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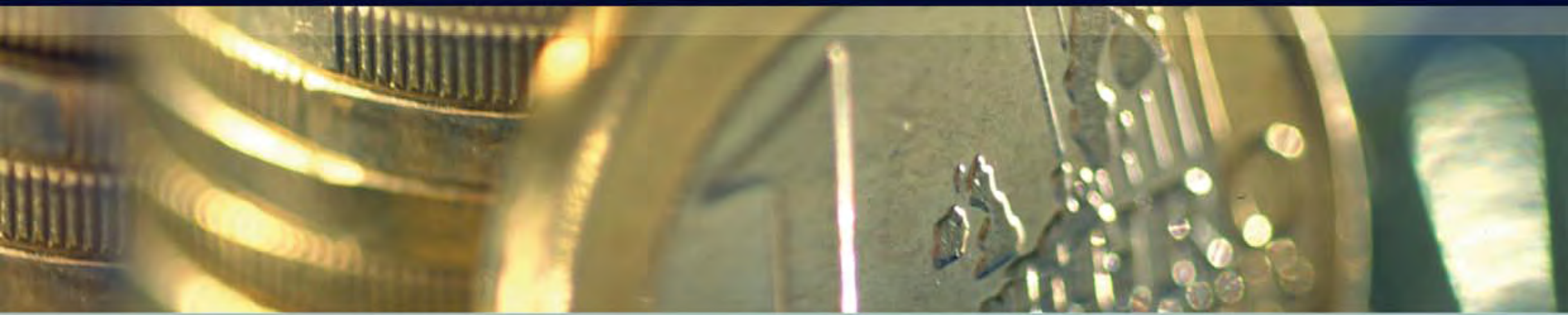

A comparison of structural reform scenarios across the EU member states: Simulation-based analysis using the QUEST model with endogenous growth

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A comparison of structural reform scenarios across the EU member states
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Francesca D'Auria, Andrea Pagano, Marco Ratto, Janos Varga*

Abstract

This paper calibrates the Roeger-Varga-Veld (2008) micro-founded DSGE model with endogenous growth for all EU member states using country specific structural characteristics and employs the individual country models to analyse the macroeconomic impact of various structural reforms. We use the country models to analyse the costs and benefits of reforms in terms of fiscal policy instruments such as taxes, benefits, subsidies and administrative costs faced by firms. Our results confirm the beneficial effects of various structural reforms, however the effects show a large variation across the member states. We employ multiple-regression analysis to explore the most important factors driving the differences within our simulation results. We find that less R&D intensive countries would benefit the most from R&D promoting and skill-upgrading policies. We also find that shifting from labour to consumption taxes, reducing the benefit replacement rate and relieving the administrative entry barriers are the most effective measures in those countries which have high labour taxes and entry barriers.

JEL Classification: E32, E62, O30, O41

Keywords: Structural reforms, endogenous growth, R&D, DSGE modelling.

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1 Introduction

In this paper we calibrate the semi-endogenous DSGE model described in Roeger et al. (2008) for all EU member states. We then use the model to analyse the reform scenarios discussed in Roeger et al. (2008): increasing knowledge investment, removing entry barriers in certain markets, addressing financial market imperfections, increasing the employment of low-skilled workers and changing the skill composition of the labour force. The Roeger et al. (2008) model is an extension of the European Commission's QUEST III model with endogenous technological change, which is sufficiently detailed to be able to address the main areas of structural reforms[1]. The behavioural equations of the model are derived from intertemporal optimisation under technological, institutional and budgetary constraints subject to nominal, real and financial frictions. Technological change is semi-endogenous using the Jones (1995) product-variety framework where investment in R&D is a result of the intertemporal optimisation decision of economic agents. The original Roeger et al. (2008) model has been applied in various simulation exercises concerning structural reform policy scenarios (see Roeger et al. 2009a and 2009b) and has been extended in multicountry environment with human capital formation in order to assess the impact of the EU Structural and Cohesion Funds in the member states (Varga and in't Veld 2009a and 2009b).

The effects of structural reforms show large variations across the member states in our simulation experiments. We employ multiple-regression analysis to explore the most important factors driving the differences between the country-specific simulation results. We find that less R&D intensive countries would benefit the most from R&D promoting and skill-upgrading policies. We also confirm the finding of Roeger et al. (2008) that the effect of reducing price mark-ups is not unambiguous and depends on the sector in which it occurs. In Jones (1995) semi-endogenous framework the mark-ups in the intermediate goods sector cover the costs associated with acquiring a patent when entering the market, therefore reducing mark-ups can have a negative impact on growth and employment if it reduces the entry-rate of new firms. We also find that shifting from labour to consumption taxes, reducing the benefit replacement rate and relieving the administrative entry barriers are the most effective in those countries which face high labour taxes, low employment rates and high entry barriers.

The paper is organised as follows. Section 1 contains a detailed description of the model. Section 2 discusses calibration and estimation of structural parameters. Section 3 then shows the properties of the model by presenting various reform scenarios for the member states and attempts to explore the underlying differences across the countries. The final section concludes.

2 Model calibration

The structure of the model is taken from Roeger et al. (2008). Each country model is a small, open economy model with representative households, final and intermediate goods producing firms, a research industry, a monetary and a fiscal authority[2]. Final goods sector firms produce differentiated goods which are imperfect substitutes for foreign goods. Final good producers use a composite of intermediate goods and three types of labour (low-, medium-, and high-skilled). Households purchase the patents of designs invented by the R&D sector and license them to the intermediate goods producing firms. The intermediate sector is composed of monopolistically competitive firms which make intermediate products from rented capital input using the designs. The production of new designs takes place in the research industry, employing high skilled labour and making use of the existing stock of domestic and foreign ideas. Technological change is modelled as increasing product variety (Jones (1995) and 2005). Throughout the next sections we assume the reader is familiar with the model, for the detailed model description see the Appendix or Roeger et al. (2008).

[1] The QUEST III model is a DSGE model employed in the Directorate-General Economic and Financial Affairs of the European Commission for quantitative policy analysis (see Ratto et al. (2009)).

[2] Varga and in 't Veld (2009a) link the individual country models into a 27 region multicountry model to analyse the macro-economic impact of Structural and Cohesion Funds spendings on the member states.

2.1 Goods Market

Following Roeger et al. (2009a), we consider the intermediate sector as the manufacturing sector and the final goods sector as the aggregate of all sectors without manufacturing. The manufacturing sector resembles the intermediate sector as this sector is more R&D and patent intensive, and a large fraction of manufacturing supplies innovative goods. Final goods sectors, including services, on the other hand are typically not subject to large (patented) innovations but rely on organisational changes partly in order to adapt to the new technologies supplied by the manufacturing sector (e.g. ICT driven productivity increase in the retail and banking sectors).

2.1.1 Mark ups

The two sectors differ in the degree of competition, with manufacturing showing smaller mark ups compared to final goods sectors (see Christopoulou and Vermeulen (2008)). Mark ups are obtained from the EUKLEMS database using the method suggested by Roeger (1995). Due to data restrictions these estimates were available for only ten of the old member states, therefore we imposed the EU average calculated from the available results for the rest of the EU countries[3]. The results on the calibrated cross country differences in the level of mark ups are interesting since they suggest a positive link between the level of intermediate mark ups and R&D investment. This was also suggested by Oliveira Martins and Price (2004) demonstrating that sectors with high R&D intensities tend to have higher mark ups. As shown in Roeger et al. (2009a)[4], the model suggests that lower mark ups in the final goods sector and higher mark ups in the intermediate sector tend to increase R&D intensities, something which we can also observe across the calibrated country models. Figure 1 shows a small negative correlation between R&D intensities and final goods mark ups, while Figure 2 reveals a somewhat larger positive correlation between R&D intensities and the mark ups in the intermediate goods sector.

2.1.2 Entry barriers

We did not find appropriate estimates on entry barriers for specific sectors, therefore we rely on the aggregate estimates provided by Djankov et al. (2002) who estimate the costs of procedures and time that a start-up must bear before the firm can operate legally. This information is directly used for the calibration of the entry cost parameter in the model. The average entry cost per firm is estimated to be around 66 percent of GDP per capita in the whole sample. Cross country variation is large and ranges from 3 percent of per capita GDP for the UK to above 100 percent of per capita GDP in Hungary.

2.2 R&D sector

Empirical evidence on output elasticities of R&D production has recently been provided by Bottazzi and Peri (2007). Concerning the subsidies to R&D investments we use the empirical evidence provided by Warda (2006) based on the B-index formula[5]. The growth rate of ideas were obtained from Pessoa (2005) with the assumption of a 5% obsolescence rate. In our model the R&D elasticity of research labour (λ) is determined by the wage cost share in the total R&D spending. The driving equation system of the semi-endogenous technological change in discrete time setting can be summarized as

$$\Delta A_t = \nu {A_{t-1}^{w}}^{\xi} A_{t-1}^{\phi} \left(L_t^{HA}\right)^{\lambda} \tag{a}$$

[3] During the calibration we found that for several countries the imposed intermediate mark ups would imply too high risk-premium on the intangible capitals, in some cases over 40% per year. To solve this problem, we lowered the intermediate mark-ups so that the intangible riks premia falls around or below 10% per annum, while trying to keep the final goods mark ups at their precalibrated level via changing the fixed cost term of production (FCY).

[4] See the derivation of the steady-state R&D share in Appendix 1 of Roeger et al. (2009a).

[5] See Appendix B of Roeger et al. (2008) for more details on the B-index and how it relates to tax parameters in the model.

Figure 1: R&D intensities and final goods mark ups (average over 2003-2007)

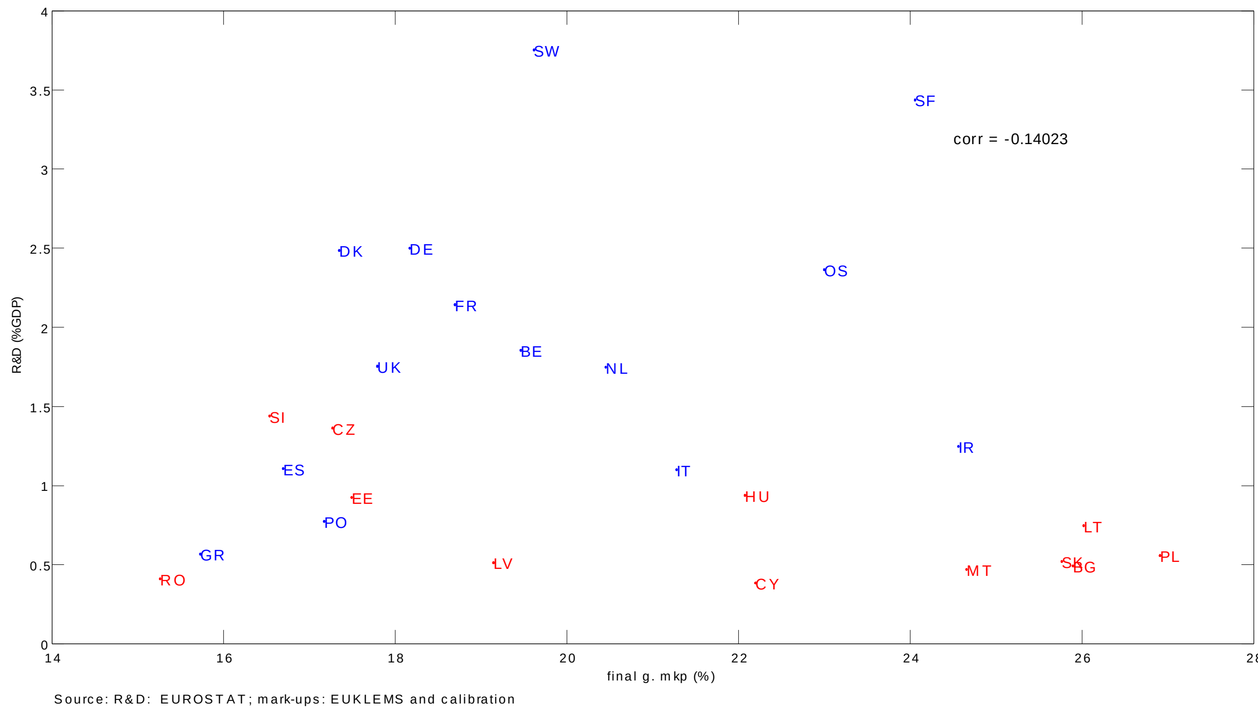
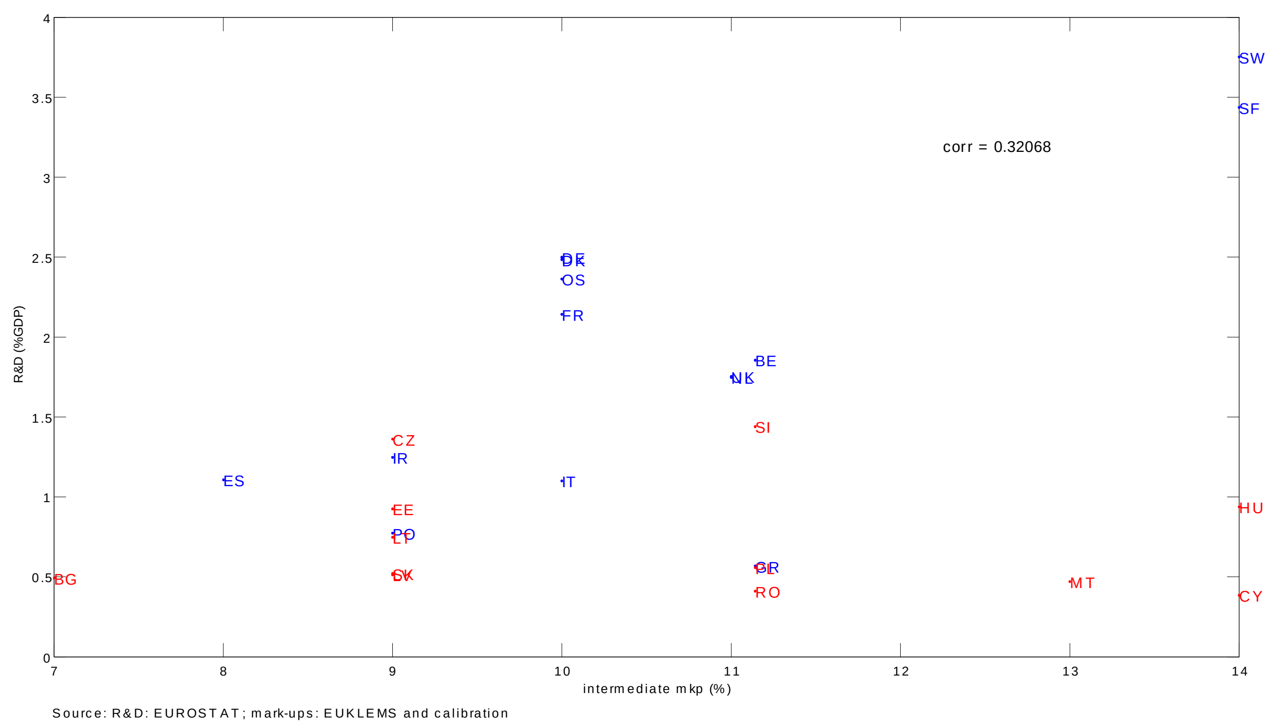


Figure 2: R&D intensities and intermediate goods mark ups (average over 2003-2007)



$$1 + g_A = (1 + g_n)^{\frac{\lambda}{1-\phi-\xi}} \tag{b}$$

$$\lambda \cdot P_t^A \Delta A_t = W_t^H \cdot L_t^{HA} \tag{c}$$

$$rdi_t = \frac{P_t^A g_A A_{t-1}}{P_t Y_t} \tag{d}$$

$$i_{A,t} P_t^A + (i_{A,t} + \pi_{A,t}) FC_A = \pi_t, \quad \text{where} \quad \pi_t = \eta (1-\theta)(1-\alpha) \frac{Y_t}{A_t} \tag{e}$$

$$i_A = \frac{(1-\tau^A)(i_t - \pi_{t+1}^A + \delta^A) - t^K \delta^A}{(1-t^K)} + rp_t^A \tag{f}$$

$$K_t = A_t x_t \tag{g}$$

The first equation is the spillover-augmented version of Jones (1995) R&D production. Equation (b) states the balanced-growth relationship between the growth of ideas $g_A (= g_{A^w})$ and population g_n, equation (c) is the first order condition of R&D production, equation (d) defines R&D-intensity: total R&D expenditure of the intermediate sector in percentage of GDP. Equation (e) states the free-entry condition between the profit of the intermediate sector (π_t), and the per unit price of R&D inventions (P^A) and the fixed (entry) cost FC_A. Equation (f) defines the rental rate of intangible capital which takes into account that households pay income tax at rate t_t^K on the period return of intangibles and they receive tax subsidies at rate τ^A. Since one unit of capital is used to produce one unit of intermediate good (x_t), equation (g) states the identity between the total intermediate goods production and physical capital under symmetric equilibrium.

In the first step of the calibration of knowledge parameters, we set the level of domestic stock of knowledge (A) at one. Although we do not have direct estimates of ν, ϖ, ϕ and λ for each country respectively, we can use the existing literature and the model restrictions to get calibrated values for them. Data on the R&D share of labour (L_t^{HA}) and on the R&D intensity $\left(\frac{P_t^A \Delta A_t^D}{P_t Y_t}\right)$ is obtained from EUROSTAT, the values of g_A and g_n are given in our baseline model[6]. Note that in our model the output elasticity of research labour (λ) corresponds to the wage share of R&D labour in the total R&D spending (equation c). These values together with the restrictions of the balanced growth dynamics and other variables of the baseline pin down P^A. In order to set ϕ and ϖ we first express the sum of these two parameters from equation (b), then we use the estimated long-term relationship between λ and ξ from Bottazzi and Peri (2007) to approximate ϖ separately. The authors do not estimate directly ϕ and ϖ, however their estimated cointegration vector contains two coefficients μ and γ, satisfying the following theoretical restrictions between the long-term coefficients of λ, ϕ and ϖ:

$$\mu = \frac{\lambda_{long-term}}{1 - \phi_{long-term}}$$

and

$$\gamma = \frac{\varpi_{long-term}}{1 - \phi_{long-term}}.$$

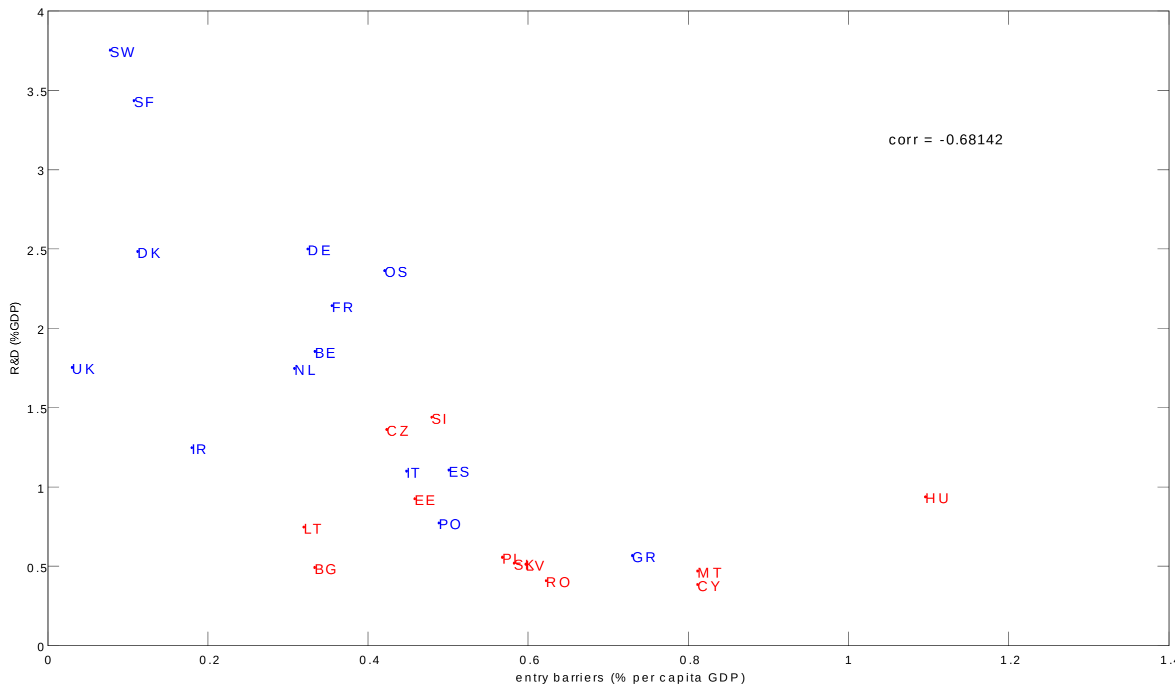
The estimated values for these two coefficients show fairly big variations under the different regressions, and it might be inadequate to apply these long-term coefficients on our "contemporary" specification. However the ratios of these two coefficients $\frac{\gamma}{\mu} = \frac{\varpi_{long-term}}{\lambda_{long-term}}$ vary less, furthermore, imposing the ratio of the long-term parameters instead of their exact values is also less restrictive[7]. In the last step we subtract this value from the sum of ϕ and ϖ as we calculated from equation (b) earlier. Finally, we normalize the stock of foreign ideas to one and therefore ν can be obtained from expression (a).

The parameters in intermediate goods production are calibrated according to the entry costs estimations of Djankov et al. (2002), and the estimations for R&D related subsidies (τ^A) in Warda

[6] Pessoa (2005) provides estimates for the growth of patents or ideas in various OECD countries at an average of $g_A = 0.057$. The population growth g_n is obtained from EUKLEMS potential output calculations.

[7] We use the estimation results without the US in the sample.

Figure 3: R&D intensity (average over 2003-2007) and entry barriers (2002)



Source: R&D: EUROSTAT; entry barriers: Djankov et. al (2002)
Entry barriers are defined as the cost of starting up a company in % of per capita GDP

(2006). Given the stock of domestic ideas (A_t), equation (g) pins down the per firm quantity of intermediate goods production. The profit of a representative intermediate firm is determined by its production and the net mark-up of the sector[8]. All other variables given, the arbitrage equation (e) gives the rental rate of intangible capital, i_t^A. The B-indices published in Warda (2006) can be applied to calibrate τ^A and t^K. Finally, we use the definition of equation (f) to obtain as residual the calibrated approximation of the risk-premium on intangibles, rp_t^A:

$$rp_t^A = \frac{\eta\,(1-\theta)\,(1-\alpha)\frac{Y_t}{A_t} - \pi_{A,t} FC_A}{P_t^A + FC_A} - \frac{(1-\tau^A)(i_t - \pi_{t+1}^A + \delta^A) - t^K \delta^A}{(1-t^K)}$$

Figures 3 and 4 demonstrates that countries with higher entry barriers and higher calibrated risk premia on intangibles tend to have lower R&D intensities, while Figure 5 show a strong positive correlation between R&D intensities and research labour inputs. Strikingly in all comparisons new member states are typically situated on the bottom part of the plots with low R&D intensities, high levels of entry barriers and risk premia while the technology leaders Sweden, Finland, Denmark and Germany are in the top corners with high R&D intensities and low levels of R&D barriers.

