Regional aggregation

The correspondence with the GTAP9 Data Base (Narayanan et al., 2015) is as follows:

European Union (EU)

AUT	Austria
BEL	Belgium
DNK	Denmark
FIN	Finland
FRA	France
DEU	Germany
ITA	Italy

GBR	United Kingdom
GRC	Greece
IRL	Ireland
LUX	Luxembourg
NLD	Netherlands
PRT	Portugal
ESP	Spain
SWE	Sweden
CZE	Czech Republic
HUN	Hungary
MLT	Malta
POL	Poland
ROU	Romania
SVK	Slovakia
SVN	Slovenia
EST	Estonia
LVA	Latvia
LTU	Lithuania
BGR	Bulgaria
CYP	Cyprus
HRV	Croatia

United States (USA)

Japan (JPN)

China (CHI)

CHN	China
HKG	Hong Kong

Latin America (LAT)

MEX	Mexico
BRA	Brazil
ARG	Argentina
BOL	Bolivia
CHL	Chile
COL	Colombia
ECU	Ecuador
PRY	Paraguay
PER	Peru
URY	Uruguay
VEN	Venezuela
XSM	Rest of South America

CRI	Costa Rica
GTM	Guatemala
NIC	Nicaragua
PAN	Panama
HND	Honduras
SLV	El Salvador
XCA	Rest of Central America
DOM	Dominican Republic
JAM	Jamaica
PRI	Puerto Rico
TTO	Trinidad and Tobago
XCB	Caribbean

Asia-Pacific (PAC)

KHM	Cambodia
LAO	Lao People's Democratic Republic
MYS	Malaysia
TWN	Taiwan
PHL	Philippines
SGP	Singapore
THA	Thailand
VNM	Vietnam
XSE	Rest of South-East Asia
KOR	Korea
IDN	Indonesia
BRN	Brunei Darussalam

Rest of the World (ROW)

IND	India
BGD	Bangladesh
XSA	Rest of South Asia
XEA	Rest of East Asia
PAK	Pakistan
LKA	Sri Lanka
NPL	Nepal
MNG	Mongolia
KGZ	Kyrgyzstan
XWF	Rest of Western Africa
XCF	Rest of Central Africa
XAC	Rest of South Central Africa
ETH	Ethiopia
KEN	Kenya

MDG	Madagascar
MWI	Malawi
MOZ	Mozambique
TZA	Tanzania
RWA	Rwanda
UGA	Uganda
ZMB	Zambia
ZWE	Zimbabwe
XEC	Rest of Eastern Africa
EGY	Egypt
MAR	Morocco
TUN	Tunisia
XNF	Rest of North Africa
BEN	Benin
BFA	Burkina Faso
CMR	Cameroon
CIV	Cote d'Ivoire
GHA	Ghana
GIN	Guinea
NGA	Nigeria
SEN	Senegal
TGO	Togo
MUS	Mauritius
BWA	Botswana
ZAF	South Africa
NAM	Namibia
XSC	Rest of South African Customs Union
AUS	Australia
NZL	New Zealand
XOC	Rest of Oceania
CAN	Canada
XNA	Rest of North America
ALB	Albania
RUS	Russia
BLR	Belarus
UKR	Ukraine
XEE	Rest of Eastern Europe
KAZ	Kazakhstan
XSU	Rest of Former Soviet Union
ARM	Armenia
AZE	Azerbaijan
GEO	Georgia

CHE	Switzerland
NOR	Norway
XEF	Rest of EFTA
XER	Rest of Europe
IRN	Iran, Islamic Republic of
BHR	Bahrain
ISR	Israel
JOR	Jordan
KWT	Kuwait
OMN	Oman
QAT	Qatar
SAU	Saudi Arabia
ARE	United Arab Emirates
TUR	Turkey
XWS	Rest of Western Asia
XTW	Rest of the World

A.2 | Sectoral aggregation

The correspondence of sectors included in Table 1 with the GTAP9 Data Base sector listing (Narayanan et al., 2015) is as follows:

Sector	Code	Description
AGR	PDR	Paddy rice
AGR	WHT	Wheat
AGR	GRO	Cereal grains nec
AGR	V_F	Vegetables, fruit, nuts
AGR	OSD	Oil seeds
AGR	C_B	Sugar cane, sugar beet
AGR	PFB	Plant-based fibres
AGR	OCR	Crops nec
AGR	CTL	Bovine cattle, sheep and goats, horses
AGR	OAP	Animal products nec
AGR	RMK	Raw milk
AGR	WOL	Wool, silk-worm cocoons
AGR	FRS	Forestry
AGR	FSH	Fishing
IND	COA	Coal
IND	OIL	Oil
IND	GAS	Gas
IND	OMN	Minerals nec
IND	CMT	Bovine meat products

