# Self-financing of fiscal measures in the EU Simulation-based analysis using the QUEST model with endogenous growth

Francesca Maria D'Auria*

October 19, 2010

**Abstract**

The question of whether and to what extent fiscal reforms can pay for themselves through higher growth is central both from the theoretical and the policymakers' point of view. This paper uses a dynamic general equilibrium model with endogenous growth to analyse the macroeconomic and budgetary effects of a series of fiscal measures on the EU economy, with an emphasis on their degree of self-financing, i.e. their ability to partially offset lost revenues due to general equilibrium incentive effects. The model includes an endogenous technological change mechanism in the form of the product-variety framework suggested by Jones (1995, 2005) and disaggregates the labour force into three skill categories. This allows an analysis of the consequences of capital and labour income and consumption tax cuts, but also of the impact of more targeted policies such as tax credits on R&D investment and skill-biased labour tax cuts. The paper finds that the degree of self-financing of the measures varies between 20% in the case of a cut in the labour income tax rate paid by high-skilled workers and 52% in the case of a reduction in the tax rate on low-skilled labour income. The paper also finds that the elasticity of labour supply is an important factor affecting the impact of a labour tax cut. Finally, we test the sensitivity of the effects of the tax reforms to the initial level of the tax rate, finding that the output expansion and the degree of self-financing are larger when the initial tax rates are higher.

*The views expressed in this paper are those of the authors and do not necessarily represent those of the European Commission. Correspondence: Francesca D'Auria, European Commission, DG ECFIN Economic and Financial Affairs, B-1160 Brussels, Belgium, email: francesca.d'auria@ec.europa.eu.

# 1 Introduction

The question of whether and to what extent expansionary fiscal measures can pay for themselves through higher growth is widely debated from both the theoretical and the policymakers' point of view. In the current economic juncture, a careful assessment of the potential budgetary impact of fiscal policy decisions is particularly needed.

One way of assessing the effects of a fiscal reform is to measure its direct impact on the government's budget. The estimation of this partial equilibrium effect is referred to as static scoring and implies that the budgetary impact is calculated without taking into account feedback effects to the economy. The assumption that a fiscal incentive does not have macroeconomic effects impacting on revenue collection is, however, unrealistic.

This is the argument underlying the concept of the Laffer curve, according to which a tax cut can result in higher government revenues through an expansion of the tax base, such that the tax cut fully or more than fully pays for itself. There is a vast literature on the existence of Laffer effects. Ireland (1994) examines the implications of a debt-financed tax cut in an endogenous growth model and finds that, under certain conditions, the measure does not require subsequent increases in the tax rate in order to balance the government's budget. However, these findings have been criticised by Pecorino (1995) and Bruce and Turnovsky (1999), who argue that Laffer effects do not arise under more realistic parameterisations of the level of taxation of the returns on human capital accumulation and of the intertemporal elasticity of substitution.

Recent studies do not support the claim that tax cuts can fully pay for themselves and argue instead in favour of a partial offsetting of their negative budget effect, i.e. of the existence of a certain degree of self-financing. The latter is measured by applying dynamic scoring techniques, which assess the budgetary impact of a fiscal reform by taking into consideration its incentive effects[1].

The tax reforms considered within this literature include labour income, capital income and consumption tax cuts. Mankiw and Weinzierl (2006) examine the revenue effects of fiscal measures in a neoclassical growth model and calculate that the steady state self-financing rates of labour and capital income tax cuts are respectively 17% and 53%. Leeper and Yang (2008) extend this analysis to explore the implications of alternative financing schemes, finding that the budgetary cost of a tax cut decreases with the aggressiveness of the government response to the budget deterioration caused by the measure. Trabandt and Uhlig (2010) use a neoclassical growth model to characterise Laffer curves for labour and capital income taxation and to estimate long-run self-financing rates for the United States and for 14 EU countries individually and as an aggregate. The study finds that at prevailing tax rates there is not a full Laffer effect, with the exception of Denmark and Sweden in the case of a reduction in the capital income tax rate. In addition, they calculate that the degree of self-financing of a labour tax cut is 32% in the US economy and 54% in the EU-14, while a capital tax cut results in a higher self-financing rate (51% for the US and 79% for the EU-14). Ganelli and Tervala (2008) analyse the macroeconomic and budgetary effects of labour income and consumption tax cuts in a two-country New Keynesian model. They find that the long-run degree of self-financing is about 17% for labour income tax cuts and 11.5% for consumption tax cuts and that the latter have larger short-run effects but a smaller long-run impact on GDP[2].

The self-financing rates found in the literature vary widely depending on the features of the model used for the simulations, and in particular on the role played by growth. This paper analyses the short and long-run effects of a series of permanent fiscal measures using a DSGE model with endogenous growth[3]. The model employs the product variety framework proposed by Dixit and Stiglitz (1977) and applies the Jones (1995) semi-endogenous growth framework to model the

[1] For a discussion of dynamic scoring and of the debate on the opportunity of its adoption instead of static scoring in the US, see Auerbach (2005).

[2] Ganelli and Tervala (2008) also carry out a sensitivity analysis for different degrees of nominal rigidity and of the disutility of labour, finding that the degree of self-financing ranges between 13% and 24% for labour income tax cuts and between 8.6% and 15.6% in the case of capital income tax cuts.

[3] The model is an extension of the QUEST III model used in the Directorate-General Economic and Financial Affairs of the European Commission and has been employed by Roeger et al. (2008) to analyse the effects of structural reforms in the EU.

development of R&D. This framework allows to assess the macroeconomic and budgetary effects of policies aimed at stimulating R&D investment. In addition, the model disaggregates the labour force into three skill categories, thereby making it possible to analyse the impact of labour tax cuts targeting high, medium or high skilled workers. A first contribution of the paper is therefore the analysis of an additional set of fiscal measures with respect to the existing literature on self-financing. Moreover, these studies (with the exception of Trabandt and Uhlig (2010)) analyse the effects of tax cuts in the presence of relatively low initial tax rates (based on the features of the US economy), consequently finding lower degrees of self-financing.

The measures considered are tax credits to investment in R&D and tangible capital and labour income tax cuts. In our simulations, no fiscal measure is fully self-financing, a result which is in line with recent studies. There is also a relatively wide variation in the degree of self-financing of skill-biased labour tax cuts: a decrease in the tax rate imposed on the income of low-skilled workers delivers the lowest decrease in revenue. Labour tax cuts aimed at low-skilled workers exhibit a higher degree of self-financing than policies benefiting medium and high skilled workers.

The paper is organised as follows. Section 2 outlines the main features of the model. Section 3 provides details on the calibration. Section 4 presents the results for our benchmark scenario and carries out a sensitivity analysis discussing how the results are affected by the elasticity of labour supply and the initial tax rates. Section 5 concludes.

# 2 The model

The model used in this paper is described in detail in Roeger et al. (2008). This section outlines its main features, focusing on the aspects most relevant for the simulation results. The economy consists of households, final and intermediate goods producing firms, a research industry, a monetary authority and a fiscal authority. In the final goods sector firms produce differentiated goods which are imperfect substitutes for goods produced abroad. Final good producers use a composite of 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).

## 2.1 Households

The household sector consists of a continuum of households $h \in [0, 1]$. A share $(1 - \epsilon)$ of these households are not liquidity constrained and indexed by $i \in [0, 1 - \varepsilon]$. They have access to financial markets where they can buy and sell domestic and foreign 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 medium and high-skilled labour services indexed by $s \in \{M, H\}$. The remaining share $\epsilon$ 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.

