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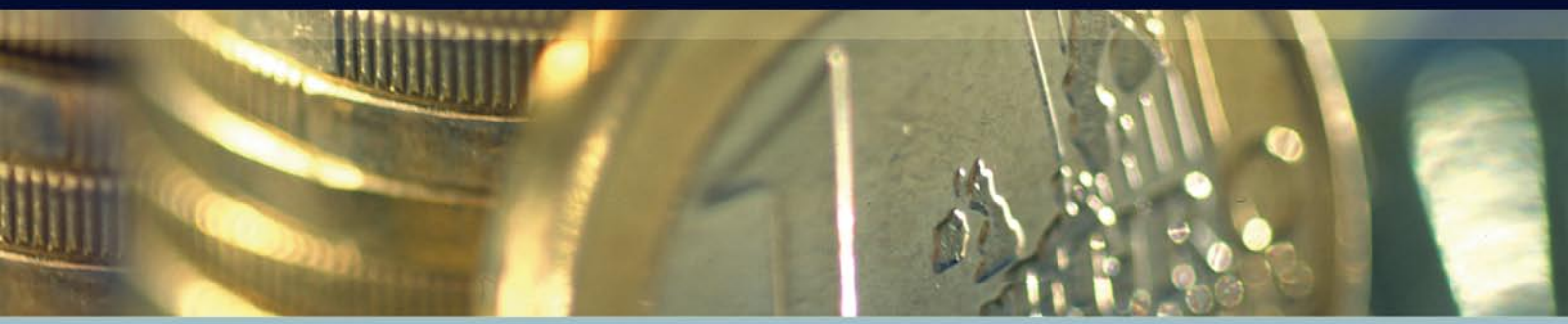

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A simulation-based analysis using the QUEST model with endogenous growth

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Structural Reforms in the EU: A simulation-based analysis using the QUEST model with endogenous growth

by

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Abstract:

This paper describes a micro-founded DSGE model with endogenous growth that is used to analyse the macroeconomic impact of structural reforms in Europe. The new QUEST III model is a useful tool for analysing the costs and benefits of 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. Our results confirm 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 model also allows us to examine the adjustment path and the time lags involved before these benefits can be reaped.

JEL Classification: E32, E62, O30, O41
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The views expressed in this paper are those of the authors and should not be attributed to the European Commission.

Executive Summary

The launch of the Lisbon Strategy in 2000 has started a lively debate on how to best design a strategy to achieve both higher growth and more employment and there has been a related discussion on how to best evaluate structural measures which have an impact on goods, labour and financial markets.

It is widely recognised by now that knowledge investment is a key to economic growth and there is a link between the growth rate of technical progress and knowledge investment, both in the form of higher R&D spending or increased education expenditure. For example, the OECD (2003) estimates that increasing R&D by 0.1% points could increase GDP by about 1.2%, while Fuente (2003) estimates that one year of additional education could raise GDP in the EU by 4 to 6%. However, it is also evident that it is not in the power of governments to increase R&D spending (of the private sector) directly. Instead one has to think about appropriate policies which induce firms to increase intangible investment. These can take a variety of forms, e. g. tax incentives, changes in market structure, supporting public R&D efforts, increasing the pool of qualified R&D personnel etc.

This paper proposes to use a Dynamic Stochastic General Equilibrium (DSGE) model which captures both investment in tangibles and intangibles (R&D), and which also disaggregates employment into various skill categories, as a tool for analysing the effects of particular policy measures. The framework that we adopt is the Jones (1995, 2005) extension of the Romer (1990) endogenous growth model, which uses a variety approach for modelling knowledge investment. DSGE models are particularly well-suited for this task since they capture nominal and real rigidities in goods and labour markets by modelling these markets as imperfectly competitive. This also allows us to look at competition-enhancing policies.

The model set up in this paper is sufficiently detailed to be able to address the main reform areas that are discussed within the EU's comprehensive strategy of structural reforms. More specifically we use the model to analyse the following reforms: increasing the employment of low-skilled workers, changing the skill composition of the labour force, fiscal measures for increasing knowledge investment, removing entry barriers and administrative burdens in certain markets and addressing financial market imperfections. Our aim is to explicitly model the 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 (for both entrants and incumbents) and regulatory indices. For each policy measure a comprehensive set of macroeconomic indicators is presented, showing how particular reforms impact on growth, employment, the composition of investment and skill premia in the short, medium and long run, thus providing insights into the transmission mechanisms of various structural and fiscal measures.

The model has been used to analyse selected structural policies published in the Annual Progress Report of the Commission and is currently used to analyse policies as put forward in the recent Communication from the Commission proposing a European Economic Recovery Plan in response to the financial crisis. The model feeds into the policy making process as a tool which can be used to assess concrete policy initiatives designed to counter adverse effects of the financial crisis concerning their short, medium and long run growth and employment impacts.

Introduction

Designing policies to foster economic growth and job creation in the European Union is one of the principal goals of the Lisbon Strategy for Growth and Jobs. Since the initiation of the Lisbon Strategy in 2000 there has been a lively debate on how to best design a strategy to achieve both higher growth and more employment. This has become even more critical in the recent financial crisis which is expected not only to lower actual growth but also to reduce the potential growth rate in the medium term[1]. However, as emphasised in a review of Lisbon related research the Commission (European Commission, 2005) states: "…at this stage we have only a partial view of the impact of specific reforms and we not yet fully understand the interactions between the different reforms envisaged in the Lisbon Strategy." Also Sapir (2007) points out that there are large deficiencies in the methodology to evaluate structural reforms. In particular he stresses that structural reforms are essentially microeconomic policy measures, which implies that without a clear view on how particular measures affect goods, labour and financial markets it will be difficult to assess their impact on growth and employment. Sapir (2007) states in this context: "…using a macro-model to assess the impact of structural reforms requires a careful modelling of the intermediate microeconomic effects." This poses a challenge to model builders. In this paper we want to make a step in the direction of dealing with this challenge.

Standard modern macro-economic models, so called Dynamic Stochastic General Equilibrium (DSGE) models, go some way in the direction of meeting the requirement of micro foundations and also typically model imperfections in goods and labour markets. DSGE models try to capture nominal and real rigidities in goods and labour markets by modelling these markets as imperfectly competitive. Nevertheless, standard models still lack sufficient detail to make a direct link between concrete reform efforts and market outcomes. For example it is typical in macro studies of the impact of structural reforms to analyse reforms by giving shocks to mark-ups and TFP (see for example Bayoumi *et al*. (2004) and studies based on CGE models). Such exercises are certainly useful if one is interested in understanding productivity and employment differences between two countries with different levels of mark-ups and TFP. However, it is less useful in a policy context as long as one cannot link these variables to policy measures. Another weak point of existing macro models is that they are not detailed enough to address specific policy areas. This becomes immediately clear when one looks at the main reform areas. For example, the employment rate in Europe differs significantly across skill groups. Therefore a policy of increasing the employment rate must devise measures to increase the demand and supply of low skilled workers or change the composition of the labour force. Analysing labour market policies therefore requires a disaggregation of the labour market, which is not a common practice in macro models. One of the most prominent Lisbon targets is to increase R&D expenditure to 3% of GDP. It is widely recognised by now that knowledge investment is a key to economic growth and there is a link between the growth rate of technical progress and R&D spending. However, it is also clear that it is not in the power of governments to increase R&D spending (of the private sector) directly but one has to think about appropriate policies which induce firms to increase intangible investment. These can take a variety of forms, e. g. tax incentives, changes in market structure, supporting public R&D efforts, increasing the pool of qualified R&D personnel etc.. What is required is a disaggregation of investment into tangibles and

[1] In response to the financial crisis, the Commission is proposing a detailed EU recovery framework, under the umbrella of the Lisbon strategy for growth and jobs, bringing together a series of targeted short term initiatives designed to help counter adverse effects of the financial crisis on the wider economy and adapting the medium to long term measures of the Lisbon strategy to take account of the crisis.

intangibles which is not standard practice in macro models. Such a disaggregation is conceptually much more demanding then for example skill disaggregation of the labour force, because these two types of goods have fundamentally different economic characteristics. Physical capital is a conventional good. Basically this means two things. First, the use of a piece of fixed capital by one firm precludes its use by another firm, i.e. it is rivalrous. Second, the quantity of output produced can be modelled within a standard production function framework with constant returns-to-scale. Knowledge capital is different in both dimensions. It usually comes in the form of a design for the production of a new good. In contrast to physical capital it is non-rivalrous (see Romer,1990), i.e. a firm which is in the possession of a new design cannot automatically preclude other firms from using it and there can be knowledge spillovers. Also, once a design has been created it can be used in production for as large a quantity as is required by the market without duplicating the design. Thus knowledge capital takes the form of a *sunk* cost for the firm and production becomes *increasing* returns-to-scale. This not only has technological implications but also has consequences for market structures which are compatible with this technology. Endogenous growth models as pioneered by Romer (1990), and further developed by Jones (1995) and Aghion and Howitt (1998), provide the conceptual framework to deal with these issues. This is also the framework we use in this paper. As implied by these models, striking an adequate balance between efficiency and competition becomes a complex issue.

In this paper we make an attempt to set up a model that is sufficiently detailed to be able to address the main reform areas that are discussed within the EU's comprehensive strategy of structural reforms. More specifically we use the model to analyse the following reforms: increasing the employment of low-skilled workers, changing the skill composition of the labour force, increasing knowledge investment, removing entry barriers in certain markets and addressing financial market imperfections. Our aim is to explicitly model the 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 (for both entrants and incumbents) and regulatory indices. This makes the model a useful tool for analysing the costs and benefits of structural reforms, but it can also be usefully applied to address questions concerning the quality of public finances.

The model we use in this paper is an extension of the QUEST III model with endogenous growth. The new QUEST III model is a global DSGE model employed in the Directorate-General Economic and Financial Affairs of the European Commission for quantitative policy analysis. This model belongs to the new class of micro-founded DSGE models that are now widely used in economic policy institutions[2]. Equations in these models are explicitly derived from intertemporal optimisation under technological, institutional and budgetary constraints and the model incorporates nominal, real and financial frictions in order to fit the data (Ratto *et al.*, 2008). The model employs the product variety framework proposed by Dixit and Stiglitz (1977) and applies the Jones (1995) semi-endogenous growth framework to explicitly model the underlying development of R&D.

Our paper can be compared to Bayoumi *et al.* (2004), which uses the IMF's Global Economy Model GEM to analyse the macroeconomic benefits from increasing competition in euro area labour and product markets to US levels. Based on empirically estimated mark-ups for the euro area and the US, they find that lowering price and wage mark-ups to US levels could raise output per capita by about 12 ½ percent and close about half the observed per-capita

[2] See for example the International Monetary Fund's Global Economy Model (Bayoumi *et al*., 2004) and the European Central Bank's New Area-Wide Model (Coenen et al., 2007).

output gap between the two regions. Coenen *et al.* (2007) employ the ECB's New Area-Wide Model NAWM to examine the effects of reducing the euro area tax wedge to levels prevailing in the US and find that this would result in an increase in hours worked and output of more than 10 percent. In our paper we investigate a wider range of policies and we use an endogenous growth framework[3]. We find that the effect of reducing price mark-ups is not unambiguous and depends on the sector in which it occurs. In our intermediate goods sector mark-ups cover the costs associated with acquiring a patent when entering the market, and reducing mark-ups can have a detrimental impact on growth and employment if it reduces entry of new firms. Concerning tax reforms, Coenen *et al.* consider reductions in the overall tax burden that are offset by changes in government transfers to households, while we look at the effects of a shift in the tax burden from labour tax to consumption tax.

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. The final section concludes.

1 Model

The model economy is populated by households, final and intermediate goods producing firms, a research industry, a monetary and a fiscal authority[4]. In the final goods sector firms produce differentiated goods which are imperfect substitutes for goods produced abroad. Final good producers use a composite of domestic and imported intermediate goods and three types of labour - (low-, medium-, and high-skilled). Households buy the patents of designs produced by the R&D sector and license them to the intermediate goods producing firms. The intermediate sector is composed of monopolistically competitive firms which produce intermediate products from rented capital input using the designs licensed from the household sector. The production of new designs takes place in research labs, employing high skilled labour and making use of the existing stock of domestic and foreign ideas. Technological change is modelled as increasing product variety in the tradition of Dixit and Stiglitz (1977).

1.1 Households

The household sector consists of a continuum of households $h \in [0,1]$. A share (1-ε) of these households are not liquidity constrained and indexed by $i \in [0,1-\varepsilon]$. They have access to financial markets where they can buy and sell domestic and foreign assets (government bonds), 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

[3] In another paper (Roeger *et al.*, 2008) we use the model to identify possible sources for the productivity gap between the EU and the US and look at policies which could help to close this gap. The framework allows us to explain differences in productivity and R&D spending levels in terms of differences in taxation, subsidies to R&D, mark ups in labour and goods markets, entry barriers, efficiency of the R&D sector and the skill composition of the labour force.

[4] The model can be used in a one-country, open-economy version and it can also be extended to more regions (e.g. Euro Area and non Euro Area blocks of the EU, US, Asia, major oil-exporters). Individual European Union member states can also be modelled separately in interaction with the rest of the EU.

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 financial and physical assets and consume their disposable income each period. Members of liquidity constrained households offer low-skilled labour services only. For each skill group we assume that both types of 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.

1.1.1 Non liquidity constrained households

Each non liquidity constrained household maximise an intertemporal utility function in consumption and leisure subject to a budget constraint. These households makes 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 corresponding 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), and receives wage income (W_t^i), unemployment benefits ($b_t^s W_t^{i,s}$)[5], transfer income from the government (TR_t^i) ,and interest income (i_t, i_t^K and i_t^A). Hence, non-liquidity constrained households face the following Lagrangian

[5] 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. It is assumed that the government makes a decision how to classify the non-working part of the population into unemployed and non-participants. The non - participation rate *NPART* must therefore be seen as a policy variable characterising the generosity of the benefit system.

