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Endogenous labour supply and negative economic shocks in a large scale spatial CGE model of the European Union

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Endogenous labour supply and negative economic shocks in a large scale spatial CGE model of the European Union*

Martin Aarøe Christensen, Damiaan Persyn

5th December 2022

Abstract

We introduce endogenous labour supply decisions with an extensive and intensive margin in a spatial computational general equilibrium model. We show that endogenising labour supply generates an additional economic loss from a negative economic shock compared to a model with fixed labour supply. Adjustments at both the intensive margin (average hours worked) and the extensive margin (labour market participation) contribute to the higher cumulative loss in employment, consumption and GDP. We show that country-level results hide substantial heterogeneity at the regional level due to regional variations in labour market characteristics and economic structures. The results carry important lessons for macro-economic models used for policy evaluation: economic effects may be underestimated by models with fixed labour supply or models considering only the intensive margin of labour supply. Aggregate country level estimates may hide large differences in effects observed at the regional level.

1 Introduction

Labour market participation, employment and unemployment are decisive factors for human well-being. Some Member States of the European Union (EU) are characterised by persistent high unemployment and low employment rates. Across the EU, inter-regional differences in labour market outcomes are stark, especially when considering

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outcomes separately by level of education. Stark differences in labour market characteristics can potentially affect the impact of economic policies and the outcome of economic shocks across the EU.

In spite of the differences in labour markets outcomes across time, space, and individuals' socio-economic characteristics, many large scale general equilibrium models which aim to assist in policy making are based on the most rigid assumptions concerning labour markets. This is also the case for the current version of the dynamic spatial general equilibrium model of the European Commission RHOMOLO.[1] The model considers the EU at the disaggregated level of 267 NUTS-2 regions. However, it contains several assumptions concerning labour supply which limit its potential use for analysing labour market outcomes and policies. The current version of RHOMOLO uses a wage curve (see Blanchflower and Oswald, 1995), which implies that wages are set above the market clearing level, giving rise to involuntary unemployment. Labour supply, however, is assumed to be fixed. Hence, the size of the labour force will not adjust to changes in the economy, and the number of individuals participating in the labour force remains the same, as does the number of hours worked per individual. This assumption ignores the role of labour supply adjustment as an transmission mechanism in the economy and the potential heterogeneity in outcome arising from varying labour market adjustments across the European economies.

The aim of this paper is to address this issue and introduce endogenous labour supply decisions into the RHOMOLO model. The framework we use is based on Kleven and Kreiner (2006) and Boeters and Savard (2013). It consists of two steps, which are solved backwards. First the household determines the optimal number of hours worked, assuming that they participate in the labour market and are employed. Second, they compare the fixed cost of participating with the expected utility obtained in the first step, in order to decide whether or not to spend time looking for a job at all. This introduces the labour supply framework suggested by Kleven and Kreiner (2006) into a general equilibrium setting which includes involuntary unemployment.

In the current version of RHOMOLO, each region is inhabited by a single representative household which supplies three types of labour. Since in reality participation decisions and labour market outcomes may differ significantly between individuals with different skill levels, we change this assumption. We now rather consider the case of three household types with different skill levels (L, M, H), and assume that of each type

[1]The RHOMOLO model is developed and maintained by the Joint Research Centre (JRC) and used for policy impact assessment and for model-based support to EU policy makers. For more information on RHOMOLO see Lecca, Barbero, Christensen, Conte, Di Comite, Diaz-Lanchas, Diukanova, Mandras, Persyn, and Sakkas (2018). Examples of impact assessments can be found in Christensen, Weiers, and Wolski (2019) and Christensen (2022).

there exists a continuum of individual households in each region. Individual households within the same skill-class and region differ by the level of the exogenous fixed cost they face for supplying labour. The assumption of a well-behaved distribution of these fixed costs among the households of each skill level will assure a smooth reaction of labour supply at the aggregate level.

In order for the model to be useful in practice for policy simulations, careful attention has to be paid to the choice of the parameter values which will ultimately drive the response of labour supply to changes in exogenous and endogenous model variables, due to policy shocks or otherwise. The model parameters are calibrated to replicate the estimated wage elasticities of labour supply of Bargain, Orsini, and Peichl (2014) around the steady state and baseline values for unemployment and participation rates, both for the intensive and extensive margin of labour supply.

To explore the properties of the model we consider a negative shock which is symmetric across all regions in the model and similar in size to the financial crisis of 2008-2009. It takes the form of a decline in extra-EU export demand, a drop in TFP and a rise in the risk premium which lowers private investments. We compare the outcome of the model with endogenous labour supply to the case of fixed labour supply.

In the model with fixed labour supply all adjustments in total hours worked in response to the negative shock takes place through a change in the unemployment rate. Allowing for endogenous labour supply in the model introduces two further channels through which total hours worked adjust in response to the negative shock. Firstly, lower wages trigger adjustment at the intensive margin reducing average hours worked. Secondly, the decrease in wages and increasing unemployment triggers a labour supply response at the extensive margin. Since searching for a job is costly in terms of lost leisure time, a lower employment probability leads discouraged workers to leaving the labour force, resulting in lower labour market participation. Introducing endogenous labour supply exacerbates economic losses following a negative shock. The cumulative losses in employment, consumption, and GDP are all magnified. For example, the cumulative loss in EU GDP relative to baseline change from -31.9% to -36.8% with endogenous labour supply in the model while the cumulative loss in household consumption changes from -16.2% to -20.1%. Furthermore, the reduction in average hours worked and discouraged workers leaving the labour force both attenuates the rise in the unemployment rate compared to the model with fixed labour supply, and in turn affects wage bargaining.

We show how differences in labour supply elasticities, labour market characteristics and economic structures across the EU lead to vastly different economic outcomes following a symmetric negative shock. Differences in economic outcomes are found at country level and at regional level.

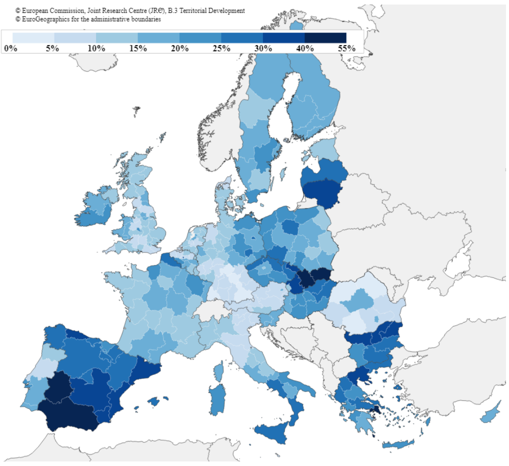
The remainder of this paper is structured as follows. In section 2 we consider some basic properties of European labour markets across regions and over the last decades. Section 3 shows how endogenous labour supply can be included in a large spatial CGE model such as RHOMOLO. Section 4 gives an overview of labour demand in the current version of RHOMOLO, while Section 5 presents the modelling of the labour market coordination through a wage curve. Section 6 shows how the extended labour market module is calibrated. In section 7 we present the model experiment. Section 8 explores the model properties and illustrates how the inclusion of endogenous labour supply at the intensive and extensive margin affects the economic outcome of a negative shock to the European economy. Section 9 concludes.

