BRUEGEL WORKING PAPER 2016/01

GETTING THE MOST FROM PUBLIC R&D SPENDING IN TIMES OF AUSTERITY: SOME INSIGHTS FROM SIMPATIC ANALYSIS

REINHILDE VEUGELERS

Highlights

- We review the evidence on the impact of public R&D spending. We first look at the evidence from micro-analysis of the impact of public intervention on private R&D and innovation, with a focus on the latest results from cross-country micro-research performed within SIMPATIC (www.simpatic.eu). To analyse the impact of public R&D on growth, we need to complement the micro-results on private R&D investment effects with a macro-perspective. To this end, we look at how public R&D performs in affecting GDP growth and jobs in applied macro-models most commonly used in EU policy analysis. We focus particularly on the NEMESIS model in development within the SIMPATIC project. We conclude with some policy recommendations from the reviewed micro and macro SIMPATIC evidence for designing public R&D projects and programmes.

Reinhilde Veugelers (reinhilde.veugelers@bruegel.org) is a Senior Fellow at Bruegel and a professor at KULeuven (Belgium). Research assistance from Diogo Machado and Marco Testoni is gratefully acknowledged.

JANUARY 2016

The dangerous cocktail of high debt and low growth in Europe calls for *smart* public investment, meaning public investment that fosters long-term growth while minimising the potentially negative short-term effect on public finances and economic activity. R&D is an area typically identified as a candidate for smart public spending, because of its alleged growth effects. But what is the evidence to justify public R&D spending as an area of smart government spending?

Identifying R&D spending as an area of smart government spending requires several boxes to be ticked. First, does R&D contribute to growth? At present, it is widely acknowledged that innovation is an important force behind long-run economic growth. In particular, models that use an endogeneous growth framework make a strong case for the growth power of R&D and innovation (eg Aghion, 2006; Conte, 2006). But this does not sufficiently make the case for public investment in R&D. Will public R&D lead to innovation and growth, to the extent that it covers the opportunity costs of using public funds for R&D? To answer these questions, we review the evidence on the impact of public R&D spending. We first look at the evidence from micro-analysis of the impact of public intervention on private R&D and innovation, with a focus on the latest results from cross-country micro-research performed within SIMPATIC[1]. To analyse the impact of public R&D on growth, we need to complement the micro-results on private R&D investment effects with a macro-perspective. To this end, we look at how public R&D performs in affecting GDP growth and jobs in applied macro-models most commonly used in EU policy analysis. We focus particularly on the NEMESIS model in development within the SIMPATIC project. We conclude with some policy recommendations from the reviewed micro and macro SIMPATIC evidence for designing public R&D projects and programmes.

1. The case for public spending on R&D: the theory

The fundamental justification for government support for research is the classic market failure argument: markets do not provide sufficient incentives for private investment in research because of the non-appropriable, public good, intangible character of knowledge and its risky nature. In addition, public research is needed to meet specific needs of public interest, 'common goods' that the market would not supply on its own, such as defence, public health or a clean environment. Once invented, the new knowledge created from R&D is non-rivalrous and only partially non-excludable. Others may learn and use the knowledge, without necessarily paying for it. It is these spillovers that lead to social rates of return that are above private rates of return, and private investment levels chosen below the socially desirable levels. This divergence between social and private rates of return, calls for government intervention to lift private R&D investment to the higher socially optimal level[2].

Beyond the case of spillovers, another market failure arises from the highly risky and uncertain nature of the outcome of R&D. This uncertainty coupled with asymmetries in information between capital

[1] SIMPATIC is a Bruegel coordinated FP7 project financed on the impact assessment of RTD policies. More information on the project can be found at www.SIMPATIC.eu. In this paper, the discussion of SIMPATIC research results is reported in dedicated boxes, which include the references to the respective SIMPATIC working papers, which can be found on the SIMPATIC website.

[2] Note that social rates of return below private rates of return is also possible, for instance when R&D is used strategically to pre-empt other research or technology avenues from developing. In this case, government intervention would be targeted at reducing private R&D investment.

markets and R&D investors, causes financial market imperfections, impeding access to finance for risky innovation projects. This will be the case particularly for small young risky innovators.

In sum, the wide scope for market failure in the case of R&D investment for growth makes a theoretical case for government intervention to bring private R&D investment closer to the socially optimal investment levels.

2. The gap between private and social rates of return

2.1. The evidence about private rates of return

Several empirical studies have tried to assess the private rate of return from R&D using data at the plant, firm, industry or country level. Hall, Mairesse & Mohnen (2009) summarise the main results: (i) the rate of return in developed countries has been strongly positive in the past 50 years, with the estimated private rate of return from R&D usually exceeding that of physical capital. Most studies obtain rates of return within the range of 10–30 percent; (ii) the rate of return from R&D varies across countries. Unfortunately, there is too much heterogeneity in the methodologies being used to pin down the sources of these country differences; (iii) the rates of return from R&D vary across firm types. Cincera and Veugelers (2014) for instance, find significantly higher rates of return from young US world-leading innovators compared to older US counterparts. This premium for young world-leading innovators is not found in Europe.

2.2. The evidence about social rates of return

The motivation for public intervention in R&D does not lie in the private rates of return, but in the social rates of return from R&D investment in excess of the private returns. As for private rates of return, the social rates of return are likely to vary between countries, depending on the distributional capacity of innovation systems and their ability to capitalise on knowledge spillovers. Unfortunately, estimates about social rates of return using large-scale econometric analysis are scarce. Most of the available empirical evidence comes from selected cases, which carry the risk of a positive selection bias towards more favourable cases. By and large, this empirical literature confirms that the social or economy-wide returns from R&D are usually much higher than the private returns to individual firms (Hall, Mairesse and Mohnen, 2009). For example, Mansfield *et al* (1977) computed the social rates of return of 17 industrial innovations and found that the median social rate of return is about 56 percent, compared to a median private rate of return of about 25 percent. Analogously, Tewksbury *et al* (1980) looking at 20 innovations, found a social rate of return of 99 percent compared to a private rate of return of 27 percent. Griliches (1958) found that the social rate of return from research in hybrid corn between 1910 and 1955 was between 35 percent and 40 percent. Jones and Williams (1998) argued that even conservative estimates of R&D spillovers (ie the discrepancy between social and private returns from R&D) suggest that optimal R&D investment in the US is at least four times the actual investment.

2.3. The evidence about spillovers

The divergence between rates of return from social and private R&D is caused by knowledge spilling over. Rather than looking at evidence about social rates of return, one could also look directly at the evidence about knowledge spillovers occurring.

One challenge is the variety of potential transmission channels, all of which bring with them problems of measurement. Knowledge spillovers are associated with researcher mobility as well as flows of goods, services and investment. SIMPATIC researchers Belderbos and Mohnen (2013) review the various methodologies for measuring spillovers and the evidence (Box 1). Trade-based indicators are most often used. The evidence suggests however that patent-based indicators are better able to capture knowledge spillovers than trade-based indicators.