(1)

$$\underset{\left\{\begin{matrix} C_t^i, L_t^i, B_t^i \\ B_t^{F,i}, J_t^i, K_t^i \\ J_t^{A,i}, A_t^i, ucap_t^i \end{matrix}\right\}_{t=0}^{\infty}}{Max} \quad V_0^i = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left(U(C_t^i) + \sum_s V(1 - L_t^{i,s}) \right)$$

$$- \mathrm{E}_0 \sum_{t=0}^{\infty} \lambda_t^i \beta^t \left(\begin{array}{l} (1+t_t^c) P_t^C C_t^i + B_t^i + E_t B_t^{F,i} + P_t^I \left(J_t^i + \Gamma_J (J_t^i) \right) + P_t^A J_t^{A,i} \\ - (1+r_{t-1}) B_{t-1}^i - \left(1 + r_{t-1}^F - \Gamma_{B^F} \left(E_t B_{t-1}^F / Y_{t-1} \right) \right) E_t B_{t-1}^{F,i} \\ - \sum_s \left(1 - t_t^{w,s} \right) W_t^{i,s} L_t^{i,s} - b_t^s W_t^{i,s} (1 - NPART_t^{i,s} - L_t^{i,s}) + \Gamma_W (W_t^{i,s}) \\ - (1 - t_{t-1}^K) \left(i_{t-1}^K ucap_{t-1}^i - rp_{t-1}^K - \Gamma_U \left(ucap_{t-1}^i \right) \right) P_t^J K_{t-1}^i - t_{t-1}^K \delta^K P_t^I K_{t-1}^i - \tau^K P_t^I J_t^i \\ - (1 - t_{t-1}^K) (i_{t-1}^A - rp_{t-1}^A) P_t^A A_{t-1}^i - t_{t-1}^K \delta^A P_t^A A_{t-1}^i - \tau^A P_t^A J_t^{A,i} \\ - TR_t^i - \sum_{j=1}^n PR_{j,t}^{f,i} - \sum_{j=1}^{A_t} PR_{j,t}^{x,i} \end{array} \right)$$

$$- \mathrm{E}_0 \sum_{t=0}^{\infty} \lambda_t^i \xi_t^i \beta^t \left(K_t^i - J_t^i - (1 - \delta^K) K_{t-1}^i \right) - \mathrm{E}_0 \sum_{t=0}^{\infty} \lambda_t^i \psi_t^i \beta^t \left(A_t^i - J_t^{A,i} - (1 - \delta^A) A_{t-1}^i \right)$$

$$s \in \{M, H\}$$

The budget constraints are written in real terms with all prices and wages normalized with P_t, the price of domestic final goods. All firms of the economy are owned by non liquidity constrained 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. As shown by the budget constraints, 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. When taking a position in the international bond market, households face a financial intermediation premium $\Gamma_{B^F}(.)$ which depends on the economy-wide net holdings of internationally traded bonds. Also, when investing into tangible and intangible capital households require premia rp_t^K and rp_t^A in order to cover the increased risk on the return related to these assets. The real interest rate r_t is equal to the nominal interest rate minus expected inflation: $r_t = i_t - E_t(\pi_{t+1})$.

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

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

For leisure we assume CES preferences with common labour supply elasticity but a skill specific weight (ω_s) on leisure. This is necessary in order to capture differences in employment levels across skill groups. Thus preferences for leisure are given by

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

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

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

(3b) $$\Gamma_U(ucap_t^i) = a_1\left(ucap_t^i - ucap_t^{ss}\right) + a_2\left(ucap_t^i - ucap_t^{ss}\right)^2 \quad ,$$

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

Wages are also subject to convex adjustment costs given by

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

Consumption (*C*) and investment (*J*) is itself an aggregate of domestic and foreign varieties of final goods, with preferences expressed by the following CES utility function

(5a) $$Z^i = \left[(1-s^M)^{\frac{1}{\sigma}} Z^{d\,i\,\frac{\sigma-1}{\sigma}} + s^{M\,\frac{1}{\sigma}} Z^{f\,i\,\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{(\sigma-1)}}$$

with $Z^i \in \left\{C^i, I^i\right\}$ 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

(5b) $$Z^{d\,i} = \left[\sum_{h=1}^{m^d}\left(\frac{1}{m^d}\right)^{\frac{1}{\sigma^d}} Z_h^{d\,i\,\frac{\sigma^d-1}{\sigma^d}}\right]^{\frac{\sigma^d}{\sigma^d-1}} \quad , \quad Z^{f\,i} = \left[\sum_{h=1}^{m^f}\left(\frac{1}{m^f}\right)^{\frac{1}{\sigma^m}} Z_h^{f\,i\,\frac{\sigma^m-1}{\sigma^m}}\right]^{\frac{\sigma^m}{\sigma^m-1}} .$$

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 the following equations:

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

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

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

(6d)

$$\frac{\partial V_0}{\partial K_t^i} => -\lambda_t^i \xi_t^i + \mathrm{E}_t\left(\lambda_{t+1}^i \xi_{t+1}^i \beta(1-\delta) + \lambda_{t+1}^i \beta\left((1-t_t^K)\left(i_t^K ucap_t^i - rp_t^K - \Gamma_u\left(ucap_t^i\right)\right) + t_t^K \delta^K\right) P_{t+1}^C\right) = 0$$

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

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

All arbitrage conditions are standard, except for a trading friction ($\Gamma_{B^F}(.)$) on foreign bonds, which is modelled as a function of the ratio of assets to GDP. Using the arbitrage conditions and neglecting the second order terms, investment is given as a function of the variable Q_t

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

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

(7b) $$Q_t = \mathrm{E}_t\left(\frac{1-\delta}{1 + i_t - \pi_{t+1}^C} Q_{t+1} + \frac{(1-t_t^K)\left(i_t^K ucap_t^i - rp_t^K - \Gamma_u\left(ucap_t^i\right)\right) + t_t^K \delta^K}{1 + i_t - \pi_{t+1}^C}\right)$$

Notice, 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_{t+1}^C).

Non-liquidity constrained households buy new patents of designs produced by the R&D sector (I_t^A) and rent their total stock of design (A_t) at rental rate i_t^A to intermediate goods producers in period *t*. Households pay income tax at rate t_t^K on the period return of intangibles and they receive tax subsidies at rate τ^A. Hence, the first order conditions with respect to R&D investments are given by

(7c) $$\frac{\partial V_0}{\partial A_t^i} => -\lambda_t^i \psi_t^i + \mathrm{E}_t\left(\lambda_{t+1}^i \psi_{t+1}^i \beta(1-\delta^A) + \lambda_{t+1}^i \beta\left((1-t_t^K)(i_t^A - rp_t^A) + t_t^K \delta^A\right) P_{t+1}^A\right) = 0$$

(7d) $$\frac{\partial V_0}{\partial J_t^{A,i}} => -\lambda_t^i P_t^A\left(1 - \tau^A\right) + \lambda_t^i \psi_t^i = 0$$

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

(7c') $$i_t^A \approx \frac{(1-\tau^A)\left(i_t - \pi_{t+1}^A + \delta^A\right) - t_t^K \delta^A}{(1-t_t^K)} + rp_t^A$$

where $1+\pi_{t+1}^A = \frac{P_{t+1}^A}{P_t^A}$.

Equation (7c') states that household require a rate of return on intangible capital which is equal to the nominal interest rate minus the rate of change of the value of intangible assets and also covers 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.

1.1.2 Liquidity constrained households

Liquidity constrained households do not optimize but simply consume their current income at each date. Real consumption of household *k* is thus determined by the net wage income plus net transfers

(8)

$$(1+t_t^c)P_t^C C_t^k + \sum_s \frac{\gamma_W L_t^{k,s}}{2} \frac{\Delta W_t^{k,s}{}^2}{W_{t-1}^{k,s}} = \sum_s \left(\left(1-t_t^{w,s}\right) W_t^{k,s} L_t^{k,s} + b_t^s W_t^{k,s} (1 - NPART_t^{k,s} - L_t^{k,s})\right) + TR_t^k .$$

1.1.3 Wage setting

Within each skill group a variety of labour services are supplied which are imperfect substitutes to each other. Thus trade unions can charge a wage mark-up ($1/\eta_t^W$) over the reservation wage[6]. The reservation wage is given as the marginal utility of leisure divided by the corresponding marginal utility of consumption. The relevant net real wage to which the mark up adjusted reservation wage is equated is the gross wage adjusted for labour taxes, consumption taxes and unemployment benefits which act as a subsidy to leisure. Thus the wage equation is given as

(9) $$\frac{U_{1-L,t}^{h,s}}{U_{C,t}^h} \frac{1}{\eta_t^W} = \frac{W_t^s (1-t_t^{w,s} - b_t^s)}{(1+t_t^C)P_t^C} \text{ for } h \in \{i,k\} \text{ and } s \in \{L,M,H\}.$$

1.1.4 Aggregation

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

[6] The mark-up depends on the intratemporal elasticity of substitution between different types of labour σ_s and fluctuations in the mark-up arise because of wage adjustment costs and the fact that a fraction *(1-sfw)* of workers is indexing the growth rate of wages π^w to wage inflation in the previous period

$$\eta_t^w = 1 - 1/\sigma_s - \gamma_W / \sigma_s \left[\beta(sfw\,\pi_{t+1}^w - (1-sfw)\pi_{t-1}^w) - \pi_t^w\right]$$

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

Hence aggregate consumption and employment is given by

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

and

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

1.2 Firms

1.2.1 Final output producers

Since 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 it acts as a monopolistic competitor facing a demand function with a price elasticity given by 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

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

with

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

Parameter 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, and σ_L is the elasticity of substitution between different labour types. Note that 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

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

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

The above production function employs the idea of product variety framework proposed by Dixit and Stiglitz (1977) and applied in the literature of international trade and R&D diffusion[7] and we will explicitly model the underlying development of R&D by the semi-endogenous framework of Jones (1995 and 2005)[8].

The objective of the firm is to maximise profits

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

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 P_t, the price of domestic final goods. In a symmetric equilibrium, the demand for labour and intermediate inputs is given by

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

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

where $\eta_t = 1 - 1/\sigma_t^d$ [9]

1.2.2 Intermediate goods producers

The intermediate sector consists of monopolistically competitive firms which have entered the market by licensing 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_t^K. Firms which have acquired a design can transform each unit of capital into a single unit of an intermediate input. Intermediate goods producing firms sell their products to domestic final good producers. In symmetric equilibrium the inverse demand function of domestic final good producers is given as equation (17b).

Each domestic intermediate firm solves the following profit-maximisation problem

$$(18)\quad PR_{i,t}^x = \max_{x_{i,t}}\left\{px_{i,t}x_{i,t} - i_t^K P_t^C k_{i,t} - i^A P_t^A - FC_A\right\}$$

---

[7] See Grossman and Helpman (1991) and Aghion and Howitt (1998).

[8] Butler and Pakko (1998) also applied Jones (1995) semi-endogenous growth framework to examine the effect of endogenous technological change on the properties of a real business cycle model without skill disaggregation.

[9] Similar to the wage mark-up, we allow for fluctuations in the mark-up of prices because of price adjustment costs and the fact that a fraction of firms is indexing price increases to inflation in the previous period (see footnote 5).

subject to a linear technology which allows to transform one unit of effective capital ($k_i \cdot ucap_t$) into one unit of an intermediate good

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

In a symmetric equilibrium the first order condition is

(20a) $$\theta\eta_t (1-\alpha)\left(Y_t + FC_Y\right)\left(\sum_{i=1}^{A_t}\left(x_{i,t}^j\right)^\theta\right)^{-1}\left(x_t\right)^{\theta-1} = i_t^K P_t^C$$

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

(20b) $$PX_t = px_{i,t} = \frac{i_t^K P_t^C}{\theta}.$$

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

(21a) $$PR_{i,t}^x = PR_t^x = i_t^A P_t^A + r_t FC_A, \quad \forall i$$

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

(21b) $$P_t^A \frac{1}{1-t_t^K\left(1-\delta^A\right)+\tau^A} + FC_A = \sum_{\tau=0}^{\infty}\prod_{j=0}^{\tau}\left(\frac{1}{1+r_{t+j}}\right)PR_{t+\tau}^x$$

.

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

1.2.3 R&D sector

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

(22) $$\Delta A_t = \nu A_{t-1}^{*\varpi} A_{t-1}^{\phi} L_{A,t}^{\lambda}.$$

In this framework we allow 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 value for these parameters 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:

$$(23) \qquad \max_{L_{A,t}} \sum_{t=0}^{\infty} d_t \left(P_t^A \Delta A_t - W_t^H L_{A,t} - \frac{\gamma_A}{2} W_t^H \Delta L_{A,t}^2 \right)$$

therefore the first order condition implies:

$$(24) \qquad \lambda P_t^A \frac{\Delta A_t}{L_{A,t}} = W_t^H + \gamma_A \left(W_t^H \Delta L_{A,t} - d_t W_{t+1}^H \Delta L_{A,t+1} \right)$$

where d_t is the discount factor.

1.3 Trade and the current account

The economies trade both final and intermediate goods. The elasticity of substitution between bundles of domestic and foreign goods Z^{di} and Z^{fi} is σ. Thus aggregate imports are given by

$$(25) \qquad IM_t = s^M \left(\frac{P_t^C}{P_t^{IM}} \right)^{\sigma} (C_t + I_t + G_t)$$

And there is producer pricing of imports and exports.

$$(26) \qquad P_t^{EX} = P_t$$

and

$$(27) \qquad P_t^{IM} = E_t P_t^*$$

Thus net foreign assets evolve according to

$$(28) \qquad E_t B_t^F = (1 + r_t^F) E_t B_{t-1}^F + P_t^{EX} EX_t - P_t^{IM} IM_t .$$

1.4 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 as follows

(29) $$BEN_t = \sum_s b_t^s W_t^s (1 - NPART_t^s - L_t^s),$$

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

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

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

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

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

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

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

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

where b^T is the government debt target.