2.3 Labour market

We use information from our estimation of the core QUEST III model (see Ratto et al. (2009)) to calibrate the parameters of the utility function, labour supply elasticity and the frictional parameters. Labour force is disaggregated into three skill groups: low-, medium- and high-skilled labour. We define high skilled workers as that segment of labour force that can potentially be employed in the R&D sector, i.e. engineers and natural scientists. Our definition of low-skilled

[8] We use the net mark-up of the manufacturing sector calculated in EUKLEMS to obtain θ, the inverse of the gross mark-up in the intermediate sector.

Figure 4: R&D intensity and risk premium on intangible capital (average over 2003-2007)

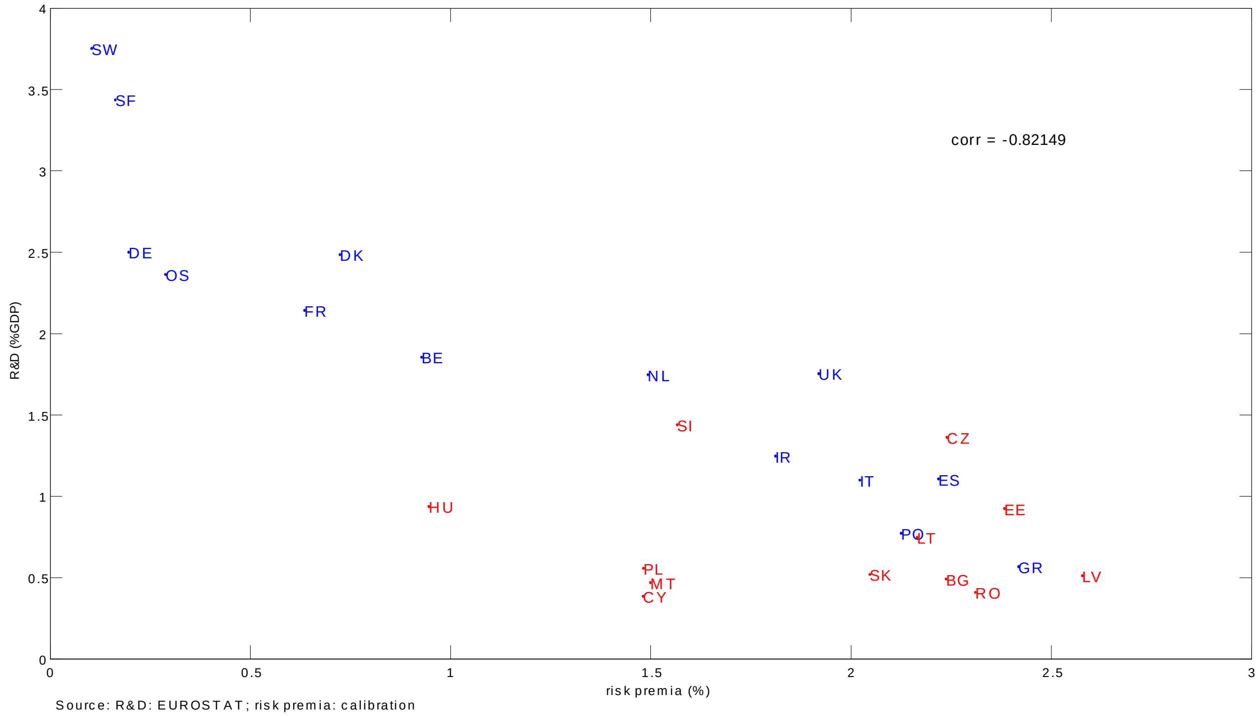


Figure 5: R&D intensity and research labour (average over 2003-2007)

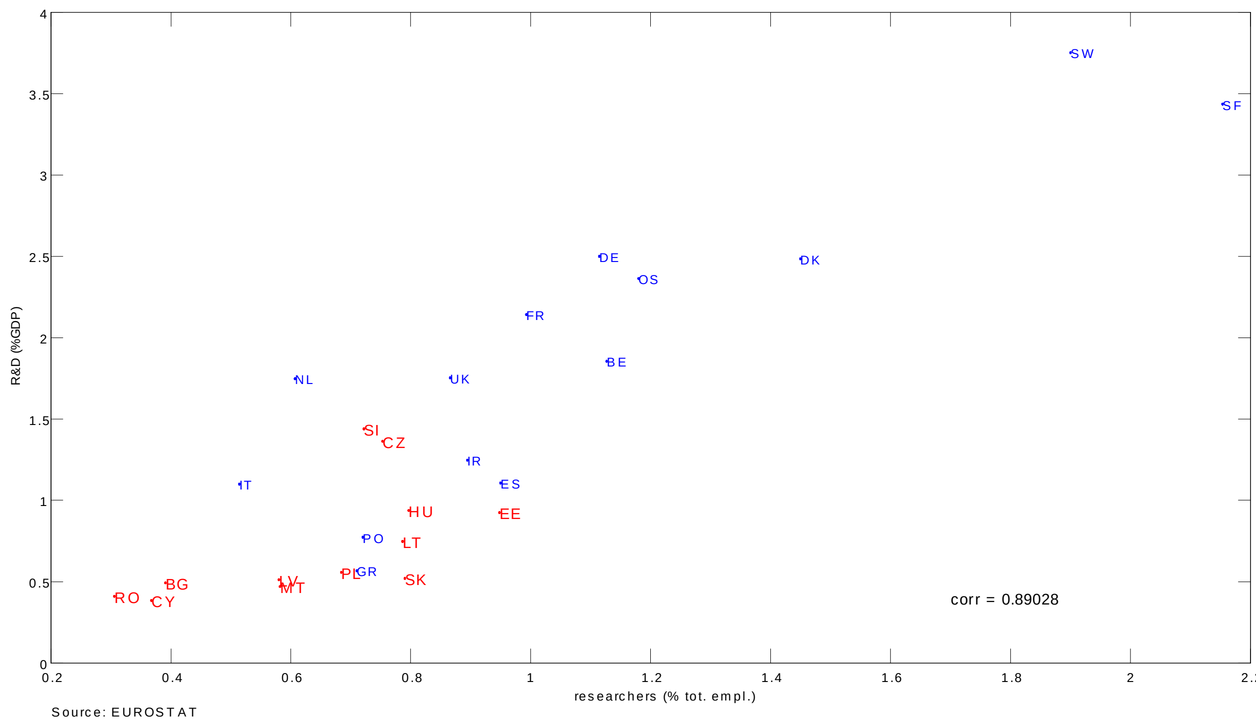
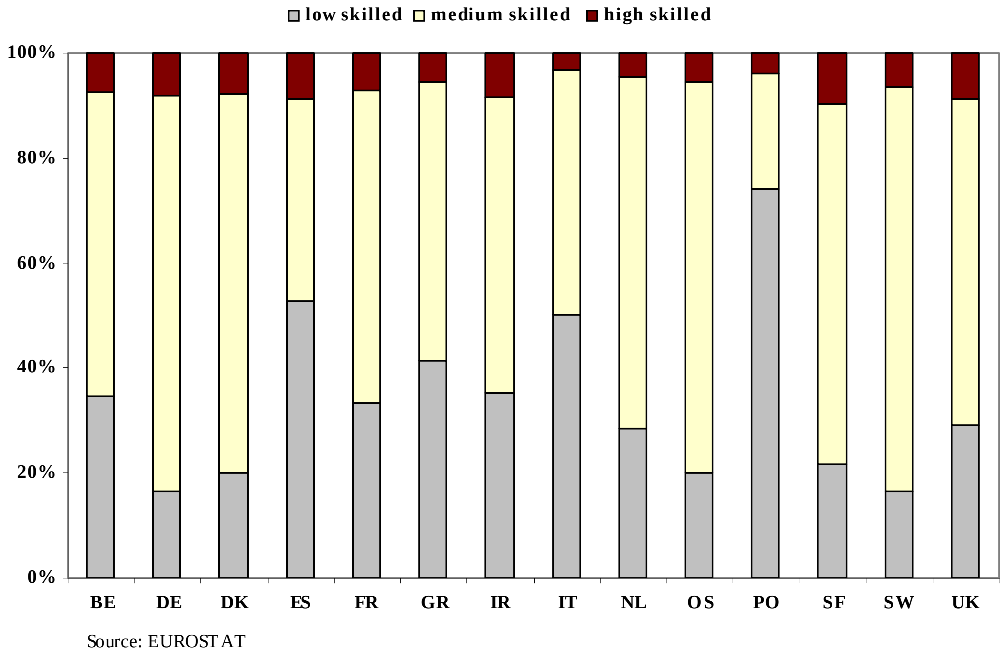


Figure 6: Population shares (OMS, average over 2003-2007)



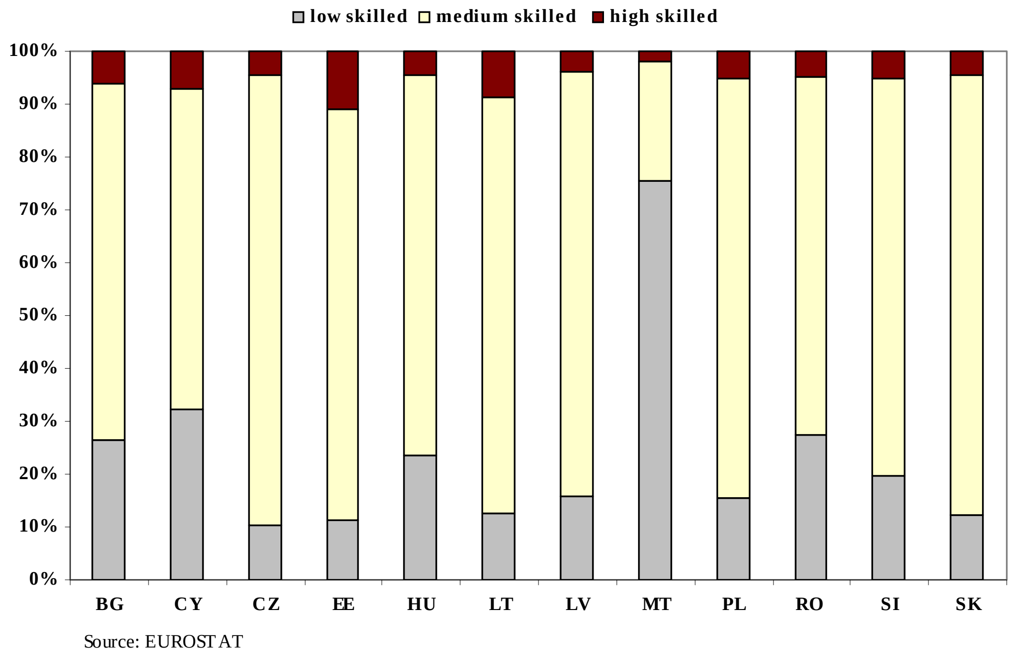
corresponds to the standard classification of ISCED 0-2 education levels and the rest of the labour force is considered as medium-skilled. Data on skill-specific population shares, participation rates and wage-premia are obtained from OECD (2006), the Labour Force Survey and Science and Technology databases of EUROSTAT. The comparison of skill-shares across countries (Figures 6 and 7) shows that the share of high-skilled varies less compared to the other two skill-categories. Malta and Portugal and to a lesser extent Spain and Italy have high shares of low-skilled labour force than other old and new member states. Although the elasticity of substitution between different labour types (σ_L) is one of the major issue addressed in the labour economics literature, to our knowledge elasticities of substitution for our three types of skills are not estimated in the literature. Therefore we set σ_L at 2, which is at the upper bound of the current estimates (Katz and Murphy (1992)). Given the efficiency of low-skilled, the other efficiency units are restricted by the labour demand equations which imply the following relationship between wages, labour-types and efficiency units:

$$ef_m = \left(\frac{w_m}{w_l}\right)^{\frac{\sigma_L}{\sigma_L-1}} \left(\frac{s_m L_m}{s_l L_l}\right)^{\frac{1}{\sigma_L-1}} ef_l$$

$$ef_h = \left(\frac{w_h}{w_m}\right)^{\frac{\sigma_L}{\sigma_L-1}} \left(\frac{s_h L_h - L_A}{s_m L_m}\right)^{\frac{1}{\sigma_L-1}} ef_m$$

Note that these efficiencies are proportional to the relative population shares and to the low-skilled efficiency level, ef_l. For the calibration exercise we set ef_l so that it satisfies the production function equation. The benefit replacement rate (b^s) is set at 30% for the old member states and 40% for the new member states, while $\chi^c = 1$ and $\chi^w = 0$ (i.e. the benefit replacement rate is indexed to consumer prices). Finally, the inverse elasticity of labour wrt. wages (κ) takes the value -5 for all countries in each skill-group.

Figure 7: Population shares (NMS, average over 2003-2007)



2.4 Taxation

Corporate tax rates and the calculated tax-credits (t^K and τ^A) are taken from Warda (2006) and we use DG TAXUD and Eurostat data to set the tax-rate on consumption (t^C) and transfer-shares (tr) respectively. Finally, we calibrate the total tax burden on labour (t^L) so that the government budget is consistent with the 2003-2006 government debt averages. Figure 8 shows the expected negative correlation between labour taxes and employment rates. It is worth noting that as a result of the calibration we obtain a somewhat negative correlation between indirect and direct taxation; countries with higher labour taxes tend to have lower taxes on consumption and vice versa (Figure 9). The calibration of the individual country models is detailed in the Appendix (Tables 1 and 2)[9].

[9] For each variable which is obtained from statistical resources we take the average over the period of 2003-2007 whenever it is possible.

Figure 8: Labour taxes and employment rates (average over 2003-2007)

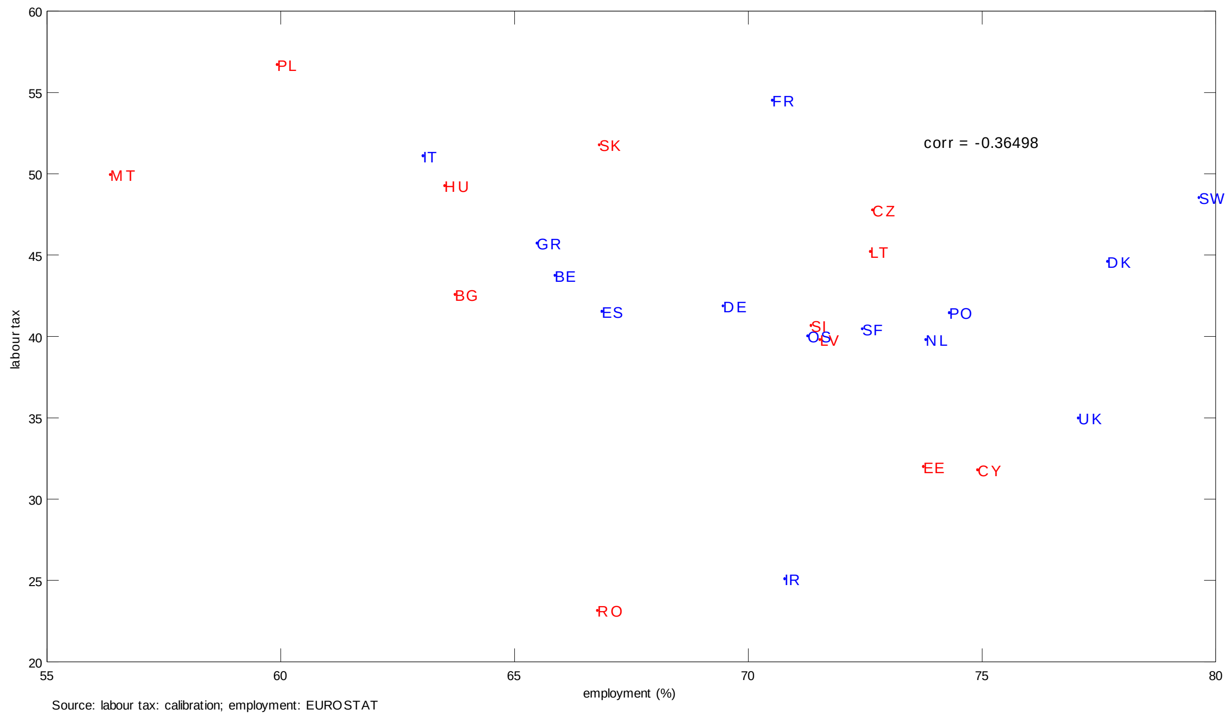
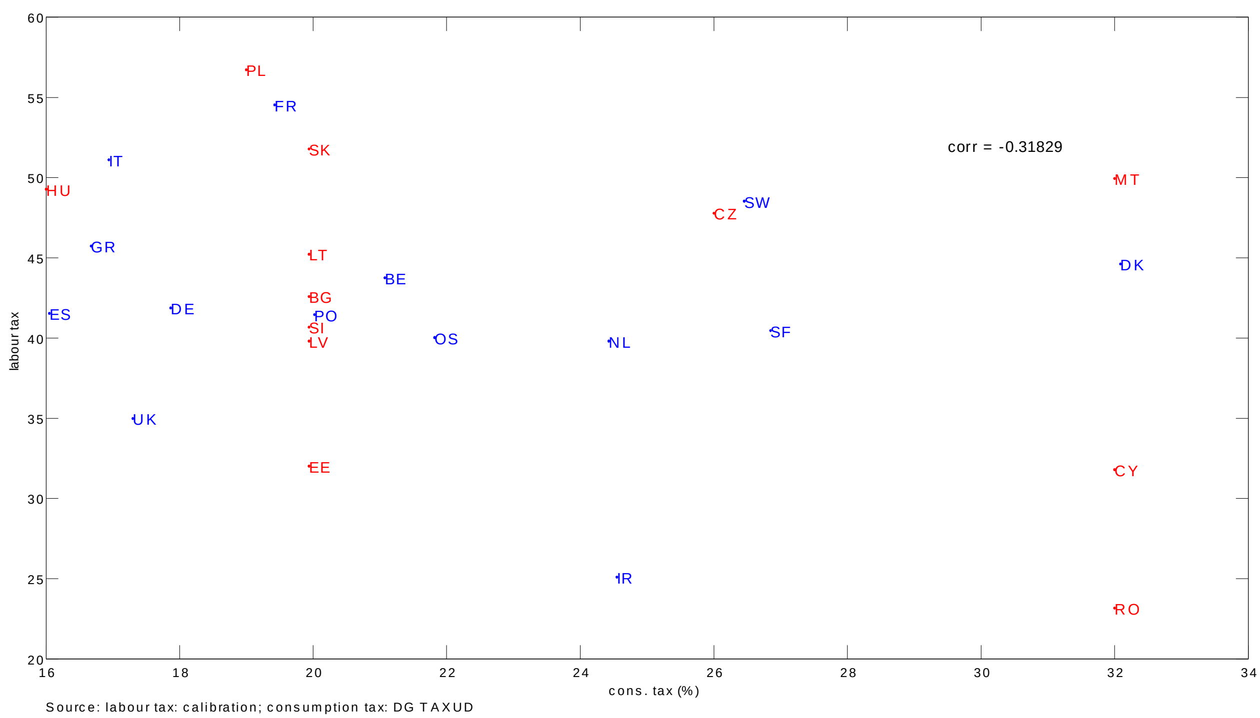


Figure 9: Labour vs. consumption taxes (average over 2003-2007)



3 Scenarios of reforms

This section presents illustrative scenarios of structural reforms and their effects on the economy using the country models. The simulations we consider are the same as in Roeger et al. (2008) and they consist of R&D promoting policies, product market reforms lowering capital costs, fixed costs, entry barriers and mark-ups, labour market reforms such as tax shifts, changes to benefit generosity and changes in skill composition. More precisely, the reform scenarios considered are the following:

1. Raising R&D through subsidies: tax-credits and wage subsidies;
2. Reducing product market mark-ups;
3. Reducing capital costs;
4. Reduction in fixed costs;
5. Exogenous productivity shock;
6. Reducing wage mark-ups;
7. Tax shifts: from labour to consumption and from low- to high-skilled;
8. Reducing benefit generosity;
9. Raising human capital.

For each reform scenario, we compare the simulation results across countries and explore the reasons behind the differences by carrying out multiple regressions on the main underlying parameters/variables. We analyse simulation results for GDP and consider the effects of the policies adopted within the various reform scenarios after 20 years[10]. For each scenario and time, we perform a stepwise linear regression and select the five parameters/variables that explain most of the cross country variations. In the sensitivity analysis plots presented hereafter, we show the scatterplots of the GDP simulation results versus the five most important parameters that affect the scenario[11]. Moreover, we report:

1. the R^2 of the multiple regression, which shows the portion of GDP variability explained by the five selected parameters;
2. the partial R_i^2 of each of the five selected parameters, which shows the portion of GDP variability that is explained by univariate regressions, using each selected parameter singularly. This indicates the 'sensitivity' of the GDP results to each of the selected parameters.

3.1 Raising R&D through tax credits and wage subsidies

Government support to R&D activity is justified by the fact that social returns on R&D investment are often higher than its private returns. R&D subsidies lower the cost of private R&D and therefore promote investment in research projects. The role of fiscal incentives in raising R&D has been the focus of a growing number of studies. Bloom et al. (2002) examine the effect of tax credits on the level of R&D investment for a panel of nine OECD countries, finding that a decrease of 10% in the cost of R&D increases its level by approximately 1% in the short run and just under 10% in the long run. Guellec and Potterie (2003) also analyse the impact of R&D funding in OECD countries and conclude that the effect of tax incentives is positive and most effective when the policy is stable over time.

[10] We will consider a 50 year horizon for the human capital scenarios where the timespan of the shocks are over 40 years.

[11] In the scatterplots, the values of the parameters/variables are highlighted in red for the countries which joined the EU from 2004 on and in blue for the old Member States.

In what follows, two alternative policies are considered. In the first scenario, the subsidy to R&D consists of a permanent tax credit (τ^A) of 0.1 percent of GDP granted to the non-liquidity constrained households on their income from intangible capital (therefore $\Delta\tau^A P_t^A J_t^{A,i}/Y = 0.1$). Figure 10 shows the GDP effect of the shock for each member state in terms of percentage deviation from the baseline. The subsidy is financed in a budgetary neutral manner through an increase in lump-sum taxes paid by households. The simulations illustrate an important feature of semi-endogenous growth models: in the long run, permanent subsidies to R&D-using sectors yield a permanent increase in the level of GDP, while GDP growth stabilizes. Note that it takes time for the output effect to emerge because of short run output losses due to the reallocation of high skilled workers from production to research.

An increase in tax credits allows households to lower the rental rate for intangibles, thereby reducing the fixed costs faced by intermediate goods producers. This translates into a rise in the demand for patents, stimulates R&D and causes a reallocation of high skilled workers from production into the research sector. The size of the effect shows large variations across the member states. After 20 years, the GDP increase relative to the baseline ranges from 0.05% (Sweden) to 1.92% (Cyprus). Because of supply constraints for high skilled workers, part of the fiscal stimulus is offset by wage increases for high skilled workers.

The second policy considered is a permanent fiscal incentive of 0.1 percent of GDP consisting of a subsidy (τ^w) granted to the R&D sector on the wages of researchers ($\Delta\tau^W w^H L_A/Y = 0.1$). Subsidies are again financed through lump-sum taxes. The results (reported in Figure 12) show less variation in the GDP effects: 0.09 (Sweden) to 0.68 (Bulgaria) percent increase in GDP relative to the baseline 20 years after the initial shock.