Box 1: Measuring intersectoral and international R&D spillovers

Patent citation data can be used to calculate direct measures of flows of technological knowledge. The intensity of patent citations in different industries and countries can be taken as a correlate of various other transfer mechanisms affecting knowledge spillovers. Information on the citing patent can be used to identify sectors of use, while information on the cited patent can be used to identify sectors of origin. This allows knowledge spillovers from manufacturing industries to be extended to service industries – a feature that is generally difficult to incorporate in trade-based measures.

SIMPATIC provides on its website an inter-country, inter-sectoral spillover matrix based on patent citation information.

Source: Belderbos and Mohnen, Intersectoral and international R&D spillovers, SIMPATIC Working Paper N°2, 2013.

+++

In the area of green/clean innovations in particular, market mechanisms alone cannot provide the socially optimal amount of 'green' innovation because of the well-known combination of environmental and knowledge externalities. The optimal level of subsidy for clean R&D that is required to address these externalities crucially depends on the magnitude of knowledge spillovers from clean technologies, relative to the amount of knowledge spillover generated by the dirty technologies they replace. SIMPATIC research has looked at patent citation information to assess the knowledge spillovers from clean versus dirty technology and found significantly higher spillovers for the former (Box 2). This has important implications for climate change policies. It would suggest that carbon pricing should be complemented with specific support for clean innovation that goes beyond standard R&D policies. R&D for clean technologies should receive higher public support than research activities targeted at improving on the existing dirty technologies.

Box 2: Spillovers for clean versus dirty technologies

A new dataset of more than one million patented inventions is used. The data clearly distinguishes between clean and dirty inventions in the areas of energy production, automobiles, fuel and lighting. The dataset includes three million citations of these patents, which are used to assess knowledge spillovers.

All other things being equal, clean patented inventions receive 43 percent more citations (between 23 percent and 160 percent, depending on the technology) than dirty inventions. These results hold for all four technological fields and are robust against a large number of sensitivity tests. Interestingly, the gap between clean and dirty technologies has been constantly increasing during the past 50 years.

Source: Dechezleprêtre, A., R. Martin, M. Mohnen, Clean Innovation and Growth, SIMPATIC WP24.

+++

3. Government support for R&D

The evidence about social returns well in excess of private returns and the evidence about knowledge spillovers would justify public intervention. This however does not yet make the case for public R&D investments. This also requires an analysis of potential government failure, ie ineffectiveness of public intervention to increase private R&D to the socially optimal level. What do we know about effectiveness of public intervention for R&D?

3.1. Public support for private R&D: why it might not work

There are several reasons why R&D policy interventions might not be effective. First, public funded R&D might directly substitute for private funding of R&D projects that would have been undertaken anyway in the absence of public funding. Second, extra R&D generated by the public funding might crowd out private R&D indirectly by increasing the demand for R&D inputs, leading to higher costs of research inputs. This crowding out effect will be more significant when the supply of research inputs is less elastic. This is the case in particular for labour supply, because the stock of R&D workers can be considered to be more or less fixed in the short run. Because the majority of R&D spending is salary payments for R&D workers, this effect could turn out to be significant, as argued by Goolsbee (1998). Goolsbee states that, because of this wage effect, conventional estimates of the effectiveness of R&D policy might be 30-50 percent too high. Wolff and Reinthaler (2008) find from a panel of 15 OECD countries (81-02) that an increase in the R&D subsidy rate increases expenditure for business research more than R&D employment by roughly 20-30 percent, which is consistent with subsidies raising scientists' wages. They find that the effect is stronger in the short run, when the increase in expenditure is 60 percent higher than the increase in employment, consistent with a more inelastic demand for R&D labour in the short run. Third, ideally, policy triggers research projects with the highest social rates of return. But this assumes that the government is sufficiently informed about these social rates of return, which is notoriously difficult, particularly *ex ante*. And finally there is the problem of political capture, resulting in the selection of the wrong projects.

3.2. Evidence about government support for R&D: (when) does it work?

Whether the costs and risk of failure of government intervention eliminate the potential positive effects from government intervention remains an empirical question. Many evaluation studies of R&D programmes have not been based on microeconometric techniques, but rather on qualitative case studies, interviews and surveys. These studies are likely to suffer from a bias in favour of more successful programmes, which are more likely to be evaluated. Furthermore, all of the evaluation studies grapple with the challenge of finding a proper counterfactual with which to compare results. Evaluation studies based on randomised trials or natural experiments are scarce.

In the remainder of this paper, we discuss the evidence from economic analysis of time series and cross section data at various levels of aggregation (firm, industry, country). We will also focus on R&D subsidies and tax credits for firms.

3.2.1. R&D tax credits

R&D tax credits are conceived to help provide finance to private R&D projects and thus to generate the socially optimal amount of R&D. A big virtue of R&D tax credits relative to R&D subsidies is that they permit firms to choose the projects and pay part of the bill. Tax credits are also a more predictable, reliable scheme, because all firms qualifying for the criteria can use it, thus avoiding selection of projects, economising on bureaucracy. There is a wide variety of R&D tax credit schemes, ranging from volume-based to increment-based, for R&D employment costs only, tax credits vs tax allowances, and others (OECD, 2010). Although mostly hailed for their generality, tax credits can be specifically targeted towards selected sectors, firms (such as SMEs or young firms) and different types of R&D projects (eg R&D collaboration with universities).

The effectiveness of fiscal incentives to stimulate private R&D is typically measured by the tax price elasticity, or the amount of additional R&D that is generated by one dollar of tax deduction[3]. There is a good deal of heterogeneity in the findings on tax price elasticities. In a review of the literature, Hall and Van Reenen (2000), report econometric estimates ranging from 0.1 to 2, concluding that the most plausible estimates of the tax price elasticity are around unity, which implies that each dollar forgone in tax credit for R&D stimulates a dollar of additional R&D. SIMPATIC researcher Mohnen (2013) equally concludes that *"the existing evidence about the effectiveness of R&D tax incentives, although it is mixed, seems to tilt towards the conclusion that they are not terribly effective in stimulating more R&D than the amount of tax revenues foregone."* Tax price elasticity is somewhat higher for incremental than for level-based R&D schemes. The benefit of the tax policy instrument seems therefore to lie more in stimulating new R&D projects and firms, rather than in supporting existing ones. In addition, some of the benefits are wiped out because of the rise in wages for R&D employees[4].

Further evidence of low additionality is the bias in favour of large persistent R&D-performing firms, even if small firms are often given higher rates of R&D tax credits (Mohnen, 2013). Unless tax credit

[3] A first step when evaluating R&D credits is to assess the size of the actual R&D tax credit. This is the well-known B-index introduced by McFertridge and Warda (1983). The B-index is the ratio of the net cost of a dollar spent on R&D, after all quantifiable tax incentives have been accounted for, to the net income from one dollar of revenue.

