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A Model-based Assessment of the Macroeconomic Impact of EU Structural Funds on the New Member States

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Abstract

This paper gives a model-based analysis of the potential macro-economic impact of European Union Structural and Cohesion Funds payments on the economies of the new member states. The model used is a four-region DSGE model with human capital accumulation and endogenous technological change. The framework that we adopt is the Jones (2005) extension of the endogenous growth model, which uses a variety approach for modelling knowledge investment. The EU funds average around 1.5 percent of GDP and are used for investment in infrastructure, human capital and R&D. The model simulations show this can lead to significant gains in output, both in the short as well as in the long run.

JEL Classification: E62, H50, O11, O41

Keywords: Fiscal transfers, Structural Funds, public investment, DSGE modelling.

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1 Introduction

The European Union's Cohesion Policy provides a framework for large fiscal transfers from the richer EU Member States to the countries and regions that lag behind in terms of income per capita. The Cohesion and Structural Funds are, after agricultural spending, the second largest item in the current EU budget, accounting for 34 per cent of total appropriations for commitments. The resources are targeted on investment in physical and human capital, and designed to increase economic and social cohesion among member states, enhancing a faster catch-up process of the less developed member states. For eligibility for Objective One status the region's GDP per capita must be less than 75 per cent of the EU average, although special ad hoc arrangements exist.

At the time of the creation of the Single Market programme, it was argued that poorer member states had to be compensated for exposing their weaker economies to more competition in the internal market, and with EU enlargement in 2004 there has been a sharp increase in EU Structural Funds. The funds are also seen as an expression of solidarity between member states and a commitment to redistribution of incomes considered necessary for an effective functioning of the Union's political institutions (Gros (2008)).

Economic theory predicts unambiguous benefits from investment in infrastructure and human capital and there is empirical evidence supporting this. However, ex-post evaluation studies of large EU transfers in the past generally give only mixed support for EU Cohesion Policy. Many of the assisted regions have remained relatively poor and growth regressions augmented with Structural Fund variables show no significant impact from these transfers (see Ederveen et al. (2002) and Ederveen et al. (2006)). Model based studies, frequently used for the purposes of ex-ante evaluation, usually show larger impacts of the demand stimulus as well as positive supply-side effects on GDP in the long run. However, these studies have often been based on macroeconometric models in which the demand side is essentially keynesian in nature and no-crowding-out appears (e.g. Bradley et al. (2007)). On the whole, empirical evidence on the positive impact of Structural

Funds on convergence of poorer regions remains inconclusive.

It should be recognised that the objective of cohesion policy is much wider than economic growth per se. A cursory look at the fields of interventions of CSF shows a wide range of policies promoting environmental protection and risk prevention, tourism, culture, urban and rural regeneration, improving social inclusion of less-favoured persons. While these policies undoubtedly promote social cohesion, they are not directly enhancing the growth potential of an economy, at least not in a unequivocal and directly measurable way. Nevertheless, economic convergence is the ultimate objective of cohesion policy and the eligibility criterium for Objective One status is clearly defined in terms of income per capita. Hence, it is important to examine whether Structural Funds can promote growth and enhance a faster catching up of the less developed member states.

This paper uses the QUEST III model to evaluate the potential impact of Structural and Cohesion Fund programmes for the new member states for the period 2007-2013. While it should be clear that an ex-ante model-based evaluation cannot provide a conclusive answer to the question whether structural funds will accelerate the economic convergence of poorer regions, an analysis based on a model that incorporates the channels through which these policies can promote growth can provide an estimate of the potential impact, assuming an optimal use of the funds.[1] The model we use in this study is based on a four region dynamic general equilibrium model with human capital accumulation and endogenous technological change. It has been used extensively for the analysis of structural reforms in the EU (the Lisbon Strategy for Growth and Jobs) (see Roeger et al. (2008)) and is particularly suitable for an evaluation of the type of structural policies that form the core of Structural Funds interventions. The model belongs to the new class of micro-founded DSGE models that are now widely used in economic policy institutions. The model incorporates productive public investment that captures the productivity-enhancing effects of infrastructure investment. The model employs the product variety framework proposed by Dixit and Stiglitz (1977) and applies the Jones

[1] In a comprehensive study of absorption problems, Herve and Holzmann (1998) list many factors that could lead to sub-optimal use of fiscal transfers and argue that the scope for problems related to e.g. rent-seeking may be very high.

(1995) semi-endogenous growth framework to explicitly model the underlying development of R&D. The endogenous modelling of R&D allows us to analyse the impact of R&D promoting policies on growth and the endogeneity of human capital accumulation can capture the effects of policies promoting vocational education and training.

The paper is organized as follows. The next section briefly discusses the Structural and Cohesion Funds programmes and the fiscal transfers involved. Section 3 describes those features of the model which enable us to carry out the impact assessment of the fiscal transfers. The model results depend crucially on 1. the assumptions on the productive impact of additional public capital and 2. on how the skill efficiencies are affected by human capital investment. The simulation results and a sensitivity analysis with respect to these assumptions are discussed in Section 4. Finally, Section 5 concludes.

2 The Structural and Cohesion Funds programme 2007-2013

For the period 2007 to 2013, Structural and Cohesion Funds programmes for the New Member States amount to a total budget of 173.9 billion euros (in 2008 prices). But because past experience in previous programme periods have shown considerable delays in payments, typically continuing for up to two more years, the proposed payments are spread over a 9 year period lasting till 2015. On the basis of payment profiles in programming prices, assuming an inflation correction of 2 per cent per year, and using the Commission's nominal GDP projections for 2008-15, we calculate in Table 1 the proposed annual payment profile in terms of GDP for 2007-2015.

The fields of interventions are divided into five main categories (plus an additional technical assistance category). Figure 1 shows the distribution of the total budget for each of the New Member States.

As the figure shows, infrastructure investment receives the largest share of funds, more than 60% of the total budget for most NMS, while investments in R&D and human capital are the second or third largest categories. The fields of intervention cover a wide range of

Table 1: Payment Profile 2007-2015

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bulgaria	1.1	1.1	1.1	1.4	1.7	2.0	2.2	2.6	1.9
Czech Republic	1.2	0.9	0.8	1.3	1.7	1.8	1.9	2.4	1.7
Estonia	1.1	1.2	1.3	1.7	2.0	1.9	1.9	1.9	1.6
Cyprus	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.7	0.4
Latvia	1.0	1.0	1.0	1.0	0.9	1.7	2.4	2.0	2.0
Lithuania	1.1	1.3	1.5	1.4	1.4	1.8	2.2	2.7	1.9
Hungary	1.0	1.3	1.6	2.0	2.4	2.7	2.9	3.0	2.6
Malta	0.5	0.5	0.4	0.8	1.2	1.9	2.6	2.2	2.4
Poland	1.1	0.9	0.7	1.1	1.5	1.8	2.2	2.7	1.9
Romania	0.7	0.8	0.8	1.0	1.2	1.4	1.5	1.7	1.3
Slovenia	0.6	0.8	1.0	1.2	1.3	1.1	0.9	1.3	0.8
Slovakia	1.1	1.1	1.1	1.3	1.4	1.7	1.9	2.3	1.6
All NMS	1.0	0.9	0.9	1.3	1.5	1.8	2.0	2.4	1.8

Source: own estimates. The payment profile in programming prices was provided by DG REGIO with an assumption of 2% inflation. GDP projections are obtained from the AMECO database and DG ECFIN's potential growth calculations.

policy programmes, details of which are shown in the annex (Table A1).