2 European labour market dynamics

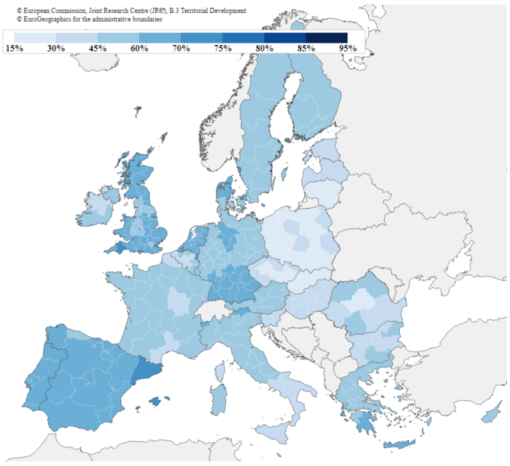
As already mentioned in the introduction, differences in labour market outcomes between European regions are stark, especially when considering outcomes separately by level of education. Figure 1 shows European regional unemployment and participation rates for the year 2013, distinguishing between low and higher educated individuals.[2] Unemployment rates for low educated varied from 4-5% in Southern Germany to levels around 40-50% in Southern Spain and Eastern Slovakia. For the higher educated, unemployment rates are lower overall. Geographical patterns are different between education groups: Whereas unemployment rates for the low educated are high in Slovakia, the Czech Republic, Bulgaria, Latvia, Lithuania and Eastern Germany, these countries and regions exhibit relatively low unemployment rates for the high educated. Within Poland the spatial pattern of unemployment rates seems opposite for the low and higher educated. In contrast, Greece, Southern Italy, Spain (especially the south) exhibit high unemployment rates among all education levels.

Likewise, regional labour market participation rates for the low educated vary between around 20% in Southern Poland and Slovakia to 70% in North East Spain, while participation rates for the highly educated vary from 70-75% in Southern Italy to 93-94% in North East Spain. Also here there are marked differences between education groups and countries. For example, whereas the participation rates for highly educated individuals are high both in Poland and Spain, only in Poland the participation rates for low educated individuals are extremely low.

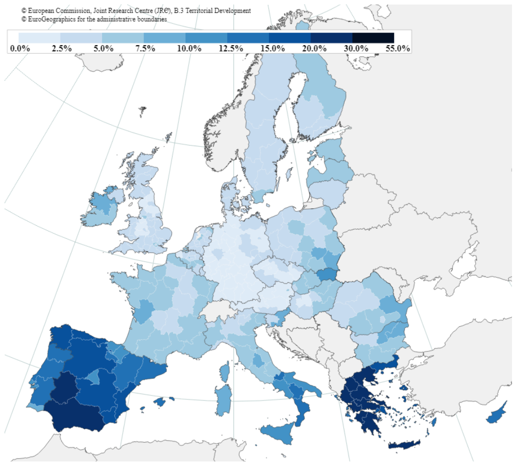
[2]We define low-educated as individuals with ISCED levels 0-2, medium-educated with ISCED levels 3-4, and high-educated with ISCED levels 5-6. Regions are defined at the NUTS2 level.



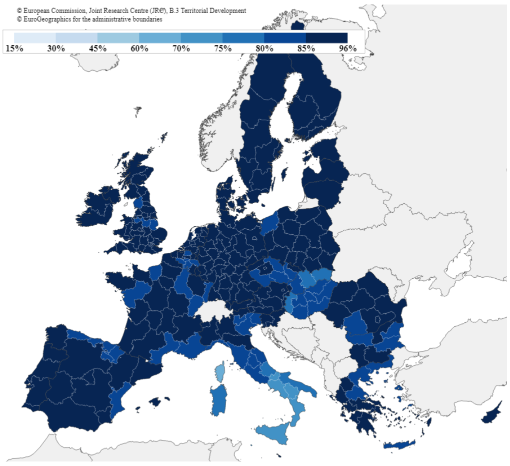
(a) unemployment rate low educ.



(b) participation rate low educ.



(c) unemployment rate high educ.



(d) participation rate high educ.

Figure 1: Regional labour markets in the EU in 2013. Source: own elaboration using Eurostat Labour Force data.

Some of the underlying reasons for these disparities may be non-economic. Some former communist countries in Eastern Europe are characterised by comparatively high education levels for older workers, for example, such that few individuals are low educated and their characteristics may be quite different from low educated individuals in, for example, Spain. Our model does not fundamentally explain these differences, but allows for them by including exogenous differences in the composition of the local labour force, and allowing for differences in the distribution of individuals' costs of labour market participation between regions and education groups.

Furthermore, labour market outcomes vary over time in response to structural

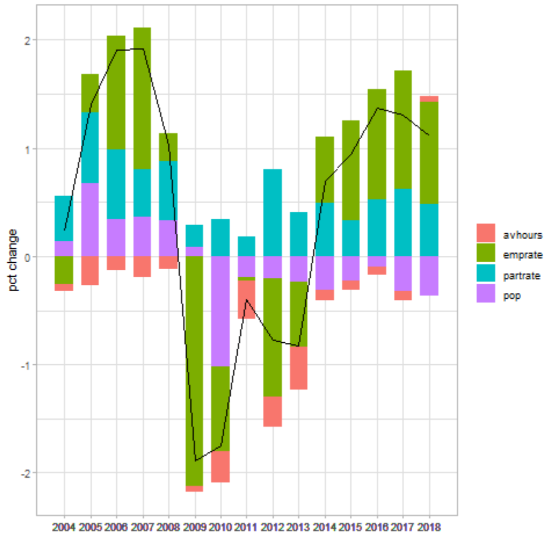


Figure 2: Growth in EU27 total hours worked and its decomposition into contribution from changes in population of working age, participation rates, employment as a share of active population and average hours worked.

changes and external shocks. Using data from the European Labour Force Survey we calculate growth in total hours worked in the EU27 for the period 2003-2018, and decompose it into the contribution from changes in population of working age, participation rates, employment as a share of the active population and average hours worked, as shown in Figure 2.[3]

Figure 2 reveals some interesting trends: the average hours worked per employee, for example, has fallen in almost every year between 2003 and 2018, at an average annual rate of -0.17% percent. In contrast the participation rate has been rising over the entire period at an average annual rate of 0.48%. As our interest rather lies with changes in labour market variables over the business cycle, we now consider detrended series over three sub periods: two in which total hours worked are growing, 2003-2008 and 2013-2018, and the period 2008-2013 in which total hours worked is falling. Table 1 shows the percentage change in the total hours worked for each of the three sub-periods and its decomposition, expressed as deviations from the annual trend in

[3]Define total hours worked as $TotH = AvgH \times \frac{Emp}{LF} \times \frac{LF}{POP}\ POP$. Where $AvgH$ is average hours worked, Emp is employment, LF is the labour force and POP is population of working age. Using data available from the Eurostat Labour Force Survey we can express this as $TotH = AvgH \times (1 - u) \times P \times POP$. where u is unemployment rate and P is the participation rate. Taking logs and differencing over time gives the growth in hours worked and its decomposition.

Table 1: Annual percentage changes in total hours worked and its components in three periods, as deviations from the overall trend 2003-2018.

	2003-2008	2008-2013	2013-2018
Average hours	0.01	−0.11	0.11
Employment share	0.36	−1.11	0.74
Participation rate	0.07	−0.09	0.02
Population	0.44	−0.24	−0.20
Total hours	0.88	−1.55	0.67

Note: Own calculations based on Eurostat, Labour Force Survey. Employment share defined as employment as share of labour force.

each component over the years 2003-2018. The employment share is strongly cyclical and accounts for a large share of the observed deviation of total hours from the trend. Changes in average hours and the participation rate over the cycle account for a smaller share of the observed deviation of total hours and are of similar magnitude.