### 2.1.1 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 rental 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 ($J_t^{A,i}$), the licensing of existing patents ($A_t^i$) and receives wage income ($W_t^i$), unemployment benefits ($b_t^s W_t^{i,s}$)[4], 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

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

The budget constraints are written in real terms 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 ($\tau^K$ and $\tau^A$) 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.

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

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

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

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

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

and

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

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

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

Wages are also subject to convex adjustment costs given by

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

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

$$Z^i = \left[(1-s^M)^{\frac{1}{\sigma}} \left(Z^{di}\right)^{\frac{\sigma-1}{\sigma}} + s^{M\frac{1}{\sigma}} \left(Z^{fi}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{(\sigma-1)}} \tag{6a}$$

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

$$Z^{di} = \left[\sum_{h=1}^{m^d} \left(\frac{1}{m^d}\right)^{\frac{1}{\sigma^d}} Z_h^{d^i \frac{\sigma^d-1}{\sigma^d}}\right]^{\frac{\sigma^d}{\sigma^d-1}}, Z^{fi} = \left[\sum_{h=1}^{m^f} \left(\frac{1}{m^f}\right)^{\frac{1}{\sigma^m}} Z_h^{f^i \frac{\sigma^m-1}{\sigma^m}}\right]^{\frac{\sigma^m}{\sigma^m-1}}. \tag{6b}$$

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:

$$\frac{\partial V_0}{\partial C_t^i} => U_{C,t}^i - \lambda_t^i(1+t_t^c)P_t^C = 0, \tag{7a}$$

$$\frac{\partial V_0}{\partial B_t^i} => -\lambda_t^i + E_t\left(\lambda_{t+1}^i \beta\left(1+r_t\right)\right) = 0, \tag{7b}$$

$$\frac{\partial V_0}{\partial B_t^{F,i}} => -\lambda_t^i + E_t\left(\lambda_{t+1}^i \beta\left(1+r_t^F - \Gamma_{B^F}\left(E_t B_t^F / Y_t\right)\right) E_{t+1}/E_t\right) = 0, \tag{7c}$$

$$\frac{\partial V_0}{\partial K_t^i} => -\lambda_t^i \xi_t^i + E_t\left(\begin{array}{c} \lambda_{t+1}^i \xi_{t+1}^i \beta(1-\delta) \\ +\lambda_{t+1}^i \beta\left((1-t_t^K)\left(\begin{array}{c} i_t^K ucap_t^i - rp_t^K \\ -\Gamma_u\left(ucap_t^i\right)\end{array}\right) + t_t^K \delta^K\right) P_{t+1}^C \end{array}\right) = 0, \tag{7d}$$

$$\frac{\partial V_0}{\partial J_t^i} => -\lambda_t^i P_t^C\left(1+\gamma_K\left(\frac{J_t^i}{K_{t-1}^i}\right) + \gamma_I \Delta J_t^i - \tau^K\right) + E_t\left(\lambda_{t+1}^i \beta P_{t+1}^C \gamma_I \Delta J_{t+1}^i\right) + \lambda_t^i \xi_t^i = 0, \tag{7e}$$

$$\frac{\partial V_0}{\partial ucap_t^i} => i_t^K - a_1 - 2a_2\left(ucap_t^i - ucap_t^{ss}\right) = 0. \tag{7f}$$

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 $Q_t$

$$Q_t - 1 = \gamma_K\left(\frac{J_t^i}{K_{t-1}^i}\right) + \gamma_I \Delta J_t^i - \tau^K - E_t\left(\frac{\gamma_I \Delta J_{t+1}^i}{1+i_t-\pi_{t+1}^C}\right) \text{ with } Q_t = \frac{\xi_t}{P_t^C}, \tag{8a}$$

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

$$Q_t = E_t\left(\frac{1-\delta}{1+i_t-\pi_{t+1}^C} Q_{t+1} + \frac{(1-t_t^K)\left(i_t^K ucap_t^i - rp_t^K - \Gamma_u\left(ucap_t^i\right)\right) + t_t^K \delta^K}{1+i_t-\pi_{t+1}^C}\right) \tag{8b}$$

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 ($\pi_{t+1}^C$).

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 $\tau^A$. Hence, the first order conditions with respect to R&D investments are given by

$$\frac{\partial V_0}{\partial A_t^i} => -\lambda_t^i \psi_t^i + E_t \begin{pmatrix} \lambda_{t+1}^i \psi_{t+1}^i \beta(1-\delta^A) \\ +\lambda_{t+1}^i \beta \left((1-t_t^K)(i_t^A - rp_t^A) + t_t^K \delta^A\right) P_{t+1}^A \end{pmatrix} = 0 \tag{8c}$$

$$\frac{\partial V_0}{\partial J_t^{A,i}} => -\lambda_t^i P_t^A \left(1-\tau^A\right) + \lambda_t^i \psi_t^i = 0 \tag{8d}$$

Therefore the rental rate can be obtained from 7b, 8c and 8d after neglecting the second order terms:

$$i_t^A \approx \frac{\left(1-\tau^A\right)\left(i_t - \pi_{t+1}^A + \delta^A\right) - t_t^K \delta^A}{\left(1-t_t^K\right)} + rp_t^A \tag{9}$$

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

Equation (9) states that households 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. The government 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.

### 2.1.2 Liquidity constrained households

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

$$(1+t_t^c)P_t^C C_t^k + \sum_s \frac{\gamma_W L_t^{k,s}}{2} \frac{\left(\Delta W_t^{k,s}\right)^2}{W_{t-1}^{k,s}} = \sum_s \begin{pmatrix} \left(1-t_t^{w,s}\right) W_t^{k,s} L_t^{k,s} \\ +b_t^s W_t^{k,s}(1-NPART_t^{k,s} - L_t^{k,s}) \end{pmatrix} + TR_t^k. \tag{10}$$

### 2.1.3 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. 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

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

### 2.1.4 Aggregation

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

$$X_t = \int_0^1 X_t^h dh = (1-\varepsilon) X_t^i + \varepsilon X_t^k, \tag{11}$$

Hence aggregate consumption and employment is given by

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

and

$$L_t = (1-\varepsilon)\, L_t^i + \varepsilon L_t^k. \tag{13}$$

## 2.2 Firms

### 2.2.1 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 denoted by $\sigma^d$. Final output ($Y^j$) is produced using $A$ varieties of intermediate inputs ($x$) with an elasticity of substitution $\theta$. The final good sector uses a labour aggregate and domestic intermediate goods with Cobb-Douglas technology, subject to a fixed cost $FC_Y$ and overhead labour $FC_L$

$$Y^j = \left(A_t^{exog}\left(L_{Y,\,t}^j - FC_L\right)\right)^{\alpha} \left(\sum_{i=1}^{A_t}\left(x_{i,t}^j\right)^{\theta}\right)^{\frac{1-\alpha}{\theta}} KG_t^{\alpha_G} - FC_Y, 0 < \theta < 1 \tag{14}$$

with

$$L_{Y,\,t} = \left(s_L^{\frac{1}{\sigma_L}}\left(ef_L L_t^L\right)^{\frac{\sigma_L-1}{\sigma_L}} + s_M^{\frac{1}{\sigma_L}}\left(ef_M L_t^M\right)^{\frac{\sigma_L-1}{\sigma_L}} + s_{H,\,Y}^{\frac{1}{\sigma_L}}\left(ef_H L_t^{HY}\right)^{\frac{\sigma_L-1}{\sigma_L}}\right)^{\frac{\sigma_L}{\sigma_L-1}}. \tag{15}$$

Parameter $s_s$ is the population share of labour force in subgroup $s$ (low, medium and high-skilled workers), $L_s$ denotes the employment rate of population $s$, $ef_s$ is the corresponding efficiency unit, and $\sigma_L$ 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 households:

$$L_t^s = \left[\int_0^1 \left(L_t^{s,h}\right)^{\frac{\sigma_s-1}{\sigma_s}} dh\right]^{\frac{\sigma_s}{\sigma_s-1}} \tag{16}$$

The parameter $\sigma_s > 1$ determines the degree of substitutability among different types of labour. Finally, $KG$ denotes the stock of public capital with an elasticity of $\alpha_G$.