Sector	Code	Description
IND	OMT	Meat products nec
IND	VOL	Vegetable oils and fats
IND	MIL	Dairy products
IND	PCR	Processed rice
IND	SGR	Sugar
IND	OFD	Food products nec
IND	B_T	Beverages and tobacco products
IND	TEX	Textiles
IND	WAP	Wearing apparel
IND	LEA	Leather products
IND	LUM	Wood products
IND	PPP	Paper products, publishing
IND	P_C	Petroleum, coal products
CRP	CRP	Chemical, rubber, plastic products
IND	NMM	Mineral products nec
IND	I_S	Ferrous metals
IND	NFM	Metals nec
IND	FMP	Metal products
MVH	MVH	Motor vehicles and parts
OTN	OTN	Transport equipment nec
ELE	ELE	Electronic equipment
OME	OME	Machinery and equipment nec
IND	OMF	Manufactures nec
SER	ELY	Electricity
SER	GDT	Gas manufacture, distribution
SER	WTR	Water
CNS	CNS	Construction
TRD	TRD	Trade
TCM	OTP	Transport nec
TCM	WTP	Water transport
TCM	ATP	Air transport
TCM	CMN	Communication
OFI	OFI	Financial services nec
SER	ISR	Insurance
OBS	OBS	Business services nec
ROS	ROS	Recreational and other services
OSG	OSG	Public Administration, Defence, Education, Health
SER	DWE	Dwellings

APPENDIX 2

As a general rule, the notation in the model is as follows: endogenous variables are denoted by capital letters, exogenous variables by capital letters with a bar and parameters by small Latin and Greek letters. There are 15 ($i,j = 1,\ldots,15$) production sectors, and each sector produces one good. The world economy is divided into seven countries and regions ($r,s = 1,\ldots,7$). In each country, the public and private sectors have been detached. There are three productive factors (pf = labour, capital and specific; F = labour, capital; S = specific). All endogenous variables, and the exogenous variables and parameters, are listed in Tables A1 and A2. The description of the model is as follows.

Production

Technology presents constant returns to scale, and firms apply a competitive pricing rule. The nested production function of good i in country r is as follows:

$$Y_{ir} = min\left(II_r^i, VA_r^i\right) \tag{1}$$

where:

$$VA_r^i = \left(\sum_f \theta_{ir}^f \left(Q_{ir}^{pf}\right)^{1-\sigma_i^{VA}}\right)^{\frac{1}{1-\sigma_i^{VA}}} \tag{2}$$

$$II_r^i = min\left(II_{i1r},\ldots,II_{i15r}\right) \tag{3}$$

$$II_{ijr} = \left(\theta_{ijr}^d \left(II_{ijr}^Y\right)^{1-\sigma_i^d} + \left(1-\theta_{ijr}^d\right)\left(II_{ijr}^m\right)^{1-\sigma_i^d}\right)^{\frac{1}{1-\sigma_i^d}} \tag{4}$$

Since the top nest is a Leontief function, the zero-profit condition for sector i in country r is as follows:

$$PROFIT_{ir}^Y = P_{ir}^Y(1-t_{ir}^O) - \theta_f P_{ir}^f - \sum_{j=1}^{15} \theta_j P_{jr}^i = 0 \tag{5}$$

where, according to the nested structure, the unit cost of the value added composite produced by sector i in country r is a CES function:

$$P_{ir}^f = \left(\sum_f \theta_{ir}^f \left(P_{ir}^{pf}\right)^{1-\sigma_i^{VA}}\right)^{\frac{1}{1-\sigma_i^{VA}}} \tag{6}$$

$$P_{ir}^{pf} = \begin{cases} P_r^F(1+t_{ir}^F) \\ P_r^S(1+t_{ir}^S) \end{cases} \tag{7}$$

where F and S denote labour and capital, and the specific factor, respectively.

The intermediate input price in $PROFIT_{ir}^Y$ is an aggregate of national and imported intermediate input prices:

$$P_{jr}^i = \left(\theta_{ijr}^d \left(1+t_{ijr}^{fd}\right)^{1-\sigma_i^d}\left(P_{jr}^Y\right)^{1-\sigma_i^d} + \left(1-\theta_{ijr}^d\right)\left(1+t_{ijr}^{fm}\right)^{1-\sigma_i^d}\left(P_{jr}^m\right)^{1-\sigma_i^d}\right)^{1/(1-\sigma_i^d)} \tag{8}$$

These zero-profit conditions are used to derive the demand functions, by applying Shephard's lemma on cost functions.

Next, we introduce the corresponding market clearing equations, with demands in the left-hand side and supplies in the right-hand side. The factor demands Q_{ir}^{pf} for capital, labour and the specific factor are represented in the left-hand side and they are, respectively:

$$\sum_{i=1}^{15}\left(Y_{ir}\left(\frac{\partial PROFIT_{ir}^{Y}}{\partial P_{r}^{labour}}\right)\right)=\overline{EVOM_{r}^{labour}}\left(1-U_{r}\right) \tag{9}$$

$$\sum_{i=AGRI,IND}\left(Y_{ir}\left(\frac{\partial PROFIT_{ir}^{Y}}{\partial P_{r}^{S}}\right)\right)=\overline{EVOM_{r}^{S}} \tag{10}$$