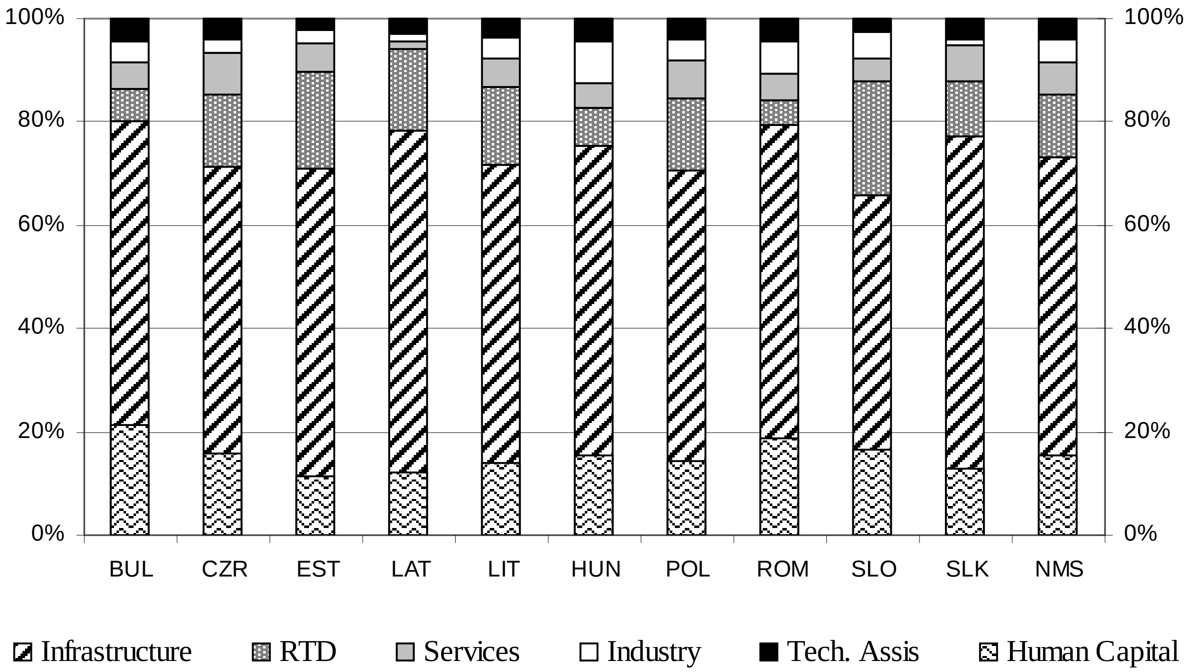
3 Modelling the impact of Structural Funds

The model used in this analysis is an extended version of the QUEST III R&D model. The model consists of four regions: the block of new member states, the Euro area and non-Euro area old member states and the rest of the world. This section describes the main channels through which the model captures the impact of the different interventions on growth. A more detailed description of the model can be found in Roeger et al. (2008).

3.1 The Model

The model economy is populated by households, final and intermediate goods producing firms, a research industry, a monetary 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 domestic and imported intermediate

Figure 1: Shares of payments by fields of interventions



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).

The model distinguises two types of households. The first group of households 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. These household members offer medium- and high-skilled labour services. Another share of households is liquidity-constrained. 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.

Below we describe in some more detail the supply side of the model and the fiscal side, which constitute the key elements for modelling the Structural Funds interventions. One extension to the model made here is an explicit formulation of human capital accumulation following Jones (2002) in order to account for the significant part of Structural Fund investments in various human resource programmes. In calibrating the model, we follow the literature of dynamic general equilibrium modelling and set the key steady-state ratios equal to their empirical counterparts for each region. While the calibration of the main steady state ratios (private consumption to output, investment to output, etc.) is based on EUROSTAT and OECD data, the remaining structural parameters and variables are adopted from the available estimates in empirical studies (see Ratto et al. (2008)) or tied down by the equations of the model.[2]

3.1.1 Final goods production and public capital

We account for the productivity-enhancing effect of infrastructure investment via the following aggregate final goods production function:

$$Y_t = A_t^{(1-\alpha)\left(\frac{1}{\theta}-1\right)} \left(K_t^P\right)^{1-\alpha} \left(L_{Y,t}\right)^{\alpha} \left(K_t^G\right)^{\alpha_G} - FC_Y, \quad \text{where } \sum_{i=1}^{A_t} x_{i,t} = K_t^P \tag{1}$$

The final good sector uses a labour aggregate ($L_{Y,t}$) and intermediate goods ($x_{i,t}$) using a Cobb-Douglas technology, subject to a fixed cost FC_Y. Our formulation assumes

[2]See the appendix for the description and the calibration of knowledge production and human capital accumulation equations.

that investment in public capital stock (K_t^G) increases total factor productivity with an exponent of α_G. Final output (Y_t) is produced using A_t varieties of intermediate inputs with an elasticity of substitution $1/(1-\theta)$. One unit of intermediate goods is produced from one unit of private capital (K_t^P), therefore in a symmetric market framework the total output of the intermediate sector amounts to the total private capital stock as $\sum_{i=1}^{A_t} x_{i,t} = A_t x_t = K_t^P$.

Public infrastructure investment (I_t^G) accumulates into the public capital stock K^G according to

$$K_t^G = (1-\delta_G)K_{t-1}^G + I_t^G \tag{2}$$

where δ_G, the depreciation rate of public capital is set at 4 per cent.

Infrastructure investment is assumed to be proportional to output

$$I_t^G = (IGS_t + \varepsilon_t^{IG})Y_t \tag{3}$$

where ε_t^{IG} is an exogenous shock to the share of government investment (IGS_t). It is through this shock that we simulate the increase in infrastructure investment.

3.1.2 Intermediate production and the R&D sector

The intermediate sector consists of monopolistically competitive firms which have entered the market by buying licenses for 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

$$px_{i,t} = \eta_t(1-\alpha)Y\left(\sum_{i=1}^{A_t}\left(x_{i,t}^j\right)^\theta\right)^{-1}\left(x_{i,t}\right)^{\theta-1} \tag{4a}$$

where η_t is the inverse gross mark-up of the final goods sector.

Each domestic intermediate firm solves the following profit-maximisation problem.

$$PR_{i,t}^x = \max_{x_{i,t}}\left\{px_{i,t}x_{i,t} - i_t^K P_t^C k_{i,t} - i^A P_t^A - FC_A\right\}. \tag{5}$$

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

$$x_i = k_i. \tag{6}$$

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

$$PR_{i,t}^x = PR_t^x = i_t^A P_t^A + r_t FC_t^A \tag{7}$$

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

$$P_t^A \frac{1}{1 - t_t^K\left(1-\delta^A\right) + \tau^A} + FC_A = \sum_{\tau=0}^{\infty}\prod_{j=0}^{\tau}\left(\frac{1}{1+r_{t+j}}\right) PR_{t+\tau}^x. \tag{8a}$$

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 the fixed entry cost FC_A.