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

(34)

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

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.
Rather than defining the output gap as the difference between actual and efficient output, 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

$$(35) \quad YGAP_t = \left(\frac{ucap_t}{ucap_t^{ss}} \right)^{(1-\alpha)} \left(\frac{L_t}{L_t^{ss}} \right)^{\alpha}.$$

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

$$(36) \quad ucap_t^{ss} = (1-\rho^{ucap})ucap_{t-1}^{ss} + \rho^{ucap} ucap_t$$

$$(37) \quad L_t^{ss} = (1-\rho^{Lss})L_{t-1}^{ss} + \rho^{Lss} L_t$$

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

2 Calibration

2.1 Goods Market

We identify the final goods sector as the service sector and the intermediate sector as the manufacturing sector. The manufacturing sector resembles the intermediate sector along various dimensions. First, this sector is more R&D and patent intensive, second, a large fraction of manufacturing supplies innovative goods (in the form of investment goods but also innovative consumer goods). Services on the other hand are typically not subject to large (patented) innovations but are subject to organisational changes possibly in relation to new technologies supplied by the manufacturing sector. A good example in this respect is the ICT investment driven productivity increase in retail, wholesale trade and banking in some countries, notably the US. Also the two sectors differ in the degree of competition, with manufacturing showing smaller mark ups compared to services. For calculating mark ups we use a method suggested by Roeger (1995). We find substantially high mark ups in services in the EU (24%) while mark ups in manufacturing are lower (12%). Similar results but with even stronger differences in manufacturing industries have been obtained by Christopoulou and Vermeulen (2008). The results on cross country differences in the level of mark ups are interesting since they suggest a positive link between the level of mark ups and R&D investment as suggested by our model. This comes out even clearer in earlier work by Oliveira Martins *et al*. (1996) which shows that sectors with high R&D intensities tend to have higher mark ups.

It is a stylised fact that product markets are more regulated in the EU compared to the US. Recent evidence can be found in Hoj *et al.* (2007). To our knowledge estimates on entry barriers for specific sectors do not exist. Therefore we rely on the aggregate estimates provided by Djankov *et al.* (2002). These estimates are particularly useful since they provide directly quantifiable evidence on costs of procedures and time that a start-up must bear before the firm can operate legally. This information can be 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. Their calculations show that the European countries impose 2 to 60 times higher entry costs than the US. Based on the Djankov *et al*. (2002) methodology Kox (2005) re-estimated the start-up costs for the EU. He estimates the EU average entry cost of setting up a standard firm at 57.3 percent of per capita GDP and only to 1.6% for the US. Cross country variation is large and ranges from 4.5 percent of per capita GDP for the UK to 1.83 times 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) [10]. Concerning the subsidies to R&D investments, empirical evidence provided by Warda (1996, 2006) indicates an average of 5 percentage point net R&D subsidies for the EU based on the B-index[11].

2.3 Labour market

We use information from our estimation of the core QUEST III model (see Ratto *et al.* (2008)) 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[12]. 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 elasticity of substitution between different labour types (σ) is one of the major issue addressed in the labour-economics literature. We follow Caselli and Coleman (2006) which analysed the cross-country differences of the aggregate production function when skilled and unskilled labour are imperfect substitutes. The authors argue in favour of using the Katz and Murphy (1992) estimate of 1.4. We set the efficiency of low-skilled at 1 for EU27, 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. In order to get comparable efficiency units we must normalize with the population share using the following correction:

$$ef_s^* = ef_s \left(s_s l_s\right)^{\frac{1}{1-\sigma_L}}, \; s \in \{L, M, H\}.$$

The calibration of the model is summarized in Table 2.1 and a simplified flow-chart of the model is presented in Figure A of the Appendix.

[10] See Appendix A for a more detailed discussion of calibrating the R&D production parameters.
[11] See Appendix B for more details on the B-index and how it relates to tax parameters in the model.
[12] 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 corresponds to the standard classification of ISCED 0-2 education levels and the rest of the labour force is considered as medium-skilled.

Table 2.1 Calibration

	Value	Source
R&D sector		
L_A	0.010	EUROSTAT/OECD
R&D intensity (%)	1.840	EUROSTAT/OECD
λ	0.729	calibration (constrained by equations)
ϕ	0.531	Bottazzi-Peri (2007)
ϖ	0.447	Bottazzi-Peri (2007)
ν	0.351	calibration (constrained by equations)
Intermediate sector		
markup	0.12	own estimates
fixed entry costs	0.38	Djankov et. al. (2002)
Final goods sector		
Final good mark up	0.242	own estimates
Depreciation rate of tangible capital	0.015	own estimates
Labour		
Skill distribution:		
s_L	0.350	EUROSTAT/OECD
s_M	0.588	EUROSTAT/OECD
s_H	0.062	EUROSTAT/OECD
Employment rates:		
L_L	0.572	EUROSTAT/OECD
L_M	0.744	EUROSTAT/OECD
L_H	0.837	EUROSTAT/OECD
σ_L (elasticity of. substitution)	1.400	Katz and Murphy (2002)
L	0.689	EUROSTAT/OECD
Skill premium % (high vs. medium)	50.11	EUROSTAT/OECD
Skill premium % (medium vs. low)	23.66	EUROSTAT/OECD
Efficiency levels:		
ef^*_L	1.000	calibration (constrained by equations)
ef^*_M	2.103	calibration (constrained by equations)
ef^*_H	8.175	calibration (constrained by equations)
Labour adjustment cost (% of total wage costs)	18	own estimates
Labour supply elasticity ($1/\kappa$)	1/4	own estimates
Benefit replacement rate	0.400	own estimates
Taxes and subsidies		
Net R&D Subsidies	0.050	OECD/Warda (2006)
Depreciation of intangible capital	0	calibration
Corporate taxes	0.448	OECD/Warda (2006)
VAT	0.170	own estimates
Labour taxes (incl. social security)	0.386	own estimates

3. Scenarios of reforms

This section describes some illustrative scenarios of structural reforms with the model. The standard simulations we consider include R&D promoting policies, product market reforms that affect capital costs, fixed costs, entry barriers and mark-ups, labour market reforms like tax shifts and changes to benefit generosity and changes in skill composition. More specifically the reform scenarios we simulate are:

- Raising R&D through subsidies: tax-credits and wage subsidies (3.1)
- Reducing product market mark-ups (3.2)
- Reducing capital costs (3.3)
- Reduction in fixed costs (3.4)
- Exogenous productivity shock (3.5)
- Reducing wage mark-ups (3.6)
- Tax shifts: from labour to consumption and from low- to high skilled (3.7 and 3.8)
- Reducing benefit generosity (3.9)
- Raising human capital (3.10)

3.1 Raising R&D through tax credits and wage subsidies

The specification of knowledge production in the model presented in this paper is consistent with the often heard argument that market economies underinvest in R&D because individual investors do not fully internalise the external effects from knowledge spillovers. Empirical studies seem to confirm this claim. Estimates of private rates of return[13] vary between 8 and 20% (see Coe and Helpman (1995) and Botazzi and Perri (2007)). Estimates of social rates of return based on interfirm technology spillovers vary between 17% (Sveikauskas (1981)) and 100% (Jones and Williams (1998)). The studies by Coe and Helpman as well as Botazzi and Perri also show that there are considerable cross country spillovers. The existence of positive externalities associated with R&D suggests that policies boosting knowledge investment yield social benefits. This section therefore considers two alternative policies. The first scenario is an R&D subsidy in the form of a tax credit (τ^4) of 0.1 percent of GDP to the non-liquidity constrained households on their income from intangible capital. Table 3.1.a presents the effects on production, R&D intensity, TFP, R&D labour, total employment and other variables[14]. Subsidies are financed in a budgetary neutral manner through an increase in lump-sum taxes to households. The simulations show the important characteristic of semi-endogenous growth models: permanent subsidies for R&D-using sectors give a permanent increase in GDP level in the long-run while GDP growth stabilizes. Higher tax-credits allow households to lower the rental rate for intangibles, thus reducing the fixed costs of firms producing intermediates. This in turn raises the demand for blueprints and stimulates R&D and reallocates high skilled workers from production into the research sector. The size of the

[13] The return on R&D is usually defined as the marginal product of the R&D stock. This can be translated into a growth effect on TFP by multiplying the social return with the share of R&D in output.

[14] Note that in the tables TFP refers to a constructed measure of technological progress defined as $Y/\left(L_Y{}^{\alpha}K^{1-\alpha}\right)$

effect is however rather limited. The results show a 0.08 percent increase in GDP relative to the baseline 20 years after the initial shock and 0.31 percent in the long run. In the long-run the number of employees in the R&D sector increases by around 4 percent and R&D intensity rises by 0.08 percentage points. Notice that it takes time for the output effects to emerge because of short run output losses due to the reallocation of high skilled workers from production to research. Because of supply constraints for high skilled workers part of the fiscal stimulus is offset by wage increases for high skilled workers

Concerning tangible capital stock we have to distinguish between two opposing effects. In the short run, the strong decline of high-skilled labour input in the final goods sector lowers the marginal product of capital which reduces the demand for physical capital. On the other hand higher tax-credits allow non-liquidity constrained households to charge less for intangibles thus reducing the costs of intermediate firms. In the long-run this latter effect unambiguously dominates as technical progress accelerates due to the higher entry rates of intermediate firms.

Table 3.1.b shows a scenario in which the subsidy takes the form of a subsidy on the wages of researchers given to the R&D sector. The results show somewhat stronger GDP effects: a 0.1 percent increase in GDP relative to the baseline 20 years after the initial shock and 0.44 percent in the long run. Compared to the R&D subsidy given in the form of tax-credits, this scenario gives more stimulus to the employment of researchers in the long-run: the number of researchers increases by 5.7 percent and R&D intensity rises by 0.12 percentage point.

According to these model simulations wage subsidies in the R&D sector are more efficient than subsidising the use of R&D. 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. It needs to be further analysed whether this result is robust to imperfections in R&D production. As noted in the literature (see Goolsbee (1998) and Wolff et al. (2008)), there are significant crowding out effects of tax subsidies in the form of higher wages for high skilled workers. This is feature is also present in our simulation experiments. About 25% of the total increase in R&D spending is due to higher wages in these simulations. Goolsbee's estimates for the US range from 30 to 50%.

Table 3.1.a 0.1% of GDP tax-credit R&D subsidy to the non-liquidity constrained households

EU	Years								
	1	2	3	4	5	10	20	50	100
GDP	-0.01	-0.04	-0.05	-0.06	-0.05	0.00	0.08	0.23	0.31
TFP	0.00	-0.02	-0.02	-0.01	0.00	0.05	0.13	0.24	0.27
"Ideas/Patents"	0.06	0.22	0.44	0.67	0.90	1.97	3.50	5.46	6.04
Capital	0.00	0.00	-0.01	-0.01	-0.02	-0.04	-0.03	0.09	0.21
Capital intensity	0.01	0.02	0.05	0.07	0.10	0.22	0.38	0.59	0.66
Employment	0.03	0.04	0.03	0.03	0.03	0.02	0.01	0.00	0.00
-low	0.02	0.04	0.05	0.06	0.07	0.08	0.07	0.05	0.04
-medium	0.01	0.01	0.01	0.01	0.01	0.00	-0.01	-0.01	-0.02
-high	-0.37	-0.89	-1.21	-1.37	-1.43	-1.38	-1.20	-0.98	-0.92
-R&D	2.59	4.85	5.78	6.14	6.26	5.95	5.17	4.20	3.91
Consumption	0.02	0.01	0.00	-0.01	-0.01	0.01	0.07	0.20	0.25
Investment	-0.01	-0.03	-0.04	-0.05	-0.05	-0.05	-0.01	0.12	0.21
Real wages	0.04	0.09	0.10	0.11	0.11	0.14	0.21	0.33	0.40
-low	-0.02	-0.03	-0.04	-0.05	-0.05	-0.01	0.07	0.22	0.29
-medium	-0.01	-0.01	-0.01	-0.01	0.00	0.04	0.12	0.26	0.33
-high	0.37	0.81	1.00	1.07	1.08	1.04	0.98	0.96	0.98
Exports	-0.02	-0.06	-0.06	-0.06	-0.05	0.00	0.07	0.20	0.26
Imports	0.02	0.04	0.03	0.02	0.01	-0.01	0.01	0.06	0.08
Terms of trade, final goods	0.01	0.04	0.04	0.04	0.03	0.00	-0.05	-0.13	-0.17
Nominal interest rate	0.03	0.05	0.06	0.05	0.04	0.02	-0.01	0.00	0.00
Real interest rate	-0.04	-0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00
Inflation	0.05	0.07	0.06	0.05	0.04	0.01	-0.01	-0.01	0.00
Consumer price inflation	0.04	0.06	0.06	0.05	0.04	0.01	-0.01	-0.01	0.00
Lump sum taxes (% of GDP)	0.01	0.04	0.06	0.08	0.09	0.14	0.15	0.14	0.14
Unemployment rate	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.01	0.00
-low-skilled	-0.02	-0.04	-0.05	-0.06	-0.06	-0.07	-0.06	-0.04	-0.04
-medium-skilled	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.01	0.01
-high-skilled	-0.19	-0.21	-0.14	-0.09	-0.06	-0.04	-0.03	-0.02	-0.02
Gov. balance (% of GDP)	-0.11	-0.11	-0.09	-0.08	-0.06	-0.01	0.02	0.00	0.00
Current account (% of GDP)	-0.01	-0.02	-0.04	-0.06	-0.08	-0.11	-0.09	-0.03	0.00
R&D intensity (% of GDP)	0.10	0.12	0.13	0.14	0.14	0.13	0.11	0.09	0.08