The market equilibrium conditions for domestic and imported intermediate inputs are as follows:

$$Y_{ir}\left(\frac{\partial PROFIT_{ir}^{Y}}{\partial P_{jr}^{Y}}\right)=II_{ijr}^{Y} \tag{11}$$

$$Y_{ir}\left(\frac{\partial PROFIT_{ir}^{Y}}{\partial P_{jr}^{m}}\right)=II_{ijr}^{m} \tag{12}$$

Finally, the goods market equilibrium conditions are as follows:

$$C_{ir}^{C}+G_{ir}^{G}+I_{ir}^{I}+\sum_{j=1}^{15}II_{ijr}^{Y}+\sum_{s=1}^{7}EXP_{irs}-IMP_{ir}=Y_{ir} \tag{13}$$

where:

$$C_{ir}^{C}=C_{ir}^{Cd}+C_{ir}^{Cm} \tag{14}$$

$$G_{ir}^{G}=G_{ir}^{Gd}+G_{ir}^{Gm} \tag{15}$$

$$I_{ir}^{I}=I_{ir}^{Id}+I_{ir}^{\mathrm{Im}} \tag{16}$$

$$IMP_{ir}=C_{ir}^{Cm}+G_{ir}^{Gm}+I_{ir}^{\mathrm{Im}}+\sum_{j=1}^{15}II_{ijr}^{m} \tag{17}$$

Consumption

The final demand functions are derived from the maximisation of the representative consumer's nested welfare function (or the equivalent dual problem, the minimisation of the expenditure function $PC_{r}C_{r}^{priv}$). The welfare functions are as follows:

$$C_{r}^{priv}=\prod_{i=1}^{15}\left(C_{ir}^{C}\right)^{\theta_{ir}^{C}} \tag{18}$$

where:

$$C_{ir}^{C} = \left(\theta_{ir}^{C}\left(C_{ir}^{Cd}\right)^{1-\sigma_i^d} + \left(1-\theta_{ir}^{C}\right)\left(C_{ir}^{Cm}\right)^{1-\sigma_i^d}\right)^{\frac{1}{1-\sigma_i^d}} \tag{19}$$

subject to the budget constraints:

$$INCOME_r^{priv} = P_r^{labour}\left(\overline{EVOM_r^{labour}}\right)\left(1-U_r\right) + P_r^{capital}\left(\overline{EVOM_r^{capital}}\right) + P_r^{s}\left(\overline{EVOM_r^{S}}\right) \tag{20}$$

$$INCOME_r^{priv} = PRIVSAV_r + PC_r C_r^{priv} \tag{21}$$

where:

$$PRIVSAV_r = PI_r\overline{C_r^{privsav}} \tag{22}$$

$$PC_r C_r^{priv} = \sum_{i=1}^{15} P_{ir}^{C} C_{ir}^{C} \tag{23}$$

$$P_{ir}^{C} = \left(\theta_{ir}^{C}\left(1+t_{ir}^{Cd}\right)^{1-\sigma_i^d}\left(P_{ir}^{Y}\right)^{1-\sigma_i^d} + \left(1-\theta_{ir}^{C}\right)\left(1+t_{ir}^{Cm}\right)^{1-\sigma_i^d}\left(P_{ir}^{m}\right)^{1-\sigma_i^d}\right)^{\frac{1}{1-\sigma_i^d}} \tag{24}$$

The solution to the dual optimisation problem with the expenditure functions yields the demand functions for final private demand of domestic and imported goods, so the market equilibrium for these goods is as follows:

$$C_r^{priv}\left(\frac{\partial PC_r C_r^{priv}}{\partial P_{ir}^{Y}}\right) = C_{ir}^{Cd} \tag{25}$$

$$C_r^{priv}\left(\frac{\partial PC_r C_r^{priv}}{\partial P_{ir}^{m}}\right) = C_{ir}^{Cm} \tag{26}$$

Public sector

Public consumption is represented through a Leontief nested function:

$$G_r^{pub} = min\left(G_{1r}^{G}, \ldots, G_{15r}^{G}\right) \tag{27}$$

where:

$$G_{ir}^{G} = \left(\theta_{ir}^{Gd}\left(G_{ir}^{Gd}\right)^{1-\sigma_i^d} + \left(1-\theta_{ir}^{Gd}\right)\left(G_{ir}^{Gm}\right)^{1-\sigma_i^d}\right)^{\frac{1}{1-\sigma_i^d}} \tag{28}$$

subject to the budget constraints:

$$INCOME_r^{pub} - PG_r G_r^{pub} = PUBSAV_r \tag{29}$$

$$\begin{aligned} INCOME_r^{pub} = {} & REV_r^{O} + REV_r^{fd} + REV_r^{fm} + REV_r^{f} + REV_r^{Cd} + REV_r^{Cm} + REV_r^{Gd} + REV_r^{Gm} \\ & + REV_r^{Id} + REV_r^{\mathrm{Im}} + REV_r^{ms} - REV_r^{xs} \end{aligned} \tag{30}$$

where the different revenues, denoted by *REV*, come from several taxes:

$$REV_r^O = \sum_{i=1}^{15} t_{ir}^O P_{ir}^Y Y_{ir} \tag{31}$$

$$REV_r^{fd} = \sum_{i=1}^{15} \sum_{j=1}^{15} t_{ijr}^{fd} P_{ir}^Y II_{ijr}^Y \tag{32}$$

