



European
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Research, innovation and economic growth

Executive summary

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Research innovation and economic growth

Executive summary

Deloitte.

EXECUTIVE SUMMARY

Within the European Commission, the responsibility for research and innovation policies primarily lies with the Directorate-General for Research and Innovation (DG RTD) which monitors and analyses national policies and provides recommendations on how member states could improve the quality and quantity of their research. In order to facilitate policy-making, DG RTD uses QUEST III, a macro-economic model developed by the Directorate General for Economic and Financial Affairs (DG ECFIN).

DG RTD commissioned Deloitte and RAND Europe to undertake a study with the aim to better understand the impact of public policy on innovation. In particular, the objective of the study is twofold:

- Enhance the evidence base around the impact of public policy on research and innovation. This objective is primarily addressed by undertaking a series of econometric analyses; and
- Explore possible modifications in QUEST III: despite its sophistication, QUEST III is not designed to evaluate a number of innovation policies and reforms. The second objective of this study is to propose a modification of QUEST III in order for the model to better support DG RTD's policy-making.

1 Innovation and public policies

There are three broad types of policies that can be used to stimulate innovation (Aschhoff & Sofka, 2008).

- 1. R&D investment.** Given that the size of the R&D sector is an important determinant of knowledge creation, policies that aim to increase R&D investment (e.g. tax incentives) are expected to stimulate innovation.
- 2. Education.** In principle, the supply of skills is positively associated with R&D activity, and education policies that aim to increase the supply and quality of high-skilled workers are expected to have a positive impact on research activity and innovation.
- 3. R&D productivity.** R&D output is not only dependent on the scale of the R&D sector (skills and investment) but also on R&D productivity. For instance, policies that aim to increase public-private R&D cooperation and research commercialisation are expected to increase R&D productivity and innovation.

These policies are the primary focus of this study, which is organised across five tasks.

- **Task 1.1: Knowledge production function.** Quantify the impact of R&D employment and international knowledge spill-overs on innovation;
- **Task 1.2: Knowledge diffusion.** Model the impact of scientific and technology diffusion on economic productivity and growth;
- **Task 1.3: Public and private R&D.** Assess the potential differential impact of public and private R&D investment on knowledge creation and understand the substitutability/complementarity of public and private R&D investment;
- **Task 2: Skills accumulation.** Quantify the impact of public policies on the quantity and quality of education, and endogenise skill accumulation within QUEST III; and

- **Task 3: R&D productivity.** Assess the impact of a number of micro policies on R&D productivity.

These tasks together with the key insights and output are summarised in the remainder of this document. The full analysis (related literature, models and detailed results) are reported in four separate reports.¹

1.1 Task 1.1: Knowledge production function

A key aspect of the R&D sector within QUEST III is the knowledge production function which assumes that innovation is generated by high-skilled workers and international knowledge spill-overs. The parameters in the knowledge production function in the current version of QUEST have been taken from Bottazzi and Peri (2007) who estimated them by means of econometric analysis using a sample of 15 OECD countries from 1973 to 1999. The objective of this task is to update the parameters of the knowledge production function by utilising more up-to-date data and a broader set of countries.² The results of the analysis suggest that:

- **The level of high-skilled workers employed in the R&D sector and international transmission of knowledge are economically and statistically significant drivers of innovation.** The estimated elasticity of innovation with respect to R&D typically ranges between 0.5 and 0.7 and is lower than the international spill-over effect which ranges between 0.8 and 1. This suggests that the international diffusion of knowledge over the last two or three decades has played a pivotal role in the innovation process.
- **International transmission of knowledge has benefited technology leaders (G7) more than technology followers (non-G7).**
- **In contrast, the impact of an additional R&D worker on knowledge creation has been found to be greater in non-G7 countries compared to G7 countries.**

1.2 Task 1.2: Technology diffusion

A key aspect of the research and innovation sector within QUEST III is that once technologies are invented they can immediately be used in production. This feature is inconsistent with the empirical evidence that suggests that technologies diffuse slowly or are adopted with a time lag. Most importantly, a number of studies have shown that technology diffusion is a significant driver of Total Factor Productivity (TFP) and long-run economic growth and can account for a large proportion of the variation in income between poor and rich countries.

Comin and Hobijn (2010), for instance, show that variations in technology diffusion account for at least a quarter of per capita income differences. Comin and Mestieri (2013) find that 82% of the income gap between Western and non-Western countries could be explained by differences in the evolution of technology diffusion. Therefore, a model that incorporates technology diffusion could in principle provide a more appropriate framework to analyse and predict differences in productivity and long-term economic growth across countries.