Note: percentage (points) difference from baseline

Table 3.1.b 0.1% of GDP wage subsidy to the R&D sector

EU	Years								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	-0.02	-0.06	-0.08	-0.08	-0.08	-0.01	0.11	0.33	0.44
TFP	-0.01	-0.03	-0.03	-0.02	-0.01	0.07	0.19	0.34	0.39
"Ideas/Patents"	0.08	0.31	0.62	0.95	1.28	2.82	5.06	7.95	8.83
Capital	0.00	0.00	-0.01	-0.02	-0.02	-0.05	-0.04	0.13	0.29
Capital intensity	0.01	0.03	0.07	0.10	0.14	0.31	0.55	0.86	0.95
Employment	0.04	0.05	0.04	0.04	0.04	0.03	0.01	0.00	-0.01
-low	0.02	0.04	0.05	0.06	0.07	0.06	0.04	0.01	0.01
-medium	0.01	0.02	0.02	0.02	0.02	0.01	0.00	-0.01	-0.02
-high	-0.53	-1.27	-1.73	-1.96	-2.05	-1.99	-1.74	-1.43	-1.33
-R&D	3.62	6.85	8.24	8.81	9.01	8.60	7.50	6.11	5.70
Consumption	0.00	-0.01	-0.02	-0.03	-0.02	0.01	0.10	0.28	0.36
Investment	-0.01	-0.03	-0.05	-0.06	-0.07	-0.07	-0.02	0.17	0.30
Real wages	0.06	0.12	0.15	0.16	0.17	0.21	0.30	0.48	0.58
-low	-0.02	-0.04	-0.04	-0.05	-0.04	0.02	0.13	0.35	0.45
-medium	-0.01	-0.02	-0.02	-0.02	-0.01	0.05	0.16	0.37	0.47
-high	0.51	1.14	1.43	1.53	1.55	1.50	1.42	1.39	1.43
Exports	-0.02	-0.07	-0.09	-0.08	-0.07	-0.01	0.10	0.28	0.37
Imports	0.02	0.03	0.03	0.02	0.01	0.00	0.01	0.08	0.11
Terms of trade, final goods	0.02	0.05	0.06	0.06	0.05	0.00	-0.07	-0.19	-0.25
Nominal interest rate	0.05	0.08	0.08	0.08	0.07	0.03	-0.01	0.00	0.00
Real interest rate	-0.05	-0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00
Inflation	0.07	0.10	0.09	0.07	0.06	0.01	-0.02	-0.01	0.00
Consumer price inflation	0.06	0.08	0.08	0.08	0.06	0.02	-0.02	-0.01	0.00
Lump sum taxes (% of GDP)	0.01	0.01	0.02	0.04	0.05	0.08	0.09	0.09	0.09
Unemployment rate	-0.03	-0.04	-0.04	-0.04	-0.04	-0.03	-0.01	0.00	0.00
-low-skilled	-0.02	-0.03	-0.05	-0.05	-0.06	-0.06	-0.03	-0.01	-0.01
-medium-skilled	-0.01	-0.02	-0.02	-0.02	-0.02	-0.01	0.00	0.01	0.02
-high-skilled	-0.26	-0.30	-0.20	-0.13	-0.09	-0.07	-0.05	-0.04	-0.03
Gov. balance (% of GDP)	-0.08	-0.08	-0.08	-0.07	-0.06	-0.01	0.02	0.00	0.00
Current account (% of GDP)	0.00	-0.02	-0.05	-0.07	-0.08	-0.13	-0.12	-0.04	-0.01
R&D intensity (% of GDP)	0.08	0.15	0.18	0.19	0.20	0.19	0.16	0.13	0.12

Note: percentage (points) difference from baseline

3.2 Reducing goods market mark-ups

Product market reforms that enhance competition in goods markets can be simulated as shocks that reduce the mark-up of prices over marginal costs. In a standard DSGE model there is no ambiguity between the degree of competition as measured by the mark-up and the level of economic activity. A reduction in the mark-up increases the demand for labour and employment unambiguously. In a comparable exercise Bayoumi *et al.* (2004) used a standard DSGE model without endogenous technical progress to calculate the effect of a 12 percentage point reduction of the mark-up in Europe. The estimated positive effect on GDP and employment was 7% and 3% respectively. In an endogenous growth model however the link between mark-ups and GDP and employment is more complicated, because a mark-up is necessary to cover the sunk costs associated with paying for a patent when entering the market for intermediate goods. Thus there are two opposing effects. The resulting fall in intermediate goods prices increases demand for intermediates of incumbents, but the lower price also reduces entry of new firms and therefore the rate of technical progress. This second effect does not arise in the final goods sector, which operates like a conventional sector. Therefore we expect a positive impact from a reduction in mark-ups in the final goods sector and an ambiguous effect in the intermediate goods sector. This is indeed what we can see from tables 3.2.a and 3.2.b.

Final goods sector:
A one percentage point reduction of the price mark-up in the final goods sector increases GDP by 0.91% in the long run and employment by 0.07%. While the employment effect is similar to the effect reported by Bayoumi *et al.*, the GDP effect is substantially larger[15]. This is due to the endogenous growth effects generated by an increased demand for capital, which stimulates entry of new firms and increases R&D. The increase in the capital stock exceeds the increase in GDP in the medium and long run because the direct effect of a reduction in the mark-up on investment is larger than the negative effect arising from the loss in the terms of trade. However, consumption rises less than GDP because of this negative terms of trade effect.

The increased demand for labour affects employment and real wages differently because of differences in the labour supply response. Because of the lower employment level of low-skilled workers, the supply of low-skilled labour is more elastic. This implies a higher increase in low-skilled labour compared to medium- and high-skilled labour and an increase in the skill premium. Notice also, the skill premium of high skilled workers increases over proportionally because there is an additional demand effect for high skilled workers in the R&D sector.

Intermediate goods sector:
Reducing the mark-up in the intermediate goods sector has no significant output effect. There are two opposing effects, namely an increase in the capital stock but also a reduction in efficiency. A reduction of mark-ups requires an increase in the scale of output of incumbents which translates into an increase of fixed capital but because it deters entry technical progress slows down. With our parameterisation (especially our level of intermediate mark-up) the two effects practically cancel each other out. It can be shown that this model can also generate an inverted U-shape relationship (see Aghion *et al.* ,2005) between mark-ups and income per capita.

[15] Notice, the output of the final goods sector is close to GDP.

Table 3.2.a A 1 pp level reduction of the final goods market mark-up

EU	Years after the shock								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.13	0.32	0.36	0.36	0.37	0.46	0.63	0.85	0.91
TFP	0.07	0.19	0.20	0.20	0.19	0.18	0.16	0.15	0.15
"Ideas/Patents"	0.01	0.05	0.08	0.11	0.13	0.20	0.29	0.39	0.43
Capital	0.02	0.09	0.17	0.26	0.35	0.69	1.16	1.72	1.88
Capital intensity	0.00	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.05
Employment	0.08	0.18	0.16	0.11	0.08	0.04	0.06	0.07	0.07
-low	0.06	0.13	0.09	0.01	-0.06	-0.18	-0.17	-0.14	-0.13
-medium	0.08	0.19	0.19	0.15	0.13	0.12	0.14	0.14	0.14
-high	-0.01	0.01	-0.04	-0.07	-0.07	-0.01	0.01	0.02	0.02
-R&D	0.63	0.95	0.85	0.69	0.58	0.40	0.33	0.30	0.28
Consumption	-0.09	-0.04	0.01	0.04	0.05	0.11	0.17	0.25	0.28
Investment	0.29	0.59	0.73	0.81	0.87	1.08	1.39	1.77	1.89
Real wages	0.53	1.05	1.31	1.43	1.50	1.62	1.78	1.97	2.03
-low	0.52	1.03	1.32	1.50	1.60	1.78	1.93	2.11	2.17
-medium	0.52	1.01	1.27	1.39	1.44	1.55	1.71	1.91	1.97
-high	0.63	1.24	1.49	1.56	1.58	1.65	1.80	2.00	2.05
Exports	0.07	0.26	0.26	0.25	0.24	0.33	0.51	0.71	0.76
Imports	-0.14	-0.12	-0.01	0.06	0.10	0.15	0.17	0.22	0.24
Terms of trade, final goods	-0.05	-0.18	-0.17	-0.16	-0.16	-0.22	-0.34	-0.47	-0.51
Nominal interest rate	-0.33	-0.37	-0.29	-0.23	-0.18	-0.09	-0.01	0.04	0.01
Real interest rate	0.25	-0.04	-0.05	-0.03	-0.01	0.01	0.01	0.00	0.00
Inflation	-0.48	-0.46	-0.29	-0.22	-0.19	-0.11	-0.02	0.04	0.01
Consumer price inflation	-0.41	-0.42	-0.31	-0.24	-0.19	-0.10	-0.02	0.04	0.01
Lump sum taxes (% of GDP)	0.01	-0.04	-0.12	-0.19	-0.25	-0.35	-0.35	-0.29	-0.26
Unemployment rate	-0.07	-0.16	-0.14	-0.10	-0.06	-0.03	-0.04	-0.05	-0.05
-low-skilled	-0.05	-0.12	-0.08	-0.01	0.05	0.16	0.15	0.12	0.12
-medium-skilled	-0.08	-0.18	-0.18	-0.14	-0.12	-0.11	-0.13	-0.13	-0.13
-high-skilled	-0.11	-0.18	-0.13	-0.07	-0.05	-0.06	-0.07	-0.07	-0.07
Gov. balance (% of GDP)	0.25	0.47	0.41	0.31	0.23	0.05	-0.03	-0.04	-0.01
Current account (% of GDP)	0.03	0.11	0.16	0.18	0.18	0.12	0.01	-0.02	0.00
R&D intensity (% of GDP)	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03

Note: percentage (points) difference from baseline

Table 3.2.b A 1 pp level reduction of the intermediate goods market mark-up

EU	Years after the shock								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.07	0.23	0.29	0.32	0.33	0.34	0.32	0.20	0.10
TFP	0.10	0.18	0.19	0.17	0.15	0.04	-0.13	-0.35	-0.41
"Ideas/Patents"	-0.11	-0.44	-0.87	-1.34	-1.80	-3.89	-6.85	-10.53	-11.62
Capital	0.02	0.07	0.14	0.21	0.28	0.58	0.96	1.22	1.14
Capital intensity	-0.01	-0.04	-0.09	-0.13	-0.18	-0.40	-0.71	-1.11	-1.23
Employment	-0.13	-0.11	-0.09	-0.08	-0.07	-0.05	-0.01	0.02	0.02
-low	-0.10	-0.10	-0.10	-0.10	-0.10	-0.07	-0.02	0.02	0.02
-medium	-0.10	-0.07	-0.06	-0.05	-0.05	-0.03	0.00	0.02	0.02
-high	0.63	1.69	2.36	2.67	2.79	2.68	2.36	1.95	1.82
-R&D	-5.12	-9.57	-11.38	-12.07	-12.27	-11.65	-10.19	-8.33	-7.78
Consumption	-0.03	-0.01	0.01	0.01	0.02	0.00	-0.06	-0.21	-0.29
Investment	0.22	0.45	0.58	0.67	0.73	0.92	1.13	1.22	1.13
Real wages	0.01	-0.04	-0.05	-0.03	-0.02	0.01	0.02	-0.06	-0.14
-low	0.13	0.18	0.22	0.24	0.25	0.25	0.22	0.10	0.01
-medium	0.10	0.14	0.18	0.20	0.21	0.23	0.21	0.10	0.01
-high	-0.62	-1.42	-1.77	-1.85	-1.84	-1.67	-1.45	-1.25	-1.25
Exports	0.01	0.17	0.22	0.24	0.24	0.25	0.25	0.17	0.09
Imports	-0.03	-0.03	0.00	0.02	0.04	0.08	0.10	0.06	0.03
Terms of trade, final goods	0.00	-0.12	-0.15	-0.16	-0.16	-0.17	-0.16	-0.11	-0.06
Nominal interest rate	-0.24	-0.30	-0.29	-0.27	-0.24	-0.12	0.00	0.04	0.00
Real interest rate	0.17	0.03	0.01	0.00	0.00	-0.01	-0.01	0.00	0.00
Inflation	-0.32	-0.36	-0.32	-0.29	-0.25	-0.13	0.00	0.04	0.01
Consumer price inflation	-0.29	-0.33	-0.31	-0.28	-0.25	-0.13	0.00	0.04	0.01
Lump sum taxes (% of GDP)	0.03	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Unemployment rate	0.11	0.10	0.08	0.07	0.07	0.04	0.01	-0.02	-0.02
-low-skilled	0.09	0.09	0.09	0.09	0.09	0.06	0.02	-0.02	-0.02
-medium-skilled	0.09	0.07	0.05	0.05	0.05	0.03	0.00	-0.02	-0.02
-high-skilled	0.47	0.47	0.30	0.18	0.13	0.10	0.07	0.05	0.04
Gov. balance (% of GDP)	0.03	0.15	0.17	0.16	0.15	0.08	0.00	-0.03	0.00
Current account (% of GDP)	0.00	0.03	0.06	0.08	0.10	0.15	0.15	0.05	0.01
R&D intensity (% of GDP)	-0.18	-0.23	-0.26	-0.26	-0.26	-0.25	-0.22	-0.18	-0.17

Note: percentage (points) difference from baseline

3.3 Reduction of capital costs

Here we simulate an exogenous reduction of capital costs of 0.5 percentage points. We think of this reduction as being induced by lowering the equity premium (rp_t^K or rp_t^A) or, equivalently, the intermediation premium required by the banking sector for loans on physical investment. Such reductions can be associated with deeper financial market integration.