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 $L_{A,t}$ and generates new designs according to the following knowledge production function:

$$\Delta A_t = \nu A_{t-1}^{*\varpi} A_{t-1}^{\phi} L_{A,t}^{\lambda}. \tag{9}$$

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 wage W^H. We also assume that the research institute faces an adjustment cost of hiring new employees and maximizes the following discounted profit-stream:

$$\max_{L_{A,t}} \sum_{t=0}^{\infty} d_t \left(P_t^A \Delta A_t - W_t^H L_{A,t} - \frac{\gamma_A}{2} W_t^H \Delta L_{A,t}^2 \right) \tag{10}$$

Therefore the first order condition implies:

$$\lambda P_t^A \frac{\Delta A_t}{L_{A,t}} = W_t^H + \gamma_A \left(W_t^H \Delta L_{A,t} - d_t W_{t+1}^H \Delta L_{A,t+1} \right) \tag{11}$$

where d_t is the discount factor.

3.1.3 Human capital accumulation

The labour aggregate $L_{Y,t}$ is composed of three skill-types of labour force:

$$L_{Y,t} = \left(s_L^{\frac{1}{\sigma_L}} \left(h_t^L L_t^L\right)^{\frac{\sigma_L - 1}{\sigma_L}} + s_M^{\frac{1}{\sigma_L}} \left(h_t^M L_t^M\right)^{\frac{\sigma_L - 1}{\sigma_L}} + s_{H,Y}^{\frac{1}{\sigma_L}} \left(h_t^H L_t^{HY}\right)^{\frac{\sigma_L - 1}{\sigma_L}} \right)^{\frac{\sigma_L}{\sigma_L - 1}}. \tag{12}$$

Parameter s_s is the population share of the labour-force in subgroup s (low-, medium- and high-skilled), L^s denotes the employment rate of population s, h_t^s is the corresponding accumulated human capital (efficiency unit), and σ_L is the elasticity of substitution between different labour types[3]. An individual's human capital is produced by participating in education and Λ_t^s represents the amount of time an individual spends accumulating human capital :

$$h_t^s = h_s e^{\psi \Lambda_t^s}, \quad \psi > 0 \tag{13}$$

The exponential formulation used here adapts Jones (2002) into a disaggregated skill-structure by incorporating human capital in a way that is consistent with the substantial growth accounting literature with adjustments for education[4]. The ψ parameter has been studied in a wealth of microeconomic research. Interpreting Λ_t^s as years of schooling, the parameter corresponds to the return to schooling estimated by Mincer (1974). The labour-market literature suggests that a reasonable value for ψ is 0.07, which we apply here. Investments in human capital can then be modelled by increasing the years of schooling (Λ_t^s) for the respective skill-groups.

3.2 The government budget constraint

For the government sector various expenditure and revenue categories are separately modelled. On the expenditure side we assume that government consumption (G_t), government transfers (TR_t) and government investment (I_t^G) are proportional to GDP and unemployment benefits (BEN_t) are indexed to wages. The government provides subsidies (S_t)

[3]Note that high-skilled labour in the final goods sector L_t^{HY} is total high-skilled employment minus the high-skilled labour working in the R&D sector ($L_{A,t}$).

[4]See Barro and Sala-I-Martin (1995).

on physical capital and R&D investments in the form of a tax-credit and depreciation allowances.

Government revenues (R_t^G) are made up of taxes on consumption as well as capital and labour income. Fiscal transfers for NMS received from the EU are denoted by COH_t (which is negative for the net contributors). There is a lump-sum tax (T_t^{LS}) used for controlling the debt to GDP ratio according to the following rule

$$\Delta T_t^{LS} = \tau^B \left(\frac{B_{t-1}}{Y_{t-1}} - b^T \right) + \tau^{DEF} \Delta \left(\frac{B_t}{Y_t} \right) \tag{14}$$

where b^T is the government debt target, τ^B and τ^{DEF} are coefficients. Therefore, government debt (B_t) evolves according to

$$B_t = (1 + r_t)\, B_{t-1} + P_t^C \cdot G_t + TR_t + BEN_t + S_t - R_t^G - T_t^{LS} - COH_t \cdot \tag{15}$$

It is assumed that the additional contributions to the EU budget are financed in the donor countries through an increase in lump-sum taxes.

Cohesion policy programmes are subject to the condition of additionality and co-financing. Additionality requires that Structural Funds are additional to domestically-financed expenditure and are not used as a substitute for it. The co-financing principle means the EU provides only matching funds to individual projects that are part of the operational programmes and that the EU funds are matched to a certain extent by domestic expenditure. The problem with defining a proper benchmark means that in practice this principle of additionality is hard to verify and is thus not always binding. Member States are not required to create new budgetary expenditure to co-finance cohesion policy support. Existing national resources that were used to finance similar areas of interventions (and are thus concerned by the additionality requirement) can be 'earmarked' to co-finance Structural Fund transfers. Total spending increases only by the amount of Structural Fund transfers.

More formally, assume a cofinancing rate of c, i.e. the EU transfer COH_t has to be matched by domestically-financed expenditure $c.COH$. The additionality and co-financing principles can be expressed as the following condition for total government spending in a beneficiary country:

$$TOTEXP_t = COH_t + \max(EXP_0, c \cdot COH_t) \tag{16}$$

where $TOTEXP_t$ is total expenditure, COH_t is the fiscal transfer received from the EU cohesion funds, EXP_0 domestically–financed expenditure in the counterfactual situation (without Structural and Cohesion Funds), and c is the co-financing rate. Examining the additionality tables of Member States, it is apparent that national public expenditure concerned by additionality usually exceeds the co-financing needs by far. In this case $EXP_0 > c \cdot COH_t$, and total expenditure is given by[5]

$$TOTEXP_t = COH_t + EXP_0 \tag{17}$$

As spending on infrastructure and education is already high in the NMS countries, this exercise takes domestically–financed expenditure EXP_0 in the counterfactual situation (without structural and cohesion funds) as the benchmark and only examines the impact of the fiscal transfer COH_t received from the EU cohesion funds (equation 17).

3.3 Implementing the interventions

The fiscal transfers under the Structural and Cohesion Policy programmes amount to additional injections of up to 3 percent of GDP for the NMS. The transfers are modelled as lump-sum transfers between governments. Table 2 shows the main fields of interventions, their respective share in the total amount of interventions and the way each of the interventions are captured as shocks to the model. We assume that these shares of the fields of interventions are constant for all the years of the payment horizon 2007-2015.

[5] Herve and Holzmann (1998) criticise earlier model-based studies of structural funds for grossly exaggerating the total impact because they assumed that the full Structural Fund spending is additional to investment in the counterfactual situation $TOTEXP_t = COH_t + c \cdot COH_t + EXP_0$ while the correct formulation of the additionality principle is given by equation (17).