[4] Mohnen (2013) reports that the elasticity of the R&D wage with respect to the fraction of the wage supported by the fiscal incentive scheme, is estimated at 0.1 in the short run and 0.13 in the long run.

rates are much more generous for SMEs, or there are caps on the tax credits that large firms can claim, there is a blatant inequality in the tax credit scheme in favour of large firms. Small and new firms or first time R&D-active firms do not bother to apply because of the too-high fixed cost of applying, and the lack of information and their lack of experience. This is particularly unfortunate because small firms have a greater tax elasticity than large firms and because these firms are also more likely to face financial constraints. In this respect, because the R&D tax credit is too general, it fails to alleviate the financial market failure. For this, a more targeted R&D tax credit approach is needed, with more generous tax credits for firms that face financial constraints, such as small, starting and first-time-R&D-performing firms.

3.2.2. Subsidies to private R&D

A growing body of econometric work has evaluated the effects of R&D subsidies on private R&D spending, correcting for other determining firm, industry and market characteristics affecting private R&D spending. The majority of the empirical literature thus focuses on the issue of whether public R&D spending is additional to private R&D spending, or whether it substitutes for and tends to crowd out private R&D. Reviewing the macro and industry-level literature, Capron and Van Pottelsberghe de la Potterie (1997) conclude that *"despite the heterogeneity of the empirical models referred to in the literature, which makes any comparison exercise hazardous, the balance seems to tilt towards the recognition of a complementary effect between the two sources of funds. However, there are some indications that in some industries, or in some countries, government R&D is a substitute for private R&D."* In a later survey of this literature, David, Hall and Toole (2000) similarly conclude that *"the findings overall are ambivalent"*, although on average there is more evidence in favour of positive effects. Also Garcia-Quevedo (2004) finds that a little less than one quarter (17 out of 74) of the reviewed studies report substitutability. Substitution is more prevalent among the studies conducted at the firm level, than among those carried out at the industry or country level. This is suggestive of the beneficial effects from positive spillover effects captured in more aggregate industry and country levels of analysis.

David *et al* (2000) warn that *"the existing literature as a whole is subject to the criticism that the nature of the experiment(s) that the investigators envisage is not adequately specified"*. A major issue is the correction for the selection bias: positive effects associated with R&D subsidies are generated from better firms being selected for subsidies, rather than that subsidies cause better performance. More recent studies have come up with better data and methodologies. Although the conclusions are still ambivalent, positive effects still seem to prevail more often.

SIMPATIC uses a novel approach, combining economic theory and advanced econometrics into a structural modelling approach which allows counterfactual policy analysis. The model incorporates the decisions firms take to engage in R&D and to apply for government support and the decisions of the government agencies about which projects to subsidise and with what subsidy rate. SIMPATIC does this on a comparable cross-country basis (currently for five countries: Belgium (Flanders), Finland, Germany, the Netherlands and Spain), so that country-specific differences in effectiveness of R&D policy can be looked at. Of these countries, Finland and Germany rely – during the period(s) studied – only on R&D subsidies, while the other three offer also R&D tax incentives of various forms.

Box 3: SIMPATIC's structural modelling of private and social rates of return to R&D policies

The structural research approach taken in SIMPATIC has three advantages compared to the traditional methods. First, it produces information on the revealed preferences of firms and governments. Second, it allows the study of counterfactual policy questions. Third, the structural approach facilitates the uncovering of causal relationships in the data. The advantages of structural modelling do not come without a cost, however. It is technically more demanding and like the results from reduced form quantitative methods, the results from the structural approach may be sensitive to modelling assumptions. The structural approach should therefore be seen as a complement to the traditional methods.

SIMPATIC's structural approach allows estimation of the values of key parameters which describe the costs for the firms of applying for a subsidy, the benefits the agency derives from a given project (including the spillovers generated), and the determinants of private R&D investment. The model and the estimated parameters can then be used in counterfactual analysis to assess the costs and benefits of the existing policy and analyse how new policies would work.

Source: SIMPATIC (2014) R&D subsidy applications, e-book on i) firm application behaviour; ii) R&D agency decision making; iii) structural modelling.

+++

Box 4: Results from SIMPATIC on applications, grants, tax credits and additionality of R&D subsidies

A first important result from SIMPATIC is that the R&D subsidy programmes for firms in the various countries studied, although quite similar in their general set-up[5]*, have nevertheless different specific features, introducing already one dimension of country heterogeneity. For instance, while most governments provide subsidies both through thematic programmes and through unsolicited applications, the Netherlands only has targeted programmes.*

An important finding, common to all five countries, is that a very small fraction of firms applies for subsidies. This is true not only of the whole firm population, but also of that part of the firm population that, according to survey data, invests in R&D. The probability of applying for a subsidy is typically round 10 percent or lower. This under-emphasised empirical regularity is the single biggest obstacle for R&D subsidies to have a large-scale effect. This finding underscores the need to understand better firms' decision on whether to apply for subsidies or not.

SIMPATIC analysis further finds that there is considerable heterogeneity in terms of which firms are more likely to apply and furthermore that this firm heterogeneity varies across countries. In all countries bar the Netherlands, younger firms are more likely to apply for subsidies. Similarly, larger firms are more likely to apply, except in Finland and the Netherlands. Taking this firm size effect into account, firms that qualify for SME status are everywhere more likely to apply, with the exception again of the Netherlands where they are less likely to apply. Being in a disadvantaged region increases the application probability in Germany and Finland.

[5] All countries engage (mostly internal) experts in the evaluation of the applications; these evaluations play an important role in the decision-making process;

When looking at decisions by government agencies whether or not to grant a subsidy and with what subsidy rate, SMEs seem to be granted a higher subsidy rate in Germany and the Netherlands. In the other countries there is no significantly higher subsidy rate for SMEs. These are unexpected results, showing much smaller differences in the actual treatment of SMEs compared to the normally announced favourable treatment of SMEs.

Overall, the firm characteristics included in the analysis (age, size, SME status, productivity) do not have a big impact on the subsidy rate decisions of the government agency. But perhaps they should not. What should matter most for the subsidy rate is the quality of the project in terms of identifying the divergence between its social and private rates of return. All of the countries studied use grading systems for applications to decide how large the subsidy rate should be. Those grades should seek to reflect the value of the project to the agency, which should reflect the associated market failures that the policy tries to rectify. Grades would help direct subsidies to those projects from which the social rates of return from R&D are highest. SIMPATIC finds for Finland, where information on grading was available for the researchers, that these grades are significantly correlated with the subsidy rate.