¹ "Task 1.1: Knowledge production function and Task 1.3: Relationship between public and private R&D"; "Task 1.2: Technology diffusion"; "Task 2: Skills accumulation"; "Task 3: R&D policy reforms and strategies".

² A total of 41 EU and/or OECD countries have been used in the analysis over a time period spanning from 1985 to 2011.

This task develops a methodology to incorporate technology diffusion within QUEST III. The proposed model builds upon the work of Comin and Gertler (2006), and Anzoategui et al. (2015), and comprises four key elements: (1) law of motion for the world technology frontier, which describes the process by which technology or new ideas are created through R&D activities³; (2) law of motion for adopted technologies, which defines the process by which invented technologies are adopted in production by engaging skilled workers into adoption activities; (3) optimal adoption of new technologies which determines the intensity with which companies invest in adoption activities; and (4) market clearing for skilled workers which ensures the full utilization of skilled workers in the economy.

Making technology adoption an endogenous variable is critical for two main reasons. First, it allows the model to capture the delayed effect of innovation on productivity. Second, it allows evaluation of the impact of the cyclical response of technology adoption on TFP.

1.3 Task 1.3: Public and private R&D

In principle, public R&D has a direct and indirect impact on knowledge creation. The direct impact is the new knowledge generated in government labs and the output of the research carried out by academic institutions. The indirect impact reflects the influence of government R&D policies and efforts, such as R&D grants and investment in basic research, on private R&D investment. The objective of this task is to (1) estimate the potential differential impact of private and public R&D on knowledge creation and (2) assess the complementarity/substitutability of public and private R&D. The econometric analysis carried out in this task is based on sample of 30 OECD and EU countries over the period 1985 to 2011 and suggests that:

- **There is some indication that private and public R&D have differential impacts on knowledge creation.** Private R&D is more effective in countries that are on the technology frontier (G7) than public R&D, whereas public R&D plays a more significant role in knowledge creation for technology followers (non-G7 countries).
- **Public R&D complements private R&D.** Public R&D grants and government investment in higher education research stimulates privately-funded R&D.
- **Investment in higher education has the largest effect on private R&D relative to the other two public R&D investments** (public grants and direct government R&D investment) with an elasticity of around 0.5. The elasticity of business-funded R&D investment with respect to public R&D grants is c.0.2%. The results related to direct government R&D investment are mixed but typically suggest no significant effects.

1.4 Task 2: Skills accumulation - University enrolment

Previous micro studies have documented that reducing the cost of education via financial subsidies provided to students and through reductions in tuition fees have a significant impact on the decision to enrol with a particular university. The elasticities reported indicate that a 1% reduction in the cost of tertiary education could lead to more than a 1% increase in university enrolment. Macro studies, on the other hand, report statistically insignificant or relatively small impacts of the cost of education on university enrolment. The higher impact reported in micro studies may reflect the internal substitution effect: universities that provide financial support or reduce fees are able to

³ The law of motion assumes that the stock of developed technologies at $t+1$ is given by the technologies available in t that do not become obsolete plus the flow of newly developed technologies.

attract students who would have otherwise enrolled with another institution with total, country-level enrolment remaining relatively unchanged.

The objective of this task is to quantify the impact of public spending on higher education enrolment using econometric analysis and macro data across a number of OECD countries. The results of the analysis suggest that:

- Consistent with the macro literature, **financial aid does not seem to have a significant impact on a country's enrolment rate.**
- However, **public investment in higher education has a significant effect on university access**; a 1% increase in tertiary government expenditure was found to be associated with a 0.1% increase in university enrolment.
- Notwithstanding this, **the main determinant of university enrolment is the macro-economic environment.** For example, it was found that a 1% increase in GDP per capita could increase enrolment rate by approximately 1%.