$$REV_r^{fm} = \sum_{i=1}^{15} \sum_{j=1}^{15} t_{ijr}^{fm} P_{ijr}^m II_{ijr}^m \tag{33}$$

$$REV_r^f = \sum_{i=1}^{15} \left(t_{ir}^S P_r^S \left(\overline{EVOM_r^S} \right) + t_{ir}^{capital} P_r^{capital} \left(\overline{EVOM_r^{capital}} \right) + t_{ir}^{labour} P_r^{labour} \left(\overline{EVOM_r^{labour}} \right) (1 - U_r) \right) \tag{34}$$

$$REV_r^{Cd} = \sum_{i=1}^{15} t_{ir}^{Cd} P_{ir}^Y C_{ir}^{Cd} \tag{35}$$

$$REV_r^{Cm} = \sum_{i=1}^{15} t_{ir}^{Cm} P_{ir}^m C_{ir}^{Cm} \tag{36}$$

$$REV_r^{Gd} = \sum_{i=1}^{15} t_{ir}^{Gd} P_{ir}^Y G_{ir}^{Gd} \tag{37}$$

$$REV_r^{Gm} = \sum_{i=1}^{15} t_{ir}^{Gm} P_{ir}^m G_{ir}^{Gm} \tag{38}$$

$$REV_r^{Id} = \sum_{i=1}^{15} t_{ir}^{Id} P_{ir}^Y I_{ir}^{Id} \tag{39}$$

$$REV_r^{\mathrm{Im}} = \sum_{i=1}^{15} t_{ir}^{\mathrm{Im}} P_{ir}^m I_{ir}^{\mathrm{Im}} \tag{40}$$

$$REV_r^{ms} = \sum_{i=1}^{15} \sum_{\substack{s=1 \\ s \neq r}}^{7} t_{isr}^{ms} \left(P_{is}^Y \left(1 - t_{isr}^{xs}\right) EXP_{isr} + \sum_{j=1}^{15} P_{jisr}^t TRN_{jisr} \right) \tag{41}$$

$$REV_r^{xs} = \sum_{i=1}^{15} \sum_{\substack{s=1 \\ s \neq r}}^{7} t_{irs}^{xs} P_{ir}^{Y} EXP_{irs} \tag{42}$$

and:

$$PG_r G_r^{pub} = \sum_{i=1}^{15} P_{ir}^{G} G_{ir}^{G} \tag{43}$$

$$P_{ir}^{G} = \left(\theta_{ir}^{Gd} \left(1 + t_{ir}^{Gd}\right)^{1-\sigma_i^d} \left(P_{ir}^{Y}\right)^{1-\sigma_i^d} + \left(1 - \theta_{ir}^{Gd}\right) \left(1 + t_{ir}^{Gm}\right)^{1-\sigma_i^d} \left(P_{ir}^{m}\right)^{1-\sigma_i^d} \right)^{\frac{1}{1-\sigma_i^d}} \tag{44}$$

$$PUBSAV_r = PI_r C_r^{pubsav} \tag{45}$$

The solution to the dual optimisation problem with the expenditure functions yields the demand functions for final public demand of domestic and imported goods used in the next equation conditions:

$$G_r^{pub} \left(\frac{\partial PG_r G_r^{pub}}{\partial P_{ir}^{Y}} \right) = G_{ir}^{Gd} \tag{46}$$

$$G_r^{pub} \left(\frac{\partial PG_r G_r^{pub}}{\partial P_{ir}^{m}} \right) = G_{ir}^{Gm} \tag{47}$$

Investment and savings

The aggregate gross capital formation enters the model as an exogenous component of final demand. It can be interpreted in this static framework as a component of final demand representing future consumption:

$$\overline{I_r} = min\left(I_{1r}^{I}, \ \ldots, I_{15r}^{I}\right) \tag{48}$$

where:

$$I_{ir}^{I} = \left(\theta_{ir}^{Id} \left(I_{ir}^{Id}\right)^{1-\sigma_i^d} + \left(1 - \theta_{ir}^{Id}\right) \left(I_{ir}^{\mathrm{Im}}\right)^{1-\sigma_i^d} \right)^{\frac{1}{1-\sigma_i^d}} \tag{49}$$

subject to:

$$PRIVSAV_r + PUBSAV_r + PC_{num} VB_r = PI_r \overline{I_r} \tag{50}$$

$$PI_r \overline{I_r} = \sum_{i=1}^{15} PI_{ir} I_{ir}^{I} \tag{51}$$

$$PI_{ir}^{I} = \left(\theta_{ir}^{Id} \left(1 + t_{ir}^{Id}\right)^{1-\sigma_i^d} \left(P_{ir}^{Y}\right)^{1-\sigma_i^d} + \left(1 - \theta_{ir}^{Id}\right) \left(1 + t_{ir}^{\mathrm{Im}}\right)^{1-\sigma_i^d} \left(P_{ir}^{m}\right)^{1-\sigma_i^d} \right)^{\frac{1}{1-\sigma_i^d}} \tag{52}$$

$$\sum_{r=1}^{7} PC_{num} VB_r = 0 \tag{53}$$

The solution to the dual optimisation problem yields the demand for gross domestic formation of domestic (I_{ir}^{Id}) and imported goods (I_{ir}^{Im}):

$$\overline{I}_r \left(\frac{\partial PI_r \overline{I}_r}{\partial P_{ir}^{Y}} \right) = I_{ir}^{Id} \tag{54}$$

$$\overline{I}_r \left(\frac{\partial PI_r \overline{I}_r}{\partial P_{ir}^{m}} \right) = I_{ir}^{\mathrm{Im}} \tag{55}$$