On the additionality effect, ie how subsidies affect firms' decisions to invest in R&D, ie whether subsidies crowd in or out private R&D investments, the results show again significant heterogeneity in how firms respond to R&D support. In the most robust specifications, a crowding-in effect for Belgium and Spain is found at the firm level, and the opposite for the rest of the countries.

Source: SIMPATIC (2014) R&D subsidy applications, e-book on i) firm application behaviour; ii) R&D agency decision making; iii) structural modelling.

+++

Box 5: Results from SIMPATIC's structural modelling

The benefit of estimating a structural model is that one can uncover information which is typically hard to assess by researchers. Three aspects are of particular interest: the cost of applying for subsidies, the quality of the R&D ideas from the point of view of firm profits, and the fixed cost of R&D.

The SIMPATIC structural model results suggest the following:

- *A large number of firms don't have R&D projects that are worth executing;*
- *A large fraction of even those firms that carry out R&D perceive the costs of applying for subsidies as very high;*
- *A comparison between countries suggests major differences in all key features related to R&D: the quality of ideas, the fixed costs of R&D, and the costs of applying for government support.*

In addition, the structural model also allows the identification of welfare (social value), as revealed by government agencies' decisions to fund which projects and at what rate. Welfare is the sum of profits, spillovers and the government cost of support for private R&D. Note that the identified welfare is not necessarily the real social value. These are the welfare levels constructed by the researchers assuming that the government agency knows the social value of the projects and selects projects to maximise these social values.

Not surprisingly, the results show again differences between countries, but nevertheless confirm for all countries a social value of funded projects substantially above private value. If *one is willing to subscribe to the assumption that the choices of government agencies reflect welfare differences, social returns would be 21 percent higher than private returns in Germany, 22 percent higher in Belgium/Flanders and 11 percent higher in Finland.*

Finally, the most interesting results from the structural modelling are the counterfactual exercises of comparing different policies. Current R&D policies can be compared with laissez-faire (no government support to private R&D). They can also be compared to (socially) optimal R&D subsidy policies or optimal R&D tax credits.

- *Compared to laissez-faire, current policies yield large gains in R&D among firms that would do R&D anyway, but next to no gains in terms of enticing new firms to start R&D.*
- *Compared to laissez-faire, current policies yield modest welfare gains.*
  - *Firms that invest in R&D even without current policies already spend so much that the marginal returns from extra R&D are quite low. Thus, pushing them to invest more has only a modest impact on their profits (while still generating spillovers).*
  - *Most of the potential for welfare gains is in enticing new firms to start investing in R&D, but this is precisely the area in which policies are not very effective.*
- *Optimal R&D policies would require major public investment to induce the private sector to spend the required higher investment levels to reach the socially optimal levels. Also optimal R&D tax credits should be high and would imply large budgetary costs. These large budgetary costs might prevent governments from reaching full socially-optimal outcomes, particularly when public budgets are in fiscal consolidation. This also explains why even with optimal R&D policies, the gains in welfare relative to laissez faire are modest.*
- *Because an R&D grant system allows better targeting of R&D projects with higher social value, an optimal R&D grant policy is better than an optimal R&D tax policy, which does not discriminate between firms.*
- *The counterfactual of an EU agency is also considered. Assuming that national agencies ignore the international spillovers their projects generate, an agency with an EU perspective would take into account the spillovers that flow to other EU countries. These spillovers are measured using the industry-specific cross-country patent citation flow matrix, available on the SIMPATIC website (see Box 1). Because there are positive international spillovers, there is room for welfare improvement from considering these spillovers.*[6]

Source: SIMPATIC (2014) R&D subsidy applications, e-book on i) firm application behaviour; ii) R&D agency decision making; iii) structural modelling.

[6] Preliminary results from a first exercise using the country dimension of the international technology spillover matrix on Belgium suggest that there is more room for policy impact. The welfare gap between first-best and laissez faire is bigger. This comes through higher application rates resulting from higher subsidy rates. But these welfare gains are at the European level. If the Belgian taxpayer would have to pay the bill for the higher subsidies required, Belgian welfare would go down. Thus, while there is more room for R&D policy making at a coordinated EU level optimising on international spillovers, this also requires EU-wide financing of such coordinated policy making.

A first important result from the SIMPATIC cross-country analysis is the substantial heterogeneity in terms of characteristics of programmes, firms and the social value of their ideas and their environment. Thus, what works in one country, does not necessarily work in another country.

Another important and robust SIMPATIC result is that public programmes for supporting private R&D are impeded in their effectiveness by low application rates. This is partly because of high application costs for firms, but also because the innovative projects of firms do not yield a high enough private rate of return to begin with. The most obvious, but in no way simple, approach to improve the effectiveness of public R&D programmes is therefore to improve the private returns from R&D projects. This calls for policies other than R&D support, namely policies aimed at, for instance, improving access to markets, skills and knowledge, reducing regulatory burdens and ensuring intellectual property protection. In addition, governments should redesign their schemes to attract more applications. Activation campaigns to attract more applications should be targeted particularly towards those firms that are likely to produce the type of R&D the government would want to subsidise, ie with the highest social rates of return.

3.3. The impact of R&D (policies) in applied macro models

The discussion so far has concentrated on the effect of public R&D support on private R&D and innovation. Ultimately this extra R&D and innovation needs to translate into economy-wide GDP growth and jobs. This requires that higher-order effects also be taken into account, such as the impact on demand, wages, interest rates and prices. To capture these higher-order effects, we need to resort to macro models. Early macro models either did not explicitly treat investment in knowledge capital differently from other capital investments, or they treated R&D exogeneously and modelled public R&D policies as total factor productivity (TFP) shocks (eg Worldscan). These early macro models lacked details about how R&D and R&D policies impact GDP.

Most current macro models treating R&D use endogenous growth models as pioneered by Romer (1990), and further developed by Jones (1995) and Aghion and Howitt (1998). We will look at the macro models presently used by the European Commission for quantitative policy analysis, more particularly the model used by the Commission Directorate-General Research and Innovation (DG RTD) to assess the impact of its R&D policies: the NEMESIS model, which has been further developed by SIMPATIC.

3.3.1. Economic impact of R&D policies as assessed by the NEMESIS model

The NEMESIS model has regularly been used by the European Commission for the assessment of the impact of innovation policies on competitiveness, growth and employment in Europe. NEMESIS is an econometric model, treating R&D endogeneously and adapted for multi-sectoral and cross-country analysis of innovation. Box 6 details how R&D is modelled in NEMESIS.