Table 2: Fields and Shares of Interventions

Field	Share	Variable to implement the shock
Infrastructure	**62.0**	Temporary increase in I^G, government investment (via ε_t^{IG})
Industry&Services	**9.1**	Reducing fixed costs faced by final goods firms (FC_Y)
-	1.5	permanent reduction FC_Y (categories 13,14, 15 of the payment profile)
-	7.6	temporary reduction FC_Y
RTD	**10.1**	Reducing the fixed costs faced by the users of R&D products (FCA)
-	4.5	permanent investment in R&D infrastructure (categories 2 and 3 of the payment profile)
-	5.6	temporary investments
Human resources	**15.3**	Raising human capital and government consumption expenditures
-	1.4	investment in high-skilled human capital (h_t^H via Λ_t^H) (category 74 of the payment profile)
-	4.8	educational investments in all skills (h_t^s via Λ_t^s) (categories 72 and 73 of the payment profile)
-	9.1	other government expenditures (G_t)
Technical assistance	**3.4**	Temporary increase in government consumption (G_t)

Source: European Commission (DG REGIO).
The detailed categories of the payment profile are shown in the Annex.

Investment in public infrastructure is modelled via a temporary increase in government investments ε_t^{IG}. Support to industry and services-related programmes are introduced via a temporary or (depending on the nature of the programme) permanent decrease in fixed costs of final goods firms (FC_Y). R&D promoting spending is modelled similarly, via decreasing the fixed costs faced by the intermediate sectors (FC_A) temporarily or permanently, depending on the nature of the programme. Concerning human capital investments we distinguish three subcategories of payments based on the detailed payment profile. Around [4.8] per cent of the funds are spent on educational investments without specific skill-specification, and allocated in the model to all skill groups. A smaller share of 1.4 per cent is directly targeting investments in high-skilled human capital and captured in the model as a shock to Λ_t^H. The remainder is accounted for as temporary increase in government consumption (G_t). On the basis of available data on current spending on education (around 5 per cent on all skill-groups and 1 per cent on high-skilled in terms of GDP) an estimate can be made of the additional years of schooling (increment to Λ_t^s) that can be financed by the fiscal transfers[6]. In order to account for the additional time spent on training, we assume that the last cohort of student population stays longer in the education system and enter into the active labour force later. Finally technical assistance is introduced as a temporary increase in government consumption.

4 The potential macro economic impact

4.1 Simulations results

The interventions of the Structural and Cohesion Policy programmes are simulated in the model as shocks described above and Table 3 shows the macroeconomic impact on the new member states. There is a large increase in government spending, in particular in government investment, and a gradual accumulation of public capital. This raises productivity and leads to a gradual increase in output in the final goods sector. Growth is further boosted by the other interventions. R&D promoting policies lower entry costs and so reduce the profit requirements for intermediate producers and encourages entry of new firms. Higher demand for patents (ideas) increases the demand for high skilled workers and boost innovation. Investment in training and education boost human capital and raises output further. It takes years for these supply side effects to build up and in the first few years the demand effects dominate. By 2020, the stock of "knowledge", or ideas, is up by 2 per cent. The incentives shift employment of high skilled workers from the final goods sector to the R&D sector. In the short run, the additional spending puts upward pressure on wages and interest rates and leads to some crowding-out, with private investment rising proportionally less than GDP. As a result of this, in the first two years GDP rises by less than the size of the demand impulse. But the output gains become gradually larger as the supply side effects become stronger, and by 2015 output rises to more than 4 per cent above baseline. These positive supply side effects are permanent, as becomes

[6] See the Appendix for a detailed description of the calibration of human capital accumulation.

apparent when looking at the effects after 2015, when the programmes are assumed to be terminated and there is no longer a demand impulse, but output is permanently higher.

Employment rises in the first years due to the demand expansion, but the employment effect is slightly negative afterwards. R&D enhancing policies account for significant increase in the employment share of high-skilled labour in the research sector. This leads to some relocation of high skilled workers from production of final goods to the R&D sector and an increase in the wage of high skilled workers. In the long run the total employment effect remains negative because of a negative terms of trade effect.[7]

Consumption of non-liquidity-constrained households is directly boosted by higher expected future income and aggregate consumption (liquidity and non-liquidity constrained) is already in the first year more than 1 per cent higher. Although the business sector receives direct support from the government, this subsidy has only a small effect in the first years of the programmes because of crowding-out due to overproportionally higher government spending on infrastructure and human resources which puts upward pressure on real interest rates. In small open economies, a significant share of the demand impulse leaks abroad through higher imports. Imports are more than 2 per cent higher and the trade balance deteriorates. The demand impulse leads to a small appreciation in the short run but as the productivity effects become stronger the effective exchange rate depreciates. Finally, the GDP effect for the donor countries is negative, due to an increase in their contributions to the EU budget of around 0.1 per cent of GDP, but the relatively smaller output loss indicates a small positive spill-over effect from higher growth in the new member states.

[7] To the extent that human capital investment improves the employability of the non-active population, it could lead to an increase in the participation rate. As this effect is ignored in model simulations, we potentially underestimate the impact on employment rates.