The changes in EU aggregate labour market participation rates may hide larger variations across socio-economic groups and across EU Member States. Such variations are captured by our model. Furthermore, the variation in EU average hours worked does not entirely arise from individuals adjusting their average working hours, the intensive margin of participation, over the cycle. Some of the variation in average hours worked may be due to compositional effects caused by changing employment shares over the cycle between different sectors or occupational groups with structurally different working hours. For example, the rise and fall of employment over the cycle for an occupational group with above average working hours would affect the reported overall average hours worked for all individuals. Such compositional effects are missing from our model. Part of the decrease in average hours over the years 2008-2013 may have stemmed from the labour demand side, with employers cutting back over-time and aiming to retain qualified workers by reducing work-time among all workers, rather than reducing head-counts. Such mechanisms are also missing from our model.

3 Modelling labour supply

Households derive income from labour, physical capital and other financial assets, as well as from government transfers. The income of households is spend on savings, consumption and taxes. Labour supply is modelled following the approach suggested by Kleven and Kreiner (2006) and Boeters and Savard (2013).

3.1 Household preferences

In order to model endogenous labour supply at both the intensive and extensive margin we assume that each region r is inhabited by three separate continua of households, with respective skill levels $s \in \{L, M, H\}$. The mass or 'number' of individual households in each continuum corresponds to the appropriately scaled number of individuals of the skill class in each region. The individual households of a specific skill group s in a specific region r have identical preferences, but have different heterogeneous fixed costs of labour market participation q. We assume that there is a continuum of these fixed costs, distributed according to the cumulative distribution function $\tilde{P}(q)$ and the density function $\tilde{p}(q)$. This will generate a smooth labour market participation response at the aggregate level.

We choose a utility function which is very commonly used in the literature (for a discussion see e.g. Keane (2011)). Write L for the hours of employment supplied on the individual household level, and C to denote the aggregate bundle of commodities consumed. The household derives utility from consumption C, and disutility from hours worked where the parameter ω scales the disutility of working. The utility of an employed household in region r with skill level s is given by

$$U^e_{r,s} = V^e_{r,s} - q_{r,s}, \tag{1}$$

where $V^e_{r,s}$ is the subutility function given by

$$V^e_{r,s} = \frac{C_{r,s}^{1-\rho_{r,s}}}{1-\rho_{r,s}} - \omega_{r,s}\frac{L_{r,s}^{1+\nu_{r,s}}}{1+\nu_{r,s}}. \tag{2}$$

The chosen utility function is convenient since it allows us to straightforwardly decompose labour supply at the intensive margin into a substitution effect and an income effect. The parameter $\nu_{r,s}$ governs the strength of the substitution effect while the parameter $\rho_{r,s}$ governs the strength of the income effect. Following Kleven and Kreiner (2006) we assume additive separability of fixed work costs $q_{r,s}$ in the household's utility function. Hence, fixed costs of labour supply will not affect the marginal rate of substitution between leisure and consumption conditional on entry. The size of the fixed costs is therefore crucial for the household's decision to enter the labour market, but it will not affect the choice of hours supplied once the entry decision has been made. Assuming identical preferences and wages for all households of a given skill type within the region, separability implies that all households of a given skill type that chose to work within a region will work the same number of hours. Since most parameters and variables are defined at the region-skill (r, s) level, we drop these indices from this point to avoid cluttering the expressions.

The bundle of commodities is a CES aggregate

$$C = \left[\sum_i \phi_i^{\frac{1}{\sigma}} c_i^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{3}$$

where c_i is the commodity of type i, the parameter σ is the elasticity of substitution between commodities and ϕ is a share parameter. The household's budget constraint can be written as

$$CP^c = (1-s)\left(WL(1-t_B-t_M)+t_M B+Y^D\right) \tag{4}$$

where W is the regional wage for the skill group, Y^D is disposable non-labour income[4], s is an exogenously determined regional household savings rate and P^c is the price of the composite consumption bundle in the region, combining varieties i sold at price p_i^c:

$$P^c = \left[\sum_i \phi_i (p_i^c)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}. \tag{5}$$

We allow for two tax brackets, with the labour income below the threshold B being taxed at the rate t_B and the labour income above the threshold being taxed at the rate $t_B + t_M$. This specification allows us to distinguish between the total tax liabilities of the individual, which is important for the participation decision; and the marginal tax rate which is important for the decision on the desired hours worked.[5]

3.2 Intensive margin: the optimal number of hours supplied by workers

The two-step labour supply decision is solved backwards. First the household determines the optimal choice of hours assuming that they participate. This problem is considered in this section. The next section considers the decision whether to participate at all.

[4]Disposable non-labour income consists of unemployment benefits, other net transfers and return on savings. For simplicity we assume that all households in a region of a given skill class have the same exogenous savings rate irrespective of their labour market status and share the return on savings.

[5]Total taxation of labour income is given by $T = t_B WL + t_M(WL - B)$

Maximising the utility function (1) with respect to the number of hours of labour supplied, L, subject to the budget constraint (4) and time endowment gives the following first order condition

$$\frac{W}{P^c}(1-s)(1-t_B-t_M)=\frac{\omega L^{\nu}}{C^{-\rho}}. \tag{6}$$

The household chooses hours so as to equate the marginal rate of substitution to the real wage after taxes and savings. Note that the marginal tax rate influences the optimal number of hours worked.[6]

Combining (4) and (6) to substitute for C and implicitly differentiating we obtain the uncompensated hours-of-work elasticity with respect to the wage rate

$$\varepsilon_W^L \equiv \frac{\partial L}{\partial W}\frac{W}{L} = \frac{1-\rho\left(\frac{(1-s)(1-t_B-t_M)\frac{WL}{P^c}}{(1-s)(1-t_B-t_M)\frac{WL}{P^c}+(1-s)t_M\frac{B}{P^c}+(1-s)\frac{Y^D}{P^c}}\right)}{\rho\left(\frac{(1-s)(1-t_B-t_M)\frac{WL}{P^c}}{(1-s)(1-t_B-t_M)\frac{WL}{P^c}+(1-s)t_M\frac{B}{P^c}+(1-s)\frac{Y^D}{P^c}}\right)+\nu}. \tag{7}$$

By implicit differentiation we also obtain the income elasticity of hours supplied, the change in hours supplied with respect to variation of non-labour income. It is given by

$$\varepsilon_Y^L \equiv \frac{\partial L}{\partial Y^D}\frac{Y^D}{L} = \frac{-\rho\left(\frac{(1-s)(1-t_B-t_M)\frac{WL}{P^c}}{(1-s)(1-t_B-t_M)\frac{WL}{P^c}+(1-s)t_M\frac{B}{P^c}+(1-s)\frac{Y^D}{P^c}}\right)\frac{Y^D}{WL(1-t_B-t_M)}}{\rho\left(\frac{(1-s)(1-t_B-t_M)\frac{WL}{P^c}}{(1-s)(1-t_B-t_M)\frac{WL}{P^c}+(1-s)t_M\frac{B}{P^c}+(1-s)\frac{Y^D}{P^c}}\right)+\nu}. \tag{8}$$

Using the Slutsky equation we decompose the uncompensated hours-of-work elasticity into separate substitution and income effects.