The multiple regressions (Figures 11 and 13) point to three major groups of factors behind the cross-country differences. An important explanatory factor lies behind the design of the shock, which depends on the intensity of the R&D environment in the respective country. In particular, we observe that countries with low R&D intensity (R&D investment as a percentage of GDP and research labour, L_A) gain the most from R&D promoting policies. This is partly due to the fact that the 0.1% of GDP policy measure finalised to boost the knowledge sector represents a proportionally stronger shock for countries investing less in R&D (notice that $\Delta\tau^A = 0.1/(P_t^A J_t^{A,i}/Y)$ and $\Delta\tau^W = 0.1/(w^H L_A/Y)$[12]) and is proportionally smaller for the R&D intensive countries (Sweden, Finland, Denmark)[13].

Concerning the role of entry costs (FC_A) and risk-premia (rp^A), first note that the countries with low R&D intensity are typically characterized by higher entry-barriers to the R&D intensive intermediate sector (high FC_A and rp^A) and, as we saw earlier, by construction of the shock, these countries receive a stronger boost to their R&D sector. In addition, one can see from the arbitrage equation (21a) that the cost of entering into the intermediate sector depends on $i_t^A FC_A$ and $i_t^A P_t^A$. Increasing the tax subsidies and therefore reducing the rental rate of intangibles is magnified by the size of administrative costs: the higher the costs, the higher the multiplier on τ^A. In the case of the wage subsidy, the effects of declining patent prices are magnified by the risk-premia in the rental rate of intangibles (which also appears among the factors explaining the cross-country differences).

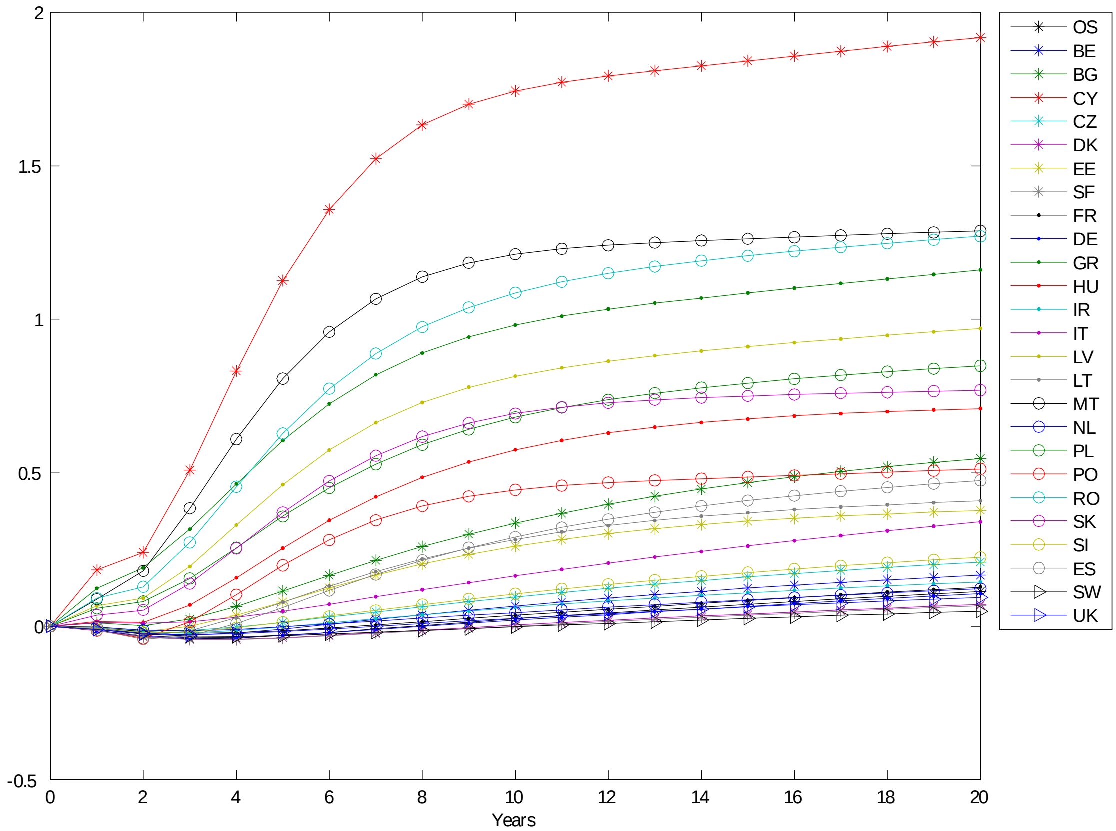
A second set of factors driving the results is given by the parameters governing knowledge production and in particular by the elasticity of R&D production on the number of researchers, λ, and the total factor efficiency of R&D production, ν. The higher the values taken by these parameter, the bigger the increase in the production of new designs in response to the tax credit. The last explanatory factor is the percentage of GDP spent on government consumption (G/Y). The role of government consumption is not obvious, but can be probably best interpreted as an indicator of the overall tax-burden in the country.

According to these model simulations, wage subsidies in the R&D sector are less efficient than tax

[12] Where $P_t^A J_t^{A,i}/Y$ is the R&D intensity and $w^H L_{RD}/Y$ is the labour cost of R&D production in terms of GDP.

[13] In order to better explore the link between R&D intensity and the effect of the subsidies on GDP, alternative simulations have been ran where the increase in the tax credit or in the subsidy on researchers' wages is identical for all countries (0.1%). Even though cross-country variations are much smaller than in the case illustrated in Figure 1, R&D intensity still plays a role in explaining the impact of the tax incentive on GDP. In the case of the wage subsidy, however, factors other than R&D intensity drive the effects of the policy.

Figure 10: 0.1% of GDP tax credit (% deviation from baseline)



Source: QUEST III simulations

credits for countries with relatively low R&D spending, while the opposite is true for countries with higher R&D intensities. It can be shown that the presence of a positive mark-up in the intermediate goods sector lowers the efficiency of the tax credit, while R&D production is assumed to be perfectly competitive. Notice that the R&D intensive countries have relatively higher intermediate mark-ups which might explain the less efficient tax credit shocks in their cases. As argued in the literature (see Goolsbee (1998) and Wolff and Reinthaler (2008)), tax subsidies have significant crowding out effects in the form of higher wages for high skilled workers as their labor supply is quite inelastic. As a result, when the government funds R&D, a significant fraction of the increased spending goes directly into higher wages. Another explanation is that a smaller relative size of research labour implies a higher rate of return from an increase of human resources devoted to R&D ($\frac{\Delta PAT}{\Delta L_{RD}}/PAT = \lambda/L_A$), which also explains the stronger endogenous growth effect for countries with lower R&D labour intensity.

3.2 Reducing goods market mark-ups

Product market reforms in goods markets can be simulated as shocks that reduce the mark-up of prices over marginal costs. In standard DSGE models, the link between the degree of competition (as measured by the mark-up) and the level of economic activity is unambiguous. A mark-up decrease always has a positive effect on the demand for labour and on employment. Everaert and Schule (2006), using the IMF's Global Economy Model and taking France and Belgium as case studies, find that lower mark-ups in the goods sector lead to an increase in GDP by $1.2-1.6\%$, while reforms in the services sector have a stronger effect ($4.9-7.3\%$). The rise in GDP is accompanied

Figure 11: Regression analysis, tax credit

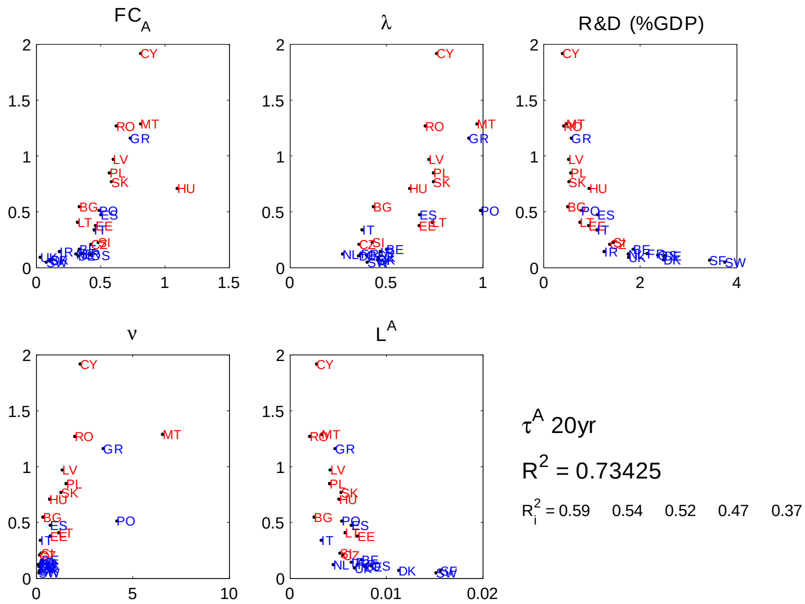


Figure 12: 0.1% of GDP wage subsidy (% deviation from baseline)

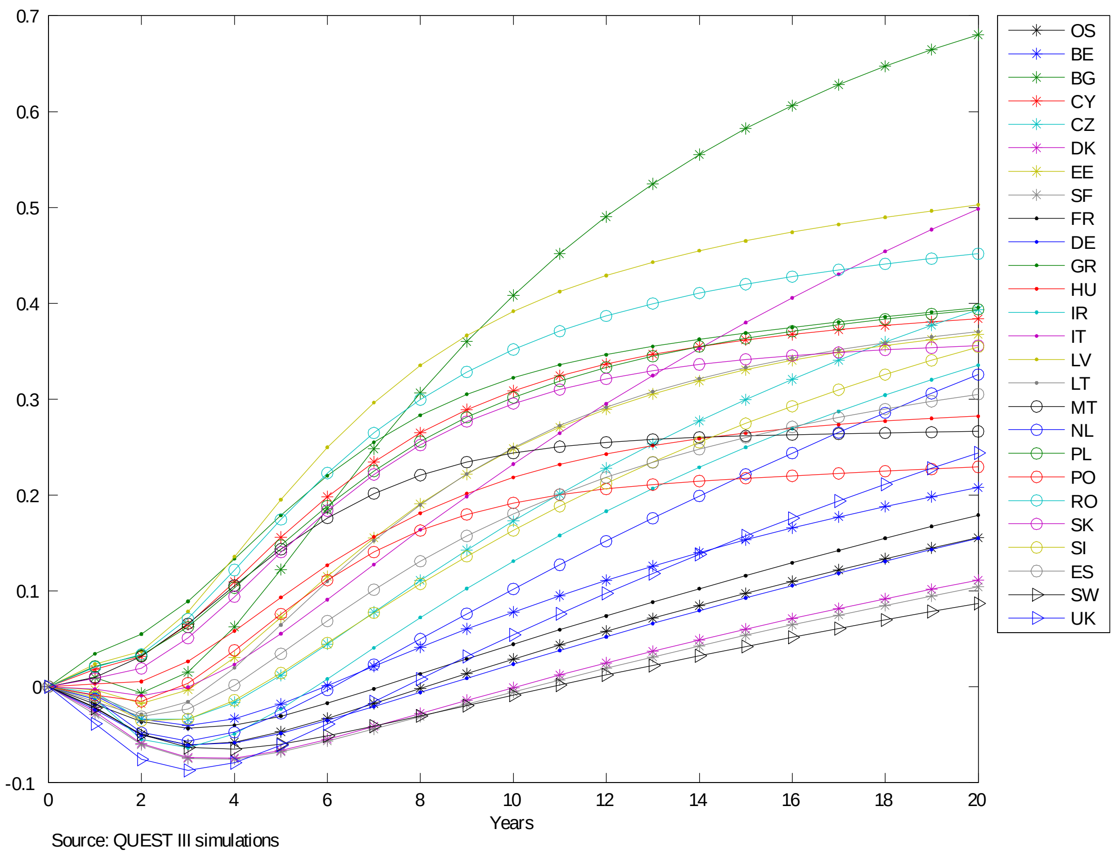
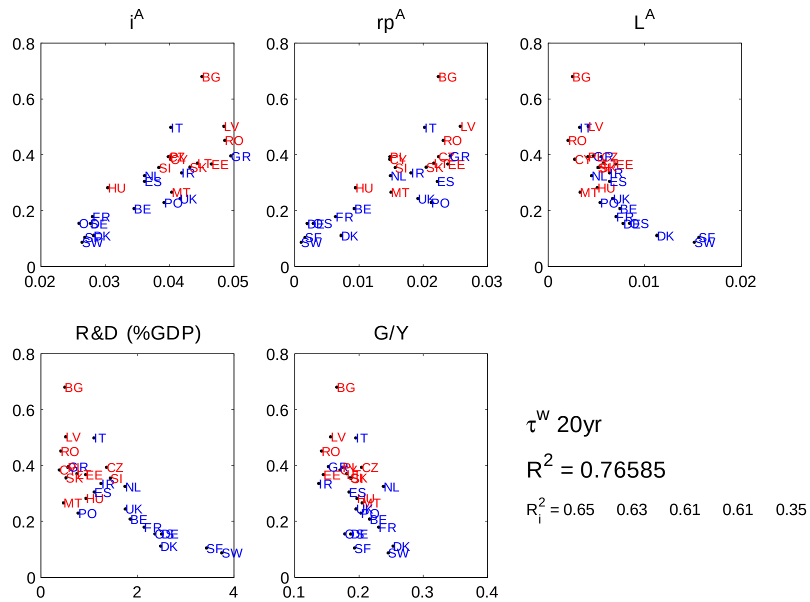


Figure 13: Regression analysis, wage subsidy



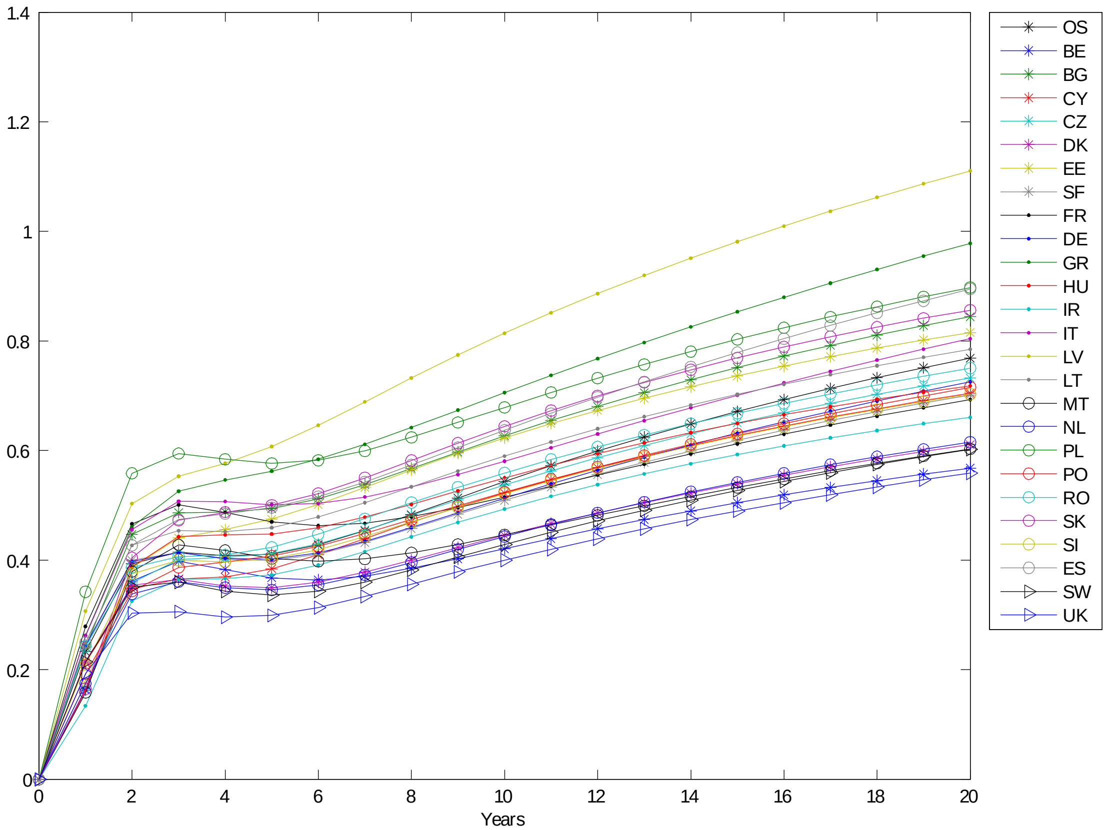
by a more than proportional increase in the capital stock and a less than proportional positive effect on hours worked and consumption. These results are mainly driven by the initial size of the mark-ups and the elasticity of output and employment to relative prices. Similar conclusions are reached by Kilponen and Ripatti (2006) for the Finnish economy.

However, the relationship between mark-ups and output is more complex in an endogenous growth model: in fact, the existence of a mark-up is required to cover the sunk costs associated with the purchase of a patent by firms entering the intermediate goods' market. Due to the presence of this additional transmission channel, a mark-up reduction in the intermediate goods sector operates through two counteracting mechanisms. First, the decline in the price of goods stimulates demand for the output of incumbent firms. On the other hand, the lower price reduces entry of new firms and thereby the rate of technical progress. Thus, a mark-up reduction is expected to have a positive impact on GDP in the final goods sector (where the second channel does not operate) and an ambiguous effect in the intermediate goods sector.

3.2.1 Final goods sector

Figure 14 shows the GDP effect of a 1% reduction of the price mark-up in the final goods sector. After 20 years, GDP increases by 0.56 (UK) to 1.11% (Latvia). This is partly ascribable to the endogenous growth effect generated by an increased demand for capital, which stimulates entry of new firms and increases R&D production. The variation in the cross-country results is mostly explained by the labour (capital) share of final good production, by the aggregate and medium-skilled workers' employment rates, L and L^M, and by the government consumption share. A mark-up reduction in the final goods sector increases the demand for all factors of production (tangible capital, K, intangible capital, A, and labour, L). Two factors are important for the output effect: the supply response of production factors and the response of output to a marginal change in the factor that is changing. Concerning the first effect, note that L is inelastically supplied in the long run, i. e. a reduction in mark-ups hardly changes the structural employment rate, but will mostly increase the real wage. Therefore, labour market characteristics are not crucial. However, tangible capital will adjust in the long run (because capital costs will not change and will be tied down by

Figure 14: 1pp level reduction of the final goods market mark-up (% deviation from baseline)



Source: QUEST III simulations

the world interest rate). Thus, the variables determining the first order condition for capital are crucial for the output effect of a mark-up reduction. This can best be seen if the FOC is rewritten in the following form:

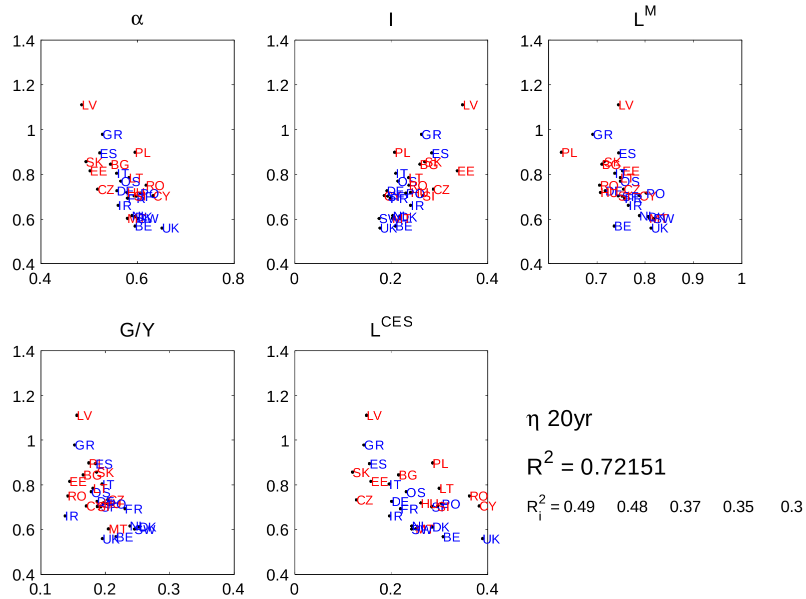
$$Y = \frac{K(r + \delta + rp^K)}{(1-\alpha)\eta} - FC_Y \tag{rk}$$

This expression shows that the output effect of a reduction in the mark up will positively covary with the share of capital in production $K \cdot MP_K$ (where MP_K is measured by the capital cost term $\left(r + \delta + rp^K\right)$) and the output elasticity of capital $(1-\alpha)$. Note that investment (I) appears instead of K as an indicator because it depends positively on K and the depreciation rate δ. The capital share is inversely related to the labour share, α, which explains the presence of L in the regression results.

3.2.2 Intermediate goods sector

As shown in Figure 16, a mark-up reduction in the intermediate goods sector has significantly smaller GDP effects (from -0.02% in Cyprus to 0.33% for Germany). This is due to the fact that two offsetting mechanisms are at work. The capital stock increases as a lower mark-up entails an increase in the scale of output of incumbents. However, the mark-up reduction also deters entry and therefore slows down technical progress. In some of the member states the two effects balance each other, so that the impact on GDP is close to zero. The smaller the negative entry-effect, the smaller the additional fixed costs which are required to enter into the market. Therefore it is not surprising that countries with a low rental rate of intangible capital, low initial entry costs (low i^A

Figure 15: Regression analysis, final goods mark-up



and FC_A) and high R&D intensity experience less of this negative effect. Finally, a low elasticity of R&D production and a high initial level of high skilled labour employed in the R&D sector are associated with bigger GDP effects, as they moderate the negative impact on R&D production of the decrease in the demand for patents arising from reduced entry in the intermediate sector.

3.3 Reduction of capital costs

This section discusses the effects of an exogenous reduction of capital costs, which can be thought of as a decrease in the equity premium on physical and intangible capital (rp_t^K or rp_t^A). These reductions are often associated with the stronger competitive pressures resulting from deeper financial market integration.

3.3.1 Final goods sector

Financial market integration is likely to reduce lending costs through an increase in risk sharing opportunities and in banking competition. Hardouvelis et al. (2007) estimate that the increased stock market integration resulting from the convergence process towards the EMU during the 1990s has substantially reduced the cost of equity capital in the countries involved. The estimated fall in the cost of equity ranges between 0.85 percentage points in the case of Spain and 1.96 percentage points for France. A large literature also finds evidence of a strong positive relationship between financial development and output growth, see, among others, King and Levine (1993), Rajan and Zingales (1998) and Levine and Zervos (1998). More recently, Guiso et al. (2004), using data on EU countries, estimate a positive effect of financial development on growth and calculate that the impact on manufacturing output growth of raising the level of financial integration to US standards would amount to 0.89 percentage points. The effect is bigger the lower the degree of financial development and the higher the degree of specialisation of the country in financially dependent sectors.