Foreign sector

The choice among imports from several sources involves the maximisation of the Armington aggregate subject to the foreign sector constraints (or the dual problem, i.e. minimisation of the cost of the Armington aggregate). The Armington aggregate is as follows:

$$IMP_{ir} = \left(\sum_{s} \theta_{isr}^{m} \left(EXPA_{isr} \right)^{1-\sigma_i^m} \right)^{\frac{1}{1-\sigma_i^m}} \tag{56}$$

where:

$$EXPA_{isr} = min \left(EXP_{isr}, TRM_{jisr} \right) \quad j = TRN \tag{57}$$

$$\sum_{i=1}^{15} \sum_{\substack{r=1 \\ r \neq s}}^{7} \sum_{\substack{s=1 \\ s \neq r}}^{7} TRM_{jisr} = \sum_{r=1}^{7} \theta_j^T Y_{jr} \tag{58}$$

The constraints related to the foreign sector in this open economy are as follows:

$$\sum_{i=1}^{15} \sum_{\substack{s=1 \\ s \neq r}}^{7} Pt_{isr}^{m} EXPA_{isr} + PC_{num} VB_{rr} = \sum_{i=1}^{15} P_{ir}^{m} IMP_{ir} \tag{59}$$

where:

$$Pt_{isr}^{m} = \theta_{isr}^{m} P_{isr} + \sum_{j} \theta_j^T P_{jisr}^{t} \tag{60}$$

$$P_{isr} = P_{is}^{Y} \left(1 - t_{isr}^{xs} \right) \left(1 + t_{isr}^{ms} \right) \tag{61}$$

$$P_{jisr}^{t} = P_j^T \left(1 + t_{isr}^{ms} \right) \tag{62}$$

$$P_j^T = \prod_{r=1}^{7} \left(P_{jr}^{Y} \right)^{\theta_r^T} \tag{63}$$

$$P_{ir}^{m} = \left(\sum_{s} \theta_{isr}^{m} \left(P_{isr} \right)^{1-\sigma_{i}^{m}} \right)^{\frac{1}{1-\sigma_{i}^{m}}} \tag{64}$$

Labour market constraint

The equilibrium in the labour market is given by the previously shown market clearing condition:

$$\sum_{i=1}^{15} \left(Y_{ir} \left(\frac{\partial PROFIT_{ir}^{Y}}{\partial P_{r}^{labour}} \right) \right) = \overline{EVOM_{r}^{labour}} \left(1 - U_{r} \right) \tag{65}$$

and the restriction related to unemployment:

$$\frac{P_{r}^{labour}}{PC_{r}} = \left(\frac{U_{r}}{\overline{U_{r}}} \right)^{\beta} \tag{66}$$

where $\beta < 0$.

Simulations

We have performed three simulations in order to get a decrease in one percentage point in the ratio of government deficit to GDP. These simulations involve some changes in the previous equations related to the EU, but not for the rest of countries. In order to be more explicit, in this section we include excerpts of the MPSGE code used to perform the simulations. We have kept the programming style of GTAPinGAMS in order to facilitate a better understanding of the instructions.

A Scenario of reduction in the size of the real public expenditure in the EU, holding all tax rates constant

The benchmark aggregates public expenditure, $\overline{G_{r}^{pub}}$, falls to $\overline{G_{r}^{simul}}$, and the new public sector budget constraint is (recall that 'country r' refers to the EU in the next equations and the number on the right-hand side of the equations is related to the equations above):

$$INCOME_{r}^{pub} - PG_{r}\overline{G_{r}^{simul}} = PUBSAV_{r} - tau_{r} \tag{29a}$$

where:

$$\overline{G_{r}^{simul}} = \overline{ADJUST_{r}}\,\overline{G_{r}^{pub}} \tag{67}$$

The parameter $\overline{ADJUST_{r}}$ takes a positive value, and lower than 1, in the simulation, so that the benchmark real public expenditure G_{r}^{pub} falls. $\overline{G_{r}^{simul}}$ is the value that matches a fall of 1 percentage point in the ratio of public deficit to GDP for the EU. The value of $\overline{ADJUST_{r}}$ is iteratively estimated (i.e. we try several values until the fall of 1 p.p. is reached). These variations lead to a change in public savings $\left(PUBSAV_{r} - tau_{r} \right)$ since tax rates do not change, even though the public income $INCOME_{r}^{pub}$ can change endogenously. $\overline{ADJUST_{r}}$ is 1 and tau_{r} is 0 at the benchmark, so Equations (29) and (29a) are then equivalent.