The above production function employs the idea of product variety framework proposed by Dixit and Stiglitz and applied in the literature of international trade and R&D diffusion[5] and we model the underlying development of R&D by the semi-endogenous framework of Jones (2005).

The objective of the firm is to maximise profits

$$PR_t^{f,j} = P_t^j Y_t^j - \left(W_t^L L_t^{j,L} + W_t^M L_t^{j,M} + W_t^H L_t^{j,HY}\right) - \sum_{i=1}^{A_t}\left(px_{\,i,t}\, x_{i,t}^j\right), \tag{17}$$

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

$$\alpha \frac{Y_t + FC_Y}{L_{Y,\,t} - FC_L}\left(\frac{L_{Y,\,t}}{L_t^s}\right)^{\frac{1}{\sigma_L}} s_s^{\frac{1}{\sigma_L}} ef_s^{\frac{\sigma_L-1}{\sigma_L}} \eta_t = W_t^s, \quad s \in \{L,\, M,\, H\} \tag{18a}$$

$$px_{i,t} = \eta_t(1-\alpha)\left(Y_t + FC_Y\right)\left(\sum_{i=1}^{A_t}\left(x_{i,t}^j\right)^{\theta}\right)^{-1}\left(x_{\,i,t}\right)^{\theta-1} \tag{18b}$$

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

where $\eta_t = 1 - 1/\sigma_t^d$[6]

### 2.2.2 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 (18b).

Each domestic intermediate firm solves the following profit-maximisation problem

$$PR_{i,t}^x = \max_{x_{i,t}} \left\{ px_{i,t}x_{i,t} - i_t^K P_t^C k_{i,t} - i^A P_t^A - FC_A \right\} \tag{19}$$

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

$$x_{i,t} = k_{i,t} \cdot ucap_t. \tag{20}$$

In a symmetric equilibrium the first order condition is

$$\theta\eta_t(1-\alpha)\left(Y_t + FC_Y\right)\left(\sum_{i=1}^{A_t}\left(x_{i,t}^j\right)^\theta\right)^{-1}\left(x_t\right)^{\theta-1} = i_t^K P_t^C \tag{21a}$$

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

$$PX_t = px_{i,t} = \frac{i_t^K P_t^C}{\theta}. \tag{21b}$$

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

$$PR_{i,t}^x = PR_t^x = i_t^A P_t^A + \left(i_t^A + \pi_{t+1}^A\right) FC_A, \quad \forall i \tag{22a}$$

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

$$P_t^A + FC_A = \sum_{j=1}^{\infty}\left(\frac{1}{1 + r_{t+j} + rp_{t+j}^A}\right)^j PR_{t+j-1}^x \tag{22b}$$

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 $FC_A$.

### 2.2.3 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:

$$\Delta A_t = \nu A_{t-1}^{*\varpi} A_{t-1}^{\phi} L_{A,\,t}^{\lambda}. \tag{23}$$

In this framework we allow for international R&D spillovers following Bottazzi and Peri . Parameters $\varpi$ and $\phi$ 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

[6] Similar to the wage mark-up, we will 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.

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 $\nu$ can be interpreted as total factor efficiency of R&D production, while $\lambda$ measures the elasticity of R&D production on the number of researchers ($L_A$). The international stock of knowledge grows exogenously at rate $g_{A^W}$. We assume that the R&D sector is operated by a research institute which employs high skilled labour at their market rate $W^H$. We also assume that the research institute faces an adjustment cost of hiring new employees and maximizes the following discounted profit-stream:

$$\max_{L_{A,\,t}} \sum_{t=0}^{\infty} d_t \left( P_t^A \Delta A_t - W_t^H L_{A,\,t} - \frac{\gamma_A}{2} W_t^H \Delta L_{A,\,t}^2 \right) \tag{24}$$

where $d_t$ is the discount factor.

## 2.3 Trade and the current account

The economies trade both final and intermediate goods. The elasticity of substitution between bundles of domestic and foreign goods $Z^{d^i}$ and $Z^{f^i}$ is $\sigma$. Thus aggregate imports are given by

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

And there is producer pricing of imports and exports.

$$P_t^{EX} = P_t \tag{26}$$

and

$$P_t^{IM} = E_t P_t^* \tag{27}$$

Thus net foreign assets evolve according to

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

## 2.4 Government

Government debt ($B_t$) evolves according to the following rule:

$$B_t = (1 + r_t) B_{t-1} + P_t^C (G_t + IG_t) + TR_t + BEN_t + S_t - R_t^G - T_t^{LS}. \tag{29}$$

Government consumption, government investment and government transfers are proportional to GDP, such that

$$X_t = s_X Y_t \tag{30}$$

where $X \in \{G, IG\}$.

The government pays unemployment benefits which are indexed to wages. Aggregate benefit payments are therefore given by:

$$BEN_t = \sum_s b_t^s W_t^s (1 - NPART_t^s - L_t^s) \tag{31}$$

where s denotes the skill group. The benefit replacement rate is linked to consumer prices and net wages according to the following rule:

$$b_t^s = \hat{b}_t^s \left[ (1 + t_t^C) P_t^C \right]^{\chi^c} (1 - t_t^W)^{\chi^w}, 0 \leq \chi^c, \chi^w \leq 1 \tag{32}$$

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

$$S_t = t_{t-1}^K \left( \delta^K P_t^I K_{t-1}^{i,H} + \delta^A P_t^A A_{t-1}^{i,H} \right) + \tau^K P_t^I J_t^{i,H} + \tau^A P_t^A J_t^{A,i,H}. \tag{33}$$

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

$$B_t = (1 + r_t) B_{t-1} + P_t^C (G_t + IG_t) + TR_t + BEN_t + S_t - R_t^G - T_t^{LS}. \tag{34}$$

The government conducts fiscal policy by following a debt rule which aims to stabilise the debt to GDP ratio. Lump-sum taxes ($T_t^{LS}$) respond to deviations according to the following rule

$$\Delta T_t^{LS} = \tau^B \left( \frac{B_{t-1}}{Y_{t-1} P_{t-1}} - b^T \right) + \tau^{DEF} \Delta \left( \frac{B_t}{Y_t P_t} \right) \tag{35}$$

where $b^T$ is the government debt target.