Box 6: The NEMESIS model's specifications for R&D

The NEMESIS model includes endogenous technical change mechanisms, which link innovations to knowledge accumulation and diffusion by production sectors and countries, and to the profit maximisation behaviour of the representative firms. Four main mechanisms are involved in the assessment of R&D policies to calculate the competitiveness, growth and employment consequences of the policy: (i) ***The crowding in or leverage effect from R&D public funds on R&D expenditures****: the current version of NEMESIS calibrates the leverage effect to be 0.74: ie one euro of extra subsidies generate 0.74 euro of new R&D expenditures. This number is based on past econometric work. (ii)* ***The knowledge spillovers across sectors and countries*** *that describe all the positive externalities induced by an R&D increase to capture the social returns: NEMESIS uses a matrix on technological flows based on PATSTAT patent data. (iii)* ***The improved performance resulting from R&D for each productive sector****: R&D investments in the sector and all the knowledge spillovers from other sectors and other countries flow into the knowledge stock of the sector. An increase in this stock boosts TFP (process innovation) and simultaneously the quality of goods produced, increasing demand (product innovation). The effects on number of jobs are highly dependent on the allocation of R&D expenditures to process innovation and product innovations. Process innovation leads to productivity gains with unfavourable effects on the labour market (at least in the short-term), whereas product innovation leads to product quality improvements which directly favour employment (higher demand for the products). The efficiency of increased knowledge is calibrated on the basis of past econometric work. The knowledge stock depreciates at a constant rate over time. (iv)* ***The intersectoral and macroeconomic feedbacks****: The NEMESIS model is a hybrid combining pure top-down forces, mainly savings and consumption, linked to wages, employment prices and profit, and bottom-up forces that come from the interactions between 30 heterogeneous sectors in terms of dynamics and R&D effort.*

+++

BOX 7: ICT and other intangible investments in the NEMESIS model

The NEMESIS R&D modelling has been updated as part of the SIMPATIC project to broaden the source of innovations beyond the classic R&D investments and their spillovers, to also include investments in ICT, software and training. This allows the general purpose or key enabling technology characteristic of ICT to be properly taken into account. This is an important modification because the volume of investments in these intangibles is greater than R&D investments.

The integration of a multifactor innovation function does not alter the structure of the results obtained with an R&D-only model. The effects from innovation inputs on growth follow four-phase impact pattern described in Box 6 for all innovation inputs, although the short-term negative effects on employment from increased productivity are more pronounced for ICT investments.

More empirical work is needed to be able to calibrate the complementarity between ICT and R&D investments.

Source: SEURICO/ERASME (2014) 'Modification of NEMESIS Technological Innovation Module', *SIMPATIC Working Paper* 13.

+++

Box 8: European Economy reference scenario from NEMESIS

The new improved version of the NEMESIS model provides a scenario describing the performance of the European economy up to 2050. This scenario is used as the reference for innovation policy impact analysis. This reference scenario shows considerable country heterogeneity in exiting the crisis. During the initial crisis period, southern European countries are facing a situation with very high levels of both unemployment and public debt, which requires a long recovery time. The eastern countries show also high levels of unemployment but are less constrained in terms of debt, which allows them to fight unemployment more effectively. Countries from central and north-west Europe succeed in reducing both their public debts and unemployment at the horizon 2050.

It is important to note that past investments in innovative assets are a determinant of the ability to exit the crisis. Investment is increasingly improved after the crisis but in highly indebted countries this improvement takes more time.

The long-term growth of countries on the technological frontier (northern and central European countries) is constrained by their ageing populations. Their growth is based on the increase in human capital and intangible investments. Eastern European countries benefit from a catching-up process. This catching up is driven by an increase in the skill level of human capital and by a strong catching up in ICT and infrastructure investments, not from R&D investments. In southern Europe, growth needs both investment in ICT and complementary intangible investments. In the reference scenario, insufficient investment in R&D and other intangibles impedes growth. These investments are all the more important given that this lack of intangible assets contributed to the weak performance of these countries during the economic crisis. Nevertheless, the model shows that, after the crisis, labour productivity growth overall in the EU will reach again its pre-crisis level only after 2030.

Source: SEURECO/ERASME (2014), SIMPATIC WP D10.3

+++

DG RTD regularly uses NEMESIS to analyse the impact of its policies. For instance, the NEMESIS model was used to assess the impact of the European Commission's Seventh Framework Programme for R&D (FP7) 2013 budget allocation of €8 billion, and the 2014 Horizon 2020 call. Box 9 details the results of this exercise.

BOX 9: EU RTD policy assessment with NEMESIS

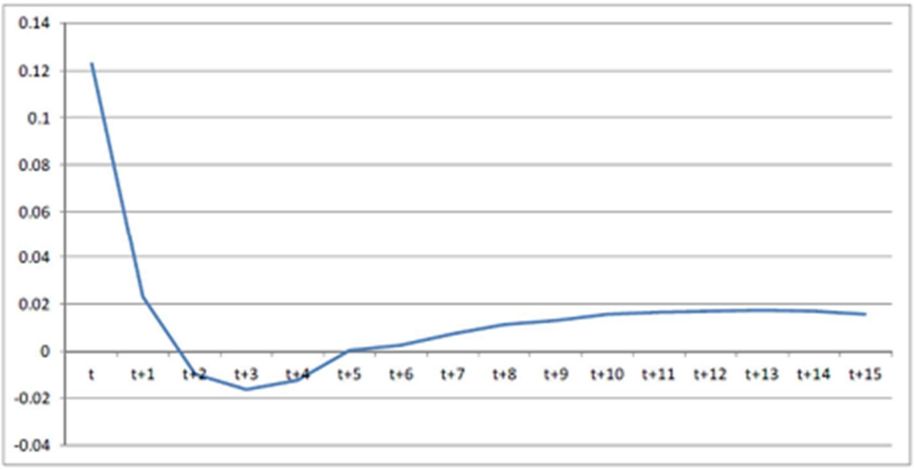
The NEMESIS model has been used to provide an ex-ante assessment of two EU innovation policy scenarios: i) the impact on GDP and employment of the FP7 2013 budget of €8 billion; and ii) the 2014 call for proposals of Horizon 2020. We discuss the first exercise in somewhat more detail to explain the methodology.

A first step to assess the impact of this shock on public R&D expenditures is to assess its impact on overall R&D investment. The allocation of the extra FP7 funding between member states is assumed to be as observed at the beginning of FP7. The allocation of research and innovation funding between economic sectors in each country is based on the 'grandfathering' principle, ie proportionate to the level of R&D expenditure in each sector. This does not necessarily accord with the actual allocation of funds. The exercise furthermore takes as an assumption that the leverage effect of FP7 2013 funded projects is the same as for all other public R&D projects and is the same for all EU countries, an assumption that is unlikely to be justified because of the differences between countries in terms of effects from public R&D funding (see SIMPATIC's micro work). Using the average calibrated leverage effect of 0.74 and the international and intersectoral technology spillover matrix as described in Box 6, yields €13.9 billion of extra R&D from the €8 billion FP7 2013 outlay.