Final goods sector:

By improving possibilities for risk sharing and increasing banking competition financial market integration is likely to reduce the costs of lending. Even though the introduction of the euro and various reform efforts associated with the Financial Services Action Plan have already lowered capital costs in Europe, the market is still not fully integrated. A recent study (London Economics 2002) suggested - on the basis of a survey among financial market participants - that financial market integration in the EU could reduce capital costs by about 50 basispoints (equity: 60bp, bonds: 40bp, loans: 20bp). More recent studies also point in this direction. In the case of equity risk premia, Hardouvelis *et al.* (2004) show that since the beginning of the 1990s, the cost of equity capital (risk premium) fell on average by about 1.5 percentage points. However, even though equity premia have converged strongly, especially at the end of the 1990s, there still remains a gap between the average equity premium in the EU in specific sectors and the country with the lowest premium in the order of magnitude of more than 100bp. Also Baele *et al.* (2004) notes that there is still room for further financial market integration effects as risk premia do not seem to have converged further since 2001. Concerning loans, integration related reductions of capital costs have been small since 2002. Baele *et al.* (2004) for example argues that integration in Euro area banking markets may be considered quite advanced from a legal perspective, but nevertheless price differentials remain relatively high. This is also shown by a recent ECB paper on loan deposit margins. The reported statistics on new loans (over the period 2003-05) - which should reflect the most recent state of competition in the market for loans - suggests that reducing loan deposit margins in EU countries to best practice levels could lead to a reduction of lending rates by about 50 to 60bp. In the bond market, integration seems to be very advanced. Recent studies (Baele *et al.* (2004)) estimate the dispersion of country risk factors to only about 10 to 15bp. Since the share of bond financing is below 10%, the evidence on the current state of financial market integration suggests that completing the single market for financial services could lead to a further reduction of capital costs by about 50 basispoints.

A reduction in capital costs unambiguously increases the demand for capital (Table 3.3.a). A 50bp reduction in capital costs increases GDP by about 0.6 percent after 10 years. The additional growth effect mostly comes from physical capital which is 1.7 percent higher after 10 years. Compared to a reduction in the mark-up of the final goods sector the employment effect is smaller because there is no direct shift of demand in favour of labour. The GDP effect exceeds the effect one would expect from a standard growth model, since the higher demand for capital stimulates market entry and thereby innovation.

Table 3.3.a Reduction of tangible capital costs of 50bp

EU	Years								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.05	0.09	0.15	0.21	0.28	0.57	0.98	1.47	1.59
TFP	0.01	-0.01	-0.02	-0.04	-0.05	-0.11	-0.18	-0.24	-0.25
"Ideas/Patents"	0.00	0.01	0.02	0.03	0.04	0.09	0.17	0.27	0.29
Capital	0.05	0.21	0.40	0.61	0.81	1.69	2.93	4.45	4.83
Capital intensity	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03
Employment	0.03	0.03	0.04	0.04	0.05	0.07	0.09	0.08	0.05
-low	0.01	0.00	-0.01	0.00	0.00	0.04	0.08	0.06	0.02
-medium	0.03	0.04	0.05	0.06	0.06	0.08	0.10	0.09	0.06
-high	0.02	-0.01	-0.02	-0.02	-0.02	-0.01	0.00	0.01	0.00
-R&D	0.13	0.22	0.25	0.26	0.27	0.28	0.26	0.21	0.18
Consumption	-0.33	-0.54	-0.58	-0.58	-0.57	-0.47	-0.31	-0.10	-0.05
Investment	0.70	1.35	1.69	1.91	2.07	2.70	3.56	4.59	4.84
Real wages	0.00	0.04	0.09	0.15	0.20	0.47	0.85	1.32	1.43
-low	0.02	0.07	0.13	0.18	0.23	0.48	0.85	1.33	1.45
-medium	-0.01	0.03	0.08	0.13	0.19	0.45	0.84	1.31	1.42
-high	0.02	0.08	0.13	0.19	0.25	0.52	0.90	1.36	1.47
Exports	0.04	0.01	0.03	0.08	0.14	0.41	0.80	1.24	1.34
Imports	-0.05	-0.02	0.02	0.04	0.06	0.13	0.25	0.38	0.42
Terms of trade, final goods	-0.03	-0.01	-0.02	-0.06	-0.09	-0.28	-0.53	-0.82	-0.88
Nominal interest rate	0.10	0.16	0.20	0.23	0.25	0.33	0.38	0.24	0.05
Real interest rate	-0.04	0.01	0.03	0.04	0.04	0.03	0.02	0.00	0.00
Inflation	0.10	0.14	0.16	0.18	0.20	0.29	0.36	0.24	0.05
Consumer price inflation	0.11	0.14	0.16	0.19	0.21	0.30	0.37	0.24	0.05
Lump sum taxes (% of GDP)	0.00	0.01	0.03	0.05	0.07	0.13	0.19	0.26	0.30
Unemployment rate	-0.03	-0.03	-0.03	-0.03	-0.04	-0.06	-0.08	-0.07	-0.04
-low-skilled	-0.01	0.00	0.01	0.00	0.00	-0.04	-0.07	-0.05	-0.02
-medium-skilled	-0.03	-0.04	-0.05	-0.05	-0.06	-0.07	-0.09	-0.08	-0.06
-high-skilled	-0.04	-0.03	-0.03	-0.03	-0.03	-0.04	-0.05	-0.04	-0.03
Gov. balance (% of GDP)	-0.07	-0.14	-0.17	-0.18	-0.18	-0.21	-0.24	-0.15	-0.03
Current account (% of GDP)	0.01	0.03	0.03	0.03	0.02	-0.01	-0.02	-0.02	0.00
R&D intensity (% of GDP)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: percentage (points) difference from baseline

Intermediate goods sector:

Transforming new ideas into marketable products and services is probably one of the most central mechanisms generating growth in modern industrial economies. Innovations can be made within existing companies but they can (and often are) made by newcomers. These can be researchers in universities or firms who intent to market their ideas by creating their own businesses. 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 hurdles when setting up a new company (although existing companies may face administrative costs when introducing new products as well).

A particular form of financing innovations, namely venture capital, was born in the US after WW II when professors from Harvard and MIT created American Research and Development (ARD) in order to raise funds from wealthy individuals and college endowments in order to invest them in high-tech entrepreneurial start-ups (see Bottazzi *et al.* 2002). Venture capital has become a popular form of financing young firms in high-tech sectors. Since the beginning of the 1990s venture capital financing has also become popular in the EU. It now amounts to 0.12% of GDP compared to 0.19% in the US[16]. 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. At the micro level a recent ZEW study (Gottschalk *et al.* 2007) shows that firms with VC finance have grown faster compared to a control group without access to VC. Similar results have been obtained for the US by Hellmann and Puri (2002). At the macro level Romain and van Pottelsbergh (2004) establish a positive relationship between VC and productivity growth.

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. 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 they require a larger risk premium[17]. Philipon and Veron (2008) suggest a number of measures to increase the supply of venture capital financing. Among others they argue for more competition in the banking sector, changes in insolvency legislation and removal of prudential regulations, which hamper equity investment by institutional investors such as pension funds and insurance companies.

Table 3.3.b shows how a reduction in financing costs for start-ups of 50 basispoints could stimulate growth in the EU. 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 0.3% and investment would be directed more towards R&D with this more targeted measure[18]. To put these effects into perspective, financing costs in the EU are about five

[16] 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.

[17] Alternatively the risk premium can also be interpreted as the shadow price of the collateral constraint for the firm investing in intangible capital.

[18] Also in this case, the labour supply elasticity of high skilled workers is a crucial determinant of the total effect.

times larger than those in the US. Reducing the financing costs to US levels could result in a long run increase of GDP of about 1.5% and an increase in the R&D expenditure share of about 0.5% points. This suggests that financing constraints for start-up companies could be an important factor preventing an increase in the R&D share.

Table 3.3.b Reduction of intangible capital costs of 50bp

EU	Years								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	-0.01	-0.05	-0.06	-0.06	-0.06	-0.01	0.08	0.25	0.33
TFP	0.00	-0.02	-0.02	-0.01	0.00	0.05	0.14	0.26	0.29
"Ideas/Patents"	0.06	0.24	0.47	0.71	0.96	2.11	3.78	5.96	6.65
Capital	0.00	0.00	-0.01	-0.01	-0.02	-0.03	-0.03	0.10	0.22
Capital intensity	0.01	0.03	0.05	0.08	0.11	0.23	0.41	0.65	0.72
Employment	0.03	0.03	0.03	0.03	0.03	0.02	0.00	-0.01	-0.01
-low	0.01	0.02	0.03	0.03	0.04	0.03	0.01	-0.01	-0.01
-medium	0.01	0.01	0.02	0.02	0.02	0.01	0.00	-0.01	-0.01
-high	-0.40	-0.95	-1.30	-1.47	-1.53	-1.48	-1.30	-1.08	-1.01
-R&D	2.77	5.19	6.19	6.59	6.72	6.41	5.63	4.62	4.32
Consumption	0.00	-0.01	-0.02	-0.02	-0.02	0.01	0.08	0.21	0.27
Investment	-0.01	-0.02	-0.04	-0.04	-0.05	-0.05	-0.01	0.12	0.23
Real wages	0.04	0.09	0.11	0.12	0.13	0.16	0.23	0.37	0.44
-low	-0.01	-0.02	-0.03	-0.03	-0.02	0.03	0.11	0.27	0.35
-medium	-0.01	-0.01	-0.02	-0.01	-0.01	0.04	0.12	0.28	0.36
-high	0.39	0.86	1.07	1.14	1.15	1.12	1.06	1.05	1.08
Exports	-0.01	-0.05	-0.06	-0.06	-0.05	-0.01	0.07	0.21	0.28
Imports	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.06	0.09
Terms of trade, final goods	0.01	0.04	0.04	0.04	0.04	0.00	-0.05	-0.14	-0.19
Nominal interest rate	0.04	0.06	0.06	0.06	0.05	0.02	0.00	0.00	0.00
Real interest rate	-0.04	-0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00
Inflation	0.05	0.07	0.07	0.06	0.05	0.01	-0.01	-0.01	0.00
Consumer price inflation	0.04	0.06	0.06	0.06	0.05	0.01	-0.01	-0.01	0.00
Lump sum taxes (% of GDP)	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.04
Unemployment rate	-0.02	-0.03	-0.03	-0.03	-0.03	-0.02	0.00	0.01	0.01
-low-skilled	-0.01	-0.02	-0.03	-0.03	-0.03	-0.03	-0.01	0.00	0.01
-medium-skilled	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	0.00	0.01	0.01
-high-skilled	-0.21	-0.23	-0.15	-0.09	-0.07	-0.05	-0.04	-0.03	-0.03
Gov. balance (% of GDP)	-0.02	-0.04	-0.05	-0.04	-0.04	-0.01	0.01	0.00	0.00
Current account (% of GDP)	0.00	-0.01	-0.03	-0.04	-0.06	-0.09	-0.09	-0.04	-0.01
R&D intensity (% of GDP)	0.10	0.13	0.14	0.15	0.15	0.14	0.12	0.10	0.09

Note: percentage (points) difference from baseline

3.4 Reducing fixed costs

While financing costs of new start-ups and the absence of venture capital are more indirect examples of entry barriers, a more direct example of removing entry barriers can be simulated as a reduction in administrative entry barriers or fixed costs.

Reduction in entry costs in intermediate goods sector

Table 3.4.a shows the effects of a 10 per cent reduction in fixed costs in the intermediate sector FC_A (i.e. entry costs for intermediate firms). Again, using the US as a benchmark, administrative costs for starting a new company are much larger in the EU compared to 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. Thus also a full elimination of start-up costs would not dramatically increase GDP. Decreasing entry costs lowers the profits requirement for intermediate producers and thus increases entry of new firms. As shown in Table 3.4.a, increased demand for patents increases the demand for high skilled worker and leads to some relocation of high skilled workers from production to the R&D sector and an increase in the wage of high skilled workers.

Reduction in administrative burden

Another example of a reduction in fixed costs is a reduction in the administrative burden. 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%. 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 therefore it leads to a downward shift in labour demand. It increases profitability of firms and therefore increases investment, however, as shown in Table 3.4.b below, the increase in investment is not strong enough to prevent employment from falling below the baseline level. The results show, a reduction in administrative burden is beneficial in terms of output, investment and consumption but it has negative employment effects. In this scenario, the overall macroeconomic impact of the reform does hardly exceed the direct cost reducing effect.