$$\varepsilon_W^L = \varepsilon_W^{cL} + \frac{WL}{Y^D}\varepsilon_Y^L. \tag{9}$$

[6]Assuming that the household is in the upper tax bracket allow us to calibrate the model such that the households is facing any observed marginal tax rate for its household type

Hence, the substitution effect (the compensated labor supply elasticity) is given by

$$\varepsilon_W^{cL} = \frac{1 + \rho\left(\frac{t_B+t_M}{(1-t_B-t_M)}\right)\left(\frac{(1-s)(1-t_B-t_M)\frac{WL}{pc}}{(1-s)(1-t_B-t_M)\frac{WL}{pc}+(1-s)t_M\frac{B}{pc}+(1-s)\frac{Y^D}{pc}}\right)}{\left(\frac{(1-s)(1-t_B-t_M)\frac{WL}{pc}}{(1-s)(1-t_B-t_M)\frac{WL}{pc}+(1-s)t_M\frac{B}{pc}+(1-s)\frac{Y^D}{pc}}\right)+\nu}, \tag{10}$$

while the income effect is given by

$$ie = \frac{WL}{Y^D}\varepsilon_Y^L = \frac{-\rho\left(\frac{(1-s)(1-t_B-t_M)\frac{WL}{pc}}{(1-s)(1-t_B-t_M)\frac{WL}{pc}+(1-s)t_M\frac{B}{pc}+(1-s)\frac{Y^D}{pc}}\right)\frac{1}{(1-t_B-t_M)}}{\rho\left(\frac{(1-s)(1-t_B-t_M)\frac{WL}{pc}}{(1-s)(1-t_B-t_M)\frac{WL}{pc}+(1-s)t_M\frac{B}{pc}+(1-s)\frac{Y^D}{pc}}\right)+\nu}. \tag{11}$$

The strengths of the substitution effect and the income effect determine the slope of the labour supply curve and, hence, the change in desired hours worked following a shift in policy or a shock to the economy.

3.3 Extensive margin: the decision to participate or not

The households' decision to participate in the labour market is governed by the fixed costs of labour market participation. To decide to participate in the labour market or not, the household compares the expected utility of supplying labour to the utility of non-participation. The concept of *expected* utility needs to be introduced due to the uncertainty of employment: given the presence of a non-market clearing wage setting mechanism in the form of a wage curve, not all labour market participants will be hired at the going wage. When contemplating on whether to enter the labour market, a potential participant therefore takes into account that the probability of employment equals $1 - u$, with u the unemployment rate.

As in Boeters and Savard (2013) we assume that unemployed workers cannot consume their whole time endowment as leisure. Instead a fraction, $\delta < 1$, of the time they would otherwise have spent working is spent searching for a job. The utility function of the household if unemployed is given by:

$$U^u = V^u - q, \tag{12}$$

where V^u is the subutility function given by

$$V^u = \frac{C^{1-\rho}}{1-\rho} - \omega \frac{(\delta L)^{1+\nu}}{1+\nu}. \tag{13}$$

When not participating in the labour force, $L = 0$, and the household does not bear the disutility of participation q. The household utility when not participating is given by:

$$U^0 = \frac{C^{1-\rho}}{1-\rho}. \tag{14}$$

Given the unemployment level, the level of unemployment benefits, and the transfers to non-participating households, the expected utility from participation equals

$$U^p = (1-u)\,U^e + uU^u, \tag{15}$$

where u is the regional unemployment rate of the relevant skill type.

Participation is conditional on $U^p \geq U^0$, and this gives a cut-off point q^* for the fixed cost of participating in the labour force, which depends on wages, the unemployment rate, total tax liabilities, unemployment benefits and other non-labour income received when working or not working. Only households with a cost $q \leq q^*$ will rationally choose to enter the labour force.

$$q \leq (1-u)V^e + uV^u - U^0 \equiv q^*. \tag{16}$$

Denote by $P(q)$ the cumulative distribution of idiosyncratic participation costs q, such that $P(q^*)$ corresponds to the share of households for which $q < q^*$, the participation rate. The wage elasticity of the number of labour market participants equals

$$\varepsilon_W^{P(q^*)} = \frac{\partial P(q^*)}{\partial q^*} \frac{\partial q^*}{\partial W} \frac{W}{P(q^*)}. \tag{17}$$

Note that $\partial P(q^*)/\partial q^*$ is simply the density function $p(q^*)$ corresponding to $P(q^*)$. As in Boeters and Savard (2013) we will assume a uniform distribution and therefore $\partial P/\partial q^* = p(q^*) = h$ with h some constant to be determined. Turning to the second factor in equation (17) it holds that

$$\frac{\partial q^*}{\partial W} = \frac{\partial U^p}{\partial W} = (1-u)\frac{\partial U^e}{\partial W}$$

and in turn (using equations (1), (2) and (4))

$$\frac{\partial U^e}{\partial W} = \frac{\partial U^e}{\partial C^e}\frac{\partial C^e}{\partial W} = C^{-\rho}(1-s)(1-t_B-t_M)\frac{L}{P^c}$$

The wage elasticity of the number of labour market participants is thus given by

$$\varepsilon_W^{P(q^*)} = h(1-u)C^{-\rho}(1-s)(1-t_B-t_M)\frac{L}{P^c}\frac{W}{P(q^*)}. \tag{18}$$

3.4 Aggregate hours of labour supplied

The aggregate hours of labour supplied $\bar{L}$ is given by

$$\bar{L} = NP(q^*)L \tag{19}$$

where N is the number of individuals in the given skill group and region under consideration, $P(q^*)$ and L have been derived in sections 3.3 and 3.2 respectively. With N fixed[7], the wage elasticity of the aggregate hours supplied therefore is given by

$$\varepsilon_W^{\bar{L}} = \varepsilon_W^{P(q^*)} + \varepsilon_W^{L}. \tag{20}$$

4 Labour demand

In the current version of RHOMOLO labour is used as an input factor in ten regional production sectors. Each production sector may be set to be perfectly or imperfectly competitive. Production requires intermediate inputs, private capital, public capital and labour of the three skill types. All producers minimise variable unit costs corresponding to a three-level nested CES production function. At the bottom nest a CES function governs the degree of substitutability between low, medium and high skilled labour

[7]RHOMOLO has the option to activate inter-regional migration. In this case, the number of individuals is fixed within the single time period for which the model is solved. Between two static equilibria for which the model is solved, however, migration takes place, with individuals basing migration decisions looking at past realisations of wages and unemployment. In this analysis we use the default assumption in RHOMOLO of no migration, leaving an analysis of the interaction between migration and labour supply to further work.

inputs. The demand for labour of skill type s by a firm in production sector j is given by

$$ld_{j,s} = \frac{\alpha_{j,s}}{TLP_j^{1-\sigma_j^l}} \left[\frac{W_s}{W^a}\right]^{-\sigma_j^l} LD_j \tag{21}$$

where LD_j is a CES composite of labour input demanded by the firm and TLP_j is an exogenous productivity shift factor. The parameter $\alpha_{j,s}$ governs the share of labour input of type s while σ_j^l is the elasticity of substitution between labour of different skill types. The aggregate wage index W^a is defined as

$$W^a = \frac{1}{TLP_j} \left(\sum_s \alpha_{j,s} {W_s}^{1-\sigma_j^l} \right)^{\frac{1}{1-\sigma_j^l}}. \tag{22}$$

5 Labour market coordination

The modelling of unemployment in RHOMOLO follows Blanchflower and Oswald (1995) and adopts the wage curve — an empirical regularity describing the negative relation between wages and unemployment. This approach allows us to pragmatically introduce unemployment, while avoiding strong assumptions on the underlying labour market imperfections causing it.[8] The wage curve implies that the wage is set above its market clearing level, hence creating involuntary unemployment. The wage curve is given by

$$\log\left(\frac{W_{r,s,t}}{P^c_{r,t}}\right) = a_r - \varepsilon_r \log\left(u_{r,s,t}\right) \tag{23}$$

where ε_r is the long-run wage curve elasticity.