A next step is to estimate with NEMESIS the impact of this extra R&D on GDP and employment. The total cumulative extra GDP estimated from the €8 billion shock amounts to €75 billion after 15 years and €86 billion after 20 years. This would imply a multiplier of around 10 from the extra €8 billion of FP7 funds. The extra jobs estimated in the EU after 15 years is 38,000 jobs each year.

While the effect on GDP and jobs from the extra EU public R&D is substantial, it takes time before the benefits can be enjoyed. The effect is cumulated over time where four phases can be identified. Initially there is only a pure effect of the shock. There is no effect on and from innovation yet. The increase in research equipment investment and research jobs results in higher pay and more consumption. Part of this higher consumption goes into imports, which results in some 'leakage' of the shock. In the second phase, innovation results are realized from the increased R&D in the form of increasing TFP, lower costs and enhanced product quality. But there are not yet positive demand effects, as these take more time to materialise. There is however job destruction from the increased productivity. The third phase is when the positive effects set in from the take-up of the innovation results. Lower prices and higher quality will increase demand and improve competitiveness. Increased profitability will continue to feed further innovations in the endogeneous growth framework employed by NEMESIS. These effects will also diffuse across sectors and countries, through the intersectoral and inter-country technology spillover matrix employed by NEMESIS. This third phase is the phase in which most of the benefits are reaped. There is however also knowledge depreciation, where the value of the innovations spurred by the one-off shock will slowly evaporate, and will be replaced by other newer innovations. In the fourth stage, the depreciation effects start to become more powerful, slowly reducing the positive effect on GDP and jobs of the shock.

Figure B1: Impact on EU employment from the FP7 2013 budget; Simulations from NEMESIS
Employment trends (% gap from central account).



Source: SIMPATIC WP n°10 (SEURECO, FPB and ICCS (2013).

Similar results are obtained for the first Horizon 2020 call. The cumulative wealth from this shock, in terms of GDP after 15 years, is €119 billion. About 49,000 extra jobs will be created each year on average over this 15 year period.

Source: SEURECO/ERASME (2014), SIMPATIC WP 10.3.

+++

Using the NEMESIS model to study the impact of more public R&D investment on GDP growth and jobs in Europe shows that there is potential for a considerable impact, which could reach a multiplier of around 10. But these positive effects will be realised over the long term, with initially the stimulus effects being absorbed in higher wages for researchers and resulting in job destruction from increased labour productivity. The endogeneous growth power of the additional private investments in R&D will only be leveraged into positive competitiveness, growth and job effects in the longer term.

An important consideration for the assessment of these policies is the impact of subsidies on private R&D decisions. In the assessments, the leverage (or crowding-in) effect was based on calibration, where an average of the older literature has been taken. But these inputs are too coarse. As the SIMPATIC micro-analysis has shown, it is important to distinguish possible differences in leverage effects in different countries, and for different types of firms and different types of R&D.

3.3.2. R&D policies assessed in other European Commission macro models

Within the European Commission, other macro-models are also used for policy simulation. Most notable is the QUEST model III, a global dynamic stochastic general equilibrium (DGSE) model employed by the Commission's Directorate-General Economic and Financial Affairs (DG ECFIN). QUEST III is an extension of QUEST incorporating R&D as a semi-endogenous growth component. While early endogenous growth models (Romer, 1990) assume non-decreasing returns of R&D inputs, semi-endogenous growth models allow for decreasing returns of R&D inputs. Annex 1 details the QUEST III model specifications for R&D. A third model used in the European Commission is RHOMOLO, a dynamic general equilibrium model covering the EU at the regional level. It was developed by the Joint Research

Centre (JRC-IPTS) together with the Commission Directorate-General for Regional Policy to assess the impact of the EU's cohesion policy. As yet, it is not an endogeneous growth model[7].

The QUEST III model is used by DG ECFIN to assess concrete policy initiatives and reform proposals for their short and long-run growth and employment impacts. For R&D policies, two types of intervention are looked at: a tax credit for private R&D and a subsidy for wages of researchers in the R&D sector.

Simulations show a characteristic feature of semi-endogenous growth models: subsidies for R&D yield a permanent increase in GDP levels but not in the growth rate of GDP (Roeger *et al*, 2008). Like in the NEMESIS model, the positive effects from public R&D instruments only play out in the long term, with initially negative effects from reallocations of high-skilled employees from production into R&D and job losses associated with improved labour productivity. Important obstacles for leveraging R&D into growth and jobs are entry barriers and market power in the intermediate and final goods sectors.

Overall, the QUEST III model allows less scope for positive effects from public R&D instruments, compared to the NEMESIS model. Despite the semi-endogeneous growth modelling and the national and international spillovers, and the lack of knowledge depreciation in QUEST III, tax credits or wage subsidies for private R&D offer limited growth potential in the QUEST III model. The lower scope for positive effects in the QUEST III model is because of differences in modelling. The QUEST III model has R&D performed in a separate R&D sector which competes with the production sector for high-skilled workers. Furthermore, the results from R&D serve only the intermediary sector, generating process innovations. There is no room for final product innovations. Finally, there are some minor differences in calibrating the impact of R&D, with respect to additionality and spillovers[8].

The lower scope for positive effects in QUEST III holds particularly for the effect on jobs. This is because in the QUEST III model the support for private innovation, with a fixed stock of high-skilled labour, leads to a reallocation of high-skilled workers from the production sector to the R&D sector. A complementary education or immigration policy to increase the stock of high-skilled workers would ease this constraint. Also the presence of market power in the intermediate goods sector using the R&D reduces the efficiency of the R&D policy instrument. The QUEST III model also does not incorporate R&D that would enhance final demand by increasing the quality of final products or new final products. With its focus on process innovations (new varieties of intermediate goods) it ignores the micro-econometric evidence of greater positive effects from final product innovations for employment compared to process innovations (see Box 10).

---

[7] In RHOMOLO, the effects of R&D investments are modelled as TFP shocks. TFP growth is determined through RTDI investment and catching up with other regions. It is assumed that the farther away a region from the technology frontier, the greater the potential for absorption and imitation of technological progress produced elsewhere. This implies that catching up by regions is assumed, that an increase in R&D produces a bigger impact on factor productivity in regions where the level of technology is originally low. In order to simulate RTDI policies, the RTDI investment under cohesion policy is first expressed as an increase in the R&D intensity compared to the baseline and subsequently a TFP equation is estimated to model the increase in TFP resulting from R&D, reflecting that it takes time for an investment in R&D to be turned into innovation and consequently a productivity improvement. RHOMOLO is at time of writing being extended by developing an endogenous R&D module.

[8] QUEST III uses trade-based measures for spillovers, rather than patent-based measures.