Table 3: Simulated macroeconomic effects

Variable	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2020
GDP	0.39	0.65	0.92	1.32	1.74	2.25	2.79	3.44	3.82	3.63	3.42
Ideas	-0.00	-0.01	-0.01	0.01	0.05	0.14	0.28	0.48	0.73	1.01	1.97
TFP	-0.00	-0.00	-0.00	0.00	0.00	0.01	0.02	0.04	0.06	0.09	0.17
Human cap. - low	0.01	0.04	0.06	0.09	0.12	0.17	0.21	0.27	0.32	0.35	0.32
Human cap. - medium	0.06	0.23	0.37	0.55	0.77	1.03	1.33	1.67	2.01	2.16	1.97
Human cap. - high	0.08	0.27	0.45	0.65	0.92	1.22	1.58	1.99	2.39	2.56	2.32
Employment	0.04	0.02	-0.02	-0.03	-0.06	-0.09	-0.13	-0.19	-0.32	-0.47	-0.45
- low.(final goods)	0.09	0.11	0.09	0.06	-0.02	-0.12	-0.25	-0.40	-0.61	-0.79	-0.61
- medium (final goods)	0.04	0.01	-0.03	-0.04	-0.06	-0.09	-0.12	-0.17	-0.30	-0.44	-0.44
- high (final goods)	0.09	0.07	0.03	-0.01	-0.11	-0.24	-0.40	-0.55	-0.77	-0.99	-0.85
- high (R&D sector)	-0.25	-0.49	-0.49	-0.26	0.19	0.81	1.55	2.33	3.03	3.38	2.42
Consumption	1.19	1.94	2.20	2.39	2.60	2.84	3.08	3.30	3.44	3.44	2.93
- non.constr. hh.	1.27	2.05	2.30	2.47	2.66	2.88	3.09	3.28	3.41	3.45	3.00
- liq.constr.hh.	0.42	0.87	1.23	1.65	2.07	2.53	2.98	3.47	3.68	3.35	2.31
Investment	0.01	0.03	0.08	0.18	0.34	0.54	0.77	1.00	1.21	1.38	1.65
Exports	-0.09	-0.07	-0.00	0.07	0.17	0.29	0.42	0.58	0.77	0.91	0.89
Imports	1.64	2.02	1.99	2.20	2.23	2.29	2.25	2.25	1.38	-0.35	-0.58
Real wages	0.19	0.51	0.83	1.16	1.55	1.98	2.44	2.90	3.30	3.54	3.36
Price level	0.01	-0.05	-0.16	-0.34	-0.64	-1.04	-1.55	-2.12	-2.70	-3.18	-3.96
Consumer.price level	-0.07	-0.08	-0.12	-0.23	-0.42	-0.71	-1.08	-1.50	-1.91	-2.26	-3.08
Terms of trade	0.11	0.03	-0.10	-0.24	-0.41	-0.59	-0.80	-1.02	-1.28	-1.48	-1.49
REER	-0.13	-0.06	0.06	0.19	0.37	0.57	0.80	1.06	1.38	1.61	1.54
Euro exchange rate	-0.15	-0.17	-0.20	-0.30	-0.47	-0.73	-1.06	-1.43	-1.75	-2.02	-2.86
Nom. interest rate	-0.01	0.05	0.06	0.03	-0.04	-0.13	-0.23	-0.31	-0.37	-0.42	-0.23
Real interest rate	0.02	0.14	0.20	0.29	0.33	0.35	0.32	0.31	0.20	-0.09	-0.11
Inflation	-0.00	-0.08	-0.13	-0.22	-0.34	-0.45	-0.54	-0.60	-0.58	-0.41	-0.13
Cons. inflation	-0.07	-0.02	-0.06	-0.13	-0.23	-0.32	-0.40	-0.43	-0.40	-0.32	-0.14
R&D intensity	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.03	0.04	0.06	0.07	0.05
Lab. productivity	0.52	0.97	1.42	2.05	2.73	3.55	4.44	5.52	6.31	6.24	5.90
Employment rate	0.03	0.01	-0.01	-0.02	-0.04	-0.06	-0.09	-0.12	-0.21	-0.31	-0.30
- low	0.04	0.05	0.04	0.02	-0.02	-0.08	-0.15	-0.23	-0.34	-0.44	-0.43
- medium	0.03	0.00	-0.02	-0.03	-0.04	-0.05	-0.07	-0.10	-0.19	-0.28	-0.26
- high	0.02	-0.02	-0.05	-0.04	-0.04	-0.03	-0.02	0.01	-0.03	-0.12	-0.12
Coh. payments. (%GDP)	1.00	0.89	0.89	1.29	1.48	1.78	1.98	2.37	1.78	0.00	0.00
Gov.debt (%GDP)	-0.32	-0.65	-0.88	-1.14	-1.36	-1.59	-1.80	-2.02	-2.01	-1.52	-0.26
Gov.balance (%GDP)	0.28	0.21	0.16	0.19	0.18	0.20	0.20	0.20	-0.01	-0.35	-0.16
Trade balance (%GDP)	-0.96	-1.23	-1.25	-1.41	-1.47	-1.56	-1.58	-1.62	-1.16	-0.20	-0.08
Euro-area GDP	0.01	-0.01	-0.03	-0.03	-0.04	-0.04	-0.05	-0.04	-0.05	-0.09	-0.07

Note: Percentage (top half) and absolute (bottom half) differences from baseline

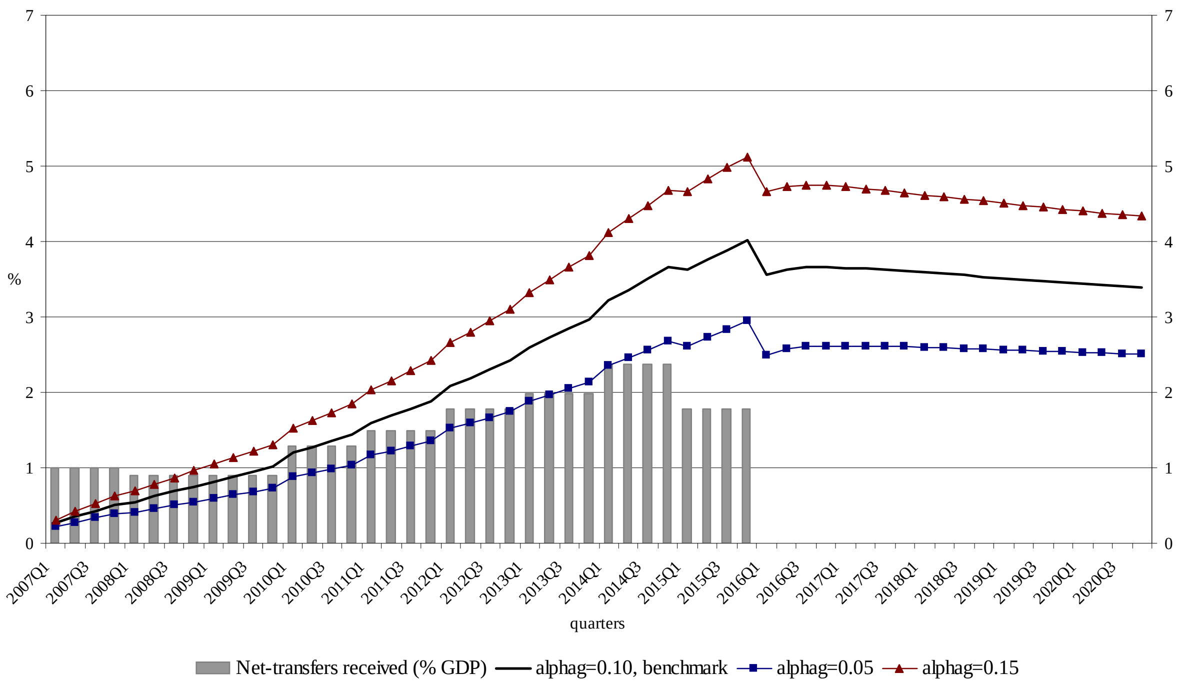
4.2 Sensitivity analysis

The results are sensitive to the assumption on the marginal product of public capital. There is much uncertainty about the productive impact of infrastructure investment and econometric studies show large variation in estimates, depending how care is taken of common trends, missing variables, simultaneity bias and reverse causation. Many of the early empirical estimates have been dismissed as implausibly high [8]. The benchmark assumption in the model is that the rate of return on public capital equals that of private capital (Gramlich (1994), p.1187). However, for some of the infrastructure interventions (e.g. environmental protection and development of cultural and social infrastructure) it could be argued that this assumption is too optimistic. Figure 2 plots the GDP effect of the programmes under three alternative scenarios relative to our baseline assumption for α_G (continuous middle line in the figure). The sensitivity analysis shows substantial variations both in the peak as well as in the long-run GDP effects, of around a quarter of the benchmark effect. The projected output gain in 2015 can be as high as 5 per cent under a more favourable assumption of $\alpha_G = 0.15$, while it could be as low as 3 per cent when $\alpha_G = 0.05$. Depending on the magnitude of the marginal productivity of capital, it can take from 1 to 6 years till the supply side improvements raise the level of GDP above the level of the direct demand injection from the programmes.