6 Calibration and parameter estimates

Up to this point our derivations have been purely theoretical. In order for the model to be useful for policy simulations it needs to be calibrated. This involves setting exogenous

[8] Three theories have been used to set up structural models of wage determination in imperfectly competitive labour markets that are consistent with a wage curve. These are: Collective wage bargaining (McDonald and Solow (1981)), efficiency wages (Shapiro and Stiglitz (1984)) and search and matching (Pissarides (1990)). For a discussion of the three different theoretical approaches see Boeters and Savard (2013).

variables and parameters to replicate the model's base year (2013) and estimates of labour supply elasticities chosen from the literature. The setting of these values can have a large impact on the simulation results. This section describes how the labour supply extension of RHOMOLO is calibrated.

6.1 Labour market status

The resident population between 15 and 64 years old (working age population) and the number of resident workers at the region-skill level was calculated from the European Labour Force Survey (LFS) microdata.

LFS based unemployment and unemployment rate data at the regions-skill level are readily available from the Eurostat website. The regional unemployment rates for two of the three education levels considered in the RHOMOLO base year 2013 are shown in the left column of Figure 1.

Regional employment, considering not the residence but workplace of workers, for each of the 10 sectors considered in RHOMOLO, was taken from the regional accounts (Eurostat website) to stay as close as possible to the core database of RHOMOLO. For the split of this employment data between skills (separately per sector and region), we use the LFS anonymized micro-data and calculate the sectoral skill shares at the NUTS1-sector level[9] (except for the Netherlands where only country level information is available), considering the reported workplace of the respondent. We then assume that the sectoral skill shares are identical for all NUTS2 regions contained within a NUTS1 region.

The regional participation rate is a residence-based concept. We calculate these values from the LFS microdata. The regional participation rates for low and high educated individuals in 2013 are shown in the right column of Figure 1.

6.2 Hours worked, income and consumption

Regional gross labour income was taken from the regionalised Social Accounting Matrix (SAM), which forms a core part of RHOMOLO. This aggregate amount was then split between the three skill groups considering total hours worked and wage premia.

Average hours worked per worker, by region and skill type was estimated from the LFS microdata. Relative wage differences between the different skill groups (skill

[9]Although some countries provide data at the NUTS2 level, sample sizes become too small to reliably estimate employment for three skill groups and ten sectors at this detailed level of spatial disaggregation. We therefore believe the value at the NUTS1 level provides a more reliable estimate.

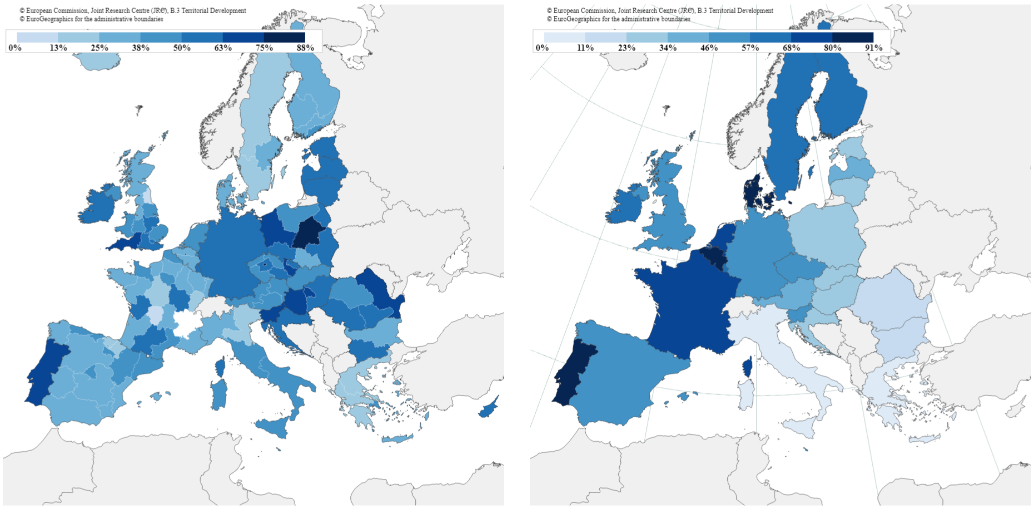


Figure 3: Left panel: wage premium of college graduates versus medium education levels. Right panel: replacement rate comparing unemployment benefits and earnings of workers at 67 percent of the average wage.

premia) were calculated from the EU-SILC cross-sectional microdata. These wage premia are residence based, and available at the NUTS1 level for all member states except for Germany, the Netherlands and Portugal, for which we had to resort to country-level data. The left panel of figure 3 shows the wage premium of the highly educated over the medium educated in the base year 2013, in percentage terms.

We obtained replacement rates expressing the unemployment benefits relative to the net wage from the OECD *Benefits, Taxes and Wages* database. We set the replacement rate of the low and medium educated to that of workers at 67 percent of the average wage. For highly educated workers we set it at 100 percent of the average wage. We consider the case of a single person without children. The right panel of figure 3 shows the replacement rates of the medium educated in the base year 2013.

We use the EU-SILC microdata from Eurostat to determine the split of total transfers between the three household types. To obtain sufficient observations to reduce sampling error, we calculate these shares at the NUTS1 level where available. For the Netherlands, no regional information is provided and we therefore have to use the same split of transfers between skills in all regions.

Having allocated gross labour income and non-labour income to households, we can calculate gross income on the individual household level per skill type and labour market status.

In the labour market module we distinguish between the average tax rate and the marginal tax rate on labour income. Tax rates are taken from the OECD Taxing Wages database using respectively data on the tax wedge and the marginal tax wedge. Tax wedges depend on family status and family compositions. For calibration we chose tax wedges for singles without children. For low skilled households we use tax wedges for an individual earning a wage which is 67% of the average wage. For medium and high skilled households we use tax wedges for an individual earning respectively 100% and 133% of the average wage.

Some of the EU Member States are not covered by the OECD Taxing Wages database (Bulgaria, Croatia, Cyprus, Malta and Romania). For these Member States tax wedges are taken from the European Commission's Tax and benefits database. We adjust the tax wedges and marginal tax wedges from the Tax and benefits database to match OECD definitions. However, for the high skilled households we use tax wedges and marginal tax wedges for an individual earning 125% of the average wages (as tax wedges for wages at 133% of the average wage are not available). For each Member State $t_B + t_M$ is set equal to the marginal tax wedges while t_B and the threshold B is calibrated to replicate the tax wedges.

The calibrated tax rates allow us to calculate disposable income at the individual household level across skill types and labour market status. Finally using the household savings rates from RHOMOLO we calculate savings and consumption at the individual household level by skill type and labour market status.