Box 10: The impact of innovation on employment: insights from SIMPATIC

> *The empirical literature on the relationship between innovation and employment at the firm level finds that whether the impact of innovation is positive or negative rests primarily on the type of innovation – whether product or process innovation. While the effects of product innovation are typically found to be more positive, process innovations have a stronger displacing, negative effect on employment (Harrison et al, 2008; Hall et al, 2008; Lachenmaier and Rottmann, 2011). SIMPATIC research, using the Harrison et al (2008) approach on four waves of Community Innovation Survey (CIS) data at the industry-country level for the period 2004-10 for 28 EU countries, confirms that product innovation has a consistent positive effect on employment growth. This effect is greater for manufacturing industries than for services. While organisational and marketing innovations also show a consistent positive impact on employment, there is no significant positive effect from process innovations.*
>
> Source: Damijan *et al* (2014) Impact of innovation on employment and skill upgrading of firms, *SIMPATIC Working Paper* 07.

+++

Compared with the NEMESIS endogeneous growth model for RTD, the QUEST III semi-endogeneous growth model for RTD gives less scope for positive effects from RTD policies on growth and jobs in Europe. It is hard to say which of the models is more consistent with the real world. In any case, the calibration of the macro models should follow as closely as possible recent estimates from micro-econometric work, as provided by SIMPATIC, for instance. These calibrated numbers should be as country-specific as possible. Transferring results obtained from other countries is not recommended because of the significant differences between countries in terms of effects from R&D (policies), as shown by SIMPATIC's cross-country analysis.

Beyond the simulation of overall effects on GDP and jobs, the QUEST III simulation results are also highly informative for RTD policies with respect to identifying the structural reforms that can enhance the effectiveness of RTD policies. The results confirm the complementarity of RTD policies in particular with product market reforms and labour market and education reforms. A more competitive intermediate goods sector and a policy to increase the stock of high-skilled workers would increase the efficiency of any R&D policy instrument.

4. The case for government R&D support as part of smart fiscal consolidation: insights from SIMPATIC micro and macro evidence for the R&D policy agenda

The evidence on whether public R&D can be part of smart fiscal consolidation suggests that it can be, though with caveats. Substantial positive effects can be expected from R&D investments: with substantial spillovers, social rates of return can substantially exceed the private rates of return from R&D investments. All this does not yet make the case for public R&D support to redress market failures in R&D. How effective and efficient is public R&D funding (through eg R&D subsidies or tax credits) to bring the optimal investment levels in R&D closer to the socially optimal level of investment? A first important policy issue is the paucity of empirical evidence based on sound evaluation studies with proper counterfactuals on the (relative) effectiveness of different policies. In particular studies with a (quasi-) experimental design to nail down the causality effect of public funding are missing. In any case, general conclusions will be difficult to draw from individual studies, because the effects of a particular programme depend on the specific programme design and management. And even for similarly designed programmes, the SIMPATIC evidence shows a substantial heterogeneity in effects across countries. Effects found for one particular intervention scheme in one country need not occur when exactly the same intervention is carried out in another region or country, on a larger scale, or in another time period. As we still do not understand what causes this heterogeneity, the practice of transferring best practice from one member state to others should be handled with great care until we have a larger set of cross-country comparable evidence.

Nevertheless, the evidence as it stands now suggests that by and large R&D grants and R&D tax credits have scope for positive effects, especially at a coordinated international level, but only if they are targeted towards firms that are impeded from developing R&D projects for which social rates of return substantially exceed private rates of return. That leaves an important challenge for policy to identify and select projects that offer higher social rates of return. Apart from subsidies for basic research and industry-science collaboration, it is not obvious that governments are able or willing to pick the projects with higher social rates of return.

The SIMPATIC evidence seems to point more to a practice whereby the government's selection of projects follows closely the market selection, looking at the private rates of return. Public funding mostly goes to firms that are already spending on R&D. Inducing firms that are already spending on R&D to spend more is costly because these firms are more likely to be in the area in which marginal returns from R&D are diminishing and need to be compensated for substantially to raise their R&D investments further. High public budget costs are a relevant issue for policy making, particularly in times of fiscal consolidation. A more promising target for public R&D programmes would be to entice 'new' firms to engage in innovative projects. But the evidence is not strong that this group is being effectively reached through current standard public R&D programmes.

Another important insight from the SIMPATIC evidence is the low rate of private-firm applications to government public R&D programmes. This low application rate can seriously impede the effectiveness of government programmes, particularly if those firms that might have the projects that offer the highest social rates of return are not applying. The low application rate may be because of the high application costs for firms. In order to attract more applications, public R&D programmes should keep the application procedures as clear, simple and transparent as possible to minimise the application costs. Campaigns to attract more applications should be targeted particularly towards those firms that are likely to produce the type of R&D the government would want to subsidise, ie with the highest social rates of return. But the SIMPATIC evidence also indicates that firms might not be applying because they lack attractive innovative projects that generate high enough private rates of return even when subsidised. Perhaps the most potent policy avenue to get more applications and improve the effectiveness of public R&D programmes is to improve the private rates of return from R&D investments. This calls for complementary policies to address the framework conditions for innovation.

When looking beyond the effects of public R&D interventions on innovation, to evaluate whether they induce economy-wide GDP growth and jobs, we need to turn to macro models. These macro models are also able to identify which complementary framework conditions needs to be in place for higher private and social rates of return from innovation. Unfortunately, few of the macro models applied in policy evaluation explicitly model the R&D growth process. Those that do, treating either R&D as semi-endogenous (like the QUEST III model) or fully endogeneous (like the DEMETER model), show that in order to see the positive effects from public R&D support on GDP growth and jobs, one needs a long-term horizon, before the positive effects fully play out, being able to more than compensate for the short-term negative effects associated with reallocations of high-skilled labour from other productive activities to generate the extra innovations, and the negative effects from displacing older more labour-intensive production processes.

Unfortunately, the available macro-models generate a large interval of predicted long-term effects on GDP growth and jobs, depending on how R&D is modelled and calibrated. Further work on testing the robustness of the results from variations in modelling is needed. Calibrations of the effectiveness of public R&D to instigate innovations should be as country-specific as possible. Transferring results obtained from other countries is hazardous because of the differences between countries in terms of effects from R&D (policies), as shown by SIMPATIC's cross-country analysis.

Where the macro models are as yet underexploited and where they would be a very useful R&D policy instrument, is in assessing which framework conditions need to be in place to improve the impact of public R&D funding instruments, such as grants and tax credits. In particular, the interaction with product market reforms, improving competition, and labour and education reforms, improving the stock of skills, seem to be the most important structural reforms to improve the impact of R&D policy instruments, particularly in southern Europe.

So on the question of whether public R&D can serve in smart fiscal consolidation strategies, the answer can only be a timid yes at this stage. Public R&D certainly has the potential, but we know very little of its actual effects. More proper micro and macro evaluations are still needed. It is clear that effectiveness will vary in different countries, reflecting differences in framework conditions, implying different policy mixes by country. Knowing which framework conditions are important for which countries and hence which structural reforms will be pivotal, is therefore of first-order importance.