The results are also highly sensitive to how we interpret the interventions on human capital formation. Total interventions classified as human capital investment in the Cohesion and Structural Funds account for 15 per cent of total spending but this category covers a wide range of measures, including e.g. various measures improving the social inclusion of less-favoured groups.(see annex). It is not *a priori* clear whether all these measures improve skill efficiencies as much as assumed in the model simulations. A sensitivity analysis to the specific assumptions concerning this category shows the impact these assumptions have on the overall results. Our benchmark scenario assumes that only those categories that are explicitly labelled as improving human capital in the programmes

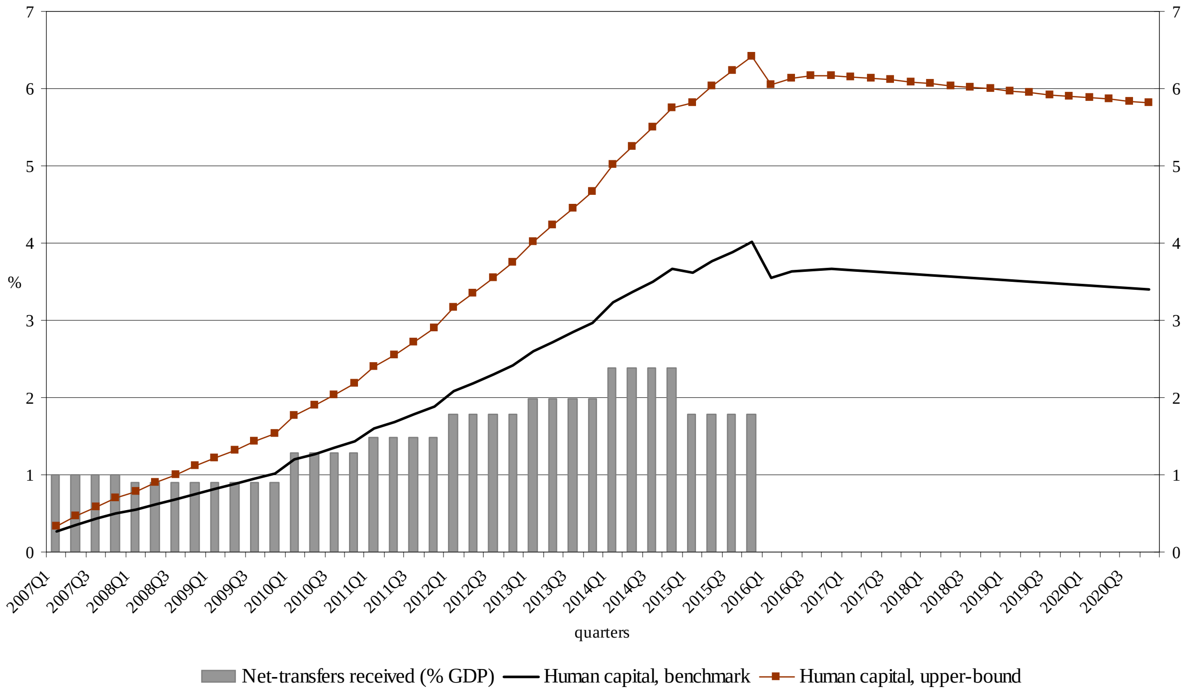
[8] For an overview of the literature and the econometric problems, see e.g. the surveys by Gramlich (1994).

Figure 2: GDP effects under different assumptions on the marginal productivity of public capital (% difference from baseline)



(i.e. categories 72,73 and 74, 6.2 per cent of total spending) are affecting human capital accumulation in the model. Our alternative scenario shown in Figure 2 plots the GDP effect if all spending on human resources (15.3 per cent of toatl spending) is assumed to be educational investments to improve human capital at each skill-level. While this assumption may be too optimistic given the social nature of some of this spending, it gives a clear upper bound of the potential impact this spending can have on output.

Figure 3: GDP effects under more optimistic scenario on human capital investments (% difference from baseline)



5 Conclusions

This paper descibes how a DSGE model with endogenous growth can be used for an ex-ante (prospective) evaluation of the potential impact of EU Cohesions and Structural Funds. The model simulates the impact of increased public infrastructure investment and captures the productivity enhancing effects of this. The model incorporates endogenous human capital accumulation and simulates the effects of policies promoting vocational education and training on skill efficiencies. And the model applies the Jones (1995) semi-endogenous growth framework to explicitly model the underlying development of R&D, which allows us to analyse the impact of R&D promoting policies on growth.

An important caveat for model based analyses like these is that they only tell us something about the *potential* impact of EU Funds, assuming an efficient and optimal use. There are strong reasons to expect at least part of the total spending to be diverted to sub-optimal use (Herve and Holzmann (1998)), and in that sense our results give an upper bound of the likely effects. It should also be recognised that the objective of EU Cohesion Policy is economic *and* social cohesion, and hence wider than economic growth *per se.* Promotion of tourism, culture, urban and rural regeneration are equally important policy objectives.

A senstitivity analysis shows how our results depend on assumptions related to the productivity of various forms of infrastructure investment and that of policies promoting vocational education and training. Much uncertainty exists on these productivity effects and more micro analysis is clearly needed to shed light on these effects. Future research should also focus on how policies promoting social inclusion increase participation in the labour force and how these effects can be incorporated in the model.

References

Barro, R. J. and Sala-I-Martin, X. (1995). *Economic Growth.* McGraw Hill, New York.

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.

Bradley, J., Untiedt, G., and Mitze, T. (2007). Analysis of the impact of cohesion policy. a note explaining the HERMIN-based simulations. Technical note, http://ec.europa.eu/regionalpolicy/sources/docgener/evaluation/pdf/hermin07.pdf.

Caselli, F. and Coleman, W. J. (2006). The world technology frontier. *American Economic Review*, 96(3):499–522.

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.

Ederveen, S., Groot, H., and Nahuis, R. (2006). Fertile soil for structural funds? a panel data analysis of the conditional effectiveness of european cohesion policy. *Kyklos, Blackwell Publishing*, 59(1):pp. 17–42.

Ederveen, S., Groter, J., de Mooji, R., and Nahuis, R. (2002). Funds and games: The economics of european cohesion policy. Special Publication 41, CPB Netherlands' Bureau for Economic Policy Analysis, The Hague.

Gramlich, E. (1994). Infrastructure investment: A review essay. *Journal of Economic Literature*, 32(3):1176–1196.

Gros, D. (2008). How to achieve a better budget for the european union? CEPS Working Document 289, Center for European Policy Studies, Brussels.

Herve, Y. and Holzmann, R. (1998). *Fiscal Transfers and Economic Convergence in the EU : An Analysis of Absorption Problems and an Evaluation of the Literature.* Nomos Verlagsgesellschaft, Baden-Baden.

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

Jones, C. I. (2002). Source of U.S. economic growth in a world of ideas. *American Economic Review*, 92(1):220–239.

Katz, L. F. and Murphy, K. M. (1992). Changes in relative wages, 1963-1987: Supply and demand factors. *Quarterly Journal of Economics*, 107(1):35–78.

Mincer, J. (1974). *Schooling, Experience, and Earnings.* Columbia University Press, New York.

OECD (2006). *Education at Glance.* OECD, Paris.

Pessoa, A. (2005). Ideas driven growth: The OECD evidence. *Portuguese Economic Journal*, 4(1):46–67.