The central bank sets interest rates according to the following interest rate rule which allows for some smoothness of the interest rate response to the inflation and output gap

$$\begin{aligned} i_t = \tau_{lag}^{INOM} i_{t-1} + (1 - \tau_{lag}^{INOM}) [r^{EQ} + \pi^T + \tau_\pi^{INOM} (\pi_t^C - \pi^T) + \tau_{y,1}^{INOM} ygap_{t-1}] \\ + \tau_{y,2}^{INOM} ({}_t ygap_{t+1} - ygap_t) + u_t^{INOM} \end{aligned} \tag{36}$$

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

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

$$YGAP_t = \left( \frac{ucap_t}{ucap_t^{ss}} \right)^{(1-\alpha)} \left( \frac{L_t}{L_t^{ss}} \right)^{\alpha}. \tag{37}$$

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

$$ucap_t^{ss} = (1 - \rho^{ucap}) ucap_{t-1}^{ss} + \rho^{ucap} ucap_t \tag{38}$$

$$L_t^{ss} = (1 - \rho^{Lss}) L_{t-1}^{ss} + \rho^{Lss} L_t \tag{39}$$

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

# 3 Calibration

The baseline calibration of the model reflects the features of the EU as a whole. Table 1 reports the values of the key parameters. The labour force is disaggregated into three skill categories: low, medium and high-skilled labour. The share of low-skilled workers corresponds to the standard classification of ISCED 0-2 education levels, while high-skilled workers are identified as the segment of the labour force which can potentially be employed in the R&D sector, i.e. engineers and natural scientists. The rest of the labour force is classified as medium-skilled.

The values of the tax rate on capital income and of the tax credit on investment in intangible capital are taken from Warda (2006), while the labour and consumption tax rates are obtained from DG TAXUD data. The benefit replacement rate is set equal to 40% for all skill groups.

Table 1: Calibration

| | Value | Source |
|---|---|---|
| **Labour market** | | |
| Skill distribution: | | |
| Low-skilled population share ($s_L$, %) | 30.04 | EUROSTAT |
| Medium-skilled population share ($s_M$, %) | 63.68 | EUROSTAT |
| High-skilled population share ($s_H$, %) | 6.28 | EUROSTAT |
| Employment rates: | | |
| Low skilled employment | 56.50 | EUROSTAT |
| Medium-skilled employment | 73.70 | EUROSTAT |
| High-skilled employment | 84.60 | EUROSTAT |
| Aggregate employment rate | 69.22 | EUROSTAT |
| Labour supply elasticity | 0.25 | Calibration |
| Benefit replacement rate | 0.4 | Calibration |
| | | |
| **R&D sector** | | |
| Researchers ($L_A$, % employment) | 1.03 | EUROSTAT |
| R&D (% GDP) | 1.84 | EUROSTAT |
| Elasticity of R&D w.r.t. labour ($\lambda$) | 0.73 | Calibration/Bottazzi and Peri (2007) |
| R&D efficiency ($\nu$) | 0.39 | Calibration |
| | | |
| **Intermediate sector** | | |
| Mark-up (%) | 11.15 | EUKLEMS |
| Entry costs (FC$_A$) | 0.33 | Djankov et al. (2002) |
| | | |
| **Final goods sector** | | |
| Mark-up (%) | 24.32 | EUKLEMS |
| Depreciation rate of tangible capital (%) | 3.33 | Calibration |
| | | |
| **Taxes/subsidies** | | |
| Labour tax (including social security)(%) | 37.08 | DG TAXUD |
| Tax rate on capital income (%) | 40.31 | Warda (2006) |
| Consumption tax (%) | 18.88 | DG TAXUD |
| Tax credit on R&D (%) | 42.84 | Warda (2006) |

# 4 Results

This section analyses the short-run and long-run effects of a series of fiscal measures, namely:

1. A reduction in labour income tax for all skill groups
2. A reduction in labour income tax for low-skilled workers
3. A reduction in labour income tax for medium-skilled workers
4. A reduction in labour income tax for high-skilled workers
5. A reduction in capital income tax
6. A reduction in consumption taxation
7. A tax credit on investment in R&D

In order to facilitate the comparison of the effects of the various measures, all policies are designed to have an initial impact on the government budget of 0.5% of GDP. The rate of self-financing is measured as the ratio between the general equilibrium effect of the tax cut or credit (resulting from the incentive effects generated by the fiscal reform) and its partial equilibrium impact, i.e. the lost revenue assuming no change in economic choices. As each measure is financed in a budgetary neutral manner through an increase in lump-sum taxes, the latter can be taken as a measure of the increase in taxation needed to balance the budget. The rate of self-financing is therefore given by the fraction of the partial equilibrium budget effect which does not require an increase in lump-sum taxes in order to stabilise the debt to GDP ratio.

## 4.1 Labour income tax

In what follows, the effects of reductions in labour income tax rates are discussed. A lower tax burden on labour income has a positive effect on employment as it increases the opportunity cost of leisure, thereby boosting labour supply. The impact on the economy of a same-size reduction in labour income taxation (as a percentage of GDP), however, varies depending on which category of workers is affected by the measure. The simulations reported below allow a comparison between an economy-wide reduction in labour taxation and skill-biased policies.

### 4.1.1 Average labour income tax reduction

Figure 1 illustrates the response of output, consumption, investment and employment to a permanent reduction in the labour tax rate over a 50-year horizon. The cut accounts for 0.5% of initial GDP, corresponding to the partial equilibrium effect of the policy, and implies a 0.84 percentage points reduction in the tax rate to 36.2%. The measure generates a strong increase in employment. Consumption also rises due to the increase in disposable income resulting from a lower tax burden on wages, notwithstanding the deterioration in the terms of trade which affects negatively households' consumption. In addition, the increase in employment yields a temporary decline in the capital to labour ratio and therefore in the marginal product of labour, leading to a decrease in wages. Investment also increases to re-establish the original capital to labour ratio and marginal product of labour, implying that real wages return to baseline in the long run. The GDP effect is initially smaller than the increase in employment, but builds up gradually over time due to the fact that higher employment in the R&D sector translates into an increase in the production of patents, which in turn boosts productivity.

Table 2 reports the GDP effect and the degree of self-financing of the measure over time. Labour tax revenue declines as a result of the lower tax rate and lower real wages earned by workers. However, the expansion of the tax base partially compensates for this effect and the negative impact on revenue collection decreases over time. Higher private consumption and investment lead to an increase in both consumption and capital tax revenue. On the expenditure side, benefit payments

Figure 1: 0.5% of GDP labour income tax cut (% deviation from baseline)