In MPSGE code, this involves a departure from the standard GTAPinGAMS model. First, the introduction of the public sector involves the inclusion of the next `$demand` block for the `public` sector (separated from the `$demand` block for the private representative agent):

```
$demand:public(r)
         d:pg(r)          q:G("pub",r)
 * Public savings:
         e:p("i",r)       q:PUBSAV(r)
         e:p("i",r)       q:(-1)          r:tau(r)
```

where the public expenditure `d:` takes the value of aggregate public expenditure denoted by G_r^{pub} or `G("pub",r);` `PUBSAV(r)` are benchmark government savings or deficit. The variable `tau(r)` activates the endogenous change in the public deficit. The aggregate public expenditure is generated in a `$prod` block with a Leontief composite (see Equation 27) of sectoral public consumption (the set `publi` is defined over goods that include public consumption):

```
$prod:ypub("pub",r)
        o:pg(r)          q:G("pub",r)
        i:p(publi,r)     q:vom(publi,r)
```

The counterfactual simulation involves the instruction (67) to reduce the EU public expenditure in order to reach the level $\overline{G_r^{simul}}$ (i.e. to fix EU `ypub` in the previous MPSGE code) to a lower level which allows to reach a decrease in 1 percentage point in the ratio of public deficit to GDP. We apply this in the following way:

```
ypub.fx("pub",r) = ADJUST(r);
```

This instruction in the counterfactual activates an endogenous change in public savings through the change in the auxiliary variable `tau(r)` displayed in the `$demand` block. The complementarity `$constraint` to this `tau(r)` is the income constraint (29a) for the EU public sector which is defined as follows:

```
$constraint:tau(r)
        pg(r)*vom("g",r)*ypub("g",r)
        + p("i",r)*tau(r)    =e=
        p("i",r)*PUBSAV(r)
        + REVTO(r) + REVTFD(r) + REVTFI(r)  + REVTF(r) + REVTXS(r) + REVTMS(r);
```

where the first line includes the public expenditure (with the endogenous price `pg(r)` and the now fixed `ypub`), the second line includes the endogenous adjustment in public savings (deficit), the third line includes the benchmark savings (deficit), and the fourth line is the endogenous tax revenue from the different taxes.

B. Scenario of increase in consumption taxes in the EU, holding public expenditure constant

The introduction of the endogenous final consumption taxes is modelled in the following way:

$$P_{ir}^{C}=\left(\theta_{ir}^{C}\left(1+(etax)\,t_{ir}^{Cd}\right)^{1-\sigma_i^d}\left(P_{ir}^{Y}\right)^{1-\sigma_i^d}+\left(1-\theta_{ir}^{C}\right)\left(1+(etax)\,t_{ir}^{Cm}\right)^{1-\sigma_i^d}\left(P_{ir}^{m}\right)^{1-\sigma_i^d}\right)^{\frac{1}{1-\sigma_i^d}} \tag{24a}$$

$$REV_r^{Cd}=\sum_{i=1}^{15}(etax)\,t_{ir}^{Cd}P_{ir}^{Y}C_{ir}^{Cd} \tag{35a}$$

$$REV_r^{Cm}=\sum_{i=1}^{15}(etax)\,t_{ir}^{Cm}P_{ir}^{m}C_{ir}^{Cm} \tag{36a}$$

$$INCOME_r^{pub}-\overline{PG_rG_r^{pub*}}=PUBSAV\left(1+\overline{ADJUST_r}\right) \tag{29a}$$

where *etax* is an endogenous multiplier which has a value of 1 at the benchmark and the parameter $\overline{ADJUST_r}$ is 0 there. Again, the value of $\overline{ADJUST_r}$ is iteratively estimated (i.e. we try several values until the fall of 1 p.p. is reached). The increase in consumption tax rates leads to a change in public savings $PUBSAV_r$ since public expenditure does not change, even though the public income $INCOME_r^{pub}$ can change endogenously.

In MPSGE, we have the EU `$demand` block explained for the previous scenario but now there will be two constraints. The first one is the constraint related to the endogenous change in the level of public savings (deficit):

```
$constraint:tau(r)
        tau(r) =e= ADJUST(r);
```

The second constraint drives the endogenous change in final consumption tax rates under a constant public expenditure level:

```
$constraint:etax
       Ypub("g",r)*p("g",r) =e= 1;
```

The variable `etax` determines the endogenously required change in tax rates in the `$prod` block burdening the final consumption (i.e. burdening goods which belong to the set `c(g)` where only final consumption goods are included):

```
$prod:y(g,r)   s:esub(g)    i.tl:esubd(i)  va:esubva(g)
        o:p(g,r)             q:(...)                   a:pub(r) t:rto(g,r)
        i:p(i,r)$(not c(g))  q:(...)   p:(...) i.tl:  a:pub(r) t:rtfd(i,g,r)
        i:p(i,r)$c(g)        q:(...)   p:(...) i.tl:  a:pub(r) N:etax M:rtfd(i,g,r)
        i:pm(i,r)$(not c(g)) q:(...)   p:(...) i.tl:  a:pub(r) t:rtfi(i,g,r)
        i:pm(i,r)$c(g)       q:(...)   p:(...) i.tl:  a:pub(r) N:etax M:rtfi(i,g,r)
        i:ps(sf,g,r)         q:(...)   p:(...)  va:   a:pub(r) t:rtf(sf,g,r)
        i:pf(mf,r)           q:(...)   p:(...)  va:   a:pub(r) t:rtf(mf,g,r)
```

Note that fields `q:` and `p:` are not defined with parameters in order to simplify the presentation.