Table 3.4.a 10% reduction in intermediate firms' entry barriers

EU	Years								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.00	-0.01	-0.02	-0.02	-0.01	0.00	0.02	0.06	0.08
TFP	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.07	0.07
"Ideas/Patents"	0.01	0.06	0.12	0.18	0.24	0.53	0.94	1.47	1.64
Capital	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	0.02	0.05
Capital intensity	0.00	0.01	0.01	0.02	0.03	0.06	0.10	0.16	0.18
Employment	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
-low	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01
-medium	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
-high	-0.10	-0.24	-0.32	-0.37	-0.38	-0.37	-0.32	-0.27	-0.25
-R&D	0.69	1.30	1.55	1.64	1.68	1.60	1.40	1.15	1.07
Consumption	0.00	-0.01	-0.01	-0.01	-0.01	0.00	0.02	0.05	0.07
Investment	0.00	0.00	-0.01	-0.01	-0.01	-0.01	0.00	0.03	0.06
Real wages	0.01	0.02	0.03	0.03	0.03	0.04	0.06	0.09	0.11
-low	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.07	0.09
-medium	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.07	0.09
-high	0.10	0.21	0.26	0.28	0.28	0.27	0.26	0.26	0.27
Exports	0.00	-0.01	-0.01	-0.01	-0.01	0.00	0.02	0.05	0.07
Imports	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Terms of trade, final goods	0.00	0.01	0.01	0.01	0.01	0.00	-0.01	-0.03	-0.05
Nominal interest rate	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00
Real interest rate	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inflation	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
Consumer price inflation	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00
Lump sum taxes (% of GDP)	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Unemployment rate	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
-low-skilled	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
-medium-skilled	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00
-high-skilled	-0.05	-0.06	-0.04	-0.02	-0.02	-0.01	-0.01	-0.01	-0.01
Gov. balance (% of GDP)	0.01	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00
Current account (% of GDP)	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.02	-0.01	0.00
R&D intensity (% of GDP)	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.02	0.02

Note: percentage (points) difference from baseline

Table 3.4.b 10% reduction in final good firms' administrative burdens (overhead labour)

EU	Years								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.42	0.52	0.54	0.56	0.57	0.62	0.69	0.80	0.83
TFP	0.53	0.61	0.61	0.61	0.61	0.62	0.64	0.66	0.67
"Ideas/Patents"	0.01	0.03	0.06	0.09	0.13	0.29	0.53	0.85	0.95
Capital	0.01	0.02	0.04	0.06	0.08	0.17	0.31	0.51	0.59
Capital intensity	0.00	0.00	0.01	0.01	0.01	0.03	0.06	0.09	0.11
Employment	-0.16	-0.14	-0.12	-0.10	-0.10	-0.09	-0.08	-0.08	-0.09
-low	-0.14	-0.13	-0.10	-0.07	-0.05	0.00	0.00	0.00	0.00
-medium	-0.17	-0.16	-0.14	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12
-high	-0.24	-0.25	-0.26	-0.27	-0.29	-0.29	-0.27	-0.23	-0.22
-R&D	0.32	0.65	0.82	0.90	0.93	0.91	0.81	0.67	0.62
Consumption	0.34	0.52	0.54	0.54	0.54	0.55	0.58	0.65	0.67
Investment	0.07	0.13	0.16	0.18	0.20	0.27	0.38	0.53	0.59
Real wages	-0.01	-0.13	-0.18	-0.19	-0.18	-0.15	-0.08	0.01	0.04
-low	-0.01	-0.14	-0.21	-0.24	-0.25	-0.22	-0.16	-0.06	-0.03
-medium	-0.01	-0.14	-0.18	-0.19	-0.19	-0.14	-0.07	0.02	0.05
-high	-0.01	-0.09	-0.09	-0.07	-0.06	-0.02	0.03	0.10	0.13
Exports	0.37	0.42	0.42	0.44	0.46	0.51	0.58	0.67	0.70
Imports	0.00	0.16	0.18	0.18	0.17	0.16	0.17	0.21	0.22
Terms of trade, final goods	-0.27	-0.28	-0.28	-0.29	-0.30	-0.34	-0.39	-0.44	-0.46
Nominal interest rate	0.00	-0.01	-0.01	-0.02	-0.03	-0.02	-0.01	0.01	0.00
Real interest rate	-0.02	-0.01	0.01	0.02	0.01	0.01	0.00	0.00	0.00
Inflation	-0.06	0.03	-0.01	-0.03	-0.04	-0.03	-0.01	0.01	0.00
Consumer price inflation	0.05	0.01	-0.01	-0.03	-0.03	-0.03	-0.01	0.01	0.00
Lump sum taxes (% of GDP)	0.03	0.07	0.10	0.13	0.15	0.20	0.23	0.22	0.22
Unemployment rate	0.15	0.13	0.11	0.09	0.09	0.08	0.07	0.07	0.07
-low-skilled	0.13	0.12	0.09	0.06	0.04	0.00	0.00	0.00	0.00
-medium-skilled	0.16	0.15	0.13	0.12	0.11	0.11	0.11	0.11	0.11
-high-skilled	0.13	0.07	0.05	0.04	0.05	0.05	0.05	0.05	0.06
Gov. balance (% of GDP)	-0.17	-0.11	-0.09	-0.06	-0.04	0.01	0.01	0.00	0.00
Current account (% of GDP)	0.03	0.03	0.02	0.00	-0.02	-0.04	-0.03	-0.01	0.00
R&D intensity (% of GDP)	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00

Note: percentage (points) difference from baseline

3.5 Exogenous productivity improvements

An exogenous productivity improvement shock is implemented as a 1 per cent increase of A_t^{exog} in the production function of final output (eq. 13). Increasing the level of labour efficiency has a permanent positive effect on GDP, consumption and capital. The level effect is larger than would be predicted by a standard neoclassical growth model. The model generates a larger GDP effect because there is 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. This increases the efficiency of capital.

It is also noticeable that, even in the long run, consumption and investment do not increase fully proportionally with GDP. This is due to a terms of trade loss associated with an output and income expansion in only one country. The terms of trade effect impacts on real consumption in two ways. First it directly reduces consumption because imported consumption goods become more expensive. Second, consumption is reduced because the terms of trade effect has a negative effect on labour supply. In the case of investment, the real depreciation increases the price of capital via an increase in the price of imported investment goods and, second, the decline in labour input in the final goods sector lowers the marginal product of capital which further reduces the demand for physical capital[19].

Concerning aggregate employment it is useful to distinguish between the short and the long term. In the short run, technical progress has a negative effect on employment because price rigidities prevent an immediate adjustment of prices to the new level of costs in the final goods sector. This generates a so-called demand externality (see Gali (1999)). Because of an insufficient decline in prices, individual firms are facing a shortfall of demand given their new level of productive capacity and find it beneficial to reduce employment. In the medium run there is a positive employment effect associated with the build up of new productive capacity. In the long run the employment effect remains slightly negative because of negative terms of trade effect. The negative terms of trade effect is also the reason behind the less than proportional increase in consumption and investment relative to GDP.

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 over-proportionally.

[19] Notice, the reduction in labour in final goods production exceeds the aggregate employment loss because of a reallocation of high skilled workers into the R&D sector.

Table 3.5 A 1 percent permanent level increase of labour productivity

EU	Years after the shock								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.57	0.76	0.78	0.77	0.77	0.81	0.89	0.98	1.01
TFP	0.60	0.74	0.74	0.74	0.74	0.75	0.75	0.76	0.76
"Ideas/Patents"	0.01	0.02	0.04	0.05	0.05	0.07	0.08	0.10	0.11
Capital	0.01	0.04	0.07	0.10	0.13	0.26	0.43	0.64	0.71
Capital intensity	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Employment	-0.06	0.02	0.02	-0.01	-0.03	-0.05	-0.05	-0.04	-0.04
-low	-0.04	0.03	0.03	0.00	-0.03	-0.07	-0.07	-0.06	-0.06
-medium	-0.06	0.01	0.01	-0.01	-0.03	-0.04	-0.04	-0.04	-0.04
-high	-0.12	-0.04	-0.05	-0.07	-0.07	-0.05	-0.04	-0.04	-0.04
-R&D	0.29	0.41	0.33	0.23	0.16	0.09	0.08	0.07	0.07
Consumption	0.39	0.65	0.71	0.72	0.72	0.73	0.75	0.79	0.81
Investment	0.12	0.23	0.28	0.31	0.32	0.40	0.51	0.67	0.71
Real wages	0.32	0.55	0.67	0.73	0.76	0.81	0.87	0.96	0.99
-low	0.30	0.51	0.64	0.71	0.76	0.82	0.89	0.97	1.00
-medium	0.32	0.55	0.67	0.73	0.75	0.80	0.87	0.96	0.98
-high	0.34	0.61	0.73	0.77	0.77	0.80	0.87	0.96	0.98
Exports	0.50	0.63	0.62	0.61	0.61	0.66	0.74	0.82	0.85
Imports	-0.09	0.10	0.19	0.22	0.23	0.23	0.23	0.25	0.26
Terms of trade, final goods	-0.37	-0.42	-0.41	-0.41	-0.41	-0.44	-0.49	-0.55	-0.56
Nominal interest rate	-0.12	-0.13	-0.09	-0.06	-0.05	-0.02	0.00	0.01	0.01
Real interest rate	0.09	-0.05	-0.03	-0.01	0.00	0.00	0.00	0.00	0.00
Inflation	-0.25	-0.14	-0.08	-0.06	-0.05	-0.03	-0.01	0.01	0.01
Consumer price inflation	-0.08	-0.13	-0.09	-0.06	-0.05	-0.03	-0.01	0.01	0.01
Lump sum taxes (% of GDP)	0.04	0.05	0.03	0.02	0.01	0.00	0.02	0.04	0.05
Unemployment rate	0.05	-0.02	-0.01	0.01	0.03	0.05	0.04	0.04	0.04
-low-skilled	0.04	-0.03	-0.03	0.00	0.02	0.07	0.06	0.05	0.05
-medium-skilled	0.06	-0.01	-0.01	0.01	0.03	0.04	0.04	0.04	0.04
-high-skilled	0.04	-0.04	-0.02	0.01	0.02	0.02	0.02	0.02	0.02
Gov. balance (% of GDP)	-0.08	0.09	0.08	0.06	0.03	0.00	-0.01	-0.01	0.00
Current account (% of GDP)	0.05	0.11	0.12	0.12	0.11	0.05	0.00	-0.01	0.00
R&D intensity (% of GDP)	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Note: percentage (points) difference from baseline

3.6 Reducing wage mark-ups

In monopolistically competitive labour markets, households act as wage setters and can charge a wage mark-up $1/\eta_t^W$ over the reservation wage (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 monopoly 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. In the simulation reported in Table 3.6 the shock to the mark-up is calibrated such that it yields a 1 percentage point increase in the employment rate in the medium term[20].

Lowering the mark-up reduces 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. Hence, 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 have the strongest decline in their wages, the high-skilled the least strong decline, and the increase in the employment rate is largest for the low-skilled and smallest for the high-skilled.

The increase in employment boosts output, but during the first years of the simulation the increase in GDP is smaller than that in employment, reflecting a negative trade-off in productivity. In the long run however, the GDP effect becomes larger due to an endogenous R&D response. A higher employment rate of high-skilled employed in the R&D sector as well as increased demand for new patents from entry of new firms in the intermediate sector boosts output of the R&D sector ("ideas/patents") and raises total productivity. Lower wages reduce consumption of liquidity-constrained households, but this is more than offset by higher consumption of non-liquidity constrained households due to the increase in permanent income. The increase in output must lead to a fall in the relative price of domestic goods in order to balance supply and demand and the terms-of-trade deteriorate. Consumption and investment grow proportionally less than GDP, due to this terms-of-trade loss.

[20] Our estimates of the elasticities of substitution among differentiated labour inputs σ_s are unfortunately not well identified, as the data does not allow separate identification of this parameter and the preference parameter for leisure ω_s . We define this shock therefore in terms of the outcome it yields for employment.

Table 3.6 Wage mark up reduction

EU	Years after the shock								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.09	0.42	0.59	0.67	0.72	0.84	0.98	1.14	1.20
TFP	-0.03	0.07	0.09	0.11	0.12	0.15	0.19	0.22	0.22
"Ideas/Patents"	0.01	0.03	0.06	0.11	0.15	0.33	0.59	0.91	1.01
Capital	0.00	0.00	0.02	0.04	0.06	0.19	0.41	0.72	0.84
Capital intensity	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.10	0.11
Employment	0.20	0.58	0.79	0.89	0.93	0.99	1.02	1.04	1.04
-low	0.34	0.91	1.29	1.50	1.60	1.68	1.72	1.75	1.76
-medium	0.16	0.49	0.66	0.72	0.75	0.80	0.84	0.85	0.85
-high	0.04	0.22	0.25	0.24	0.23	0.28	0.35	0.39	0.39
-R&D	0.28	0.73	0.99	1.09	1.11	1.01	0.85	0.71	0.67
Consumption	0.21	0.42	0.54	0.61	0.66	0.77	0.85	0.93	0.96
Investment	0.00	0.06	0.13	0.18	0.23	0.35	0.52	0.76	0.84
Real wages	-0.29	-0.55	-0.57	-0.52	-0.47	-0.33	-0.20	-0.06	-0.01
-low	-0.43	-0.89	-1.03	-1.04	-0.99	-0.81	-0.68	-0.55	-0.50
-medium	-0.26	-0.47	-0.46	-0.39	-0.33	-0.19	-0.06	0.09	0.14
-high	-0.15	-0.20	-0.09	0.01	0.06	0.17	0.29	0.42	0.46
Exports	-0.04	0.31	0.46	0.53	0.56	0.66	0.81	0.96	1.01
Imports	0.08	0.05	0.07	0.10	0.14	0.22	0.26	0.29	0.31
Terms of trade, final goods	0.03	-0.22	-0.31	-0.35	-0.37	-0.44	-0.53	-0.64	-0.67
Nominal interest rate	-0.44	-0.61	-0.61	-0.56	-0.49	-0.25	-0.07	0.01	0.01
Real interest rate	0.36	0.13	0.05	0.02	0.01	0.01	0.01	0.00	0.00
Inflation	-0.54	-0.77	-0.71	-0.63	-0.55	-0.27	-0.08	0.01	0.01
Consumer price inflation	-0.52	-0.67	-0.67	-0.62	-0.54	-0.27	-0.08	0.01	0.01
Lump sum taxes (% of GDP)	0.03	0.06	0.03	-0.01	-0.05	-0.20	-0.26	-0.21	-0.19
Unemployment rate	-0.19	-0.55	-0.76	-0.86	-0.90	-0.95	-0.99	-1.00	-1.00
-low-skilled	-0.30	-0.82	-1.16	-1.35	-1.44	-1.51	-1.54	-1.57	-1.58
-medium-skilled	-0.15	-0.45	-0.61	-0.67	-0.69	-0.74	-0.78	-0.79	-0.79
-high-skilled	-0.08	-0.30	-0.38	-0.39	-0.38	-0.41	-0.43	-0.43	-0.43
Gov. balance (% of GDP)	0.19	0.46	0.52	0.49	0.43	0.18	0.02	-0.02	-0.01
Current account (% of GDP)	-0.03	-0.03	-0.01	0.02	0.03	0.04	-0.01	-0.02	0.00
R&D intensity (% of GDP)	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00

Note: percentage (points) difference from baseline

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 Table 3.7 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. The budgetary impact is more complex as there are many channels affecting the budget either directly or indirectly. As the reform consists of changes in tax rates, there is a direct impact on the budget, but the shift is constructed to be *ex ante* budgetary neutral on the baseline. The budget is indirectly affected as the reform is accompanied by compensatory payments for benefit and transfer recipients and there is a further indirect effect from changes in expenditures and in the tax bases due to the macroeconomic impact of the reform. A loss in the terms of trade has a negative impact on consumption and leads to less consumption tax revenue. The net effect is an initial increase in the government deficit and in order to stabilise government debt around its target level lump-sum taxes (or transfers) have to rise (fall)[21].