Ratto, M., Roeger, W., and in 't Veld, J. (2008). QUEST III: An estimated DSGE model of the euro area with fiscal and monetary policy. *Economic Modelling (forthcoming)*, (also published as: European Economy Economic Paper no.335 , European Commission Directorate-General for Economic and Financial Affairs, Brussels, July 2008).

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.

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.

Appendix: Calibrating the parameters of knowledge production, intermediate goods production and human capital accumulation

Our semi-endogenous model builds on Jones (1995) version of R&D modelling, but we account for international R&D spillovers following Bottazzi and Peri (2007). The model economy is populated by households, final and intermediate goods producing firms, a research industry, a monetary and a fiscal authority. 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 consists of monopolistically competitive firms which have entered the market by licensing a design from domestic households (at rate of $i_{A,t}$) 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. The production of new designs takes place in research labs, employing high skilled labour and making use of the existing stock of ideas. The driving equation system of the semi-endogenous technological change can be summarized as

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

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

$$\lambda \cdot P_{A,t}\Delta A_t = w_H \cdot L_{A,t} \tag{c}$$

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

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

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

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

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). 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 makes use of the existing stock of domestic and foreign ideas to generate new designs (ΔA_t). 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. 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 wage w_H. Equation (b) states the balanced-growth relationship between the growth of ideas $g_A(= g_{A^w})$ 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. Decreasing entry costs lowers the profits requirement for intermediate producers and thus increases entry of new firms and the demand for patents. Equation (f) defines the rental rate of intangible capital which takes into account that households pay income tax at rate t_t^K on the period return of intangibles and they receive tax subsidies at rate τ^A. Since one unit of capital is used to produce one unit of intermediate good (x_t), equation (g) states the identity between the total intermediate goods production and physical capital under symmetric equilibrium.

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[9]. These values together with the restrictions 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:

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

and

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

The estimated values for these two coefficients show fairly big variations under the different regressions, and it might be inadequate to apply these long-term coefficients on our

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

"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[10]. 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 (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[11]. 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 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.

A. 3. Human capital accumulation

Labour force is disaggregated into three skill-groups: low-, medium- and high-skilled labour. The CES-aggregate for labour have the following form:

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

where the subscripts denote the skill-groups (low-L, medium-M and high-H), s_s is the population share of labour-force in subgroup s, L_s denotes the employment rate of population s, h_t^s is the skill-specific efficiency unit of labour, and σ_L is the elasticity of substitution between different labour types. Note that high-skilled labour in the final goods sector is the total high-skill employment minus the high-skilled labour working for the R&D sector ($L_{A,t}$). The calibration is mostly based on EUROSTAT and OECD data. Data on skill-specific population shares, participation rates and wage-premiums are obtained from the Labour Force Survey and Science and Technology databases of EUROSTAT. The elasticity of substitution between different labour types (σ_L) is one of the major issue addressed in the labour-economics literature. We follow Caselli and Coleman (2006) which analyzed the cross-country differences of the aggregate production function when skilled and unskilled labour are imperfect substitutes. The authors argue in

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

[11] 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.

favour of using the Katz and Murphy (1992) estimate of 1.4. We normalize the efficiency of low-skilled at 1 the other efficiency units are restricted by the labour demand equations which imply the following relationship between wages, labour-types and efficiency units:

$$h_t^M = \left(\frac{w_M}{w_L}\right)^{\frac{\sigma_L}{\sigma_L - 1}} \left(\frac{s_M L_M}{s_L L_L}\right)^{\frac{1}{\sigma_L - 1}} h_t^L, \quad and \quad h_t^H = \left(\frac{w_H}{w_M}\right)^{\frac{\sigma_L}{\sigma_L - 1}} \left(\frac{s_H L_H}{s_M L_M}\right)^{\frac{1}{\sigma_L - 1}} h_t^M.$$

In the next step we adapt Jones (2002) into a disaggregated skill-structure and impose that the functional form of $h_t^s = h_s e^{\psi \Lambda_t^s}$ describes the evolution of skill-specific human capital. In line with Jones (2002), we fix the return to schooling parameter of ψ at 0.07. The number of school years, Λ_t^s for the respective skill-groups are obtained from OECD (2006). For simulation purposes, the participation in trainings can be interpreted as an addition to the years of schooling with a depreciation according to the exit rate of working age population, i.e.:

$$\Lambda_t^s = \Lambda^s + l_t^{s,TR}, \quad where \quad l_t^{s,TR} = (1 - \chi_s)\, l_{t-1}^{s,TR} + \varepsilon_t^{s,TR},$$

where for each skill-group s, Λ^s is the average number of years of schooling in the regular education system, $l_t^{s,TR}$ is the year equivalent of the average time spent in training in period t, χ_s is the exit-rate of the working age population, and $\varepsilon_t^{s,TR}$ is the average year-equivalent of training in period t. Finally, in the baseline we set the variables of training $l_t^{s,TR}$ and $\varepsilon_t^{s,TR}$ to zero and given the years of schooling from OECD (2006) we can compute h_s from the definition of efficiency. In order to simulate the educational investments in human capital we increase the years of schooling (Λ_t^s) for the respective skill-groups by the additional years of schooling that can be financed from the fiscal transfers (shock to $\varepsilon_t^{s,TR}$).

A. 4. Population dynamics

Denote by $NS_s(t)$ and $NW_s(t)$, $s \in \{L, M, H\}$ respectively the number of students and workers in skill-group s, in year t.

The evolution of school population can be written as

$$NS_s(t) = (1 - \chi_s + b_s)\, NS_s(t-1),$$

and for the working population

$$NW_s(t) = (1 - \xi_s)\, NW_s(t-1) + \chi_s NS_s(t-1),$$

where χ_s is the exit rate from student skill cohort s, b_s is the birth-rate of skill group s, and ξ_s is the exit rate from working age population. The exit rate is the inverse of average duration spent in a skill-group. For example, if the duration of education for high skilled is 20 years (80 quarters), then $\chi_s = 1/80$.

The parameters b_s, χ_s, and ξ_s determine the evolution of the (inverse) dependency ratios

$$IDEPRATE_s(t) = \frac{NW_s(t)}{NS_s(t)}$$

and the growth rate of working age population ($gpopw_s(t)$). Combining the dynamic equations of the student and working age population we get

$$IDEPRATE_s(t) = \frac{1-\xi_s}{1-\chi_s+b_s} IDEPRATE_s(t-1) + \frac{\chi_s}{1-\chi_s+b_s},$$

therefore the growth rate of the working age population is given by

$$\frac{NW_s(t)}{NW_s(t-1)} = \frac{\chi_s}{IDEPRATE_s(t-1)} - \xi_s.$$

Finally, by adding the definitions

$$sh_s(t) = \frac{NW_s(t)}{\sum_{s\in\{L,M,H\}} NW_s(t)}$$

we obtain the evolution of the skill population shares. For the calibration, we use the education statistics of OECD (2006) and data on the skill-distribution of working age population from EUROSTAT.