C. Scenario of increase in labour taxes in the EU, holding public expenditure constant

The new equations are as follows:

$$P_{ir}^{f} = \left(\sum_{f} \theta_{ir}^{f} \left(P_{ir}^{pf} \right)^{1-\sigma_i^{VA}} \right)^{\frac{1}{1-\sigma_i^{VA}}} \tag{6a}$$

$$P_{ir}^{pf} = \begin{cases} P_r^{labour} \left(1 + (etax)\, t_{ir}^{labour}\right) \\ P_r^{capital} \left(1 + t_{ir}^{capital}\right) \\ P_r^{S} \left(1 + t_{ir}^{S}\right) \end{cases} \tag{7a}$$

$$REV_r^f = \sum_{i=1}^{15} \left(t_{ir}^{S} P_r^{S} \left(\overline{EVOM_r^{S}} \right) + t_{ir}^{capital} P_r^{capital} \left(\overline{EVOM_r^{capital}} \right) + (etax)\, t_{ir}^{labour} P_r^{labour} \left(\overline{EVOM_r^{labour}} \right) (1 - U_r) \right) \tag{34a}$$

$$INCOME_r^{pub} - \overline{PG_r}\,\overline{G_r^{pub*}} = PUBSAV \left(1 + \overline{ADJUST_r}\right)_r \tag{29b}$$

where the endogenous multiplier *etax* is 1 and the parameter $\overline{ADJUST_r}$ is 0 at the benchmark. Again, the value of $\overline{ADJUST_r}$ is iteratively estimated (i.e. we try several values until the fall of 1 p.p. is reached). Public expenditure does not change, even though the public income $INCOME_r^{pub}$ can change endogenously.

In this scenario, where labour tax rates are allowed to change endogenously with the multiplier `etax`, the approach includes the same two constraints to those shown above for the previous scenario, and a different `$prod` block where labour tax rates change endogenously (note that `pf(f,r)$lab(f)` defines the input labour set):

```
$prod:y(g,r)$reu(r)   s:esub(g)    i.tl:esubd(i)  va:esubva(g)
        o:p(g,r)            q:(...)                    a:pub(r) t:rto(g,r)
        i:p(i,r)            q:(...)   p:(...) i.tl:   a:pub(r) t:rtfd(i,g,r)
        i:pm(i,r)           q:(...)   p:(...) i.tl:   a:pub(r) t:rtfi(i,g,r)
        i:ps(sf,g,r)        q:(...)   p:(...)  va:    a:pub(r) t:rtf(sf,g,r)
        i:pf(f,r)$(not lab(f)) q:(...) p:(...)  va:    a:pub(r) t:rtf(f,g,r)
        i:pf(f,r)$lab(f)    q:(...)   p:(...)  va:    a:pub(r) N:etax M:rtf(f,g,r)
```

TABLE A1 Endogenous variables

Symbol	Definition
C_{ir}^{C}	Final private consumption of good i in country r
C_{ir}^{Cd}	Final private consumption of good i in country r, origin domestic production
C_{ir}^{Cm}	Final private consumption of good i in country r, origin imports
C_{r}^{priv}	Aggregate final private consumption in country r
C_{r}^{pubsav}	Aggregate public savings in country r
EXP_{irs}	Exports of good i from country r to country s
$EXPA_{irs}$	Exports of good i from country r to country s, including transportation margins
G_{ir}^{G}	Final public consumption of good i in country r
G_{ir}^{Gd}	Final public consumption of good i in country r, origin domestic production
G_{ir}^{Gm}	Final public consumption of good i in country r, origin imports
G_{r}^{pub}	Aggregate final public consumption in country r
I_{ir}^{I}	Investment (gross capital formation) in goods produced by sector i in country r
I_{ir}^{Id}	Investment (gross capital formation) in goods produced by sector i in country r, origin domestic production
I_{ir}^{Im}	Investment (gross capital formation) in goods produced by sector i in country r, origin imports
II_{ijr}	Intermediate inputs from sector j used by good i in country r
II_{r}^{i}	Aggregate intermediate inputs used by good i in country r
II_{ijr}^{Y}	Intermediate inputs from sector j used by good i in country r, origin domestic production
II_{ijr}^{m}	Intermediate inputs from sector j used by good i in country r, origin imports
IMP_{ir}	Imports of good i in country r
$INCOME_{r}^{priv}$	Private income in country r
$INCOME_{r}^{pub}$	Public income in country r
P_{isr}	Price (unit cost) of good i exported from country s to country r, excluding transportation margins
P_{ir}^{C}	Price (unit cost) for private consumption of good i in country r
$P_{r}^{capital}$	Price (unit cost) for capital in country r
P_{jr}^{i}	Price (unit cost) for aggregate intermediate input j used by good i in country r
P_{ir}^{f}	Price (unit cost) for aggregate factors used in good i produced at country r
P_{r}^{F}	Price (unit cost) for factor F (= labour, capital) in country r
P_{ir}^{G}	Price (unit cost) for public consumption of good i in country r
P_{ir}^{I}	Price (unit cost) for investment in sector i in country r
P_{r}^{labour}	Price (unit cost) for labour in country r
P_{ir}^{m}	Price (unit cost) for good i imported and used in country r
P_{ir}^{pf}	Price (unit cost) for factor pf (= labour, capital, specific) used in good i in country r
P_{r}^{S}	Price (unit cost) for specific factor S in country r
P_{j}^{T}	World price (unit cost) for transportation margins ($j = TRN$)
P_{jisr}^{t}	Price (unit cost) for international transportation ($j = TRN$) margins in good i traded from country s to country r, including tariffs
P_{ir}^{Y}	Price (unit cost) for good Y_{ir}