In our simulations, a 0.5% reduction in capital costs increases GDP by between 1.14% (Lithuania) and 2.13% (Greece) after 20 years (Figure 18). The output effect is driven by an increase in the demand for capital, which in turn stimulates market entry and innovation, and is therefore

Figure 16: 1pp level reduction of the intermediate goods market mark-up (% deviation from baseline)

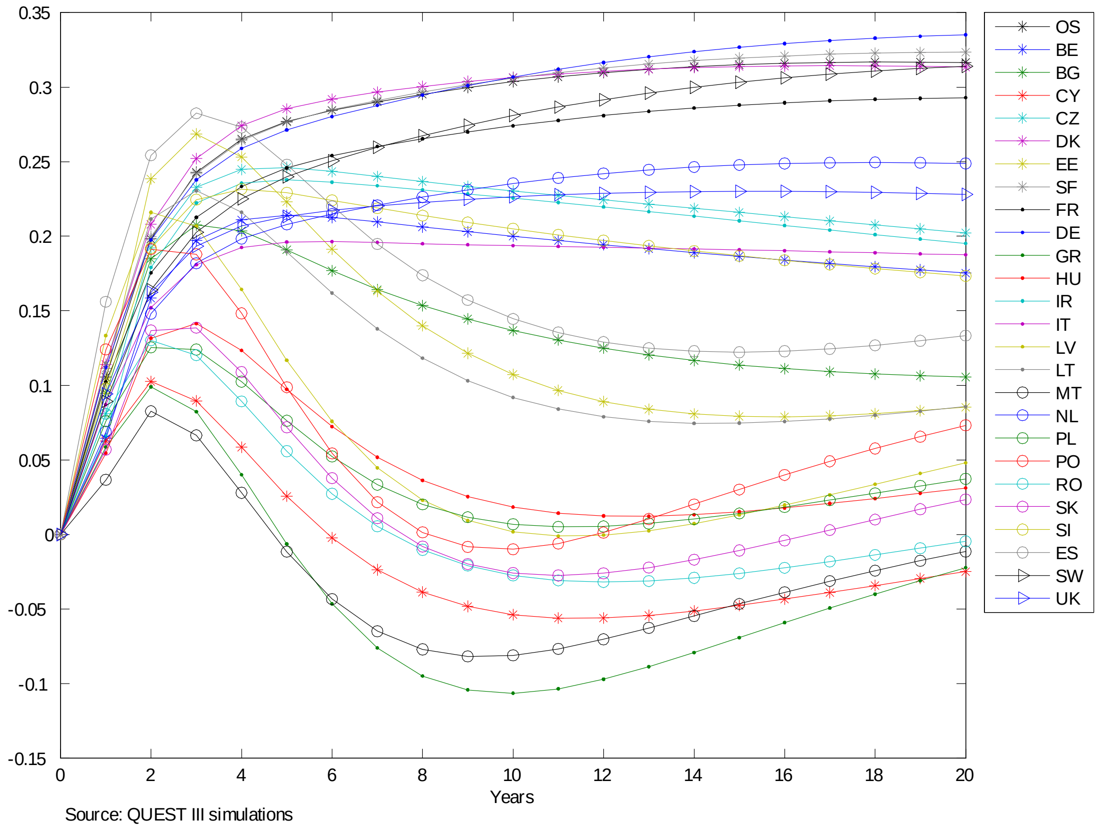


Figure 17: Regression analysis, intermediate goods mark-up

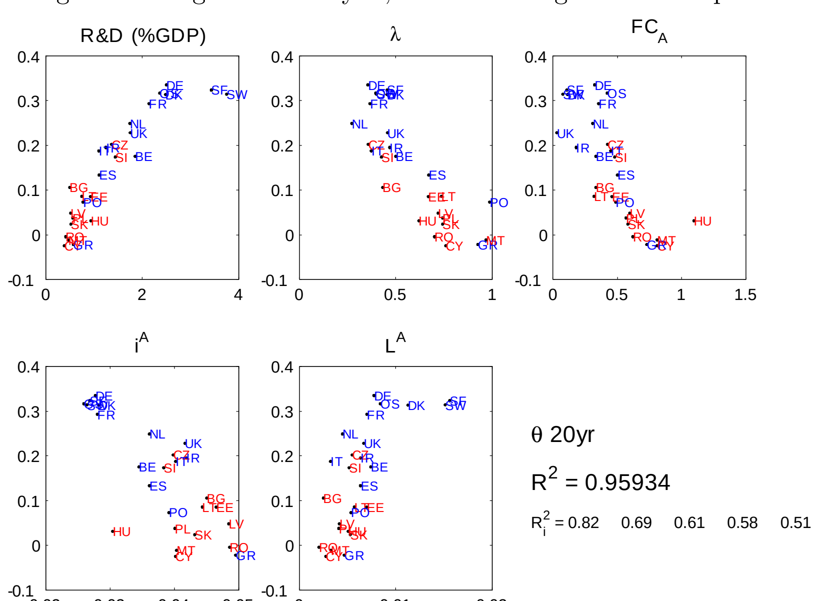
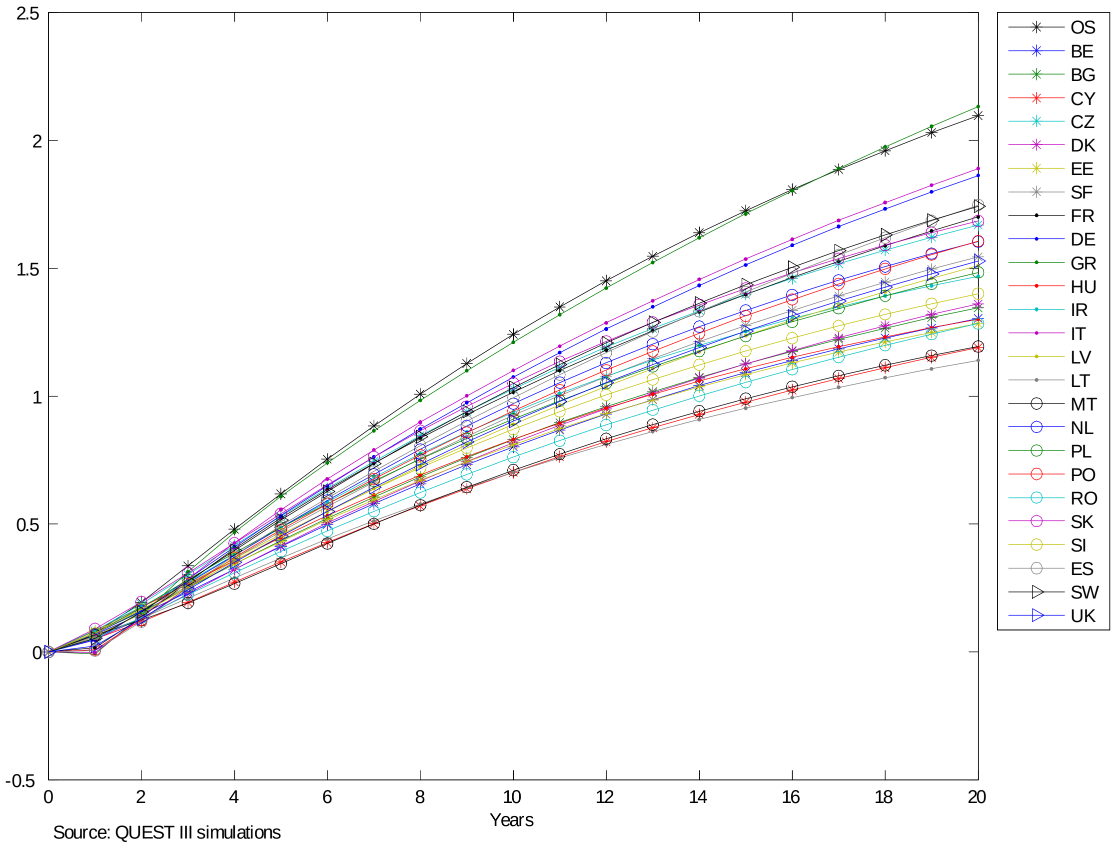
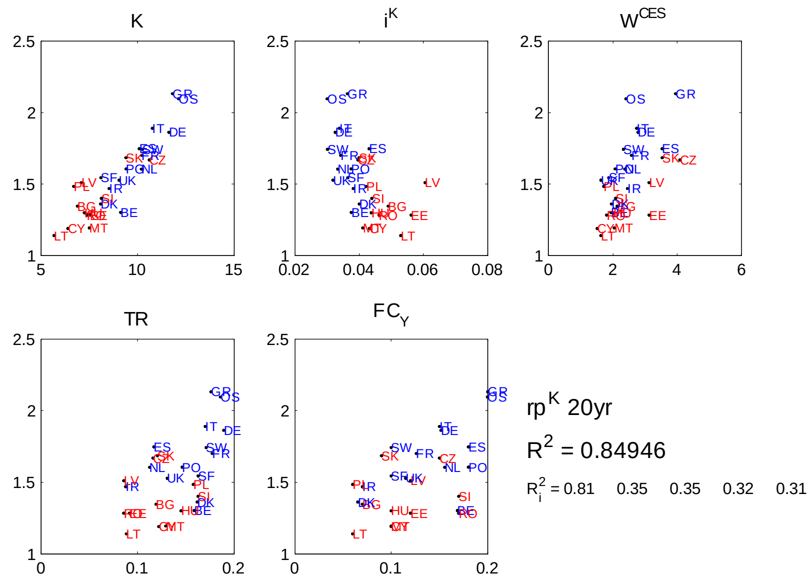


Figure 18: Reduction of tangible capital costs, final goods sector (% deviation from baseline)



higher than the impact the same shock would have in a standard growth model. Figure 19 shows that the cross-country impact of a reduction in capital costs depends positively on the stock of capital in the economy (K) and negatively on the initial level of the rental rate of tangible capital (i^k). The output effect is also larger the higher the aggregate wage level (as expressed by the CES aggregate of wages in the final goods sector, W^{CES}). As the wage level depends on the efficiency of the different skill groups, it can be taken as an indicator of the efficiency of labour in the country of interest and is therefore associated with a bigger increase in production following a same size decrease in capital costs. The first order condition for capital (equation rk, section 4.2.1) helps explaining the role of fixed costs (FC_Y). Countries with large fixed costs in production tend to show a larger (%) output expansion with a reduction in capital cost. This is not a sign that countries with high fixed costs respond more flexibly to changes in capital cost but it rather reflects a base effect. Everything else equal, countries with higher fixed costs will have a lower level of output for the same capital input. Since fixed costs do not affect the first order condition for capital, both countries expand their capital stock equally in percentage terms. However, since the country with higher fixed costs produces less final output, the same percentage change in capital leads to a larger percentage increase in output. Finally, the role of transfers can be explained by a wealth effect. In fact, the bigger the transfer component of households' income the smaller the response of real wages to changes in the level of economic activity and the bigger the increase in employment and output.

Figure 19: Regression analysis, tangible capital costs



3.3.2 Intermediate goods sector

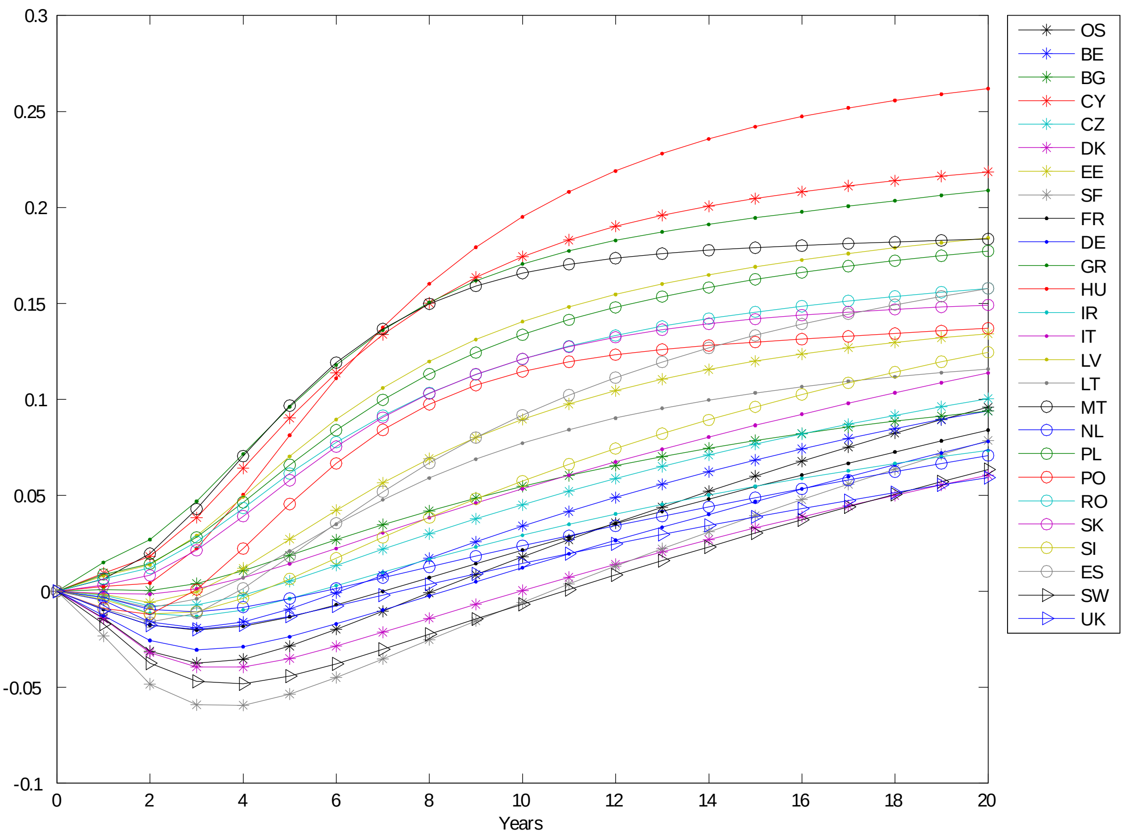
Investing in ideas is more risky compared to physical capital investment because in the case of failure of the project the initial investment (patent) may have to be written off completely, while physical investment goods still have a sizeable resale value in case of bankruptcy. Because intangibles do not constitute collateral to the same extent as tangible capital, financing constraints are likely to be more acute. And although both existing firms and start-up companies face similar problems when marketing new products, in the case of start-ups these problems are likely to be more severe. Start-ups do not have access to public capital markets and in the absence of a track record they may have more difficulties to obtain bank finance. New firms also have to overcome administrative obstacles when setting up a new company (although existing companies may face administrative costs when introducing new products as well). As pointed out in a study by Aghion et al. (2007), financial constraints related to entry could be as important as labour market rigidities in terms of obstacles to growth. When it comes to innovation, there are numerous examples which indicate that a larger share of innovations is undertaken by young firms in the US compared to the EU.

A particular form of financing innovations, namely venture capital has become a popular form of financing young firms in high-tech sectors in the US and since the beginning of the 1990s it has also become popular in the EU. It now amounts to 0.12% of GDP compared to 0.19% in the US[14]. There are numerous studies both at the micro and the macro level suggesting a positive relationship between the availability of venture capital and economic performance.[15] Venture capitalists provide loans to start-ups and they require a return to compensate for the opportunity cost of not investing in alternative assets as well as for the risk associated with such an investment. With underdeveloped venture capital markets investors lack opportunities to diversify risk and therefore require a larger risk premium. Philippon and Véron (2007) suggest a number of measures to increase the supply of venture capital financing. Among others they argue for more competition in the banking

[14] These figures are calculated as an average over the period 2004-2006 (source: Meyer (2008)). Notice however, some countries in the EU, notably those with a high-tech specialisation such as the UK, Sweden and Denmark have a share of venture capital investment that exceeds that of the US. However high tech states in the US such as California have VC investment shares far larger than EU regions.

[15] At the micro level Hellmann and Puri (2000) and at the macro level Romain and Pottelsberghe (2004) establish a positive relationship between venture capital and (productivity) growth.

Figure 20: Reduction of intangible capital costs, intermediate goods sector (% deviation from baseline)



Source: QUEST III simulations

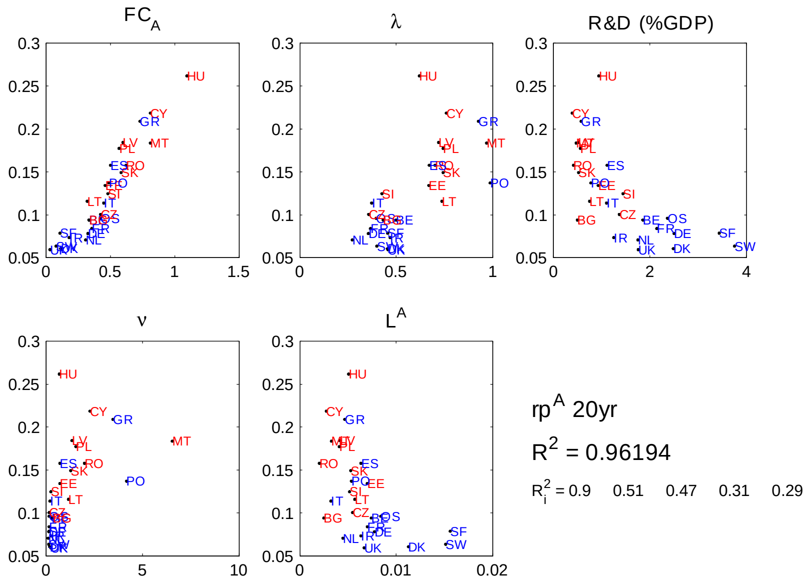
sector, changes in insolvency legislation and removal of prudential regulations, which hamper equity investment by institutional investors such as pension funds and insurance companies.

Figure 20 shows the GDP effects of a 0.5% reduction in financing costs for start-ups. Improving access to credit for start-ups makes projects which generate a lower present discounted value of profits profitable and thereby stimulates entry and the introduction of new products. In the long run the level of output could increase by about 0.06 (UK) to 0.26 % (Hungary) and investment would be directed more towards R&D with this more targeted measure. The cross-country variations are largely explained by the entry costs, FC_A, and the R&D share. Note that fixed costs for intangibles and the R&D share are closely negatively correlated. This suggests the following interpretation: the presence of high entry barriers for intangibles reduces the level of intangible capital (R&D) and keeps up the marginal product of intangible capital. The same absolute reduction in capital costs will therefore yield higher output effects in countries with a high marginal product of intangible capital. The multiple regressions also show that in countries with a higher elasticity of R&D with respect to research labour, λ, and higher R&D efficiency, ν, the knowledge sector and thus production receive a stronger boost from the reduction in intangible capital costs.

3.4 Reducing fixed costs

Financing costs faced by start-ups and the absence of venture capital, whose role was discussed in the previous section, represent indirect examples of entry barriers. This section examines a more direct example of entry barriers removal in the form of a reduction in administrative entry barriers

Figure 21: Regression analysis, intangible capital costs



or fixed costs.

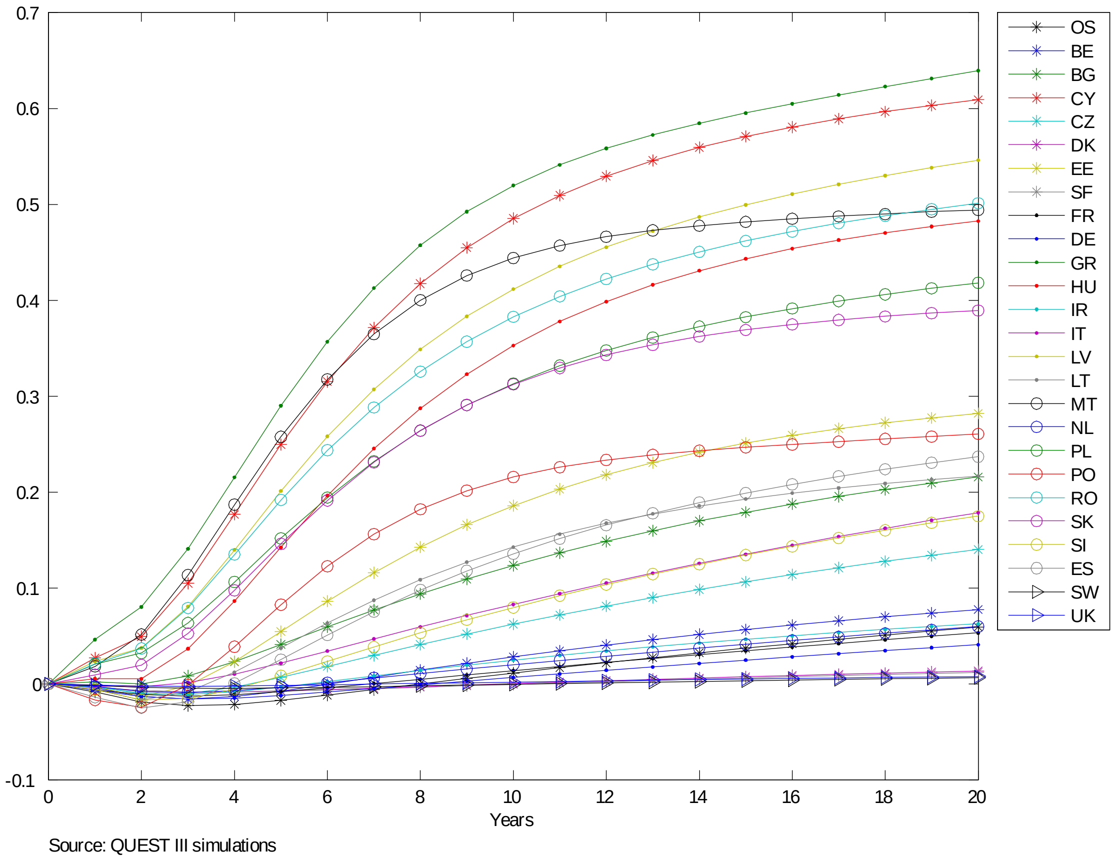
3.4.1 Reduction in entry costs in intermediate goods sector

Recent empirical studies link cross-country differences in growth performance to their degree of market regulation. Nicoletti and Scarpetta (2003) find a negative relationship between multi-factor productivity and economy-wide and sector-specific entry barriers, while Alesina et al. (2005) focus on the impact of regulations, and in particular entry barriers, on investment, providing evidence of a negative relationship between the two. Both studies also conclude that the biggest impact of the reforms occurs in potentially competitive markets. Buttner (2006) finds that reducing entry fees increases the steady state rate of innovation and therefore growth.

Figure 22 shows the GDP effects of a 10% reduction in fixed costs in the intermediate sector, FC_A (entry costs faced by intermediate firms). In the EU, administrative costs for starting a new company are much larger than in the US. However, one has to be careful when making a comparison as one important argument for a downward bias of the US level of entry regulation is the high standard of consumer protection legislation in the US. In the case of non-compliance, firms operating in the US are facing costly litigation procedures and high fines. Entry regulation in Europe can be seen as forcing firms to comply with certain health and safety standards. But given the wide variation of start-up costs in the EU it seems feasible to lower administrative entry costs towards levels prevailing in best practice countries. Here we look at the effects of reducing administrative entry barriers by 10%.