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 real wages that firms are willing to pay return to the baseline level at a higher level of 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.

[21] If however the same scenario is ran under the assumption that labour taxes have to be changed to stabilise government debt at its target, the *ex post* labour tax reduction would be considerably smaller and the employment and output effects proportionally lower.

Table 3.7 A 1 percent of GDP tax shift from labour to VAT, lump-sum tax

EU	Years after the shock								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.06	0.12	0.17	0.19	0.20	0.24	0.28	0.34	0.35
TFP	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.07
"Ideas/Patents"	0.00	0.01	0.01	0.02	0.03	0.09	0.16	0.27	0.30
Capital	0.00	0.00	0.00	0.00	0.01	0.04	0.11	0.21	0.25
Capital intensity	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03
Employment	0.07	0.17	0.22	0.25	0.27	0.29	0.30	0.31	0.31
-low	0.10	0.24	0.34	0.40	0.43	0.48	0.50	0.51	0.51
-medium	0.07	0.15	0.19	0.21	0.22	0.24	0.25	0.25	0.25
-high	0.04	0.08	0.09	0.08	0.08	0.09	0.10	0.11	0.12
-R&D	0.05	0.15	0.23	0.27	0.28	0.29	0.26	0.21	0.20
Consumption	0.20	0.17	0.17	0.18	0.19	0.21	0.24	0.27	0.28
Investment	-0.01	0.00	0.02	0.03	0.04	0.09	0.14	0.22	0.25
Real wages	-0.09	-0.15	-0.16	-0.15	-0.14	-0.10	-0.06	-0.02	0.00
-low	-0.12	-0.23	-0.27	-0.27	-0.27	-0.24	-0.20	-0.16	-0.14
-medium	-0.08	-0.13	-0.13	-0.12	-0.10	-0.06	-0.02	0.02	0.04
-high	-0.05	-0.06	-0.04	-0.01	0.01	0.04	0.08	0.12	0.14
Exports	-0.04	0.07	0.13	0.15	0.16	0.20	0.24	0.28	0.30
Imports	0.13	0.06	0.03	0.03	0.03	0.05	0.07	0.09	0.09
Terms of trade, final goods	0.03	-0.05	-0.09	-0.10	-0.11	-0.13	-0.16	-0.19	-0.20
Nominal interest rate	-0.11	-0.16	-0.17	-0.16	-0.14	-0.07	-0.02	0.00	0.00
Real interest rate	0.12	0.05	0.02	0.01	0.01	0.00	0.00	0.00	0.00
Inflation	-0.14	-0.22	-0.20	-0.18	-0.16	-0.08	-0.03	0.00	0.00
Consumer price inflation	-0.14	-0.19	-0.19	-0.18	-0.16	-0.08	-0.03	0.00	0.00
Labour tax rate	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68
-low skilled	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68
-medium skilled	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68
-high skilled	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68	-1.68
Corporate tax rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption tax rate	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
Lump sum taxes (% of GDP)	0.04	0.09	0.11	0.13	0.14	0.15	0.14	0.13	0.13
Unemployment rate	-0.07	-0.16	-0.21	-0.24	-0.26	-0.28	-0.29	-0.29	-0.29
-low-skilled	-0.09	-0.22	-0.31	-0.36	-0.39	-0.43	-0.45	-0.46	-0.46
-medium-skilled	-0.06	-0.14	-0.18	-0.20	-0.21	-0.22	-0.23	-0.23	-0.23
-high-skilled	-0.04	-0.09	-0.11	-0.11	-0.11	-0.12	-0.13	-0.13	-0.13
Gov. balance (% of GDP)	-0.09	0.01	0.05	0.07	0.08	0.06	0.02	0.00	0.00
Current account (% of GDP)	-0.04	-0.07	-0.07	-0.07	-0.07	-0.04	-0.01	0.00	0.00
R&D intensity (% of GDP)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: percentage (points) difference from baseline

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

Another tax shift simulated here is shifting 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 so 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[22].

Table 3.8 shows the macro economic impact of a 1 per cent of GDP shift from low-skilled to high-skilled workers. The reduction in the tax wedge for low-skilled workers amounts to a decline in wage taxes of roughly 8 percentage points, while taxes for high-skilled workers (a smaller group) rise by almost twice that. Lower taxes for low-skilled workers increase employment for that skill group, higher taxes for high skilled reduce their employment rate. Total employment increases by 0.7 percent. 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 0.19 percent higher after 10 years but only 0.05 per cent higher in the long run.

[22] 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.

Table 3.8 1% of GDP tax shift from low to high skilled labour

EU	Years								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.11	0.09	0.13	0.16	0.18	0.19	0.17	0.10	0.05
TFP	-0.01	-0.14	-0.18	-0.20	-0.22	-0.25	-0.31	-0.39	-0.42
"Ideas/Patents"	-0.02	-0.11	-0.26	-0.44	-0.64	-1.54	-2.80	-4.37	-4.84
Capital	0.00	-0.01	-0.01	-0.01	-0.01	0.03	0.09	0.10	0.04
Capital intensity	0.00	-0.01	-0.03	-0.05	-0.07	-0.17	-0.32	-0.50	-0.55
Employment	0.17	0.32	0.44	0.52	0.56	0.61	0.65	0.67	0.67
-low	1.03	2.34	3.19	3.65	3.85	3.94	3.96	3.98	3.98
-medium	0.04	0.01	0.01	0.01	0.02	0.07	0.11	0.12	0.12
-high	-1.55	-3.53	-4.58	-5.05	-5.23	-5.27	-5.34	-5.49	-5.54
-R&D	-1.11	-2.91	-4.17	-4.86	-5.16	-4.91	-4.22	-3.43	-3.20
Consumption	0.62	0.13	0.06	0.08	0.10	0.15	0.14	0.07	0.04
Investment	-0.05	-0.05	-0.02	0.01	0.03	0.08	0.12	0.09	0.04
Real wages	-0.20	-0.40	-0.51	-0.55	-0.55	-0.53	-0.53	-0.59	-0.64
-low	-1.25	-2.40	-2.82	-2.90	-2.85	-2.70	-2.71	-2.79	-2.83
-medium	-0.05	-0.05	-0.04	-0.04	-0.03	-0.03	-0.05	-0.13	-0.17
-high	1.73	3.27	3.80	3.96	3.99	3.96	4.02	4.07	4.06
Exports	-0.20	0.04	0.14	0.17	0.17	0.16	0.14	0.08	0.04
Imports	0.47	0.03	-0.08	-0.07	-0.05	0.01	0.05	0.03	0.01
Terms of trade, final goods	0.15	-0.03	-0.10	-0.11	-0.11	-0.11	-0.09	-0.05	-0.03
Nominal interest rate	-0.23	-0.36	-0.39	-0.37	-0.33	-0.16	-0.04	0.00	0.00
Real interest rate	0.29	0.11	0.03	0.01	0.00	0.00	0.00	0.00	0.00
Inflation	-0.27	-0.51	-0.45	-0.41	-0.36	-0.17	-0.04	0.00	0.00
Consumer price inflation	-0.32	-0.43	-0.43	-0.40	-0.36	-0.17	-0.04	0.00	0.00
Labour tax rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-low skilled	-8.41	-8.41	-8.41	-8.41	-8.41	-8.41	-8.41	-8.41	-8.41
-medium skilled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-high skilled	14.47	14.47	14.47	14.47	14.47	14.47	14.47	14.47	14.47
Corporate tax rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumption tax rate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lump sum taxes (% of GDP)	0.01	0.04	0.05	0.05	0.04	0.00	-0.04	-0.05	-0.05
Unemployment rate	-0.21	-0.43	-0.60	-0.69	-0.74	-0.79	-0.82	-0.84	-0.84
-low-skilled	-0.92	-2.10	-2.87	-3.28	-3.46	-3.54	-3.56	-3.58	-3.58
-medium-skilled	-0.04	-0.01	-0.01	-0.01	-0.02	-0.07	-0.10	-0.11	-0.11
-high-skilled	1.41	3.27	4.31	4.81	5.00	4.99	4.91	4.88	4.88
Gov. balance (% of GDP)	0.16	0.23	0.26	0.25	0.23	0.12	0.02	0.00	0.00
Current account (% of GDP)	-0.14	-0.22	-0.20	-0.15	-0.11	-0.01	0.05	0.02	0.00
R&D intensity (% of GDP)	0.01	-0.01	-0.02	-0.03	-0.03	-0.02	-0.01	0.01	0.01

Note: percentage (points) difference from baseline

3.9 Reducing unemployment benefit generosity

Households set wages by maximising a weighted average of their utility functions and the wage rule in the model is obtained by equating the ratio between a weighted average of the marginal utility of leisure and a weighted average of the marginal utility of consumption, to 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, puts downward pressure on wages and so boosts labour demand.

The effects of a reduction in b_t^s of 5 percentage points for all three skill groups are shown in Table 3.9. The impact on output and employment are similar to those of a reduction in the wage mark-up. Lower wage income reduces consumption of liquidity-constrained households, but this is more than offset by an increase in consumption of non-liquidity-constrained households due to higher permanent income. 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. Our estimated average positive employment effect of 1.8% is however large compared to other recent empirical evidence as provided for example by Bassanini and Duval (2006). Their estimates suggest an employment effect in the range between 0.5 and 0.6% for a similar reduction in the replacement rate. Further work is required in order to better understand these quantitative discrepancies.

The dynamic adjustment of real wages, employment and productivity are 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 reduces labour productivity initially. 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 increased demand for new patents from entry of new firms in the intermediate sector.

Table 3.9 A 5 pp reduction in the benefit replacement rate

EU	Years after the shock								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.15	0.77	1.07	1.22	1.30	1.52	1.77	2.06	2.16
TFP	-0.07	0.12	0.16	0.19	0.21	0.28	0.34	0.39	0.40
"Ideas/Patents"	0.01	0.05	0.12	0.20	0.28	0.61	1.07	1.64	1.83
Capital	0.00	0.01	0.04	0.08	0.13	0.36	0.74	1.30	1.51
Capital intensity	0.00	0.01	0.01	0.02	0.03	0.07	0.12	0.18	0.20
Employment	0.35	1.05	1.45	1.62	1.69	1.78	1.85	1.88	1.88
-low	0.61	1.68	2.37	2.74	2.92	3.02	3.08	3.15	3.17
-medium	0.28	0.88	1.19	1.31	1.36	1.45	1.52	1.54	1.53
-high	0.05	0.38	0.44	0.42	0.40	0.51	0.63	0.70	0.71
-R&D	0.53	1.39	1.85	2.03	2.06	1.83	1.53	1.28	1.20
Consumption	0.30	0.71	0.95	1.09	1.19	1.40	1.54	1.68	1.73
Investment	0.01	0.13	0.26	0.35	0.43	0.65	0.94	1.36	1.52
Real wages	-0.53	-1.01	-1.04	-0.94	-0.85	-0.58	-0.36	-0.10	-0.02
-low	-0.80	-1.64	-1.90	-1.88	-1.79	-1.43	-1.19	-0.97	-0.89
-medium	-0.47	-0.86	-0.83	-0.70	-0.59	-0.35	-0.11	0.15	0.25
-high	-0.28	-0.36	-0.15	0.02	0.12	0.32	0.52	0.75	0.83
Exports	-0.05	0.59	0.85	0.96	1.01	1.19	1.45	1.73	1.82
Imports	0.08	0.05	0.11	0.18	0.25	0.41	0.47	0.53	0.56
Terms of trade, final goods	0.04	-0.41	-0.57	-0.64	-0.67	-0.79	-0.96	-1.14	-1.19
Nominal interest rate	-0.81	-1.11	-1.11	-1.02	-0.89	-0.44	-0.12	0.01	0.01
Real interest rate	0.65	0.22	0.09	0.03	0.01	0.01	0.01	0.00	0.00
Inflation	-0.98	-1.39	-1.28	-1.14	-0.98	-0.49	-0.14	0.01	0.01
Consumer price inflation	-0.94	-1.22	-1.22	-1.11	-0.98	-0.48	-0.14	0.01	0.01
Lump sum taxes (% of GDP)	0.02	0.02	-0.06	-0.16	-0.26	-0.57	-0.67	-0.57	-0.52
Unemployment rate	-0.34	-1.01	-1.39	-1.56	-1.63	-1.72	-1.78	-1.81	-1.81
-low-skilled	-0.55	-1.51	-2.13	-2.47	-2.62	-2.71	-2.77	-2.83	-2.85
-medium-skilled	-0.26	-0.82	-1.11	-1.22	-1.26	-1.34	-1.41	-1.43	-1.42
-high-skilled	-0.14	-0.55	-0.69	-0.70	-0.70	-0.74	-0.77	-0.78	-0.78
Gov. balance (% of GDP)	0.54	0.96	1.02	0.94	0.81	0.30	0.01	-0.03	-0.01
Current account (% of GDP)	-0.03	-0.02	0.04	0.09	0.12	0.11	-0.02	-0.05	-0.01
R&D intensity (% of GDP)	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00

Note: percentage (points) difference from baseline

3.10 Improving human capital

Compared to the US, Europe employs a relatively large share of low skilled workers (35% vs. 12%) while the share of medium skilled in the US is substantially higher compared to the EU (80% vs. 58%)[23]. Table 3.10a shows the simulation results of increasing the EU medium-skilled labour share. The shock is designed to linearly increase the share of medium-skilled workers by 1 percentage point after 40 years and decrease the low-skilled share accordingly. The output effect is gradually building up as the share of medium-skilled workers is increasing relative to the low-skilled share, with a positive impact of 0.17 per cent after 20 years and around 0.41 per cent in the long run, when the full adjustment in population shares has taken place. The additional medium-skilled labour will be employed at higher efficiency than the replaced low-skilled workers in the production of final goods, with decreasing skill-premium relative to the other skill-groups (low,- and high-skilled). The results are in line with previous study by de la Fuente (2003) on the social returns to education. The author estimated the long-term productivity impact of an extra year's schooling in the EU at 9.3%. Our simulation corresponds to a 0.043 year increase in the average years of schooling with an EU-wide productivity increase of 0.19%. Implied by imperfect substitutability between different types of workers, an increase in the share of medium-skilled workers has positive wage effects, especially for low-skilled workers.