6.3 Labour supply elasticities

In order for the model to be useful for policy simulations, careful attention has to be paid to the parameter values which ultimately drive the response of labour supply to changes in exogenous and endogenous model variables, due to policy shocks or otherwise. Obtaining relevant values for these parameters can be problematic, as RHOMOLO is a large model with a high level of disaggregation. We rely on the labour supply elasticities estimates of Bargain, Orsini, and Peichl (2014) for both the intensive and extensive margin of labour supply. Bargain, Orsini, and Peichl (2014) report separate estimates for individual EU member states. Although RHOMOLO operates at the regional level, we believe fixing elasticities of labour supply at the national level is relatively innocuous, especially compared to a situation where labour supply is fixed, or the case of assuming a single value for a labour supply elasticity for the whole EU.[10] The estimates by Bargain,

[10]The use of national estimates is less problematic if the differences in preferences regarding participation are high between countries and less so within countries, which we believe to be the case. It seems likely that in most countries large regional differences in labour market outcomes are mainly

Orsini, and Peichl (2014) do not allow to differentiate labour supply elasticities across skill levels. Elasticities are therefore assumed identical for low, medium and high skilled individuals.[11]

Table 2 reports the labour supply elasticities used for calibration. These are calculated as the means of the labour supply elasticities reported for different demographic groups in Bargain, Orsini, and Peichl (2014).

Model parameters are calibrated with the aim to exactly replicate the labour supply elasticities in the model around the initial steady state. More specifically, the parameters for household preferences ρ and v are calibrated to replicate the estimated compensated hours elasticities at the intensive margin with respect to wages and the income elasticity of hours. The distribution of fixed costs h is calibrated to replicate the estimated compensated hours elasticities at the extensive margin.

7 Experiments

To explore the properties of the model we consider a negative shock to the European economy of the same approximate scale as the 2007-2009 crisis. The negative shock we consider takes the form of a decline in external export demand, a drop in total factor productivity (TFP) and a rise in the risk premium which lowers private investment. We assume that the negative shock hits all regions in the model uniformly.[12] All regions experience an exogenous decline in extra-EU demand. We impose that the extra-EU export in period t_2 declines by 4% below the baseline and 20% below the baseline in t_3. This correspond approximately to the drop in EU export below trend growth in respectively 2008 and 2009 as reported by Eurostat. Furthermore, all regions are subject to a decline in TFP across all sectors of 1% below the baseline in t_2 and 5% below baseline in t_3. This approximates the decline in TFP below trend in 2008 and 2009 for the EU12 countries included in EU-KLEMS (Van Ark and Jäger (2017)). Finally, all regions experience a rise in the risk premium of a magnitude that generates a fall in private sector investments of 4% below baseline in t_2 and 15% below baseline in t_3. This corresponds approximately to the decline in EU private investments below trend

explained by individuals with similar preferences facing different local conditions, rather than reflecting fundamentally different preferences of individuals.

[11] This could potentially be problematic if systematic differences in labour supply elasticities exist between individuals of different skill levels. We have not been able to identify any estimates that differentiate between skill levels in a format that fits our model specification.

[12] The version of RHOMOLO used for the experiments was built prior to the UK leaving the EU, and hence includes the UK regions as endogenous to the model. For simplicity we shock also UK regions, but report EU aggregates as covering EU27.

Table 2: The labour supply elasticities used for calibration.

	Intensive margin (hours) (1)	Extensive margin (hours) (2)	Income elasticity (hours) (3)	Total hours (compensated) (4)
AT	0.033	0.140	-0.0006	0.173
BE	0.035	0.295	-0.0040	0.325
BG*	0.027	0.176	-0.0026	0.202
CY*	0.027	0.176	-0.0026	0.202
CZ*	0.027	0.176	-0.0026	0.202
DE	0.033	0.173	-0.0056	0.208
DK	0.028	0.190	-0.0017	0.210
EE	0.005	0.108	-0.0001	0.113
ES	0.070	0.268	-0.0054	0.340
FI	0.003	0.190	0.0000	0.193
FR	0.020	0.095	-0.0011	0.113
EL	0.023	0.315	-0.0048	0.333
HR*	0.027	0.176	-0.0026	0.202
HU	0.008	0.113	-0.0001	0.118
IE	0.043	0.338	-0.0103	0.378
IT	0.030	0.288	-0.0049	0.315
LT*	0.027	0.176	-0.0026	0.202
LU*	0.027	0.176	-0.0026	0.202
LV*	0.027	0.176	-0.0026	0.202
MT*	0.027	0.176	-0.0026	0.202
NL	0.043	0.110	-0.0022	0.155
PL	0.005	0.073	0.0000	0.080
PT	0.030	0.050	-0.0001	0.073
RO*	0.027	0.176	-0.0026	0.202
SE	0.035	0.113	-0.0011	0.148
SI*	0.027	0.176	-0.0026	0.202
SK*	0.027	0.176	-0.0026	0.202
UK	0.018	0.145	-0.0030	0.160

*Note: Calculated as the mean of labour supply elasticities for different demographic groups reported in Bargain, Orsini, and Peichl (2014) except for countries indicated by * for which no estimates were available. Instead the average of the EU countries included in the sample was taken.*

in 2008 and 2009 as reported by Eurostat. From t_4 the exogenous decline in extra EU demand, TFP and the shock to the risk premium all gradually recover following an auto-regressive process with a persistence parameter of 0.5. For the experiment we do not consider any policy measures to mitigate the negative shock.

We compare the outcome of the model with labour supply decisions at the intensive and extensive margin (model 1) to two alternative model specifications. The first alternative model is the case of endogenous labour supply at the intensive margin only (model 2). In this model labour supply decision is calibrated such that labour supply at the intensive margin follows the total hour compensated elasticity estimated by Bargain, Orsini, and Peichl (2014) (column 4 in Table 2). The second alternative model considers the case of exogenous labour supply (model 3). Model 3 mirrors the default assumption of a fixed labour force in the RHOMOLO model and, thus, provides a benchmark against which we can consider the implication of including endogenous labour supply.

8 Results

The large symmetric negative shock to the European economy leads to a sharp decline in GDP, investments and household consumption (Figure 4). Aggregate GDP, investment and household consumption for the EU is respective 6.0%, 14.0% and 2.7% lower than in the baseline scenario in period t_3. Employment also falls sharply and is 2.2% below the baseline in period t_3. The decline in economic activity leads to a large fall in extra EU import to 18.5% below baseline in t_3. From t_4 the economy slowly recovers. However, the impact of the shock is persistent and most economic aggregates stay below the baseline for more than 30 periods, the exception being extra-EU imports that rise above baseline from period t_7. The negative shock initially triggers a sharp decline in domestic demand and a fall in domestic prices making imported commodities less competitive. This drives the initial decline in extra EU imports. However, as domestic prices starts to rise Rest of World commodities gain competitiveness and extra EU imports rise.

To capture the economic loss suffered from the negative shock we calculate the cumulative deviation of selected EU aggregates relative to the baseline (Table 3, column 1). The shock causes a cumulative GDP loss of 36.8%. Households suffer a cumulative loss in consumption of 20.1% and a cumulative loss of employment of 24.4%.