Qualitatively, the effects on the composition of investment (tangible vs. intangible) are similar to the experiment of reducing financing costs, since administrative entry barriers act like a sunk cost for potential entrants in the same way as financing costs do. However, initial financing costs exceed start-up costs significantly. Therefore also a full elimination of start-up costs would not dramatically increase GDP. Decreasing entry costs lowers the profits requirement for intermediate producers and thereby increases entry of new firms. The higher demand for patents increases the demand for high skilled workers and leads to some reallocation of high skilled workers from production to the R&D sector and an increase in their wage. The output gain ranges from close to zero (Sweden, 0.01%) to 0.64% (Greece). The cross-country differences are explained by the same factors as in the case

Figure 22: 10% reduction in intermediate firms' entry barriers (% deviation from baseline)



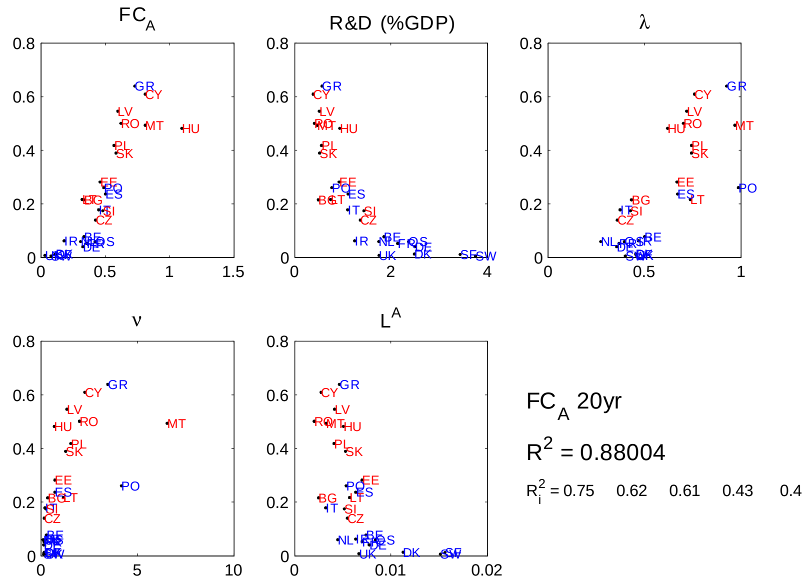
of other R&D promoting policies. There is a base-effect from the initial size of entry costs and the GDP effect is bigger in countries with low R&D intensity and research labour share. Moreover, bigger output effects are experienced by countries with a high elasticity of R&D with respect to research labour, λ, and higher R&D efficiency, ν.

3.4.2 Reduction in administrative burden

A reduction in the administrative burden is another example of a policy decreasing the fixed costs faced by firms. The EU has proposed to reduce this burden through a reduction of EU related regulation (which is estimated to constitute 35% of the total burden) by 25%. In our simulations, consistent with the fixed cost nature of administrative costs, the reform is implemented as a reduction in overhead labour (FC_L).

A reduction in administrative costs is beneficial for firms since it reduces average production costs, i.e. less overhead labour is required for producing the same level of output. However, unlike an increase in labour augmenting technical progress, a reduction of fixed costs does not increase the marginal product of labour and thereby leads to a downward shift in labour demand. It increases profitability of firms and therefore increases investment, however the increase in investment is typically not strong enough to prevent employment from falling below the baseline level. In this scenario, the overall macroeconomic impact of the reform does hardly exceed the direct cost-reducing effect. The output gain ranges from 0.38% (Slovakia) to 0.61% (Portugal). The negative impact of openness $(1 - s^M)$ on the GDP effect is related to the stronger negative terms of trade effect under higher degrees of openness. The real depreciation increases the price of capital via an increase in the price of imported investment goods and the decline in labour input in the final goods sector

Figure 23: Regression analysis, intermediate firms' entry barriers



lowers the marginal product of capital which further reduces the demand for physical capital. The second group of explanatory factors is related to the share of wage costs via the employment rates and wages. Under higher employment rates for low-skilled workers (which are associated with a low preference parameter for leisure, ω_L) the reduction of overhead labour has a stronger GDP effect.[16] Consumption by liquidity constrained households, who provide exclusively low skilled labour services, also appears among the explanatory factors as it depends on the corresponding employment rate. Finally, higher wages for high-skilled workers (who partially reallocate from the final goods to the research sector as a result of the reduction in overhead labour) are associated with a bigger increase in output.

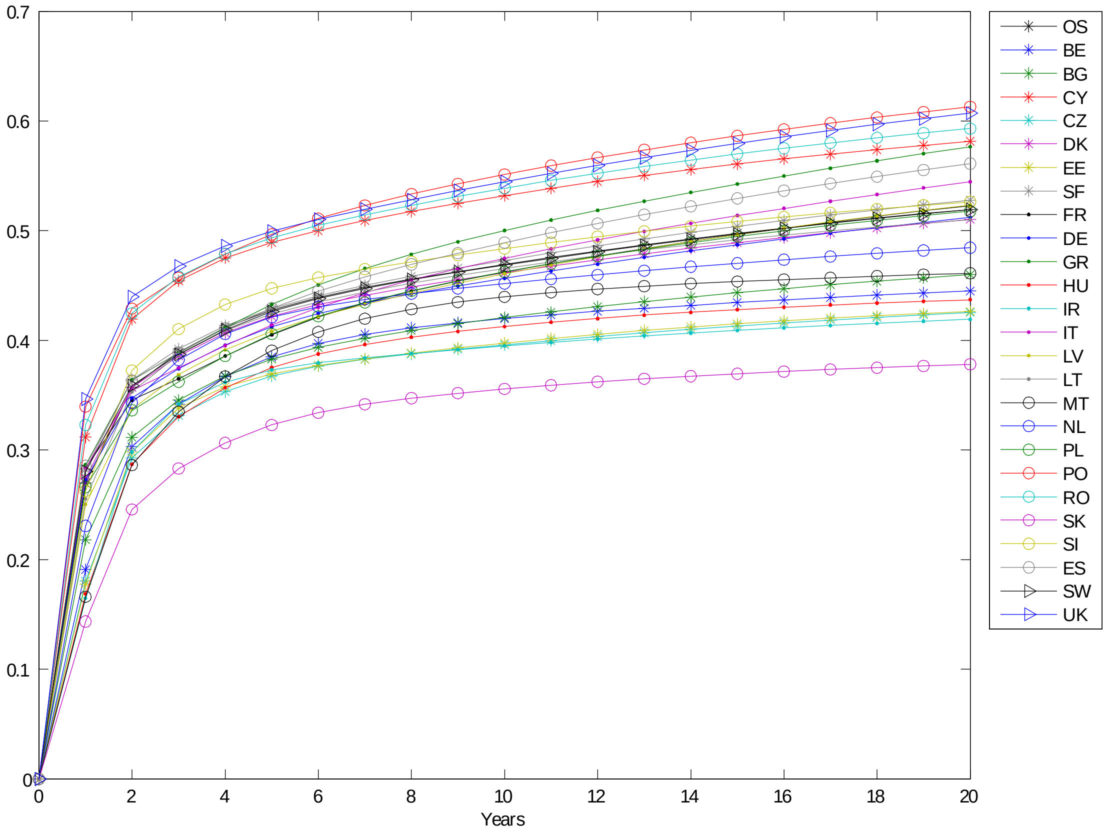
3.5 Exogenous productivity improvements

In this section, we consider the effects of an exogenous productivity improvement shock, which is simulated as a 1% increase of A_t^{exog} in the production function of final output (equation 13). An increase in the level of labour efficiency has a permanent positive impact on output, consumption and capital. The model engenders a larger GDP effect than a standard neoclassical growth model as it generates an endogenous R&D response to the TFP shock in the final goods sector. The increased demand for investment goods stimulates entry into the intermediate goods production sector, thereby increasing the efficiency of capital. The TFP shock also affects the skill premium positively. This is because the technology shock leads to an increase in the demand for R&D, which in turn raises the demand for high skilled workers more than proportionally.

The output gain ranges from 0.60% (Slovakia) to 0.91% (UK). As in the case of a reduction in the administrative burden, the negative relationship between the degree of openness and the GDP effect is explained by the stronger negative terms of trade effect experienced by more open economies. Moreover, labour augmenting technical progress has a stronger impact on output in countries with higher employment rates. Finally, a high level of consumption by liquidity constrained households and a low preference parameter for leisure are among the factors explaining the cross-country variations, as they are linked to high employment rates for low-skilled workers.

[16] Note that the effective labour input of final good firms is $L(1 - fcl)$, where fcl is the overhead labour-share.

Figure 24: 10% reduction in final good firms' administrative burdens (% deviation from baseline)



Source: QUEST III simulations

Figure 25: Regression analysis, final good firms' administrative burdens

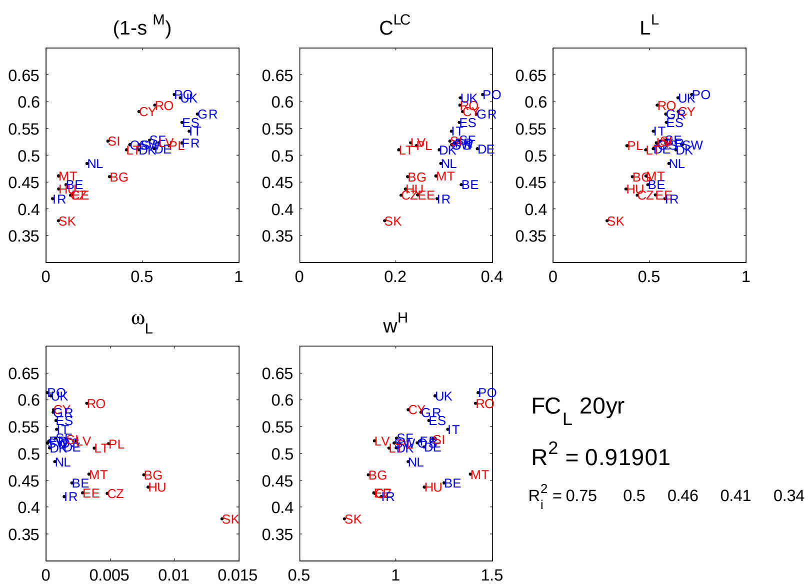


Figure 26: 1% permanent level increase of labour productivity (% deviation from baseline)

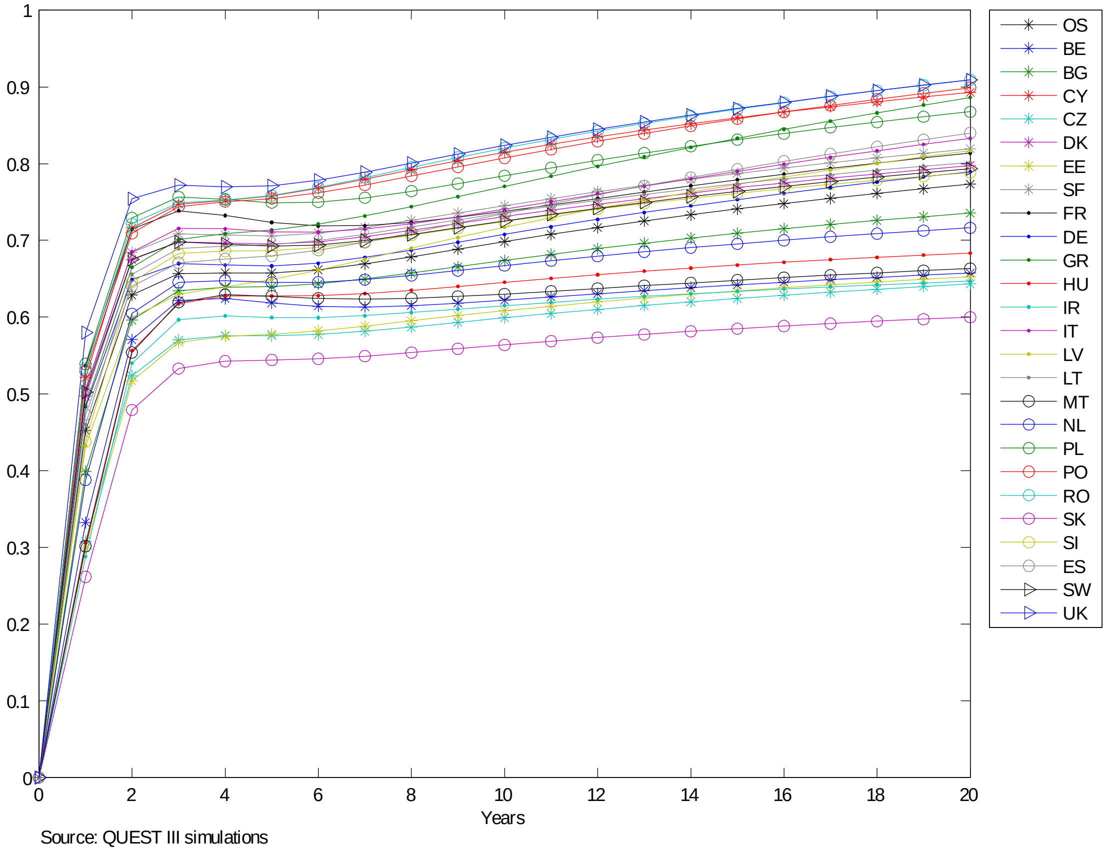
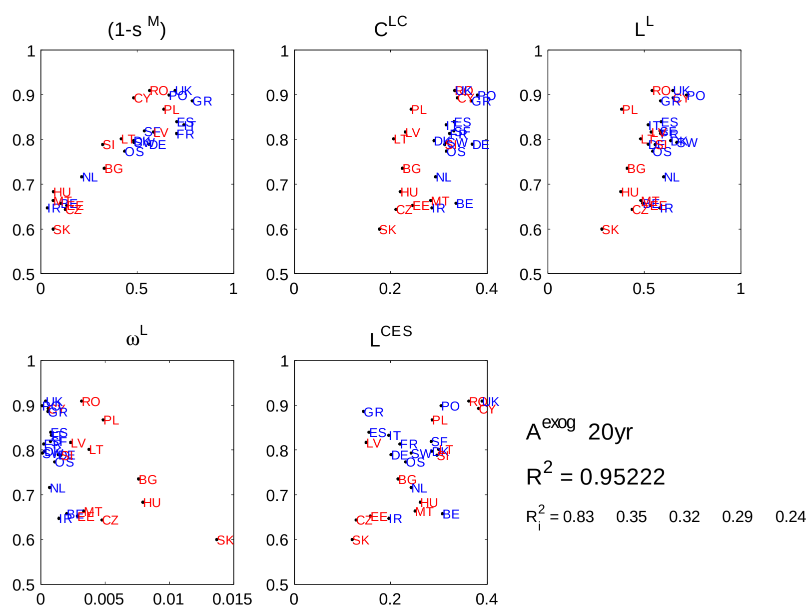


Figure 27: Regression analysis, labour productivity



3.6 Reducing wage mark-ups

In the monopolistically competitive labour market of our model, households act as wage setters and can charge a wage mark-up $1/\eta_t^W$ over the reservation wage (given by the ratio of the marginal disutility of labour to the marginal utility of consumption). The mark-up depends on the intratemporal elasticity of substitution between the differentiated labour services supplied and a lower mark-up implies a reduction in the monopolistic power of workers (or trade unions) and an increase in substitutability among different labour services. Institutional reforms in the labour market that reduce this mark-up will unambiguously raise the employment rate. Everaert and Schule (2006) analyse the transition dynamics and the long-run effects of a reduction in wage mark-ups in the Euro Area. They find that labour market reforms lead to a gradual increase in output and employment, while consumption remains at its baseline for about eight quarters and real wages decline. In the long run, hours worked increase more than proportionally and investment less than proportionally than output and consumption. This leads the authors to argue that reforms in the product and labour markets should be synchronised in order to mitigate the transition costs and achieve a faster adjustment.

In the simulation reported in Figure 28 the mark-up shock is calibrated as a 1% increase in the elasticity between different labour services. A lower mark-up yields a reduction in wages and gradually raises employment. Although the proportional change in the mark-up is the same for all three skill groups, the employment rate on the baseline is highest for the high-skilled group and lowest for low-skilled. Therefore, the same increase in employment is a proportionally larger reduction in leisure for the high-skilled and this puts upward pressure on their wages. As a result, the low-skilled face the strongest decrease in wages, the high-skilled the smallest decline, and the increase in the employment rate is largest for the low-skilled and smallest for the high-skilled.

Output increases following the boost to employment, but the increase in GDP is initially less than proportional because of a negative productivity trade-off. However, in the long run, the GDP effect becomes larger due to an endogenous R&D response. A higher employment rate of high-skilled in the R&D sector as well as increased demand for new patents from entry of new firms in the intermediate sector boost output of the R&D sector and raise total productivity. The output gain ranges from 0.19% (Sweden) to 0.46% (Poland). There is a tendency for countries with low employment rates to experience a larger output (labour supply) effect from an increase in the demand for labour. This is because leisure is a normal good and has an upper limit (formally the marginal utility of leisure is given by $\omega(1-L)^{-\kappa}$).

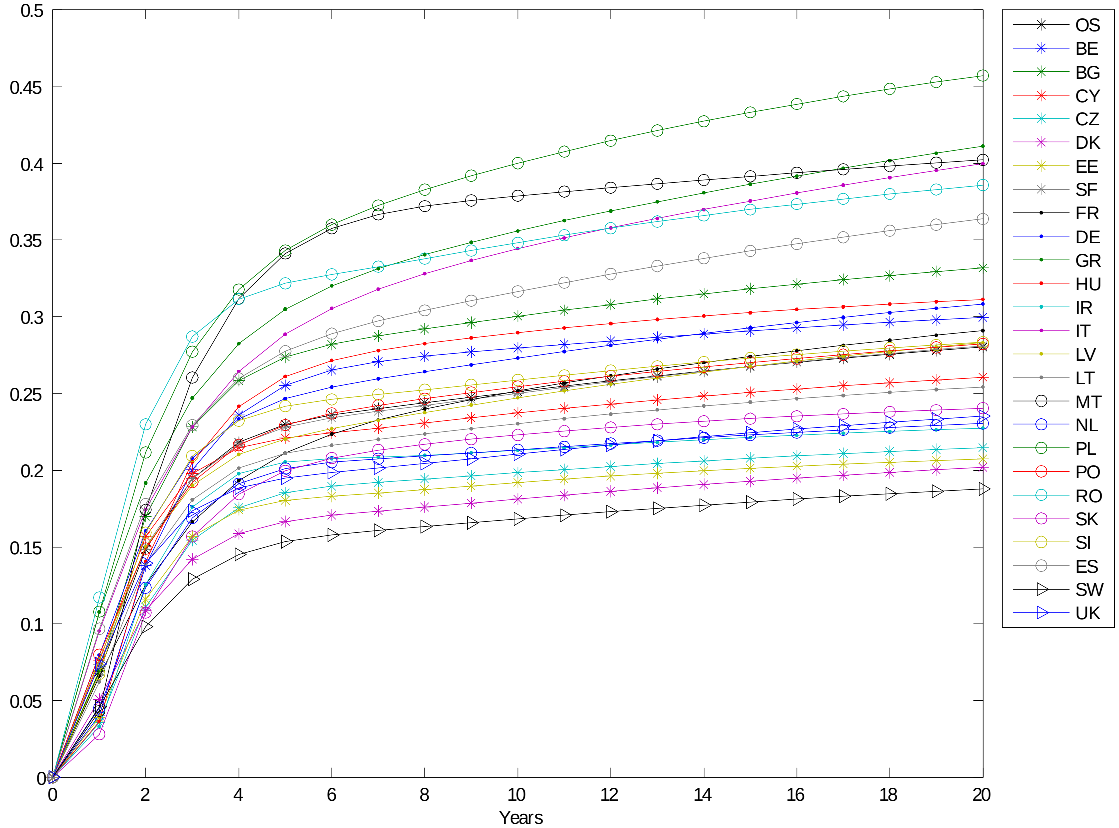
3.7 Tax shift from labour tax to consumption tax

Shifting the burden of taxation from direct taxes towards indirect taxes may yield positive labour market effects. Labour supply (and therefore wages) depends on the total tax burden of a worker household, but by shifting the tax burden from wage income to other sources of income, like transfer income, profit and interest income, total distortions on employment decisions can be reduced and one could expect favourable labour supply effects from such a tax shift.

The effects of a switch from labour to consumption taxation will depend on how other income groups are compensated for the tax increase. The simulation shown in Figure 30 shows the effects of the reduction in labour taxes t_t^w and an increase in consumption taxes t_t^C of 1 percent of (baseline) GDP under the assumption of benefit and transfer indexation to consumer prices. The reduction in labour tax leads to an increase in employment and in output.

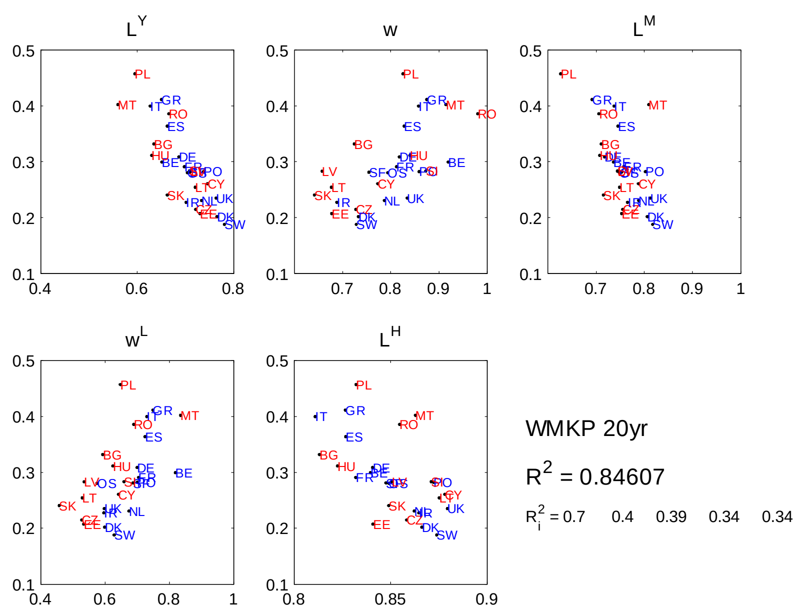
Layard et al. (1991) have raised doubts about the potential gains from a shift in taxation towards indirect taxes based on the empirical observation that real wages will only fall temporarily after such a tax shock. Interestingly real wage costs only fall temporarily in these simulations as well. Nevertheless there is a real positive employment and GDP effect. This can be explained when we take into account various dynamic adjustment mechanisms. The basic intuition behind this result is the fact that a temporary increase in employment leads to an increase in the capital stock in the medium term until the pre-existing capital/labour ratio is re-established. However once the initial capital-labour ratio is re-established the marginal product of labour returns to its initial level and therefore the real wages that firms are willing to pay return to the baseline level at a higher level of

Figure 28: Wage mark-up reduction (% deviation from baseline)



Source: Quest III simulations

Figure 29: Regression analysis, wage mark-up



employment and capital. For a more detailed discussion of the short and long term effects of such a tax shift see European Commission (2008), part IV.

Note again that the long run output effect of this tax shift is proportionally larger than the increase in employment and capital accumulation due to an endogenous R&D increase. Employment in the R&D sector is higher and the increase in output ("ideas/patents") leads to an increase in total productivity. The output gain is the lowest for Romania (0.07%) and the highest for France (1.14%).