The share of high skilled labour in the EU is 1.4 percentage point less compared to the US (6.2% vs. 7.6%). Table 3.10b shows the effects of increasing the EU high-skilled labour share by 1 percentage point after 40 years and decreasing the medium-skilled share accordingly. The large 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 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. In the first five years of the simulation the anticipated decline in the price of patents exceeds the reduction of high skilled wages therefore R&D production and R&D employment slightly decline. Increasing the high-skilled share results in a much stronger 'real' R&D effect in terms of R&D employment and patent-growth in the medium and long run which explains the significantly higher output effect compared to the previous scenario. Output is gradually building up with a positive impact of 0.26 per cent after 20 years and around 1.40 per cent in the long run. Notice that the employment share of R&D workers increases over time but the nominal R&D share declines because of the wage reduction.

The larger GDP effect in the second scenario originates largely from two sources. First, the difference in the marginal product of labour between high skilled and medium skilled is larger than the corresponding difference between medium skilled and low skilled and, second, because high skilled workers have a lower share compared to medium skilled workers, a 1 percentage point increase in high skilled workers constitutes a larger percentage increase of high skilled compared to a 1 percentage point increase of medium skilled workers.

[23] The qualification levels of the skill groups are not comparable between the EU and the US. In particular, the qualification level of the low skilled in the US is lower compared to the same group in the EU.

Table 3.10.a A 1 pp increase of the share of medium skilled workers

EU	Years after the shock								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.00	0.01	0.02	0.03	0.04	0.08	0.17	0.38	0.41
TFP	0.00	0.01	0.01	0.01	0.02	0.04	0.08	0.17	0.18
"Ideas/Patents"	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.17	0.20
Capital	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.22	0.29
Capital intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02
Employment	0.00	0.01	0.02	0.02	0.03	0.05	0.10	0.20	0.21
-low	-0.05	-0.12	-0.20	-0.28	-0.36	-0.77	-1.58	-3.24	-3.24
-medium	0.02	0.06	0.10	0.13	0.17	0.35	0.72	1.47	1.47
-high	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.03
-R&D	0.02	0.04	0.06	0.07	0.08	0.10	0.14	0.15	0.14
Consumption	-0.01	-0.01	0.00	0.01	0.02	0.06	0.14	0.32	0.33
Investment	0.00	0.01	0.01	0.02	0.02	0.04	0.10	0.24	0.29
Real wages	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.12	0.15
-low	0.04	0.10	0.16	0.22	0.28	0.60	1.24	2.61	2.64
-medium	-0.01	-0.04	-0.06	-0.08	-0.10	-0.21	-0.42	-0.82	-0.79
-high	0.01	0.01	0.02	0.03	0.03	0.06	0.11	0.25	0.28
Exports	0.01	0.02	0.03	0.03	0.04	0.06	0.14	0.32	0.35
Imports	-0.01	-0.01	-0.01	-0.01	0.00	0.02	0.05	0.10	0.11
Terms of trade, final goods	0.00	-0.01	-0.02	-0.02	-0.02	-0.04	-0.09	-0.21	-0.23
Nominal interest rate	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	0.00	0.00
Real interest rate	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inflation	-0.02	-0.02	-0.03	-0.03	-0.03	-0.04	-0.04	-0.01	0.00
Consumer price inflation	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.01	0.00
Lump sum taxes (% of GDP)	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03
Unemployment rate	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03
-low-skilled	0.00	-0.01	-0.02	-0.02	-0.02	-0.03	-0.05	-0.08	-0.09
-medium-skilled	0.00	0.01	0.01	0.01	0.01	0.02	0.05	0.09	0.09
-high-skilled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share of low skilled	-0.02	-0.04	-0.07	-0.09	-0.12	-0.24	-0.49	-1.00	-1.00
- medium skilled	0.02	0.04	0.07	0.09	0.12	0.24	0.49	1.00	1.00
- high-skilled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gov. balance (% of GDP)	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.00	0.00
Current account (% of GDP)	0.00	0.01	0.02	0.02	0.03	0.05	0.07	0.01	0.00
R&D intensity (% of GDP)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: percentage (points) difference from baseline

Table 3.10.b A 1 pp increase of the share of high skilled workers

EU	Years after the shock								
	1	**2**	**3**	**4**	**5**	**10**	**20**	**50**	**100**
GDP	0.01	0.03	0.04	0.05	0.06	0.11	0.26	0.93	1.40
TFP	0.01	0.02	0.03	0.04	0.05	0.11	0.27	0.85	1.08
"Ideas/Patents"	-0.01	-0.04	-0.07	-0.08	-0.09	0.14	1.57	10.10	14.76
Capital	0.00	0.00	0.00	-0.01	-0.01	-0.02	-0.01	0.31	0.89
Capital intensity	0.00	0.00	-0.01	-0.01	-0.01	0.02	0.17	1.08	1.55
Employment	0.00	0.00	0.00	0.01	0.01	0.03	0.07	0.12	0.10
-low	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.02	-0.07	-0.08
-medium	-0.02	-0.06	-0.10	-0.14	-0.18	-0.37	-0.75	-1.54	-1.55
-high	0.34	0.86	1.34	1.76	2.16	4.07	7.95	16.10	16.61
-R&D	-0.51	-0.78	-0.64	-0.34	0.03	2.05	5.74	12.08	9.81
Consumption	0.05	0.08	0.09	0.10	0.10	0.14	0.26	0.79	1.13
Investment	-0.01	-0.01	-0.02	-0.02	-0.02	-0.03	0.00	0.41	0.93
Real wages	-0.01	-0.01	-0.01	-0.01	0.00	0.04	0.15	0.72	1.12
-low	0.00	0.01	0.02	0.02	0.03	0.06	0.17	0.77	1.21
-medium	0.02	0.06	0.09	0.12	0.15	0.32	0.70	1.84	2.29
-high	-0.26	-0.66	-0.98	-1.26	-1.52	-2.77	-5.18	-9.46	-9.37
Exports	0.00	0.00	0.01	0.02	0.03	0.08	0.22	0.79	1.18
Imports	0.03	0.05	0.05	0.05	0.05	0.05	0.06	0.21	0.36
Terms of trade, final goods	0.00	0.00	-0.01	-0.01	-0.02	-0.05	-0.14	-0.52	-0.78
Nominal interest rate	0.00	0.00	0.00	0.00	0.01	0.01	0.01	-0.02	0.01
Real interest rate	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.00
Inflation	0.00	-0.01	-0.01	-0.01	0.00	0.00	-0.01	-0.04	0.01
Consumer price inflation	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.03	0.01
Lump sum taxes (% of GDP)	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.09
Unemployment rate	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.05
-low-skilled	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.06	0.07
-medium-skilled	0.00	0.00	0.00	0.00	0.00	-0.01	-0.02	-0.03	-0.02
-high-skilled	0.07	0.10	0.09	0.08	0.09	0.14	0.26	0.51	0.53
Share of low skilled	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
- medium skilled	-0.02	-0.04	-0.07	-0.09	-0.12	-0.24	-0.49	-1.00	-1.00
- high-skilled	0.02	0.04	0.07	0.09	0.12	0.24	0.49	1.00	1.00
Gov. balance (% of GDP)	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	-0.01
Current account (% of GDP)	-0.01	-0.02	-0.04	-0.06	-0.08	-0.15	-0.25	-0.20	-0.03
R&D intensity (% of GDP)	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	0.00	0.01	-0.03

Note: percentage (points) difference from baseline

5. Conclusions

In this paper we described a micro-founded DSGE model with endogenous growth 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 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. Our results confirm 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 model also allows us to examine the adjustment path and the time lags involved before these benefits can be reaped.

The model can also be used to study possible sources for the productivity gap between the EU and the US and look at policies which could help to close this gap. In Roeger *et al.* (2008) we identify differences in product market competition, labour taxation, R&D subsidies, entry costs, skill composition of the labour force and R&D technology and examine how differences in these factors account for differences in productivity, employment, skill premium and R&D expenditure. We are currently setting up such models for all EU member states, using country specific information on basic country specific structural characteristic.

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, possibly by looking more into human capital formation, and to examine differences in the efficiency of the R&D sector.

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Appendix A. Calibrating the parameters of knowledge production and intermediate goods production

We start from the Jones (1995) version of R&D modelling, but we account for the international R&D spillovers following Bottazzi and Peri (2007):

$$\Delta A_t = \nu A_{t-1}^{*\varpi} A_{t-1}^{\phi} L_{A,t}^{\lambda} \tag{a}$$

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

$$\phi P_{A,t} A_t = w_H L_{A,t} \tag{c}$$

$$rdi = \frac{P_{A,t}\Delta A_t}{P_Y Y_t} \tag{d}$$

$$i_{A,t} P_{A,t} + r_t FC_A = \pi_t, \quad where \ \pi_t = \left(\frac{1}{\theta} - 1\right) x_t \tag{e}$$

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

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

The first equation is the spillover-augmented version of Jones(1995) R&D production. This form of R&D equation accounts for international spillovers almost identically to the specification of Bottazzi and Peri (2007). Equation (b) states the steady-state relationship between the growth of ideas g_A and population g_n, equation (c) shows the first order condition of R&D production, equation (d) is the definition of 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. 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.

A.1. R&D production

Although we do not have direct estimates of ν, ϖ, ϕ and λ, we can use the existing literature and the model restrictions to get calibrated values for them. Data on the R&D share of labour ($L_{A,t}$) and on the R&D intensity $\left(\frac{P_{A,t}\Delta A_t^D}{P_Y Y_t}\right)$ is obtained from EUROSTAT, the values of g_A and g_n are given in our baseline model[24]. These values together with the restrictions

[24] Pessoa (2005) provides estimates for the growth of patents or ideas in various OECD countries at an average

of the balanced growth dynamics and the other variables of the baseline pin down λ and P_A. In order to set ϕ and ϖ in the first step we express the sum of these two parameters from equation (b). In the second step 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:

$$\phi = \frac{\gamma_{long-term}}{1 - \lambda_{long-term}}$$

and

$$\varpi = \frac{\mu_{long-term}}{1 - \lambda_{long-term}}.$$

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 $\left(\frac{\gamma}{\mu} = \frac{\varpi_{long-term}}{\lambda_{long-term}}\right)$ vary less, furthermore, imposing the ratio of the long-term parameters instead of their exact values is also less restrictive. To approximate our ϖ for the EU27, we use the ratio of these parameters from the specification in which the authors omitted the US from their regressions[25]. 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 domestic and foreign ideas to one and therefore the values for ν and θ can be obtained from expressions (a) and (e).

A.2. Intermediate goods production

The calibration of the parameters in intermediate goods production relies on the entry costs estimations of Djankov et al. (2002), and the estimations for R&D related subsidies (τ^A) of Warda (1996 and 2006). Given that we normalized the stock of domestic ideas to one (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[26]. All other variables given, the arbitrage equation e determines the rental rate of intangible capital, i_t^A. The B-indices published in Warda (2006) can be applied to calibrate

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of $g_A = 0.057$. The population growth g_n is obtained from EUKLEMS potential output calculations.

[25] The full sample consists of fifteen OECD countries including the US and ten member states of the European Union.

[26] 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.

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.

Appendix B. The tax treatment of intangible capital

The model is formulated in such a way that statutory corporate tax rates, depreciation allowances and tax credits can be incorporated in the analysis. This section explains how the tax measures in the model relate to Warda's (1996) B-index which serves as a comprehensive measure of the tax treatment of R&D as, for example, advocated by the OECD. Algebraically the B index is equal to the after tax cost of a Euro expenditure on R&D, divided by one minus the corporate income tax rate (t^K). Apart from the corporate income tax rate, the relevant tax parameters for an investor in R&D are the investment tax credit (τ) and the present discounted value of depreciation allowances (*A*). Depreciation allowances depend on the corporate tax rate and the depreciation scheme for a specific investment good as defined in the national tax laws. Standard depreciation schemes are declining balance and straight line depreciation as well as combinations of both. In the model we implicitly assume a declining balance scheme since it yields a simple representation for the user cost of capital. With a declining balance scheme, the present discounted value at period *t* of depreciation allowances of an investment good with unit value in *t* and rate of depreciation δ is given by

$$A_t = t^K\delta + \left(\frac{1}{1+r}\right)t^K\delta\ (1-\delta) + \left(\frac{1}{1+r}\right)^2 t^K\delta\ (1-\delta)^2 + ...$$

$$= \sum_{j=0}^{\infty}\left(\frac{1}{1+r+\delta}\right)^j t^K\delta = \frac{t^K\delta}{r+\delta}.$$

The B-index is defined as

$$B-index = \frac{(1-\tau - A)}{(1-t^K)}$$

and one obtains the standard neoclassical user cost of capital (*cc*) when multiplying the B-index with the sum of the real interest rate and the rate of depreciation. Using the definition of *A* it can be seen immediately that Warda's user cost approach can be linked directly to the user cost formula (7c') used in the model

$$cc = \frac{(1-\tau - A)}{(1-t^K)}(r+\delta) = \frac{(1-\tau - \frac{t\delta}{r+\delta})}{(1-t^K)}(r+\delta) = \frac{(1-\tau)(r+\delta) - t^K\delta}{(1-t^K)}.$$

Figure A. Simplified flow chart of the model