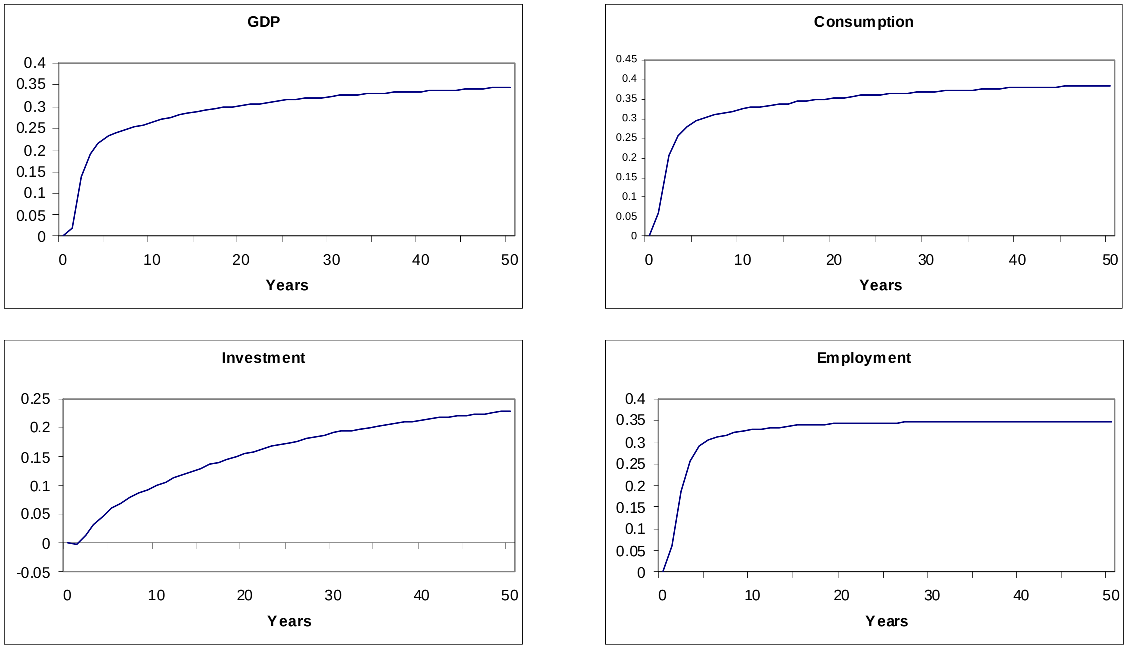



Table 2: Average labour income tax cut - Effect on GDP and degree of self-financing

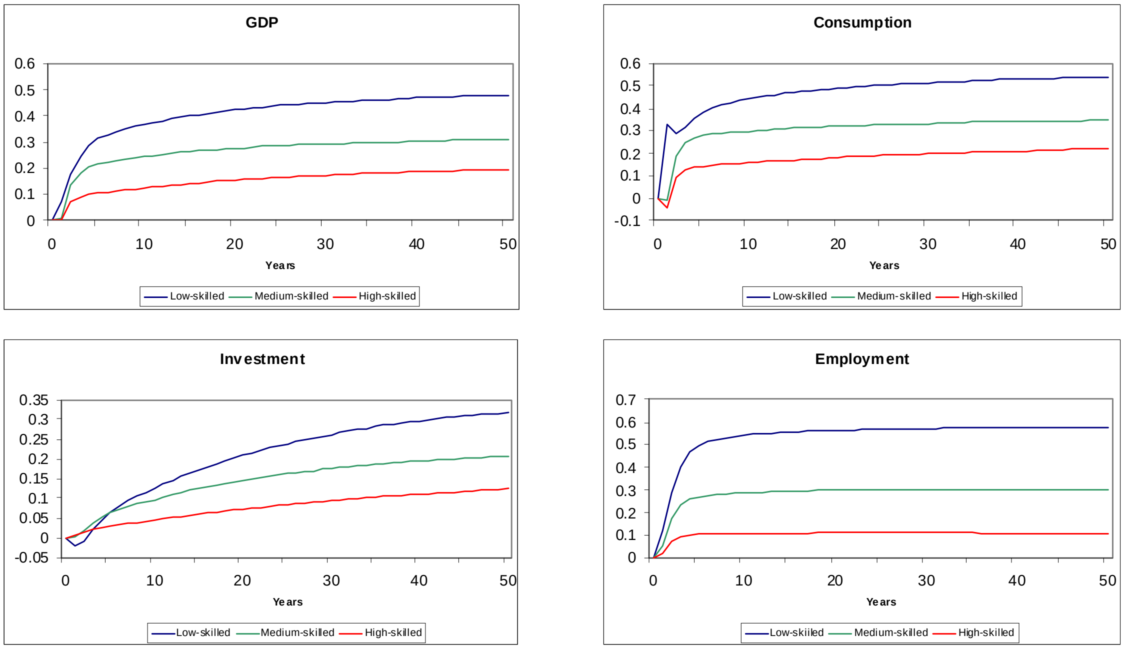
| | Years after the measure | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 10 | 20 | 50 | 100 |
| GDP (% deviation from baseline) | 0.02 | 0.14 | 0.19 | 0.22 | 0.23 | 0.27 | 0.30 | 0.34 | 0.36 |
| Degree of self-financing (%) | 0 | 18 | 22 | 26 | 28 | 32 | 34 | 36 | 38 |

decrease as a result of the increase in employment and the decline in real wages. In the first year, the measure has an impact on revenue collection close to zero, as the expansion of the tax base triggered by the measure is not yet sufficient to compensate for the budget effect of the reduction in the tax rate. The degree of self-financing of the labour tax cut increases rapidly over time and, in the long run, accounts for 38% of the initial budget effect of the policy measure.

### 4.1.2 Skill-biased reductions in labour income tax

As noted above, a reduction in the labour income tax rate has very different implications for the economy depending on the category of households it targets. Workers with different skill levels differ in terms of their preference for leisure and of the efficiency level at which they contribute to production. Labour adjustment costs also vary across skill groups and are higher for high-skilled workers. As shown in Figure 2, the most effective measure is a reduction in labour income taxation paid by low-skilled workers. In the long run, aggregate employment is 0.6% higher than in the baseline. This effect is driven by a 2.3% increase in low-skilled workers employment. The lower initial employment rate of low-skilled workers relative to other skill groups largely explains the stronger employment effect observed. A lower employment rate implies a lower marginal utility of leisure and that an increase in labour supply of the same magnitude represents a proportionally smaller decrease in leisure. This translates into a stronger downward pressure on wages and a larger increase in the employment rate than in the case of medium-skilled and high-skilled workers.

Figure 2: 0.5% of GDP skill-biased labour tax cut (% deviation from baseline)




The degree of self-financing also varies widely between the measures. The stronger response of the economy to a labour tax cut targeted at low-skilled workers yields a larger increase in labour, consumption and capital tax revenue and a larger decline in benefit payments.

Table 3: Skill-biased labour income tax cuts-GDP effect and degree of self-financing

| | Years after the measure | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 10 | 20 | 50 | 100 |
| | Low-skilled workers | | | | | | | | |
| GDP (% deviation from baseline) | 0.07 | 0.18 | 0.25 | 0.29 | 0.31 | 0.37 | 0.43 | 0.48 | 0.50 |
| Degree of self-financing (%) | 2 | 20 | 28 | 34 | 36 | 44 | 48 | 52 | 52 |
| | Medium-skilled workers | | | | | | | | |
| GDP (% deviation from baseline) | 0.01 | 0.13 | 0.18 | 0.20 | 0.22 | 0.24 | 0.28 | 0.31 | 0.32 |
| Degree of self-financing (%) | -2 | 18 | 22 | 24 | 26 | 28 | 32 | 34 | 34 |
| | High-skilled workers | | | | | | | | |
| GDP (% deviation from baseline) | 0.00 | 0.07 | 0.09 | 0.10 | 0.10 | 0.12 | 0.15 | 0.19 | 0.21 |
| Degree of self-financing (%) | 2 | 10 | 12 | 12 | 12 | 14 | 16 | 18 | 20 |

## 4.2 Capital income tax

A reduction in the capital income tax rate, $\tau^k$, increases the marginal net return to capital, which in turn stimulates private investment and leads to an increase in the stock of capital. In our simulations, the capital income tax rate decreases by 3.5 percentage points to 36.8% (from an initial rate of 40.3%), boosting investment, which, in the long run, is approximately 4% higher than in the baseline.