The source of the positive employment (and GDP) effect is due to the shift in taxation from wages to income from financial wealth. To understand the labour supply effect of the tax shift consider the following simplified labour supply equation:

$$L = 1 - \omega \left(\frac{P^C C}{W \frac{1-t^w}{1+t^C}} \right)^{\kappa}$$

where κ denotes the elasticity of labour supply, L, ω is the preference parameter for leisure and the tax wedge is given by

$$twedge = \frac{1-t^w}{1+t^C}$$

The % change of the tax wedge (w. r. t. a constant absolute change in the labour tax rate) increases with the initial level of the tax rate:

$$\frac{\partial twedge}{\partial t^w} \frac{1}{twedge} = \frac{1}{1-t^w}$$

This explains why in countries with an initially high tax rate the % increase in net income of such a tax shift is a positive function of the initial level of the labour tax. Note that there is also a negative relationship between the level of labour taxation and the employment rate. Nevertheless, the level of the employment rate has an independent effect, because (see the discussion in the section on the wage mark up) the labour supply elasticity is inversely related to the employment rate (see Figure 31). Finally, countries with a high level of transfers (normally associated with higher government debt, B) experience a stronger output effect due to the wealth effect discussed in section 4.3.1.

3.8 Shift in labour tax from low skilled to high skilled workers

We also simulate a shift in the burden of taxation from low-skilled workers to high-skilled workers. As the average employment rate for low-skilled workers in the EU is much lower than that for medium- and high-skilled workers, many member states have focussed their reforms towards policies that aim to raise the employment rate of this group by reducing their tax burden. For instance, in the period 2000 to 2006, the total tax wedge for low-skilled workers has been reduced by almost 4 percent[17].

Figure 32 shows the macroeconomic impact of a 0.1 per cent of GDP shift from low-skilled to high-skilled workers in the Member States. Lower taxes for low skilled workers increase employment for that skill group, higher taxes for high skilled reduce their employment rate. There is a negative endogenous TFP effect as employment in the R&D sector declines, and this reduces the GDP impact in the long run. GDP is 0.02 (Cyprus) to 0.24% (Poland) higher after 20 years. For similar reasons as explained in the earlier tax-shift scenario, the baseline levels of labour taxes and employment rates play an important role here. Higher taxes and lower employment levels result in a stronger employment response. Note that lower employment in the baseline means that the changes in taxes should also be higher to achieve the 0.1% of GDP tax-shift.

[17] Based on the change in the total tax wedge (including social security contributions by employees and employers) for representative groups of earners (percentage relative to average wage) over the period 2000 to 2006.

Figure 30: 1% of GDP tax shift from labour to consumption taxes (% deviation from baseline)

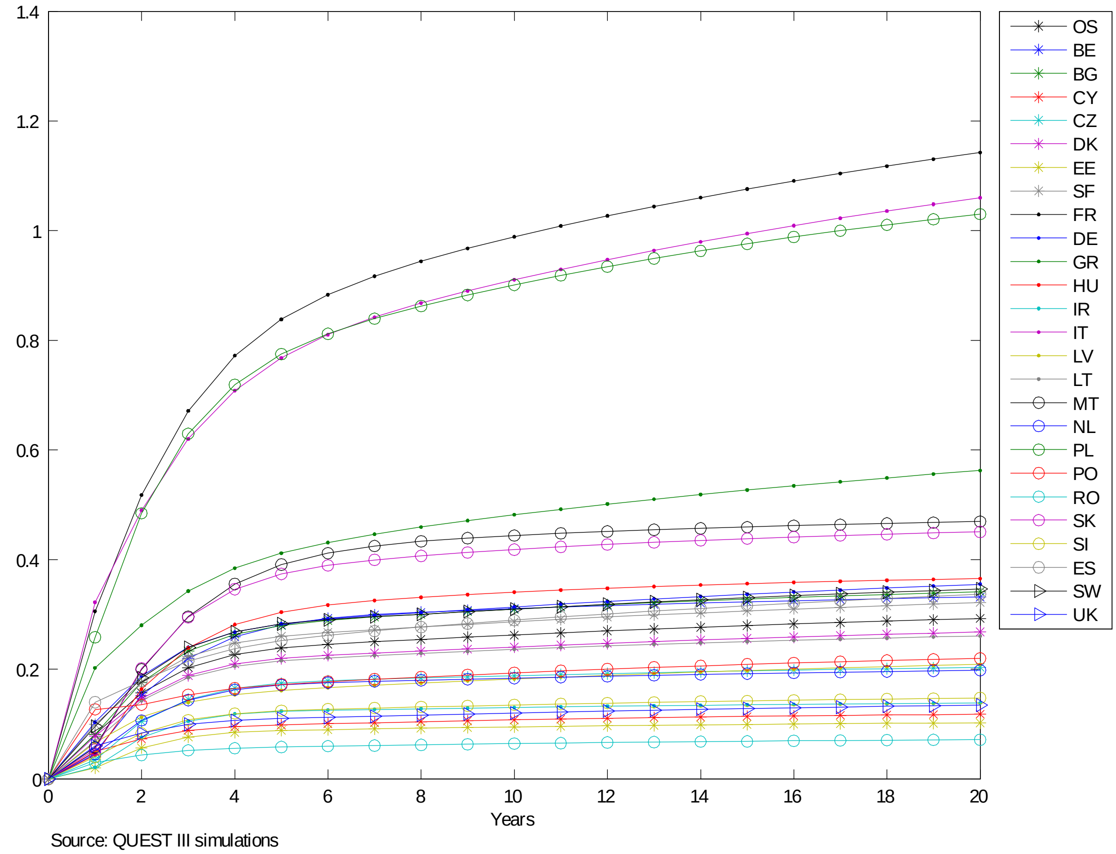


Figure 31: Regression analysis, labour to consumption tax

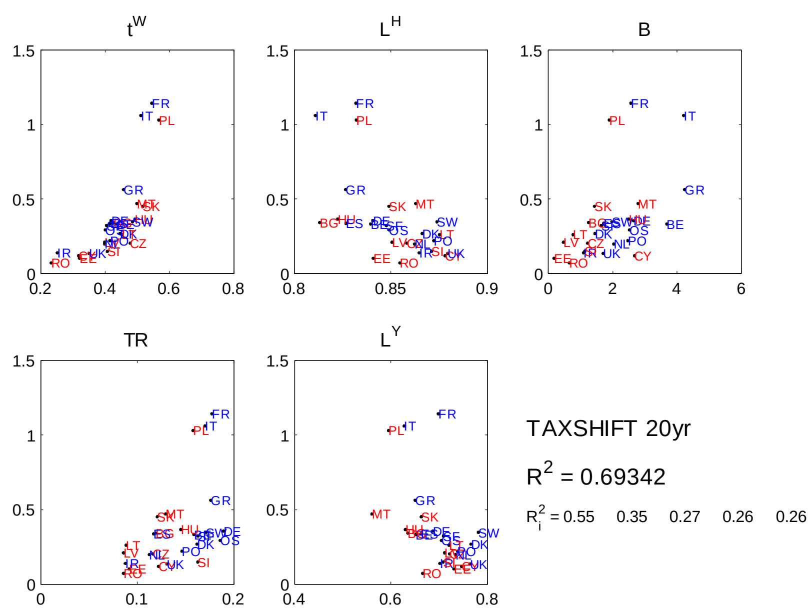
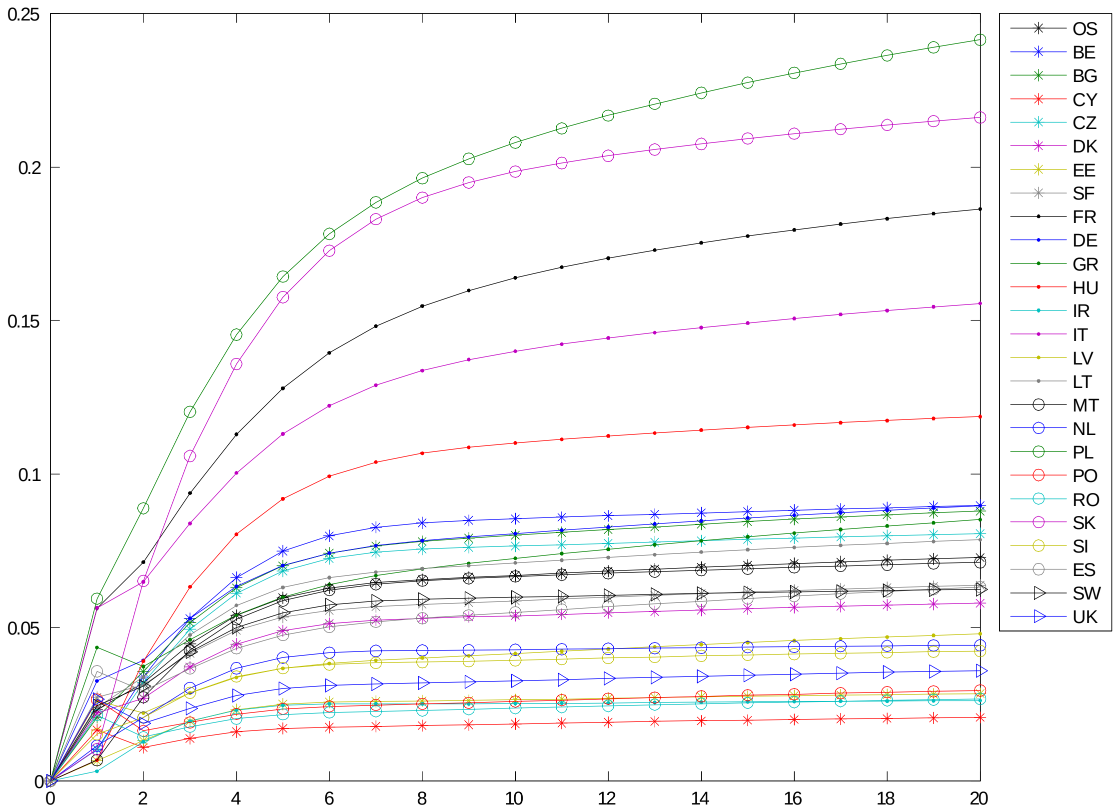
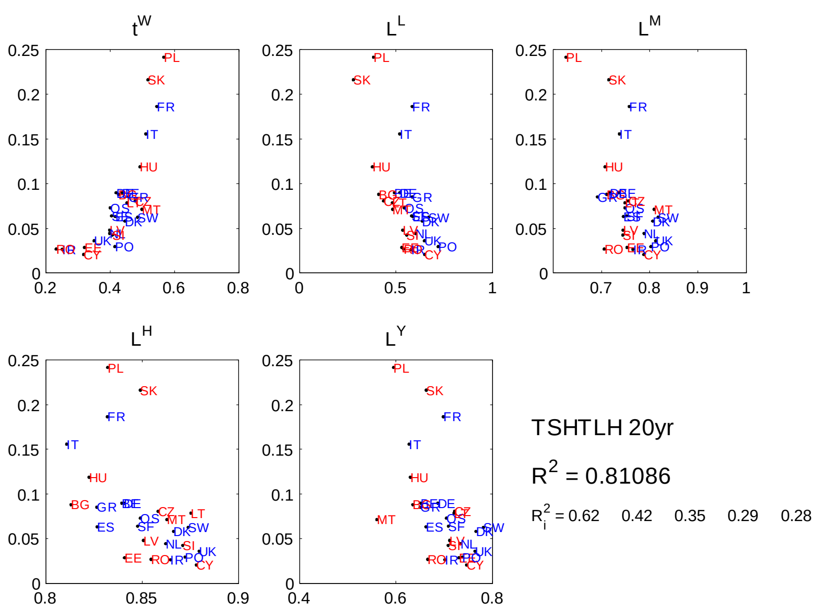


Figure 32: 0.1% tax shift from low to high-skilled labour



Source: QUEST III simulations

Figure 33: Regression analysis, tax shift from low to high skilled



3.9 Reducing unemployment benefit generosity

In the model, households set wages by maximising a weighted average of their utility functions and the wage rule is obtained by equating the ratio between the weighted average of the marginal utility of leisure and the weighted average of the marginal utility of consumption, and the difference between the real wage and unemployment benefits, adjusted for a mark-up. Unemployment benefits act in the model like a subsidy to leisure. A reduction in the benefit replacement rate is like a reduction in the reservation wage as it puts downward pressure on wages and so boosts labour demand.

The effects of a 5% reduction in b_t^s for all three skill groups are shown in Figure 34. The impact on output and employment is similar to that of a reduction in the wage mark-up. As the employment rate on the baseline is lowest for the low-skilled group, the same increase in employment is a proportionally smaller reduction in leisure for this group and this puts less upward pressure on their wages. As a result, the decline in wages for low-skilled is larger than that for other skill groups, and the increase in their employment is also larger.

The dynamic adjustment of real wages, employment and productivity is similar to the previous case of a reduction in the wage mark-up. The benefit reduction acts like a negative shock to wages, which increases the demand for labour and initially reduces labour productivity. Wages and productivity increase over time and return to their baseline values as investment picks up. Unlike in a model with exogenous technical progress there is a small positive long term productivity effect due to a higher employment rate of high-skilled workers in the R&D sector as well as an increased demand for new patents from entry of new firms in the intermediate sector. GDP is 0.59 (Estonia) to 4.36% (France) higher after 20 years. The cross-country differences are again largely due to the baseline effect of taxes and the corresponding employment rates. Extending our earlier analysis with the benefit replacement rate, the inverse labour supply is given as

$$\frac{W}{P} = \frac{1+t^C}{1-t^L-b}\omega^{1/\kappa}\frac{C}{(1-L)^{1/\kappa}}.$$

One can see that under higher labour taxes, there is a stronger multiplier with respect to the changes in the benefit replacement rate. The role of transfers and government debt is again due to the wealth effect.

3.10 Improving human capital

Europe employs a relatively large share of low skilled workers compared to the US (35% vs. 12%), while the US share of medium skilled is substantially higher than in the EU (80% vs. 58%). Figure 36 shows the simulation results for an increase in the EU medium-skilled labour share. The shock is designed to linearly increase the share of medium-skilled workers by 1 percentage point in 40 years and decrease the low-skilled share accordingly. The output effect gradually builds up as the share of medium-skilled workers increases relative to the low-skilled share, with a positive impact of 0.27 (Ireland) to 0.90 (Portugal) per cent after 50 years. The additional medium-skilled labour will be employed at higher efficiency than the replaced low-skilled workers in the production of final goods, with the skill-premium decreasing relative to the other skill-groups (low- and high-skilled). Implied by imperfect substitutability between different types of workers, an increase in the share of medium-skilled workers has positive wage effects for low-skilled workers. The cross-country differences are driven by the real wages and the efficiency level of medium-skilled (w^M, ef^M), by the high-skilled and medium-skilled labour in final goods production (L^{HY} and L^{MY}) and by the level of efficiency of R&D production, υ. The higher the relative efficiency of medium-skilled, the higher their marginal productivity and the output gain from a marginal increase in their employment. The role of the efficiency of R&D production, on the other hand, can be explained by the fact that the shock generates a reallocation of high-skilled labour from final goods production to the research sector. The higher υ, the bigger the increase in the production of new designs following an increase in high-skilled labour employed in the R&D sector. Finally, countries with lower employment rates experience a more sizeable output effect.

Figure 34: 5pp reduction in the benefit replacement rate (% deviation from baseline)

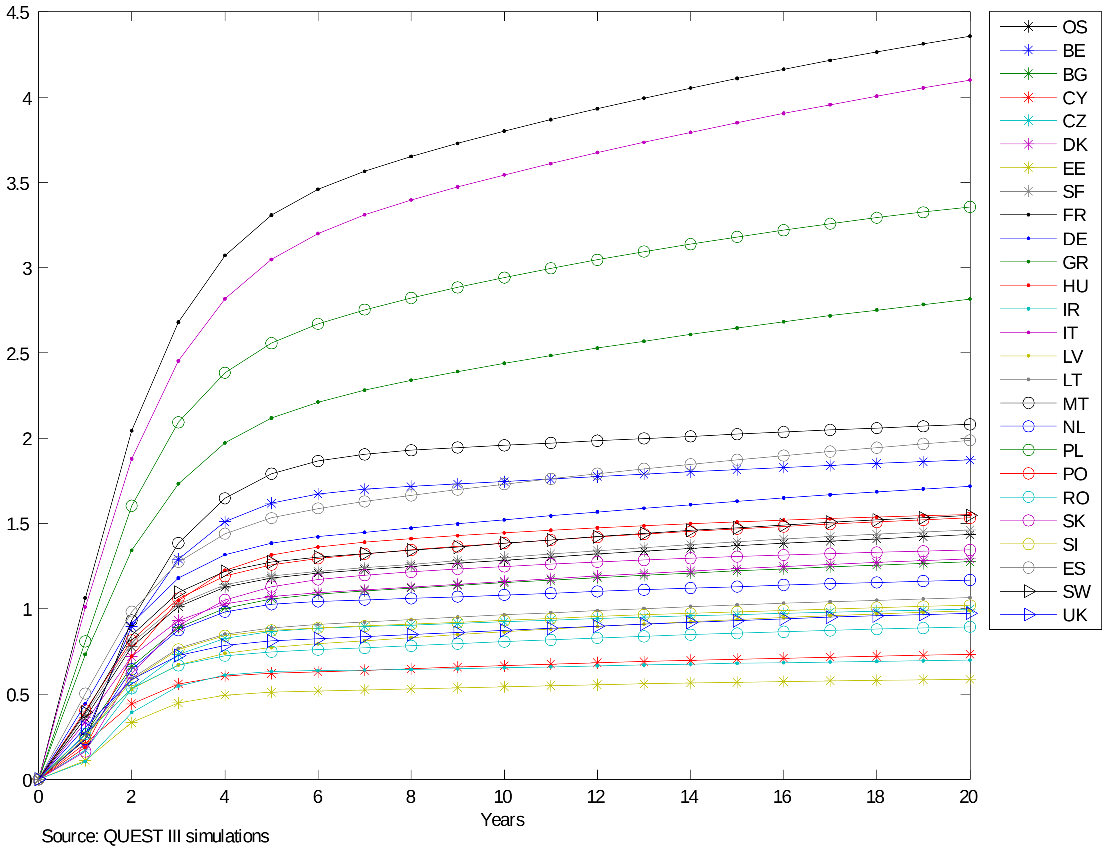


Figure 35: Regression analysis, benefit replacement rate reduction

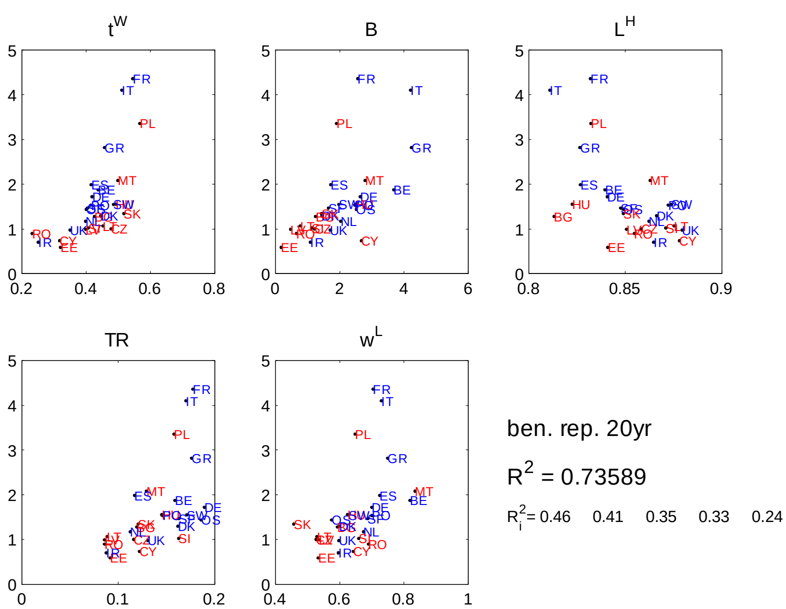
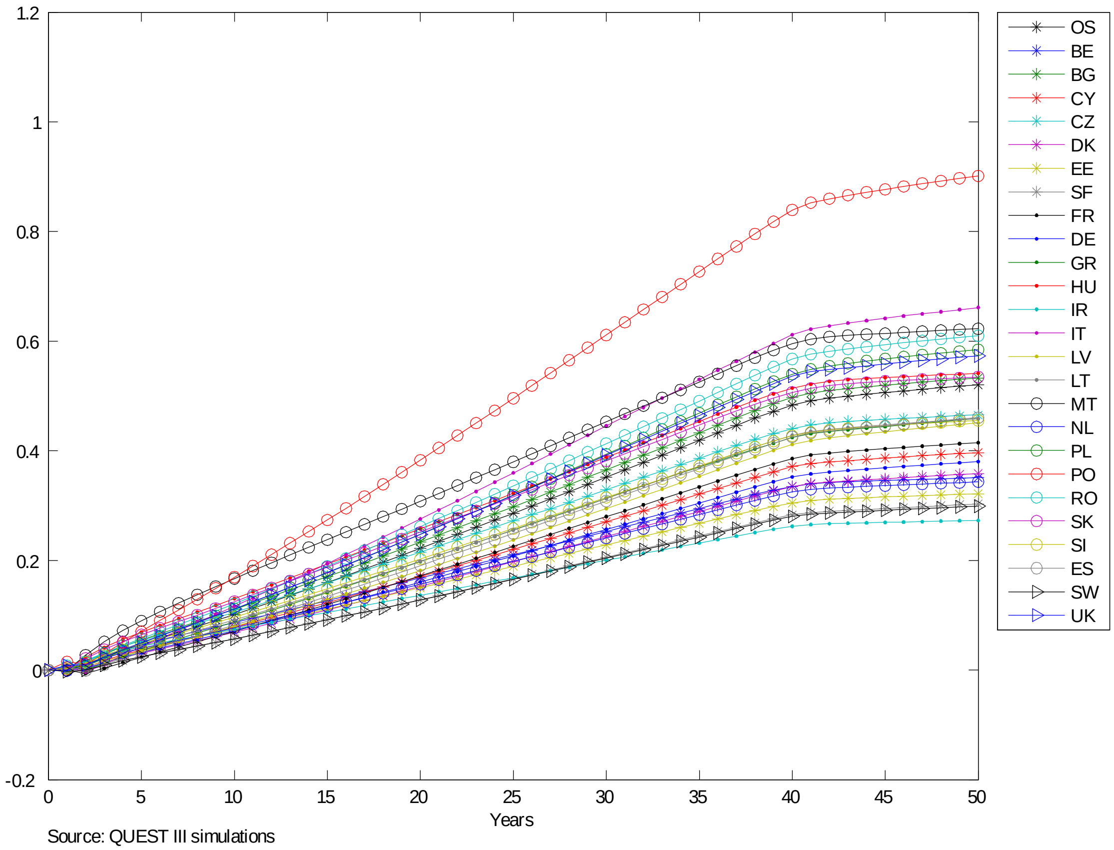


Figure 36: 1pp increase of the share of medium skilled (% deviation from baseline)



The share of high skilled labour in the EU is 1.4% lower than in the US (6.2% vs. 7.6%). Figure 38 shows the effects of increasing the EU high-skilled labour share by 1 percentage point and decreasing the medium-skilled share accordingly. The largest fraction of the additional high skilled labour will be employed in the production of final goods (replacing the less efficient medium skilled workers). However, after around five years there is an increase in employment in the R&D sector because of a decline in the wage of high skilled workers. This reduces the price of patents and stimulates entry in the intermediate goods sector. Output is gradually building up with a positive impact of 0.35 (Slovakia) to 0.82 (Italy) per cent in the long run. The cross country differences are explained by the degree of openness of the economy, $(1 - s^M)$, because of the negative terms of trade effect, and by the wage paid to high skilled workers (w^H). The higher the wage and the corresponding relative marginal productivity of the high skilled, the higher the output gain from a marginal increase in their employment. A further explanatory factor is the low-skilled workers' preference parameter on leisure, ω_L. Its role can be explained by the stronger fluctuations in employment in response to wage changes in the presence of high values of ω (which is generally higher for low-skilled workers than for the other skill groups). Finally, high taxation on consumption, t^C, is associated with smaller GDP effects.