1.5 Task 2: Skills accumulation - Quality of secondary education

Policy-makers can affect the quality of secondary education through a number of policy instruments including class size, teacher quality and curriculum design. The objective of this task is to estimate the impact of a number of policy variables on the quality of education. The analysis is based on the 2012 PISA dataset with quality of education being proxied by the PISA test scores. The results of the econometric analysis carried out in this task suggest that:

- After controlling for student and school characteristics as well as family background, **student-teacher ratio and class size have no statistically significant impact on student achievement** within the range observed in the sample (for example, class size typically ranges between 20 and 30 students). This finding is consistent with previous studies that find either statistically insignificant effects or coefficient estimates that are typically small in magnitude.
- **Teacher quality and availability of resources (instructional material and teacher shortages) is found to be positively associated with student performance**; however, the effects are relatively small.
- **Students' family background has a large impact on student achievement, significantly larger than observed policy variables**, i.e. class size and teacher quality. These findings are consistent with the existing literature.
- This study extends the insights provided by the existing literature by also looking at the impact of unobserved policies on student achievement. Apart from class size and teacher qualifications, other education policies related to curriculum design, teaching methods, term duration and student evaluation policies are expected to have an impact on test performance, however they are unobserved and/or difficult to quantify econometrically. This study exploits the availability of international data, i.e. the panel structure of the dataset, and estimates the unobserved policy effects by using country-specific dummies in the regression models. The estimated country-specific effects suggest that **unobserved education policies could lead to a greater than 10% impact on student achievement.**
- Finally, it was found that **education quality has little correlation with government expenditure suggesting that higher public spending does not**

always lead to better education quality and that there is an important qualitative aspect to consider in the design of successful education systems.

1.6 Task 2: Skills accumulation - Endogenise skills accumulation within QUEST III

In QUEST III, the supply of high-skilled workers, one of the key determinants of innovation, is assumed to be exogenous. This feature is inconsistent with economic theory and empirical evidence that suggests that human capital and R&D employment respond to business cycle shocks, education investment and public policies.

This task proposes a modification of QUEST III which could facilitate evaluation of the impact of a number of different policies on skill accumulation. The proposed model assumes three types of workers: those with low skills (no higher education qualification), medium skills (higher education qualification in non-STEM subjects) and high skills (higher education qualification in STEM subjects); only high-skilled workers are assumed to be employed in the R&D sector. Furthermore, it is assumed that high skills require more effort to acquire and potentially associated with greater financial costs. Finally, it is assumed that liquidity-constrained individuals may accumulate skills by going to higher education, assuming that the government subsidises the tuition fees of these agents.

1.7 Task 3: R&D productivity

The objective of this task is twofold: (1) assess the impact of a number of public policies on R&D productivity and innovation; and (2) propose a model which could be integrated into QUEST III to facilitate policy evaluation. Five policies are investigated: performance-based funding, R&D specialisation, public-private R&D cooperation, research commercialisation, and R&D tax incentives. The evaluation of these policies has been carried out through a review of the related literature. The key insights gained for this review are summarised below.

- **Performance-based funding.** Several EU member states have recently adopted a performance-based funding policy whereby research funds to higher education institutions are allocated on the basis of some performance indicators such as the number of publications and citations. The empirical literature that seeks to evaluate the impact of performance-based funding on research productivity provides mixed results: although some studies document a significant increase in the quantity of university research following adoption of performance-based funding, other studies fail to identify statistically significant effects.
- **R&D specialisation.** R&D specialisation policies seek to incentivise R&D investment in either specific geographical areas (e.g. cluster policies) and/or technology field (e.g. smart specialisation policies). The literature primarily focuses on the evaluation of cluster policies and agglomeration effects, and suggests that R&D productivity is positively related to a firm's geographical proximity to a technology cluster.
- **Public-private R&D cooperation.** There is a lack of empirical evidence that directly assesses the effectiveness of policies that seek to stimulate public-private R&D cooperation. However, there are several studies that look at the impact of some form of public-private cooperation on private R&D productivity. This literature suggests that firms that collaborate with universities or other public research organisations tend to innovate more.
- **Research commercialisation.** The available literature primarily focuses on the evaluation of Technology Transfer Offices (TTOs) and suggests that research

commercialisation proxied by university income from patents and licences is associated with presence, size, and characteristics of TTOs.

- **R&D tax incentives.** R&D tax incentives such as reduced corporate tax have been found to increase R&D expenditure and innovation. The elasticity of R&D expenditure with respect to tax credits is typically close but less than one suggesting that tax credits considerably stimulate R&D investment without significantly reducing tax revenues.

Excepting tax incentive policies, which are already present in the model, the rest of the policies could be integrated within QUEST III through a modification of the knowledge production function. The proposed modifications allow public and private R&D to have a differential impact on innovation; private R&D productivity is assumed to be a function of public-private cooperation; and public R&D productivity is a function of R&D commercialisation and performance-based funding policies.

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This report sets out the objectives and key insights gained from the research undertaken.

Studies and reports