The high level of disaggregation in our model allow us to explore variations in economic outcome at both country level and regional level. Considering cumulative deviations at country level (Table 4) reveals that the symmetric negative shock to the European economy generates vastly different outcomes across countries. For example, the cumulative loss in national GDP relative to the baseline varies from 32.4% for

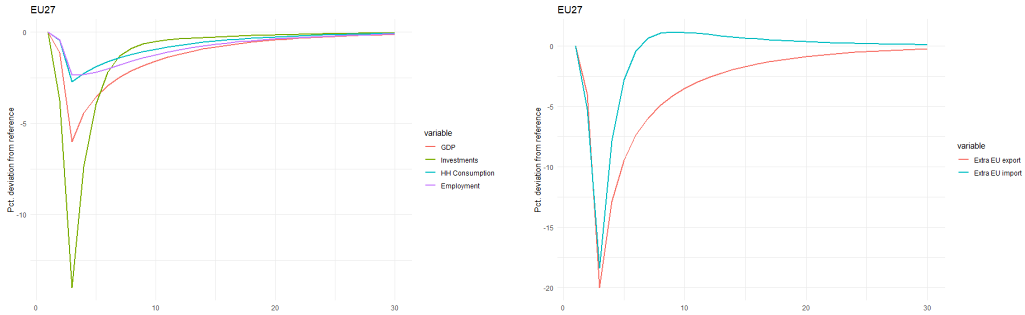


Figure 4: Changes in EU aggregates following a negative shock to model 1. Changes of domestic EU aggregates (left) and changes in Extra-EU trade (right).

Table 3: Cumulative deviation of EU aggregates relative to baseline.

	*Model*1 (1)	*Model*2 (2)	*Model*3 (3)
GDP	−36.8	−34.2	−31.9
Household Consumption	−20.1	−17.8	−16.2
Investments	−38.2	−35.6	−33.2
Extra EU export	−94.5	−91.9	−88.5
Extra EU import	−22.6	−21.6	−21.6
Employment	−24.4	−21.4	−18.9
Labour supply	−7.8	−3.3	0.0

Note: 30 period cumulative change relative to baseline.

Germany to 51.4% for Greece (column 1).

Our simulation results also show vast variations in economic outcome at the regional level. Figure 5 shows cumulative deviations in GDP and labour supply across EU regions. The cumulative deviation in GDP and labour supply is positively correlated. Focusing on regions within countries reveals that regions from the same country tend to cluster. For example, regions in Greece suffer from large cumulative declines in both GDP and labour Supply. Regions in Poland suffer relative large declines in cumulative GDP but relative small declines in labour supply. We notice that regions in Italy form two clusters with respectively large and low declines in both GDP and labour supply.

To explore what triggers such differences in economic outcome we examine correlations between cumulative losses in selected variables at the regional level and a set of regional characteristics in the model's base year. The characteristics that we consider are labour supply elasticities, labour market conditions (replacement rates,

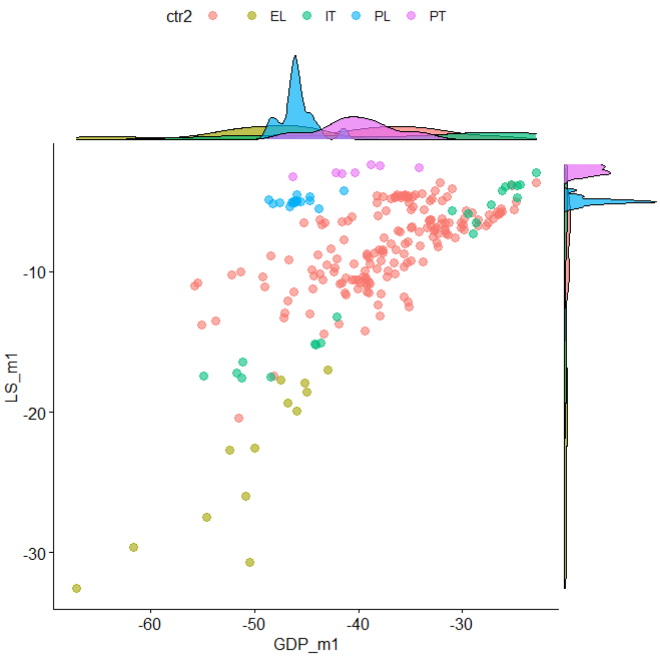


Figure 5: Cumulative deviations in regional GDP and labour supply relative to baseline

unemployment rates, participation rates) and economics structures (trade openness, capital-labour ratio). Correlations are reported in table 5. We notice that higher labour supply elasticities correlate with higher labour supply deviations. Thus, regions with higher labour supply elasticities at the intensive and extensive margin suffer a larger decline in the labour force when hit by the negative shock. In contrast regions with higher income elasticities suffer smaller cumulative losses in labour supply. Correlations with labour market characteristics indicate that regions characterized by higher replacement rates and higher participation rates suffer smaller cumulative losses, whereas regions with higher initial unemployment rate suffer higher cumulative losses. Higher replacement rates work as stabilisers that mitigate a loss in regional income when faced with rising unemployment. Higher initial unemployment rates imply smaller adjustment in wages through the wage curve when faced with a negative shock and this exacerbates the loss in employment, household consumption and GDP. Correlations with variables for economic structure indicate that regions with a higher degree of trade openness suffer higher cumulative losses. These regions suffer the most from a worsening in terms of trade. In contrast, regions with a higher capital-labour ratio suffer lower cumulative losses as capital accumulation adjusts faster than employment.

We now turn to comparing the three alternative model specifications which al-

Table 4: Cumulative deviation of country aggregates relative to baseline.

	GDP			Household Consumption			Employment		
	Model 1 (1)	Model 2 (2)	Model 3 (3)	Model 1 (4)	Model 2 (5)	Model 3 (6)	Model 1 (7)	Model 2 (8)	Model 3 (9)
AT	-33.5	-31.2	-28.2	-17.4	-15.5	-13.5	-18.1	-15.6	-12.2
BE	-38.6	-34.0	-30.1	-17.8	-14.2	-11.9	-25.1	-19.9	-15.3
BG	-50.1	-47.3	-45.0	-33.7	-31.0	-29.0	-37.0	-33.6	-31.0
CY	-35.0	-32.6	-31.5	-26.2	-23.4	-22.2	-24.8	-22.1	-20.8
CZ	-38.7	-35.8	-32.4	-25.6	-23.0	-20.4	-24.7	-21.3	-17.5
DE	-32.4	-30.3	-26.9	-17.3	-15.5	-13.2	-17.5	-15.1	-11.2
DK	-34.6	-32.3	-29.4	-17.4	-15.4	-13.6	-20.1	-17.7	-14.4
EE	-35.3	-33.8	-32.6	-19.6	-18.5	-17.6	-22.6	-20.9	-19.5
ES	-39.4	-36.2	-35.2	-24.1	-20.7	-19.7	-30.1	-26.3	-25.2
FI	-33.5	-31.0	-29.2	-17.4	-15.0	-13.7	-18.2	-15.5	-13.6
FR	-36.8	-35.0	-33.5	-18.7	-17.1	-16.1	-22.6	-20.5	-19.0
EL	-51.4	-48.0	-47.6	-31.0	-28.0	-27.8	-39.0	-34.2	-33.7
HR	-49.2	-45.4	-43.9	-29.4	-26.0	-24.9	-37.5	-33.0	-31.4
HU	-40.4	-38.3	-36.6	-22.3	-21.0	-19.8	-27.5	-25.1	-23.2
IE	-51.0	-44.1	-41.1	-32.3	-25.4	-23.2	-37.9	-29.3	-25.9
IT	-36.0	-32.9	-30.9	-18.9	-16.3	-14.9	-20.0	-16.4	-14.2
LT	-43.4	-39.8	-37.3	-27.9	-25.2	-23.4	-32.8	-28.7	-25.8
LU	-32.6	-30.5	-27.5	-14.1	-12.5	-10.9	-18.8	-16.4	-13.1
LV	-42.6	-40.1	-37.1	-16.0	-14.8	-13.4	-36.4	-33.4	-30.0
MT	-34.1	-32.5	-28.6	-24.5	-22.6	-19.3	-23.1	-21.2	-16.9
NL	-37.8	-33.9	-31.7	-18.3	-14.5	-13.1	-21.8	-17.4	-14.8
PL	-45.6	-43.8	-42.7	-31.2	-29.7	-28.7	-30.4	-28.4	-27.2
PT	-38.1	-37.1	-36.5	-16.3	-15.4	-15.0	-25.1	-23.9	-23.3
RO	-45.5	-41.8	-38.5	-31.6	-28.2	-25.7	-28.5	-24.3	-20.6
SE	-33.9	-32.1	-29.8	-19.3	-17.5	-15.7	-20.1	-18.1	-15.7
SI	-38.4	-36.0	-33.4	-19.6	-17.6	-15.8	-27.1	-24.3	-21.4
SK	-46.2	-42.5	-40.5	-30.6	-27.7	-26.2	-33.9	-29.5	-27.2
EU	-36.8	-34.2	-31.9	-20.1	-17.8	-16.2	-24.4	-21.4	-18.9