Conclusions

In this paper we described a calibrated micro-founded dynamic general equilibrium model with endogenous growth for all EU member states that can be used to analyse the macroeconomic impact of structural reforms in Europe. The new QUEST III model allows us to explicitly model the

Figure 37: Regression analysis, medium skilled

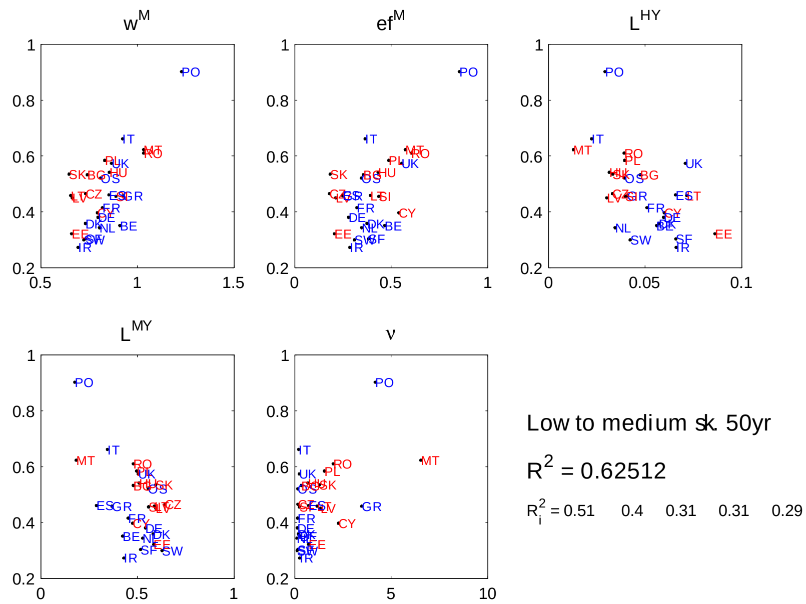


Figure 38: 1pp increase of the share of high skilled (% deviation from baseline)

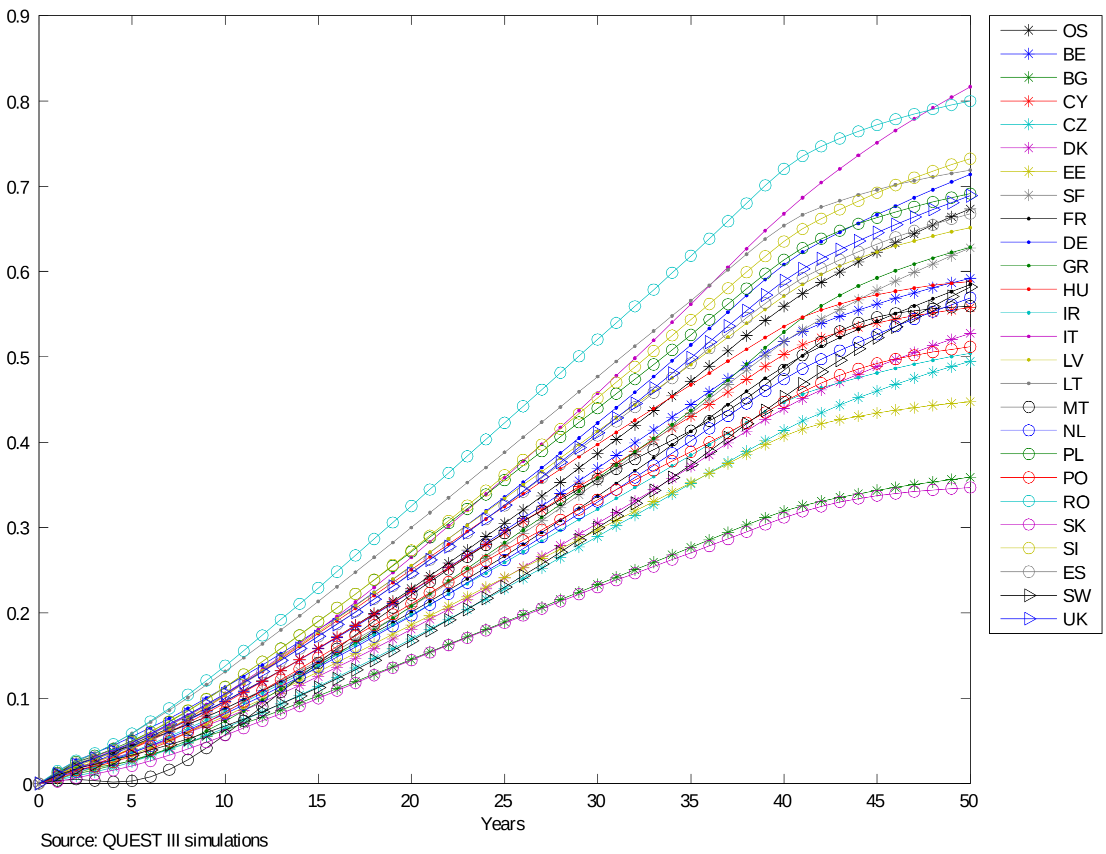
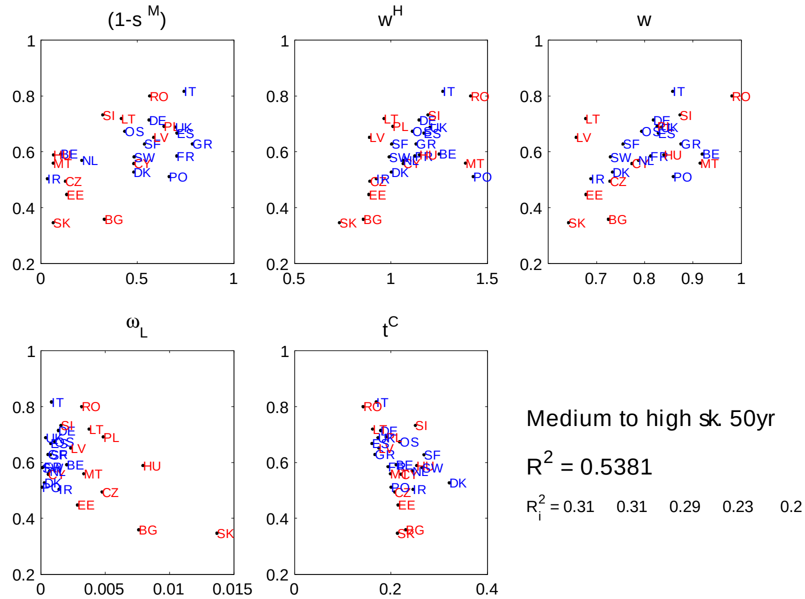


Figure 39: Regression analysis, high skilled



reforms in terms of concrete and quantifiable policy measures, in particular fiscal policy instruments such as taxes, benefits, subsidies and education expenditures, administrative costs faced by firms and regulatory indices. This makes the model a useful tool for analysing the costs and benefits of structural reforms at member state level. Our results confirm Roeger et al. (2008) on the beneficial effects on output and employment of skill-biased tax reforms, measures that improve the skill composition of the labour force, R&D subsidies, raising competition in final goods market, increased financial market integration and measures that remove entry barriers in certain markets.

The effects of structural reforms show large variations across the member states. We employ multiple-regression analysis to explore the most important factors driving the differences between our country-specific simulation results. We find that less R&D intensive countries would benefit the most from R&D promoting and skill-upgrading policies. We also find that shifting from labour to consumption taxes, reducing the benefit replacement rate and easing administrative entry barriers are most effective in countries where initial labour taxes and entry barriers are high.

One can think of many directions in which this model can be extended. A further disaggregation of taxes would be desirable to fully capture the differential impacts individual taxes can have on the economy. Further work is also needed to endogenise the skill premium, and to endogenise the risk-premia via the introduction of a banking sector.

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Appendix A: The model

Households

The household sector consists of a continuum of households $h \in [0,1]$. A share $(1-\epsilon)$ of these households are not liquidity constrained (Ricardian) $i \in [0, 1-\varepsilon]$ and they have access to financial markets where they can purchase and sell domestic and foreign assets. These households accumulate physical capital which they rent out to the intermediate sector, and they also buy the patents of designs produced by the R&D sector and license them to the intermediate goods producing firms. Non-liquidity constrained household members offer medium- and high-skilled labour services indexed by $s \in \{M, H\}$. The remaining share ϵ of households is liquidity constrained and indexed by $k \in [1-\varepsilon, 1]$. These households cannot trade in any type of assets but consume their disposable income each period. We assume that liquidity constrained households offer low-skilled labour services only. In each skill group households supply differentiated labour services to unions which act as wage setters in monopolistically competitive labour markets. The unions pool wage income and distribute it in equal proportions among their members. Nominal rigidity in wage setting is introduced by assuming that households face adjustment costs for changing wages.

Non liquidity constrained households

Non liquidity constrained households maximise an intertemporal utility function in consumption and leisure subject to a budget constraint. They make decisions about consumption (C_t^i), labour supply (L_t^i), investments into domestic and foreign financial assets (B_t^i and $B_t^{F,i}$), the purchases of investment good (J_t^i), the renting of physical capital stock (K_t^i), the degree of capacity utilisation ($ucap_t^i$), the purchases of new patents from the R&D sector ($J_t^{A,i}$), and the licensing of existing patents (A_t^i). On the revenue side, households receive wage income (W_t^i), unemployment benefits ($b_t^s W_t^{i,s}$)[18], transfer income from the government (TR_t^i) and interest income (i_t, i_t^K and i_t^A). The Lagrangian of this maximisation problem is given by

$$
\begin{aligned}
&\underset{\left\{ \begin{array}{l} C_t^i, L_t^i, B_t^i \\ B_t^{F,i}, J_t^i, K_t^i \\ J_t^{A,i}, A_t^i, ucap_t^i \end{array} \right\}_{t=0}^{\infty}}{Max} \quad V_0^i = E_0 \textstyle\sum_{t=0}^{\infty} \beta^t \left(U(C_t^i) + \sum_s V(1 - L_t^{i,s}) \right) \\
&-E_0 \textstyle\sum_{t=0}^{\infty} \lambda_t^i \beta^t \left(\begin{array}{l}
(1+t_t^c) P_t^C C_t^i + B_t^i + E_t B_t^{F,i} + P_t^I \left(J_t^i + \Gamma_J(J_t^i) \right) + P_t^A J_t^{A,i} \\
-(1+r_{t-1}) B_{t-1}^i - \left(1 + r_{t-1}^F - \Gamma_{B^F}\left(E_t B_{t-1}^F / Y_{t-1} \right) \right) E_t B_{t-1}^{F,i} \\
-\sum_s (1 - t_t^{w,s}) W_t^{i,s} L_t^{i,s} - b_t^s W_t^{i,s} (1 - NPART_t^{i,s} - L_t^{i,s}) + \Gamma_W(W_t^{i,s}) \\
-(1 - t_{t-1}^K) \left(i_{t-1}^K ucap_{t-1}^i - rp_{t-1}^K - \Gamma_U\left(ucap_{t-1}^i \right) \right) P_t^J K_{t-1}^i \\
-t_{t-1}^K \delta^K P_t^I K_{t-1}^i - \tau^K P_t^I J_t^i \\
-(1 - t_{t-1}^K)(i_{t-1}^A - rp_{t-1}^A) P_t^A A_{t-1}^i - t_{t-1}^K \delta^A P_t^A A_{t-1}^i - \tau^A P_t^A J_t^{A,i} \\
-TR_t^i - \sum_{j=1}^{n} PR_{j,t}^{f,i} - \sum_{j=1}^{A_t} PR_{j,t}^{x,i}
\end{array} \right) \quad s \in \{M, H\} \\
&-E_0 \textstyle\sum_{t=0}^{\infty} \lambda_t^i \xi_t^i \beta^t \left(K_t^i - J_t^i - (1-\delta^K) K_{t-1}^i \right) - E_0 \sum_{t=0}^{\infty} \lambda_t^i \psi_t^i \beta^t \left(A_t^i - J_t^{A,i} - (1-\delta^A) A_{t-1}^i \right)
\end{aligned} \tag{1}
$$

The budget constraints are written in real terms normalized with P_t, the price of domestic final goods. All firms are owned by the Ricardian households who share the total profit of the final and intermediate sector firms, $\sum_{j=1}^{n} PR_{j,t}^{f,i}$ and $\sum_{j=1}^{A_t} PR_{j,t}^{x,i}$, where n and A_t denote the number of firms in the final and intermediate sector respectively. All households pay t_t^w wage income taxes and t_t^K capital income taxes less tax credits (τ^K and τ^A) and depreciation allowances ($t_t^K \delta K$ and $t_t^K \delta A$) after their earnings on physical capital and patents. There is no perfect arbitrage between different types of assets, households face a financial intermediation premium $\Gamma_{B^F}(.)$ which depends on the economy-wide net holdings of internationally traded bonds. When investing into tangible and intangible capital households require premia rp_t^K and rp_t^A in order to cover the increased risk

[18] Notice, households only make a decision about the level of employment but there is no distinction on the part of households between unemployment and non participation. See Roeger et al. (2008).

on the return related to these assets. The real interest rate r_t is equal to the nominal interest rate minus expected inflation: $r_t = i_t - E_t(\pi_{t+1})$.

We assume additively separable utility function in consumption (C_t^i) and leisure ($1 - L_t^{i,s}$). We assume log-utility for consumption and allow for habit persistence.

$$U(C_t^i) = (1 - habc) \log \left(C_t^i - habc C_{t-1}\right) \tag{2a}$$

For leisure we assume CES preferences with common labour supply elasticity but a skill specific weight (ω_s) on leisure which is necessary in order to capture differences in employment levels across skill groups:

$$V(1 - L_t^{i,s}) = \frac{\omega_s}{1-\kappa}(1 - L_t^{i,s})^{1-\kappa}, \quad \text{with } \kappa > 0. \tag{2b}$$

The investment decisions w.r.t. real capital and decisions w.r.t. the degree of capacity utilisation are subject to convex adjustment costs Γ_J and Γ_U, which are given by

$$\Gamma_J(J_t^i) = \frac{\gamma_K}{2}\frac{\left(J_t^i\right)^2}{K_{t-1}^i} + \frac{\gamma_I}{2}(\Delta J_t^i)^2 \tag{3a}$$

and

$$\Gamma_U(ucap_t^i) = a_1\left(ucap_t^i - ucap_t^{ss}\right) + a_2\left(ucap_t^i - ucap_t^{ss}\right)^2, \tag{4a}$$

where $ucap_t^{ss}$ is the steady state capacity utilisation.

Wages are also subject to convex adjustment costs given by

$$\Gamma_W(W_t^{i,s}) = \sum_s \frac{\gamma_W L_t^{i,s}}{2}\frac{\left(\Delta W_t^{i,s}\right)^2}{W_{t-1}^{i,s}} \tag{5}$$

We denote with P^C the corresponding utility based deflator for the C and J aggregate. The first order conditions of the household with respect to consumption, financial and real assets are given by

$$\frac{\partial V_0}{\partial C_t^i} => U_{C,t}^i - \lambda_t^i(1 + t_t^c)P_t^C = 0, \tag{6a}$$

$$\frac{\partial V_0}{\partial B_t^i} => -\lambda_t^i + E_t\left(\lambda_{t+1}^i \beta\left(1 + r_t\right)\right) = 0, \tag{6b}$$

$$\frac{\partial V_0}{\partial B_t^{F,i}} => -\lambda_t^i + E_t\left(\lambda_{t+1}^i \beta\left(1 + r_t^F - \Gamma_{B^F}\left(E_t B_t^F / Y_t\right)\right) E_{t+1}/E_t\right) = 0, \tag{6c}$$

$$\frac{\partial V_0}{\partial K_t^i} => -\lambda_t^i \xi_t^i + E_t\left(\begin{array}{c}\lambda_{t+1}^i \xi_{t+1}^i \beta(1-\delta) \\ +\lambda_{t+1}^i \beta\left((1 - t_t^K)\left(\begin{array}{c} i_t^K ucap_t^i - rp_t^K \\ -\Gamma_u\left(ucap_t^i\right)\end{array}\right) + t_t^K \delta^K\right) P_{t+1}^C\end{array}\right) = 0, \tag{6d}$$

$$\frac{\partial V_0}{\partial J_t^i} => -\lambda_t^i P_t^C\left(1 + \gamma_K\left(\frac{J_t^i}{K_{t-1}^i}\right) + \gamma_I \Delta J_t^i - \tau^K\right) + E_t\left(\lambda_{t+1}^i \beta P_{t+1}^C \gamma_I \Delta J_{t+1}^i\right) + \lambda_t^i \xi_t^i = 0, \tag{6e}$$

$$\frac{\partial V_0}{\partial ucap_t^i} => i_t^K - a_1 - 2a_2\left(ucap_t^i - ucap_t^{ss}\right) = 0. \tag{6f}$$

From the above arbitrage conditions after neglecting the second order terms, investment is given as a function of the variable Q_t

$$Q_t - 1 = \gamma_K\left(\frac{J_t^i}{K_{t-1}^i}\right) + \gamma_I \Delta J_t^i - \tau^K - E_t\left(\frac{\gamma_I \Delta J_{t+1}^i}{1 + i_t - \pi_{t+1}^C}\right) \text{ with } Q_t = \frac{\xi_t}{P_t^C}, \tag{7a}$$

where Q_t is the present discounted value of the rental rate of return from investing in real assets

$$Q_t = E_t \left(\frac{1-\delta}{1+i_t-\pi^C_{t+1}} Q_{t+1} + \frac{(1-t^K_t)\left(i^K_t ucap^i_t - rp^K_t - \Gamma_u\left(ucap^i_t\right)\right) + t^K_t \delta^K}{1+i_t-\pi^C_{t+1}} \right) \tag{7b}$$

Notice that the relevant discount factor for the investor is the nominal interest rate adjusted by the trading friction minus the expected inflation of investment goods (π^C_{t+1}).

Ricardian households purchase new patents of designs produced by the R&D sector (I^A_t) and rent their total stock of design (A_t) at rental rate i^A_t to intermediate goods producers in period t. Households pay income tax at rate t^K_t on the period return of intangibles and they receive tax subsidies at rate τ^A. The first order conditions with respect to R&D investments are given by

$$\frac{\partial V_0}{\partial A^i_t} => -\lambda^i_t \psi^i_t + E_t \left(\begin{array}{c} \lambda^i_{t+1}\psi^i_{t+1}\beta(1-\delta^A) \\ +\lambda^i_{t+1}\beta\left((1-t^K_t)(i^A_t - rp^A_t) + t^K_t\delta^A\right) P^A_{t+1} \end{array} \right) = 0 \tag{7c}$$

$$\frac{\partial V_0}{\partial J^{A,i}_t} => -\lambda^i_t P^A_t \left(1-\tau^A\right) + \lambda^i_t \psi^i_t = 0 \tag{7d}$$

where the rental rate can be obtained from 6b, 7c and 7d after neglecting the second order terms:

$$i^A_t \approx \frac{(1-\tau^A)\left(i_t - \pi^A_{t+1} + \delta^A\right) - t^K_t \delta^A}{(1-t^K_t)} + rp^A_t \tag{8}$$

where $1+\pi^A_{t+1} = \frac{P^A_{t+1}}{P^A_t}$.

Equation (8) shows that households require a rate of return on intangible capital equal to the nominal interest rate minus the rate of change of the value of intangible assets and has to cover the cost of economic depreciation plus a risk premium. Governments can affect investment decisions in intangible capital by giving tax incentives in the form of tax credits and depreciation allowances or by lowering the tax on the return from patents.

Liquidity constrained households

Liquidity constrained households do not optimize but simply consume their current income in each period. Real consumption of liquidity household are determined by the net wage income plus net transfers

$$(1+t^c_t)P^C_t C^k_t + \sum_s \frac{\gamma_W L^{k,s}_t}{2} \frac{\left(\Delta W^{k,s}_t\right)^2}{W^{k,s}_{t-1}} = \sum_s \left(\begin{array}{c} (1-t^{w,s}_t)\, W^{k,s}_t L^{k,s}_t \\ +b^s_t W^{k,s}_t (1 - NPART^{k,s}_t - L^{k,s}_t) \end{array} \right) + TR^k_t. \tag{9}$$

Wage setting

In each skill group a variety of labour services are supplied which are imperfect substitutes to each other. Therefore trade unions can charge a wage mark-up ($1/\eta^W_t$) over the reservation wage. The reservation wage is the ratio of the marginal utility of leisure to the corresponding marginal utility of consumption. The relevant net real wage is the gross wage adjusted for labour taxes, consumption taxes and unemployment benefits:

$$\frac{U^{h,s}_{1-L,t}}{U^h_{C,t}} \frac{1}{\eta^W_t} = \frac{W^s_t(1-t^{w,s}_t - b^s_t)}{(1+t^C_t)P^C_t} \text{ for } h \in \{i,k\} \text{ and } s \in \{L,M,H\}.$$

Aggregation

The aggregate of any household specific variable X_t^h in per capita terms is given by

$$X_t = \int_0^1 X_t^h dh = (1-\varepsilon) X_t^i + \varepsilon X_t^k, \tag{10}$$

and the aggregate consumption and employment is given by

$$C_t = (1-\varepsilon) C_t^i + \varepsilon C_t^k \tag{11}$$

and

$$L_t = (1-\varepsilon) L_t^i + \varepsilon L_t^k. \tag{12}$$

Firms

Final output producers

Each firm j ($j = 1, ..., n$) produces a variety of the domestic good which is an imperfect substitute for the varieties produced by other firms and acts as a monopolistic competitor facing a demand function with a price elasticity of σ^d. Final output (Y^j) is produced using A varieties of intermediate inputs (x) with an elasticity of substitution θ. The final good sector uses a labour aggregate and domestic intermediate goods with Cobb-Douglas technology, subject to a fixed cost FC_Y and overhead labour FC_L

$$Y^j = \left(A_t^{exog}\left(L_{Y,t}^j - FC_L\right)\right)^{\alpha} \left(\sum_{i=1}^{A_t} \left(x_{i,t}^j\right)^{\theta}\right)^{\frac{1-\alpha}{\theta}} KG_t^{\alpha_G} - FC_Y, 0 < \theta < 1 \tag{13}$$

with

$$L_{Y,t} = \left(s_L^{\frac{1}{\sigma_L}} \left(ef_L L_t^L\right)^{\frac{\sigma_L - 1}{\sigma_L}} + s_M^{\frac{1}{\sigma_L}} \left(ef_M L_t^M\right)^{\frac{\sigma_L - 1}{\sigma_L}} + s_{H,Y}^{\frac{1}{\sigma_L}} \left(ef_H L_t^{HY}\right)^{\frac{\sigma_L - 1}{\sigma_L}}\right)^{\frac{\sigma_L}{\sigma_L - 1}}, \tag{14}$$

where s_s is the population share of labour-force in subgroup s (low-, medium- and high-skilled), L_s denotes the employment rate of population s, ef_s is the corresponding efficiency unit, σ_L is the elasticity of substitution between different labour types and KG denotes the stock of public capital with an elasticity of α_G. High-skilled labour in the final goods sector, L_t^{HY}, is the total high-skill employment minus the high-skilled labour working for the R&D sector ($L_{A,t}$). The employment aggregates L_t^s combine varieties of differentiated labour services supplied by individual household

$$L_t^s = \left[\int_0^1 \left(L_t^{s,h}\right)^{\frac{\sigma_s - 1}{\sigma_s}} dh\right]^{\frac{\sigma_s}{\sigma_s - 1}}, \tag{15}$$

where $\sigma_s > 1$ determines the degree of substitutability among different types of labour.