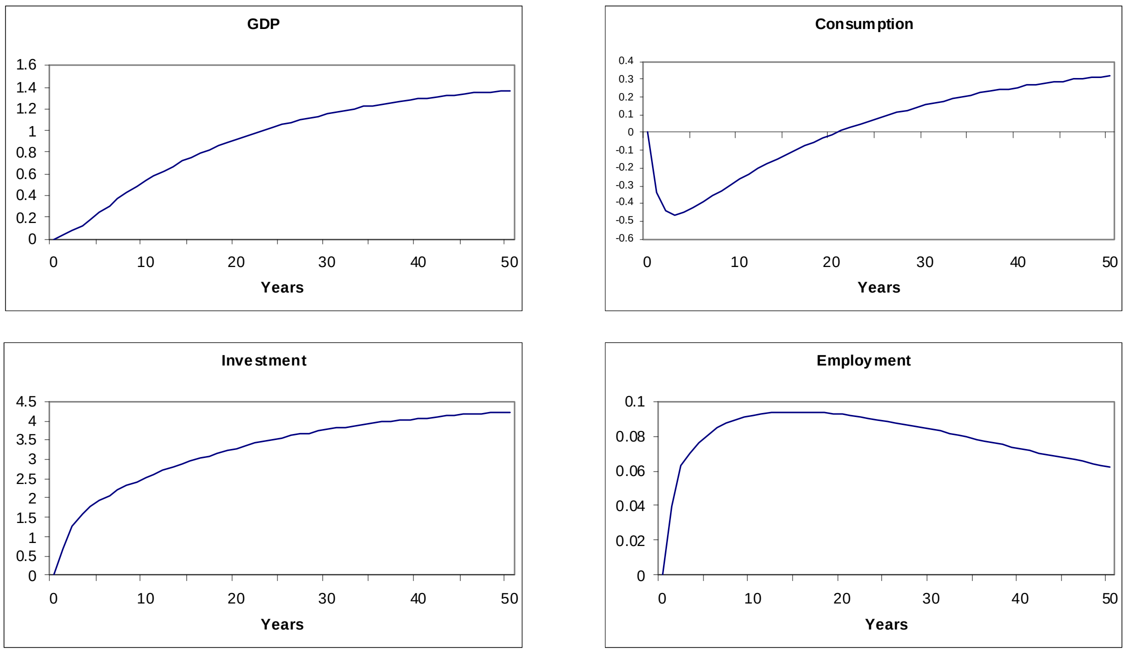
The strong increase in investment and thereby in the stock of capital translates into a gradual increase in GDP, while consumption declines in the short to medium run. The tax cut also impacts on real wages which increase due to the higher marginal product of labour. Moreover, the tax cut stimulates investment in intangible capital, increasing the demand for patents and triggering a reallocation of high-skilled workers from the final goods sector to the research sector. As output grows, consumption also increases and is, after 50 years, 0.4% higher than in the baseline.

In the long run, the reduction in capital income taxation has a relatively high rate of self-financing. However, in the short run the effect is mixed, as the positive contribution from an increase in labour tax revenue (due to higher wages and higher employment) is more than offset by a decline in consumption tax receipts. In addition, the increase in R&D investment triggered by the tax cut requires larger tax credit payments. Over time, the labour tax base expands further and consumption tax revenues also start to increase, leading to a long-run self-financing rate of 40%. This dynamics is consistent with the findings of Trabandt and Uhlig (2010), who calculate that the largest contribution to total tax receipts from a cut in capital taxation comes from an increase in labour tax revenue.

Table 4: Capital income tax cut-Degree of self-financing

| | **Years after the measure** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 10 | 20 | 50 | 100 |
| GDP (% deviation from baseline) | 0.03 | 0.07 | 0.12 | 0.18 | 0.25 | 0.53 | 0.92 | 1.36 | 1.46 |
| Degree of self-financing (%) | 8 | 0 | -2 | -2 | 0 | 10 | 24 | 40 | 40 |

Figure 3: 0.5% of GDP decrease in capital income tax




## 4.3 Consumption tax

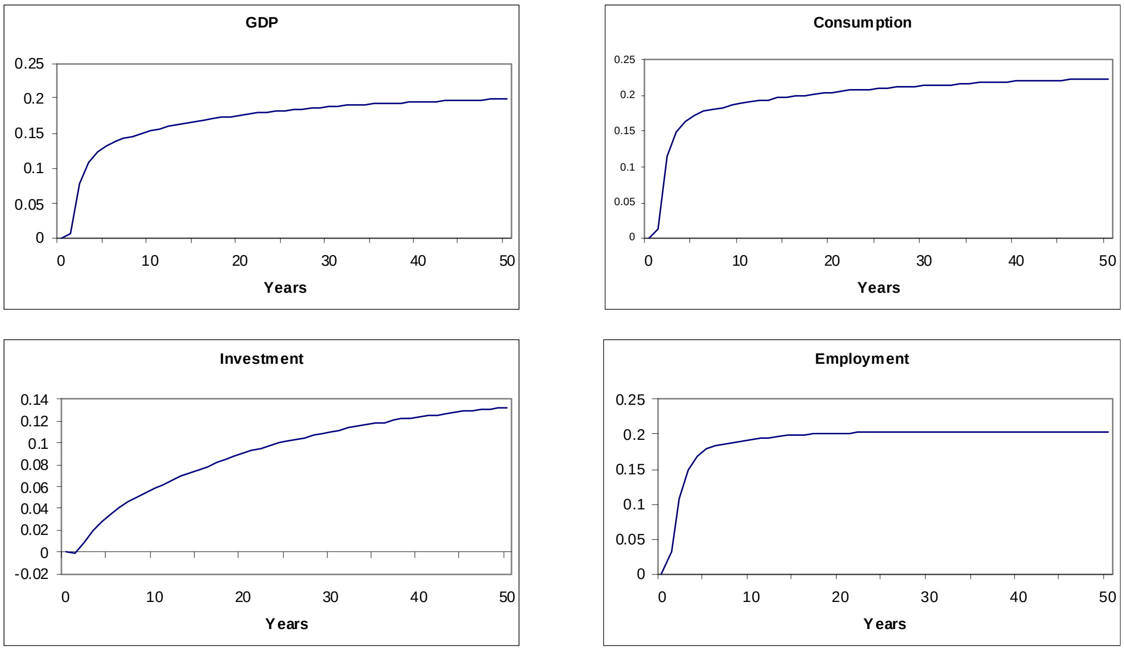
A 0.5% of GDP consumption tax cut entails a 0.9 percentage points reduction in the tax rate to 18%. The policy has smaller GDP effects than equivalent (in terms of the initial budget impact) cuts in labour or capital income tax rates. The measure translates into a decrease in consumer prices, thereby increasing the real value of profit and labour income received by individuals and boosting consumption. In addition, the increase in lump-sum taxes needed to keep the debt-to-GDP ratio constant strengthens the incentives to work and leads to an increase in employment. The decline in the capital to labour ratio, in turn, stimulates investment to re-establish the original ratio in the long run.

The self-financing rate of the policy is relatively modest at 24% in the long run. Labour tax revenue increases and benefit payments decrease as a result of the rise in employment triggered by the tax cut. However, most of the feedback effect on the government budget comes from an increase in consumption tax revenues which partially offsets the negative impact of the reduction in the tax rate.