(Continues)

TABLE A1 (Continued)

Symbol	Definition
PC_{num}	Price (unit cost) for aggregate final private consumption in numeraire country
PC_r	Price (unit cost) for aggregate final private consumption in country r
PG_r	Price (unit cost) for aggregate final public consumption in country r
PI_r	Price (unit cost) for aggregate savings in country r
Pt^m_{isr}	Price (unit cost) of exports from country s to country r, including transportation margins
$PRIVSAV_r$	Private savings in country r
$PROFIT^Y_{ir}$	Unit profits for Y_{ir}
$PUBSAV_r$	Public savings in country r
Q^{pf}_{ir}	Quantity demanded of factor for good i in country r
REV^{Cd}_r	Revenue in country r from taxes on final private consumption of domestic goods
REV^{Cm}_r	Revenue in country r from taxes on final private consumption of imports
REV^f_{ir}	Revenue in country r from factor taxes
REV^{fd}_r	Revenue in country r from taxes on domestic intermediate inputs
REV^{fm}_r	Revenue in country r from taxes on imported intermediate inputs
REV^{Gd}_r	Revenue in country r from taxes on final public consumption of domestic goods
REV^{Gm}_r	Revenue in country r from taxes on final public consumption of imported goods
REV^{Id}_r	Revenue in country r from taxes on investment of domestic goods
REV^{Im}_r	Revenue in country r from taxes on investment of imported goods
REV^{ms}_r	Revenue in country r from tariffs
REV^O_r	Revenue in country r from output tax
REV^{xs}_r	Export subsidies in country r
TRM_{jisr}	Transportation ($j = TRN$) margin for good i exported from country s to country r
U_r	Unemployment rate in country r
VA^i_r	Aggregate value added used by good i in country r
VB_r	Foreign savings in country r
Y_{ir}	Quantity of good i produced in country r

TABLE A2 Exogenous variables and parameters

Symbol	Definition
$\overline{ADJUST_r}$	Parameter for adjustments in simulations, for country r (benchmark = 1)
$\overline{C_r^{privsav}}$	Aggregate private savings in country r
$\overline{EVOM_r^{capital}}$	Capital endowment in country r
$\overline{EVOM_r^{labour}}$	Labour endowment in country r
$\overline{EVOM_r^{S}}$	Specific factor S endowment in country r
$\overline{G_r^{pub*}}$	Benchmark public expenditure in country r
$\overline{I_r}$	Aggregate gross capital formation in country r
$\overline{U_r}$	Benchmark unemployment rate
$t_{ir}^{capital}$	Taxes on capital for good i in country r
t_{ir}^{Cd}	Taxes on private consumption for good i in country r, origin domestic production
t_{ir}^{Cm}	Taxes on private consumption for good i in country r, origin imports
t_{ir}^{F}	Taxes on factor F (=labour, capital) for good i in country r
t_{ijr}^{fd}	Taxes on domestic intermediate input j for good i in country r
t_{ijr}^{fm}	Taxes on imported intermediate input j for good i in country r
t_{ir}^{Gd}	Taxes on public consumption for good i in country r, origin domestic production
t_{ir}^{Gm}	Taxes on public consumption for good i in country r, origin imports
t_{ir}^{Id}	Taxes on investment for good i in country r, origin domestic production
t_{ir}^{Im}	Taxes on investment for good i in country r, origin imports
t_{ir}^{labour}	Taxes on labour for good i in country r
t_{isr}^{ms}	Tariff for good i exported from country s to country r
t_{ir}^{O}	Output taxes for good i in country r
t_{ir}^{S}	Taxes on specific factor S for good i in country r
t_{isr}^{xs}	Export subsidy for good i exported from country s to country r
β	Parameter of flexibility of the real wage to the unemployment rate
θ	Share parameters
σ_i^d	Armington elasticity of substitution domestic-imported components in good i
σ_i^m	Armington elasticity of substitution among imported components in good i
σ_i^{VA}	Elasticity of substitution among factors in good i