The objective of the firm is to maximise profits in terms of

$$PR_t^{f,j} = P_t^j Y_t^j - \left(W_t^L L_t^{j,L} + W_t^M L_t^{j,M} + W_t^H L_t^{j,HY}\right) - \sum_{i=1}^{A_t} \left(px_{\,i,t}\, x_{i,t}^j\right), \tag{16}$$

where px is the price of intermediate inputs and W_t^s is a wage index corresponding to the CES aggregate $L_t^{j,s}$. All prices and wages are normalized with the price of domestic final goods, P_t. In a symmetric equilibrium, the demand for labour and intermediate inputs is given by

$$\alpha \frac{Y_t + FC_Y}{L_{Y,t} - FC_L} \left(\frac{L_{Y,t}}{L_t^s}\right)^{\frac{1}{\sigma_L}} s_s^{\frac{1}{\sigma_L}} ef_s^{\frac{\sigma_L - 1}{\sigma_L}} \eta_t = W_t^s, \quad s \in \{L, M, H\} \tag{17a}$$

$$px_{i,t} = \eta_t(1-\alpha)\left(Y_t + FC_Y\right)\left(\sum_{i=1}^{A_t}\left(x^j_{i,t}\right)^\theta\right)^{-1}\left(x_{\,i,t}\right)^{\theta-1} \tag{17b}$$

where, following the literature, we define the inverse mark up factor as a function of the elasticity of substitution and changes in forward and backward looking inflation $\eta_t = 1 - 1/\sigma^d_t - \gamma_p/\sigma^d_t\left(\beta\left(sfpE_t\pi_{t+1} + (1-sfp)\pi_{t-1}\right) - \pi_t\right)$.

Intermediate goods producers

In the intermediate sector monopolistically competitive firms have entered the market by renting a design from domestic households and by making an initial payment FC_A to overcome administrative entry barriers. Capital inputs are also rented from the household sector for a rental rate of i^K_t. Firms which have rented a design can transform each unit of capital into a single unit of an intermediate input (Jones 2005 and 1995). Intermediate goods producing firms sell their products to domestic final good producers only, therefore the inverse demand function of domestic final good producers is given as in equation (17b).

Each domestic intermediate firm faces the following profit-maximisation problem

$$PR^x_{i,t} = \max_{x_{i,t}}\left\{px_{i,t}x_{i,t} - i^K_t P^C_t k_{i,t} - i^A P^A_t - FC_A\right\} \tag{18}$$

subject to the linear technology which allows to transform one unit of effective capital ($k_{i,t}ucap_t$) into one unit of an intermediate good

$$x_{i,t} = k_{i,t}\cdot ucap_t. \tag{19}$$

In a symmetric equilibrium the first order condition is

$$\theta\eta_t(1-\alpha)\left(Y_t + FC_Y\right)\left(\sum_{i=1}^{A_t}\left(x^j_{i,t}\right)^\theta\right)^{-1}\left(x_t\right)^{\theta-1} = i^K_t P^C_t \tag{20a}$$

Intermediate goods producers set prices as a mark up over marginal cost. Therefore prices for the domestic market are given by:

$$PX_t = px_{i,t} = \frac{i^K_t P^C_t}{\theta}. \tag{20b}$$

The no-arbitrage condition requires that entry into the intermediate goods producing sector takes place until

$$PR^x_{i,t} = PR^x_t = i^A_t P^A_t + \left(i^A_t + \pi^A_{t+1}\right)FC_A, \quad \forall i \tag{21a}$$

or equivalently, the present discounted value of profits is equated to the fixed entry costs plus the net value of patents

$$P^A_t + FC_A = \sum_{j=1}^{\infty}\left(\frac{1}{1 + r_{t+j} + rp^A_{t+j}}\right)^j PR^x_{t+j-1} \tag{21b}$$

For an intermediate producer, entry costs consist of the licensing fee $i^A_t\,P^A_t$ for the design or patent which is a prerequisite of production of innovative intermediate goods and a fixed entry cost FC_A.

R&D sector

In our semi-endogenous growth framework innovation corresponds to the discovery of a new variety of producer durables that provides an alternative way to produce the final good. The R&D sector hires high-skilled labour (L_A) and generates new designs according to the following knowledge production function:

$$\Delta A_t = \nu A^{*\varpi}_{t-1} A^{\phi}_{t-1} L^{\lambda}_{A,t}, \tag{22}$$

where we account for international R&D spillovers following Bottazzi and Peri (2007). Parameters ϖ and ϕ measure the foreign and domestic spillover effects from the aggregate international and domestic stock of knowledge (A^* and A) respectively. Negative values can be interpreted as the "fishing out" effect, i.e. when innovation decreases with the level of knowledge, while positive values refer to the "standing on shoulders" effect and imply positive research spillovers. Note that $\phi = 1$ would give back the strong scale effect feature of fully endogenous growth models with respect to the domestic level of knowledge. Parameter ν can be interpreted as total factor efficiency of R&D production, while λ measures the elasticity of R&D production on the number of researchers (L_A). The international stock of knowledge grows exogenously at rate g_{A^W}. We assume that the R&D sector is operated by a research institute which employs high skilled labour at their market rate W^H. We also assume that the research institute faces an adjustment cost of hiring new employees and maximizes the following discounted profit-stream:

$$\max_{L_{A,t}} \sum_{t=0}^{\infty} d_t \left(P^A_t \Delta A_t - W^H_t L_{A,t} - \frac{\gamma_A}{2} W^H_t \Delta L^2_{A,t} \right) \tag{23}$$

where d_t is the discount factor.

Trade and the current account

In order to facilitate aggregation we assume that private and government consumption (C, G) and investment (I, IG) are aggregates of domestic and foreign varieties of final goods, with preferences expressed by the following CES utility function

$$Z^i = \left[(1 - s^M)^{\frac{1}{\sigma}} \left(Z^{di}\right)^{\frac{\sigma-1}{\sigma}} + s^{M\,\frac{1}{\sigma}} \left(Z^{fi}\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{(\sigma-1)}} \tag{24a}$$

with $Z^i \in \left\{C^i, I^i, G^i, IG^i\right\}$ and Z^{d^i} and Z^{f^i} are indexes of demand across the continuum of differentiated goods produced respectively in the domestic economy and abroad, given by

$$Z^{di} = \left[\sum_{h=1}^{m^d} \left(\frac{1}{m^d} \right)^{\frac{1}{\sigma^d}} Z_h^{d^i\,\frac{\sigma^d-1}{\sigma^d}} \right]^{\frac{\sigma^d}{\sigma^d-1}}, Z^{fi} = \left[\sum_{h=1}^{m^f} \left(\frac{1}{m^f} \right)^{\frac{1}{\sigma^m}} Z_h^{f^i\,\frac{\sigma^m-1}{\sigma^m}} \right]^{\frac{\sigma^m}{\sigma^m-1}}. \tag{24b}$$

The elasticity of substitution between bundles of domestic and foreign goods Z^{d^i} and Z^{f^i} is σ. Thus aggregate imports are given by

$$IM_t = s^M \left(\frac{P^C_t}{P^{IM}_t} \right)^{\sigma} (C_t + I_t + G_t + IG_t) \tag{25}$$

$$P^{IM}_t = E_t P^*_t \tag{26}$$

Net foreign assets evolve according to

$$E_t B^F_t = (1 + r^F_t) E_t B^F_{t-1} + P^{EX}_t EX_t - P^{IM}_t IM_t. \tag{27}$$

Policy

On the expenditure side we assume that government consumption, government transfers and government investment are proportional to GDP and unemployment benefits are indexed to wages

$$BEN_t = \sum_s b^s_t W^s_t (1 - NPART^s_t - L^s_t), \tag{28}$$

where the benefit replacement rate b_t^s can be indexed to consumer prices and net wages in different degrees according to the following rule

$$b_t^s = \hat{b}_t^s \left[(1+t_t^C)P_t^C\right]^{\chi^c} (1-t_t^W)^{\chi^w}, 0 \le \chi^c, \chi^w \le 1 \tag{29}$$

The government provides subsidies (S_t) on physical capital and R&D investments in the form of a tax-credit and depreciation allowances

$$S_t = t_{t-1}^K \left(\delta^K P_t^I K_{t-1}^{i,H} + \delta^A P_t^A A_{t-1}^{i,H}\right) + \tau^K P_t^I J_t^{i,H} + \tau^A P_t^A J_t^{A,i,H}. \tag{30}$$

Government revenues $R_t^G$are made up of taxes on consumption as well as capital and labour income. Government debt (B_t) evolves according to

$$B_t = (1+r_t)B_{t-1} + P_t^C(G_t + IG_t) + TR_t + BEN_t + S_t - R_t^G - T_t^{LS}. \tag{31}$$

We assume that a lump-sum tax (T_t^{LS}) used for controlling the debt to GDP ratio according to the following rule

$$\Delta T_t^{LS} = \tau^B \left(\frac{B_{t-1}}{Y_{t-1}P_{t-1}} - b^T\right) + \tau^{DEF} \Delta \left(\frac{B_t}{Y_t P_t}\right) \tag{32}$$

where b^T is the government debt target.

Monetary policy is modelled via a standard Taylor rule, which allows for some smoothness of the interest rate response to the inflation and output gap

$$\begin{aligned} i_t = {} & \tau_{lag}^{INOM} i_{t-1} + (1-\tau_{lag}^{INOM})[r^{EQ} + \pi^T + \tau_{\pi}^{INOM}(\pi_t^C - \pi^T) + \tau_{y,1}^{INOM} ygap_{t-1}] \\ & + \tau_{y,2}^{INOM}({}_t ygap_{t+1} - ygap_t) + u_t^{INOM} \end{aligned} \tag{33}$$

The central bank has a constant inflation target π^T and it adjusts interest rates whenever actual consumer price inflation deviates from the target and it also responds to the output gap. There is also some inertia in nominal interest rate setting.

We use a measure that closely approximates the standard practice of output gap calculation as used for fiscal surveillance and monetary policy (see Denis et al. (2006)), in which a production function framework is used where the output gap is defined as deviation of capital and labour utilisation from their long run trends. Therefore we define the output gap as

$$YGAP_t = \left(\frac{ucap_t}{ucap_t^{ss}}\right)^{(1-\alpha)} \left(\frac{L_t}{L_t^{ss}}\right)^{\alpha}. \tag{34}$$

where L_t^{ss} and $ucap_t^{ss}$ are moving average steady state employment rate and capacity utilisation:

$$ucap_t^{ss} = (1-\rho^{ucap})ucap_{t-1}^{ss} + \rho^{ucap} ucap_t \tag{35}$$

$$L_t^{ss} = (1-\rho^{Lss})L_{t-1}^{ss} + \rho^{Lss} L_t \tag{36}$$

which we restrict to move slowly in response to actual values.

Table 1: Calibration of old member state models

	BE	DE	DK	ES	FR	GR	IR	IT	NL	OS	PO	SF	SW	UK	Source
R&D sector															
researchers (L_A,% empl.)	1.13	1.11	1.45	0.95	0.99	0.71	0.89	0.51	0.61	1.18	0.72	2.15	1.90	0.87	EUROSTAT
R&D (% GDP)	1.86	2.50	2.49	1.11	2.14	0.57	1.25	1.10	1.75	2.36	0.77	3.44	3.75	1.75	EUROSTAT
elast. of R&D wrt. labour (λ)	0.50	0.36	0.45	0.67	0.37	0.93	0.47	0.37	0.27	0.40	0.99	0.46	0.40	0.46	calibr./Botazzi-Peri
elast. of R&D wrt. dom. ideas (ϕ)	0.52	0.66	0.57	0.36	0.65	0.11	0.55	0.64	0.74	0.62	0.06	0.56	0.62	0.56	calibr./Botazzi-Peri
elast. of R&D wrt. for. ideas (ϖ)	0.46	0.32	0.41	0.61	0.34	0.84	0.43	0.34	0.25	0.36	0.90	0.42	0.36	0.42	calibr./Botazzi-Peri
R&D efficiency (ν)	0.28	0.13	0.18	0.72	0.15	3.46	0.26	0.20	0.10	0.16	4.17	0.16	0.13	0.24	calibration
depr. rate of ideas (δ^A,%)	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	Pessoa (2005)
growth rate of ideas (g^A,%)	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	Pessoa (2005)
Intermediate sector															
mark up ($1/\theta-1$,%)	11.14	10.00	10.00	8.00	10.00	11.14	9.00	10.00	11.00	10.00	9.00	14.00	14.00	11.00	EUKLEMS
entry costs (FC_A)	0.33	0.32	0.11	0.50	0.36	0.73	0.18	0.45	0.31	0.42	0.49	0.11	0.08	0.03	Djankov et al.
risk pr. on intangibles (rp^A,%)	0.93	0.20	0.72	2.22	0.64	2.42	1.81	2.02	1.49	0.29	2.13	0.16	0.10	1.92	calibration
Final g. sector															
mark up (τ,%)	19.46	18.17	17.35	16.70	18.70	15.73	24.56	21.28	20.45	23.00	17.17	24.06	19.62	17.79	EUKLEMS
depr. rate of capital (δ,%)	1.86	1.22	2.27	2.39	1.52	1.80	2.39	1.52	1.57	1.34	2.03	1.96	1.28	1.53	calibration
Labour market															
low sk. pop. share (s_L,%)	34.77	16.36	20.00	52.68	33.28	41.33	35.30	50.03	28.54	20.08	74.17	21.63	16.55	29.05	EUROSTAT
medium sk. pop. share (s_M,%)	57.69	75.64	72.12	38.60	59.76	53.19	56.33	46.83	66.95	74.31	21.88	68.76	76.89	62.15	EUROSTAT
high sk. pop. share (s_H,%)	7.54	8.01	7.89	8.72	6.96	5.48	8.37	3.14	4.51	5.61	3.96	9.61	6.56	8.80	EUROSTAT
low sk. employment (L_L,%)	49.18	51.94	63.62	58.66	58.48	58.50	57.96	51.96	60.10	54.32	71.86	58.12	66.90	64.76	EUROSTAT
medium sk. employment (L_M,%)	73.56	71.70	80.60	74.50	75.74	69.14	76.48	73.68	78.80	74.82	80.22	75.22	81.72	81.26	EUROSTAT
high sk. employment (L_H,%)	83.94	84.06	86.62	82.66	83.18	82.64	86.46	81.08	86.22	84.90	87.22	84.76	87.38	87.94	EUROSTAT
skill elast. of subs. (σ_L)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	Katz-Murphy
employment rate (L,%)	65.87	69.46	77.68	66.87	70.51	65.48	70.78	63.05	73.80	71.27	74.30	72.44	79.64	77.06	EUROSTAT
wage prem. high vs. medium (%)	37.26	44.09	37.26	37.26	37.26	22.00	33.28	37.26	32.41	37.26	16.00	37.26	37.26	38.97	EUROSTAT
wage prem. medium vs. low (%)	11.11	13.64	21.95	17.65	16.28	23.68	16.28	26.58	19.05	40.85	75.44	6.38	14.94	44.93	EUROSTAT
low sk. efficiency level (ef_L)	0.38	0.22	0.25	0.18	0.24	0.16	0.21	0.23	0.24	0.17	0.28	0.34	0.23	0.26	calibration
medium sk. efficiency level (ef_L)	0.47	0.28	0.37	0.25	0.32	0.25	0.29	0.36	0.35	0.34	0.85	0.38	0.31	0.55	calibration
high sk. efficiency level (ef_L)	0.88	0.58	0.71	0.47	0.61	0.37	0.51	0.69	0.61	0.65	1.15	0.72	0.58	1.07	calibration
labour adj. costs (γ_L,% of total)	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	QUEST III
Taxes/subsidies															
tax credit (τ^A,%)	16.40	17.51	25.59	46.17	25.97	14.98	10.54	29.97	25.38	18.35	34.27	12.41	12.92	19.88	Warda (2006)
tax rate on cap. income (t^K,%)	33.99	38.70	28.00	35.00	34.33	32.00	12.50	33.00	29.25	25.00	27.50	26.00	28.00	24.50	Warda (2006)
consumption tax (t^C,%)	21.07	17.87	32.09	16.05	19.43	16.67	24.55	16.94	24.43	21.82	20.02	26.85	26.46	17.30	DG TAXUD
labour tax (t^L,%)	43.76	41.87	44.61	41.54	54.52	45.74	25.10	51.11	39.81	40.03	41.46	40.47	48.53	34.99	calibration
transfers (tr,% GDP)	15.88	18.95	16.19	11.69	17.75	17.61	8.77	17.03	11.25	18.59	14.63	16.29	17.13	13.07	EUROSTAT

Table 2: Calibration of new member state models

	BG	CY	CZ	EE	HU	LT	LV	MT	PL	RO	SI	SK	Source
R&D sector													
researchers (L_A,% empl.)	0.39	0.37	0.75	0.95	0.80	0.79	0.58	0.58	0.68	0.31	0.72	0.79	EUROSTAT
R&D (% GDP)	0.49	0.39	1.36	0.93	0.94	0.75	0.51	0.47	0.56	0.41	1.44	0.52	EUROSTAT
elast. of R&D wrt. labour (λ)	0.43	0.76	0.36	0.67	0.62	0.74	0.72	0.97	0.74	0.70	0.43	0.74	calibr./Botazzi-Peri
elast. of R&D wrt. dom. ideas (ϕ)	0.59	0.28	0.66	0.36	0.41	0.30	0.32	0.08	0.29	0.33	0.59	0.29	calibr./Botazzi-Peri
elast. of R&D wrt. for. ideas (ϖ)	0.39	0.69	0.33	0.61	0.57	0.67	0.66	0.88	0.68	0.64	0.39	0.68	calibr./Botazzi-Peri
R&D efficiency (ν)	0.34	2.27	0.17	0.71	0.68	1.16	1.33	6.54	1.54	1.99	0.24	1.27	calibration
depr. rate of ideas (δ^A,%)	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	Pessoa (2005)
growth rate of ideas (g^A,%)	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	Pessoa (2005)
Intermediate sector													
mark up ($1/\theta-1$,%)	7.00	14.00	9.00	9.00	14.00	9.00	9.00	13.00	11.14	11.14	11.14	9.00	EUKLEMS
entry costs (FC_A)	0.33	0.81	0.42	0.46	1.10	0.32	0.60	0.81	0.57	0.62	0.48	0.58	Djankov et al.
risk pr. on intangibles (rp^A,%)	2.24	1.48	2.24	2.38	0.95	2.17	2.58	1.50	1.48	2.31	1.57	2.05	calibration
Final g. sector													
mark up (τ,%)	25.89	22.20	17.27	17.49	22.07	26.02	19.15	24.66	26.91	15.26	16.54	25.77	EUKLEMS
depr. rate of capital (δ,%)	3.34	2.48	2.28	4.05	2.89	3.74	4.49	2.28	2.68	2.78	2.84	2.44	calibration
Labour market													
low sk. pop. share (s_L,%)	26.41	32.41	10.36	11.25	23.44	12.49	15.94	75.52	15.49	27.26	19.70	12.16	EUROSTAT
medium sk. pop. share (s_M,%)	67.46	60.45	85.16	77.68	72.14	78.69	80.05	22.61	79.29	67.94	75.15	83.32	EUROSTAT
high sk. pop. share (s_H,%)	6.14	7.14	4.48	11.07	4.42	8.82	4.02	1.87	5.22	4.80	5.15	4.53	EUROSTAT
low sk. employment (L_L,%)	41.02	64.86	43.60	52.96	37.78	48.12	53.60	48.26	38.28	54.04	55.54	27.96	EUROSTAT
medium sk. employment (L_M,%)	71.02	78.76	75.50	75.28	70.72	74.82	74.42	80.90	62.62	70.56	74.40	71.50	EUROSTAT
high sk. employment (L_H,%)	81.30	87.80	85.82	84.08	82.24	87.52	85.06	86.28	83.20	85.46	87.10	84.90	EUROSTAT
skill elast. of subs. (σ_L)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	Katz-Murphy
employment rate (L,%)	63.73	74.90	72.66	73.74	63.51	72.61	71.53	56.35	59.92	66.77	71.34	66.81	EUROSTAT
wage prem. high vs. medium (%)	15.68	34.25	21.65	34.25	34.25	47.30	34.25	34.25	21.55	36.74	34.00	13.36	EUROSTAT
wage prem. medium vs. low (%)	24.88	23.46	38.89	23.68	36.99	23.68	23.68	23.68	28.21	49.79	34.75	41.30	EUROSTAT
low sk. efficiency level (ef_L)	0.23	0.35	0.09	0.13	0.23	0.26	0.14	0.37	0.30	0.27	0.24	0.09	calibration
medium sk. efficiency level (ef_L)	0.35	0.54	0.18	0.21	0.43	0.39	0.21	0.57	0.49	0.60	0.44	0.18	calibration
high sk. efficiency level (ef_L)	0.48	0.97	0.27	0.37	0.78	0.85	0.38	1.03	0.72	1.13	0.78	0.24	calibration
labour adj. costs (γ_L,% of total)	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	QUEST III
Taxes/subsidies													
tax credit (τ^A,%)	17.34	14.98	35.35	17.34	21.61	17.34	17.34	14.98	8.61	14.64	17.34	17.34	Warda (2006)
tax rate on cap. income (t^K,%)	19.94	32.00	26.00	19.94	16.00	19.94	19.94	32.00	19.00	32.00	19.94	19.94	Warda (2006)
consumption tax (t^C,%)	23.08	22.08	20.77	21.50	25.28	16.18	17.50	19.88	19.04	14.21	25.04	21.34	DG TAXUD
labour tax (t^L,%)	42.59	31.80	47.78	32.01	49.27	45.23	39.82	49.95	56.72	23.16	40.68	51.78	calibration
transfers (tr,% GDP)	11.91	12.22	11.61	9.17	14.52	8.85	8.57	12.94	15.79	8.58	16.27	12.07	EUROSTAT