Table 5: Consumption tax cut-Degree of self-financing

| | Years after the measure | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 10 | 20 | 50 | 100 |
| GDP (% deviation from baseline) | 0.01 | 0.08 | 0.11 | 0.12 | 0.13 | 0.15 | 0.18 | 0.20 | 0.21 |
| Degree of self-financing (%) | 2 | 12 | 16 | 18 | 18 | 20 | 22 | 24 | 24 |

Figure 4: 0.5% of GDP cut in consumption tax




## 4.4 Tax credit to R&D

Finally, we discuss the effects of a tax credit set to stimulate R&D activity. The tax credit is granted to the non liquidity constrained households on their income from the licensing of patents (bought from the R&D sector) to intermediate firms. Figure 5 shows the effects of the shock on the main macroeconomic variables, while Table 6 reports the GDP effects and the degree of self-financing of the measure. The tax credit encourages households to lower the rental rate of intangible capital, reducing the costs faced by intermediate firms and stimulating the demand for patents. This in turn yields a reallocation of high-skilled workers from the final goods sector to the R&D sector. In the short run, the process translates into a decline in GDP. The decrease in high-skilled labour employed in the final goods sector is associated with a lower marginal product of capital, which has a negative effect on the demand for tangible capital. As shown in Figure 5, investment declines steadily over the first 8 years following the introduction of the tax credit, when it starts increasing again. In the long run, however, the reduction in the entry costs faced by firms leads to an acceleration of technological progress and an increase in the demand for capital. After 50 years, investment in tangible capital and GDP are respectively 1.15% and 0.55% higher than in the baseline.

Table 6 shows that over the initial years of the policy the adoption of the tax credit has a negative effect on the government budget which exceeds its static scoring effect by as much as 90% (in the fourth year). This is mostly due to the large increase in tax credit payments caused by the expansion of the R&D sector which is not fully compensated by the wider tax base. The strong increase in demand for high-skilled workers in the R&D sector leads to an increase in their real wages. Over time, labour, consumption and capital income tax revenue increase, such that the measure is partially self-financing in the long run. Unlike the measures discussed in the previous subsections, the effects on the government budget of an increase in the tax credit rate on investment in intangible capital depend strongly on the size of the shock.

Figure 5: 0.5% of GDP tax credit to R&D sector

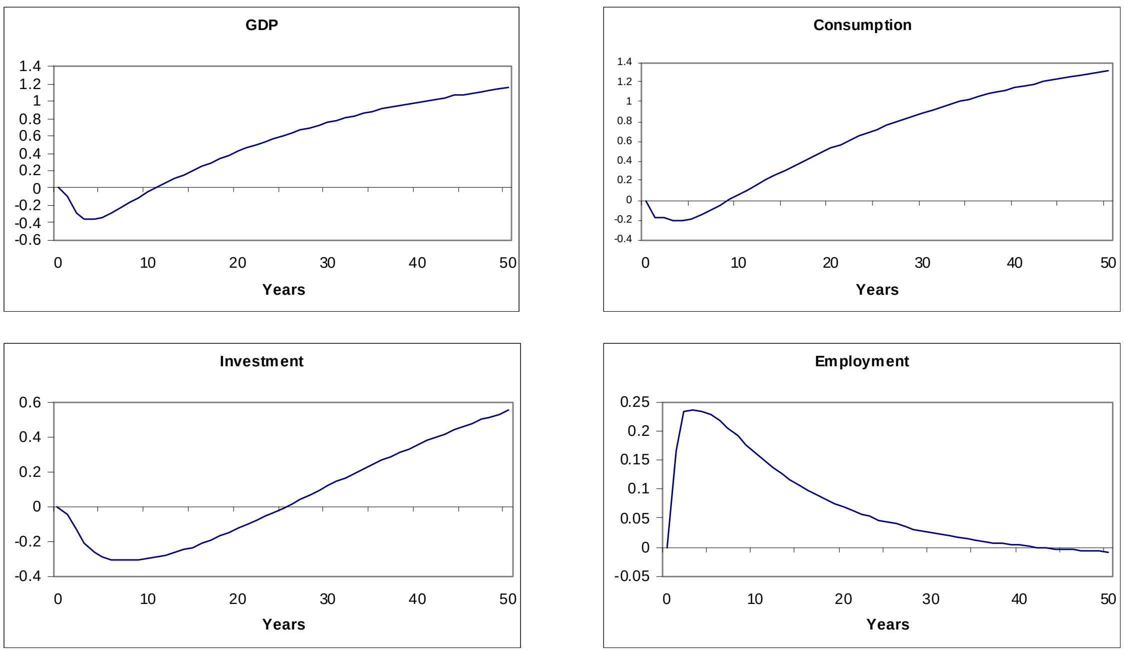



Table 6: Tax credit on investment in intangible capital-Degree of self-financing

| | Years after the measure | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 10 | 20 | 50 | 100 |
| GDP (% deviation from baseline) | -0.1 | -0.29 | -0.37 | -0.37 | -0.34 | -0.06 | 0.41 | 1.15 | 1.45 |
| Degree of self-financing (%) | -54 | -80 | -88 | -90 | -88 | -72 | -40 | 10 | 28 |

Table 7: Elasticity of labour supply-GDP effect and degree of self-financing

| | Years after the measure | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 10 | 20 | 50 | 100 |
| | Labour tax cut | | | | | | | | |
| | Low elasticity (0.1) | | | | | | | | |
| GDP (% deviation from baseline) | 0.01 | 0.08 | 0.10 | 0.11 | 0.11 | 0.13 | 0.14 | 0.16 | 0.16 |
| Degree of self-financing (%) | -2 | 9 | 12 | 13 | 14 | 15 | 16 | 17 | 17 |
| | High elasticity (0.5) | | | | | | | | |
| GDP (% deviation from baseline) | 0.03 | 0.20 | 0.28 | 0.33 | 0.35 | 0.43 | 0.50 | 0.58 | 0.60 |
| Degree of self-financing (%) | 1 | 27 | 34 | 39 | 43 | 51 | 58 | 63 | 64 |
| | Capital tax cut | | | | | | | | |
| | Low elasticity (0.1) | | | | | | | | |
| GDP (% deviation from baseline) | 0.02 | 0.05 | 0.10 | 0.15 | 0.22 | 0.49 | 0.87 | 1.33 | 1.44 |
| Degree of self-financing (%) | 8 | -3 | -5 | -5 | -4 | 6 | 20 | 36 | 39 |
| | High elasticity (0.5) | | | | | | | | |
| GDP (% deviation from baseline) | 0.03 | 0.08 | 0.14 | 0.21 | 0.28 | 0.57 | 0.97 | 1.41 | 1.49 |
| Degree of self-financing (%) | 9 | 2 | 1 | 2 | 4 | 15 | 30 | 44 | 43 |

## 4.5 Sensitivity analysis

In this section, we analyse the sensitivity of the results presented above to variations in the elasticity of labour supply and the initial level of the tax rate, which previous studies have identified as key factors affecting the impact of fiscal reforms. Mankiw and Weinzierl (2006), for example, find that the rate of self-financing of a cut in the capital tax rate increases from 50% to 75% if the initial tax rate is set to 40% instead of 25%, as in their baseline calibration.

### 4.5.1 Elasticity of labour supply

The elasticity of labour supply determines the size and speed of the labour supply response to the shock. Mankiw and Weinzierl (2006) experiment for different values of the elasticity of labour supply and find that increasing its value from 0.5 to 1.5 raises the degree of self-financing of a labour tax cut from 17% to 30%. In our baseline calibration the elasticity of labour supply is set equal to 0.25. However, estimates of the parameter vary widely in the literature. Studies based on micro data tend to estimate smaller elasticities than those obtained at the aggregate level (see Kimball and Shapiro, 2003, for a discussion). In this section, we consider a low (0.1) and a high (0.5) elasticity scenario and compare the effects of labour and capital tax cuts.