Annex: Detailed payment profile categories

Table A1. Fields of interventions, detailed tables

Code	Category	Priority themes	% of total
		Research and technological development (R&TD), innovation and entrepreneurship	
01	RTD	R&TD activities in research centres	1.21
02	RTD	R&TD infrastructure and centres of competence in a specific technology	2.78
03	RTD	Technology transfer and improvement of cooperation networks between small businesses (SMEs), between these and other businesses and universities, postsecondary education establishments of all kinds regional authorities, research centres and scientific and technological poles (scientific and technological parks, technopoles, etc).	1.32
04	RTD	Assistance to R&TD, particularly in SMEs (including access to R&TD services in research centres)	0.73
05	S	Advanced support services for firms and groups of firms	1.17
06	I	Assistance to SMEs for the promotion of environmentally-friendly products and production processes (introduction of effective environment managing system, adoption and use of pollution prevention technologies, integration of clean technologies into firm production	0.46
07	RTD	Investment in firms directly linked to research and innovation (innovative technologies, establishment of new firms by universities, existing R&TD centres and firms, etc.)	2.85
08	I	Other investment in firms	2.88
09	RTD	Other measures to stimulate research and innovation and entrepreneurship in SMEs	1.13
		Information society	
10	INF	Telephone infrastructures (including broadband networks)	0.75
11	INF	Information and communication technologies (access, security, interoperability, risk-prevention, research, innovation, e-content, etc.)	1.05
12	INF	Information and communication technologies (TEN-ICT)	0.08
13	S	Services and applications for citizens (e-health, e-government, e-learning, e-inclusion, etc.)	1.55
14	S	Services and applications for SMEs (e-commerce, education and training, networking, etc.)	0.65
15	S	Other measures for improving access to and efficient use of ICT by SMEs	0.45

Code	Category	Priority themes	% of total
		Transport	
16	INF	Railways	0.94
17	INF	Railways (TEN-T)	6.96
18	INF	Mobile rail assets	0.29
19	INF	Mobile rail assets (TEN-T)	0.40
20	INF	Motorways	1.87
21	INF	Motorways (TEN-T)	8.37
22	INF	National roads	3.47
23	INF	Regional/local roads	3.69
24	INF	Cycle tracks	0.22
25	INF	Urban transport	0.78
26	INF	Multimodal transport	0.23
27	INF	Multimodal transport (TEN-T)	0.19
28	INF	Intelligent transport systems	0.43
29	INF	Airports	0.54
30	INF	Ports	0.58
31	INF	Inland waterways (regional and local)	0.06
32	INF	Inland waterways (TEN-T)	0.27
		Energy	
33	I	Electricity	0.08
34	INF	Electricity (TEN-E)	0.15
35	I	Natural gas	0.30
36	INF	Natural gas (TEN-E)	0.14
37	I	Petroleum products	0.09
38	INF	Petroleum products (TEN-E)	0.00
39	I	Renewable energy: wind	0.25
40	I	Renewable energy: solar	0.18
41	I	Renewable energy: biomass	0.52
42	I	Renewable energy: hydroelectric, geothermal and other	0.25
43	I	Energy efficiency, co-generation, energy management	1.28

Code	Category	Priority themes	% of total
		Environmental protection and risk prevention	
44	INF	Management of household and industrial waste	2.60
45	INF	Management and distribution of water (drink water)	2.52
46	INF	Water treatment (waste water)	5.37
47	INF	Air quality	0.48
48	INF	Integrated prevention and pollution control	0.23
49	INF	Mitigation and adaption to climate change	0.01
50	INF	Rehabilitation of industrial sites and contaminated land	1.17
51	INF	Promotion of biodiversity and nature protection (including Natura 2000)	0.77
52	INF	Promotion of clean urban transport	2.56
53	INF	Risk prevention (including the drafting and implementation of plans and measures to prevent and manage natural and technological risks)	1.57
54	INF	Other measures to preserve the environment and prevent risks	0.45
		Tourism	
55	S	Promotion of natural assets	0.31
56	INF	Protection and development of natural heritage	0.35
57	S	Other assistance to improve tourist services	1.13
		Culture	
58	INF	Protection and preservation of the cultural heritage	0.82
59	INF	Development of cultural infrastructure	0.78
60	S	Other assistance to improve cultural services	0.11
		Urban and rural regeneration	
61	INF	Integrated projects for urban and rural regeneration	2.52

Code	Category	Priority themes	% of total
		Increasing the adaptability of workers and firms, enterprises and entrepreneurs	
62	HC	Development of life-long learning systems and strategies in firms; training and services for employees to step up their adaptability to change; promoting entrepreneurship and innovation	1.56
63	HC	Design and dissemination of innovative and more productive ways of organising work	0.50
64	HC	Development of specific services for employment, training and support in connection with restructuring of sectors and firms, and development of systems for anticipating economic changes and future requirements in terms of jobs and skills	0.75
		Improving access to employment and sustainability	
65	HC	Modernisation and strengthening labour market institutions	0.57
66	HC	Implementing active and preventive measures on the labour market	1.76
67	HC	Measures encouraging active ageing and prolonging working lives	0.25
68	HC	Support for self-employment and business start-up	0.43
69	HC	Measures to improve access to employment and increase sustainable participation and progress of women in employment to reduce gender-based segregation in the labour market, and to reconcile work and private life, such as facilitating access to childcare and care for dependent persons	0.37
70	HC	Specific action to increase migrants' participation in employment and thereby strengthen their social integration	0.03
		Improving the social inclusion of less-favoured persons	
71	HC	Pathways to integration and re-entry into employment for disadvantaged people; combating discrimination in accessing and progressing in the labour market and promoting acceptance of diversity at the workplace	1.50
		Improving human capital	
72	HC	Design, introduction and implementation of reforms in education and training systems in order to develop employability, improving the labour market relevance of initial and vocational education and training, updating skills of training personnel with a view to innovation and a knowledge based economy	2.86
73	HC	Measures to increase participation in education and training throughout the life-cycle, including through action to achieve a reduction in early school leaving, gender-based segregation of subjects and increased access to and quality of initial vocational and tertiary education and training	1.95
74	HC	Developing human potential in the field of research and innovation, in particular through post-graduate studies and training of researchers, and networking activities between universities, research centres and businesses	1.36

Code	Category	Priority themes	% of total
		Investment in social infrastructure	
75	INF	Education infrastructure	2.32
76	INF	Health infrastructure	2.19
77	INF	Childcare infrastructure	0.19
78	INF	Housing infrastructure	0.39
79	INF	Other social infrastructure	0.85
		Mobilisation for reforms in the fields of employment and inclusion	
80	HC	Promoting the partnerships, pacts and initiatives through the networking of relevant stakeholders	0.16
		Strengthening institutional capacity at national, regional and local level	
81	HC	Mechanism for improving good policy and programme design, monitoring and evaluation	1.24
		Reduction of additional costs hindering the outermost regions development	
82	S	Compensation of any additional costs due to accessibility deficit and territorial fragmentation	0.00
83	S	Specific action addressed to compensate additional costs due to size market factors	0.00
84	I	Support to compensate additional costs due to climate conditions and relief difficulties	0.00
		Technical assistance	
85		Preparation, implementation, monitoring and inspection	2.71
86		Evaluation and studies; information and communication	0.74