Note: 30 period cumulative change relative to baseline.

Table 5: Correlations between cumulative deviations from baseline and base year characteristics at regional aggregations.

	GDP	Household Consumption	Employment	Labour Supply
Intensive margin	0.15*	0.13*	0.06	−0.24**
Extensive margin	−0.03	−0.05	−0.09	−0.64**
Income elasticity	−0.04	0.12	−0.02	0.41**
Replacement rate	0.42**	0.46**	0.41**	0.49**
Unemployment rate	−0.50**	−0.42**	−0.60**	−0.33**
Participation rate	0.29**	0.21**	0.24**	0.10
Trade openness	−0.48**	−0.08	−0.39**	−0.33**
KL-ratio	0.45**	0.51**	0.53**	0.19**

*Note: Correlations calculated on model 1 results, ** indicates $P < 0.05$, * indicates $P < 0.01$.*

lows exploring the impact of a large economic shock under varying labour supply specifications. Let us first consider the impact on unemployment and labour market participation (figure 6). Model 1 is the only of our model specifications that includes labour supply at the extensive margin. This introduces a discouraged worker effect and a decline in the participation rate (right panel). Model 1 and Model 2 include labour supply at the intensive margin leading to a reduction in average hours worked per employee (the elasticity being highest in model 2). In contrast, model 3 contains no changes in labour supply. Adjustments in labour supply at the intensive and extensive margin lower the rise in unemployment. We note that the EU unemployment rate rises most in model 3 and less in model 1 (left panel). The difference in labour supply behaviour affects wage bargaining. It is the unemployment rate that enters the wage curve as a wage disciplining force. Union bargaining does not consider the workers leaving the workforce. As a result the reduction in real wage is highest in model 3 and lowest in model 1. In period t_3 the real wage in model 3, model 2 and model 1 is respectively 2.6%. 2.4% and 2.2% below baseline.

Table 3 shows how the cumulative loss following the negative economic shock increases when allowing for endogenous labour supply. Including endogenous labour supply adjustments in the model increases the cumulative loss in employment and labour supply measured in hours. This is driven by retirement from the workforce (model 1) and a reduction in average hours worked (model 1 and model 2). Endogenous labour supply adjustments also increase the cumulative loss in GDP, household consumption, investments and export. For example, the cumulative loss in GDP relative to the

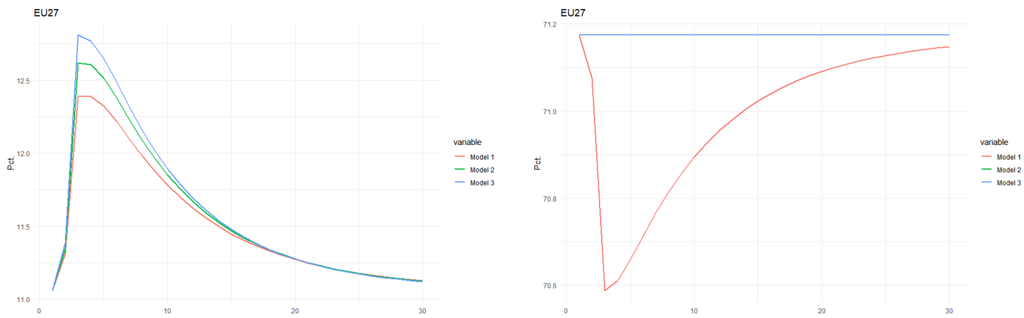


Figure 6: Change in EU unemployment rate (left) and participation rate (right).

baseline is 36.8% in model 1, 34.2% in model 2 and 31.9% in model 3. Thus, introducing adjustments in labour supply increases the cumulative economic costs of a crisis. Put differently, the cumulative loss in GDP and household consumption is respectively 14.5% and 24.0% higher in model 1 than in model 3, and respectively 7.2% and 9.6% higher in model 2 than in model 3.

Table 4 reveals that across all EU countries the cumulative loss in national GDP, household consumption and employment becomes higher when allowing for endogenous adjustments in labour supply. All EU countries suffer the highest cumulative losses in the model with labour supply adjustments at both the intensive and extensive margin (model 1) and the lowest losses when labour supply is fixed (model 3). For example, the cumulative loss in GDP ranges from being 4.5% higher in model 1 than in model 3 for Portugal to being 28.4% higher for Belgium. In comparison, the cumulative loss in GDP ranges from being 0.7% higher in model 2 than in model 3 for Greece to being 13.6% higher for Malta.

9 Conclusion

This paper introduces endogenous labour supply decisions into the spatial CGE model RHOMOLO. The framework we use is based on Kleven and Kreiner (2006) and Boeters and Savard (2013). It consists of two steps, which are solved backwards. First the household determines the optimal choice of hours, assuming that they participate in the labour market and are employed. Afterward, they compare the expected utility of joining the labour force with the fixed cost of participating, in order to decide whether or not to spend time looking for a job at all.

Introducing endogenous labour supply into the model adds two additional channels through which total hours worked adjust in response to a negative shock to the economy.

Firstly, endogenous labour supply at the intensive margin triggers a reduction in the average hours worked. Secondly, labour supply at the extensive margin triggers a decline in the labour force as discouraged workers leave the labour force. Both these effects reduce the total hours worked. Our simulation results suggest that a reduction in average hours worked and discouraged workers leaving the workforce both attenuates the rise in unemployment rates and in turn affects unions wage bargaining.

Furthermore, we show that the introduction of endogenous labour supply into the model increases the cumulative economic loss following a negative shock to the European economy. The cumulative losses in employment, consumption, investments and GDP are all highest in the model with labour supply adjustments at both the intensive and extensive margin.

Finally, we show that differences in labour supply elasticities, labour market characteristics and economic structures across the EU generates vastly different economic outcomes in response to a symmetric shock in different regions.

Our results suggest that labour supply adjustments play an non-negligible role in our understanding of the economic response to economic shocks. Hence, any macroeconomic model built for policy evaluations or projections should address the impact from labour supply adjustments.

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