Table 7 illustrates the role of the elasticity of labour supply in determining the effects of a 0.5% of GDP labour tax cut. As can be observed from the table, the short and long run self-financing rate of a labour tax cut are strongly affected by how strongly workers react to changes in the tax rate.

## 4.6 The role of the initial tax rate

Another important factor affecting the magnitude of the rate of self-financing is the initial level of the tax rate. Ganelli and Tervala (2008) consider an initial labour income tax rate of 20% (and a 1 percentage point cut) and a consumption tax rate of 8%. Mankiw and Weinzierl (2006) carry out their calculations of the self-financing effect of a tax cut assuming initial labour and capital income tax rates of 25%. Trabandt and Uhlig (2010) calibrate their model using effective tax rates calculated according to the method described by Mendoza et al. (1994). The labour, capital and consumption tax rates used for their calibration of the EU-14 economy are respectively 41%, 33% and 17%.

In order to assess the role of the initial level of the tax rate in determining the macroeconomic effects of a tax cut, we carry out a sensitivity analysis by comparing the impact of a 0.5% of GDP

Table 8: Initial labour tax rate-Degree of self-financing

| | Years after the measure | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 10 | 20 | 50 | 100 |
| | Low tax rate | | | | | | | | |
| GDP (% deviation from baseline) | 0.02 | 0.11 | 0.15 | 0.16 | 0.17 | 0.19 | 0.22 | 0.25 | 0.25 |
| Degree of self-financing (%) | -1 | 13 | 16 | 18 | 19 | 21 | 23 | 24 | 24 |
| | High tax rate | | | | | | | | |
| GDP (% deviation from baseline) | 0.03 | 0.20 | 0.29 | 0.33 | 0.36 | 0.43 | 0.51 | 0.59 | 0.61 |
| Degree of self-financing (%) | 1 | 28 | 36 | 42 | 46 | 55 | 63 | 69 | 71 |

labour tax cut for alternative values of the labour tax rate prevailing in the economy before the adoption of the measure. In our baseline calibration, the labour tax rate is set equal to 37.1%. Below, we discuss the budgetary implications of labour income tax cuts of the same magnitude discussed in Section 4.1 starting from different values of the initial tax rate. For the purpose of these simulations, we consider a "low tax" scenario characterised by an initial tax rate 10 percentage points lower than in the baseline (27.1%) and a "high tax" scenario with an initial tax rate 10 percentage points higher (47.1%). As shown in Table 8, the initial level of the tax rate plays a key role in determining the effects of a cut on the goverment budget, with a degree of self-financing as high as 71% in the case of an economy starting from a high tax rate.

The reason behind the wide variations in the self-financing rate of the measure can be explained by considering a simplified labour supply equation:

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

where $\kappa$ denotes the elasticity of labour supply, $\omega$ is the preference parameter for leisure and the tax wedge is given by

$$tw = \frac{1-t^L}{1+t^{VAT}}$$

The percentage change in the tax wedge with respect to a constant absolute change in the labour tax rate increases with the initial level of the tax rate:

$$\frac{\partial tw}{\partial t^L} \frac{1}{tw} = \frac{1}{1-t^L}$$

# 5 Conclusions

This paper analyses the macroeconomic effects of a set of fiscal measures in a DSGE model with endogenous growth, with a focus on their degree of self-financing, i.e. on the extent to which they are able to pay for themselves through general equilibrium incentive effects.

The main findings are the following. First of all, a reduction in the capital income tax rate has larger long-run GDP effects and self-financing rates than same-size cuts in the average labour tax rate or in the consumption tax rate. However, these effects take time to materialise as the stock of capital increases over time, while labour and consumption fiscal reforms have a larger short-run impact.

Secondly, the model allows to consider more targeted policies such as skill-biased labour tax cuts and tax credits to R&D. A labour tax decrease targeting low-skilled workers, whose employment rates are low relative to other skill groups, exhibits the highest self-financing rate at 52%.

Finally, a sensitivity analysis shows that the degree of self-financing of labour tax cuts increases with the elasticity of labour supply, which determines the size and the speed of the labour supply response to the policy change (while the effects of a capital tax cut are much less dependent from the parameter). Moreover, the impact on output and the degree of self-financing of expansionary fiscal measures are positively related to the initial level of the tax rate.

# References


Aghion, P. and Howitt, P. (1998). *Endogenous Growth Theory.* Cambridge, MA: The MIT Press.

Auerbach, A. J. (2005). Dynamic scoring: An introduction to the issues. *American Economic Review*, 95(2):421–425.

Bottazzi, L. and Peri, G. (2007). The international dynamics of R&D and innovation in the long run and in the short run. *The Economics Journal*, 117(3):486–511.

Bruce, N. and Turnovsky, S. J. (1999). Budget balance, welfare, and the growth rate: "dynamic scoring" of the long-run government budget. *Journal of Money, Credit and Banking*, 31(2):162–86.

Denis, C., Grenouilleau, D., McMorrow, K., and Roeger, W. (2006). Calculating potential growth rates and output gaps. a revised production function apporach. European Economy Economic Paper 247, European Commission Directorate-General for Economic and Financial Affairs, Brussels.

Dixit, A. K. and Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. *American Economic Review*, 67(3):297–308.

Djankov, S., Porta, R. L., Lopez-De-Silanes, F., and Shleifer, A. (2002). The regulation of entry. *The Quarterly Journal of Economics*, 117(1):1–37.

Ganelli, G. and Tervala, J. (2008). Tax reforms, "free lunches", and "cheap lunches" in open economies. IMF Working Papers 08/227, International Monetary Fund.

Grossman, G. and Helpman, E. (1991). *Innovation and Growth in the Global Economy.* The MIT Press, Cambridge, MA.

Ireland, P. N. (1994). Supply-side economics and endogenous growth. *Journal of Monetary Economics*, 33(3):559–571.

Jones, C. I. (1995). R&D-based models of economic growth. *Journal of Political Economy*, 103(4):759–84.

Jones, C. I. (2005). Growth and ideas. In Aghion, P. and Durlauf, S., editors, *Handbook of Economic Growth*, volume 1, chapter 17, pages 1063–1111. North-Holland, Amsterdam.

Leeper, E. M. and Yang, S.-C. S. (2008). Dynamic scoring: Alternative financing schemes. *Journal of Public Economics*, 92(1-2):159–182.

Mankiw, N. G. and Weinzierl, M. (2006). Dynamic scoring: A back-of-the-envelope guide. *Journal of Public Economics*, 90(8-9):1415–1433.

Mendoza, E. G., Razin, A., and Tesar, L. L. (1994). Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption. *Journal of Monetary Economics*, 34:297–323.

Pecorino, P. (1995). Tax rates and tax revenues in a model of growth through human capital accumulation. *Journal of Monetary Economics*, 36(3):527–539.

Roeger, W., Varga, J., and in 't Veld, J. (2008). Structural reforms in the EU: A simulation-based analysis using the QUEST model with endogenous growth. European Economy Economic Paper 351, European Commission Directorate-General for Economic and Financial Affairs, Brussels.

Trabandt, M. and Uhlig, H. (2010). How far are we from the slippery slope? the laffer curve revisited. ECB Working Papers 1174.

Warda, J. (2006). Tax treatment of business investments in intellectual assets: An international comparison. OECD Science, Technology and Industry Working Papers 2006/4, OECD, Paris.