The European Commission's 2014 Communication '*Research and innovation as sources of renewed growth"*, rightly pointed out the need for a stronger evidence base in support of the structural reform agenda in European countries. This requires more micro-econometric impact assessment with the proper counterfactual exercises, preferably of the (quasi-)experiment type. This requires also more macro-economic work to improve the modelling of the impact of R&D and to improve the calibration of pivotal parameters with results from state-of-the-art cross-country comparable micro-econometric impact assessments exercise.

References

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

Aghion, P. (2006) 'A primer on innovation and growth', *Bruegel Policy Brief*, issue 2006/06

Belderbos, R. and P. Mohnen (2013) 'Intersectoral and international R&D spillovers', *SIMPATIC Working Paper* N°2

Blanchard, O. and D. Leigh (2013) 'Growth Forecast Errors and Fiscal Multipliers', *International Monetary Fund* Working Paper no. 13/1, Washington DC

Capron, H. and B. van Pottelsberghe de la Potterie (1997)' Public support to business R&D: A survey and some new quantitative evidence', in *Policy Evaluation in Innovation and Technology, Towards best practices*, OECD, Paris

Cincera, M. and R. Veugelers (2014) 'Differences in the rates of return to R&D for European and US Young Leading R&D firms', *Research Policy* 43: 1413-1421

Conte, A. (2006) 'The Evolution of the Literature on Technological Change over time: A Survey' *Max Planck Institute of Economics*, Discussion Paper No. 107

David, P. A., B. H. Hall and A. A. Toole (2000) 'Is public R&D a complement or substitute for private R&D? A review of the econometric evidence', *Research Policy* 29(4): 497-529

Garcia-Quevedo, J. (2004) 'Do public subsidies complement business R&D? A meta-analysis of the econometric evidence', *Kyklos* 57, 1: 87–102

Goolsbee, A. (1998) 'Does government R&D policy mainly benefit scientists and engineers?' *NBER Working Paper* 6532

Griliches, Z. (1958) 'Research cost and social returns: hybrid corn and related innovations', *Journal of Political Economy* 66: 419-431

Harrison, R., J. Jaumandreu, J. Mairesse and B. Peters (2014) 'Does innovation stimulate employment? A firm-level analysis using comparable micro-data from four European countries', *International Journal of Industrial Organization* 35: 29-43

Hall, B.H. and J.V. Reenen (2000) 'How effective are fiscal incentives for R&D? A review of the evidence', *Research Policy* 29: 449–469

Hall, B.H. and J. Mairesse (2009) 'Measuring the returns to R&D', in B.H. Hall and N. Rosenberg (eds) *Handbook of the Economics of Innovation*, vol 2, Elsevier

Jones, C. and J. Williams (1998) 'Measuring the Social Rate of Return to R&D', *Quarterly Journal of Economics*, 113(4): 119-35

Jones, Charles I. (1995) 'R&D-Based Models of Economic Growth', *Journal of Political Economy*, Vol. 103: 759-84

Mansfield, E., J. Rapoport, A. Romeo, S. Wagner and G.Beardsley (1977) 'Social and private rates of return from industrial innovations', *Quarterly Journal of Economics*, 77: 221-240

Mohnen, P. (2013) 'R&D tax incentives', *i4g Policy Brief* 2013 no, 25, European Union, Brussels

OECD (2010) *R&D tax incentives: rationale, design, evaluation*, Paris

OECD (2013) *Science Technology Innovation Scoreboard*, Paris

Romer, Paul M. (1990) 'Endogenous Technological Change' *Journal of Political Economy*, 98(5): S71-S102

Roeger, W., J. Varga and J. in 't Veld (2008) 'Structural Reforms in the EU: A simulation-based analysis using the QUEST model with endogenous growth', *DG ECFIN Economic Papers* 351, European Commission

Roeger, W., J. Varga and J. in 't Veld (2010) 'How to close the productivity gap between the US and Europe. A quantitative assessment using a semi-endogenous growth model', *DG ECFIN Economic Papers* 399, European Commission

SEURECO, FPB and ICCS (2013) 'Reference scenarios with state of the art modelling, NEMESIS and GEM-E3', *SIMPATIC working paper*, no10

SIMPATIC, (2013) *R&D subsidy applications. E-book on i) firm application behaviour; ii) R&D agency decision making; iii) structural modelling*, SIMPATIC e-book

Stare, M. (2013a) 'Services and innovation', *SIMPATIC working paper*, no 1

Stare, M. (2013b) 'Socio-economic dimensions of innovation', *SIMPATIC working paper*, no 5

Tewksbury, J.G., M.S. Crandall and W.E. Crane (1980) 'Measuring the societal benefits of innovation' *Science*, 658-62

Varga, J., W. Roeger and J. in 't Veld (2013) 'Growth effects of Structural Reforms in Southern Europe', *DG ECFIN Economic Papers* 511, European Commission

Wolff, G. B. and V. Reinthaler (2008) 'The effectiveness of subsidies revisited: Accounting for wage and employment effects in business R&D', *Research Policy* 37(8): 1403-1412

Annex 1: The QUEST III model specifications for R&D

The QUEST III 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 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 intermediate sector, following Romer (1990). The QUEST III model includes knowledge externalities. Domestic and international R&D spillovers are calibrated, based on trade data. Foreign R&D stock is calibrated to grow at a constant rate and there is no depreciation of intangible capital. The total factor productivity of R&D and the elasticity of R&D with respect to skilled labour are calibrated (constrained by equations). The stock of high-skilled labour is calibrated in the model and fixed. The research sector competes with intermediate and final producers for high skilled labour. It faces an adjustment cost of hiring.

An increase in tax credits for R&D allows the non-liquidity constrained households to lower the rental rate for intangibles, thereby reducing the fixed costs faced by intermediate goods producers. This translates into a rise in the demand for patents and stimulates R&D. In the short-run, the reallocation of high-skilled labour to R&D reduces final goods production and has a negative impact on growth, but in the long-run, the positive output effects dominate as productivity increases. Due to the supply constraints for high skilled workers, part of the fiscal stimulus is offset by wage increases for these workers.

In Roeger *et al* (2008), two alternative R&D policies are modelled using QUEST III. The first scenario is an *R&D tax credit* of 0.1 percent of GDP to the non-liquidity constrained households on their income from intangible capital. These R&D tax credits are financed in a budgetary neutral manner through an increase in lump-sum taxes to households. The results for the EU show a 0.31 percent increase in GDP in the long run. Important to note is that the positive effects on GDP only start occurring after 10 years, because of the initial short run output losses due to the reallocation of high skilled workers from production to research. For employment, QUEST III generates no significant long-run effect. In the long-run the number of employees in the R&D sector increases by around 4 percent and R&D intensity rises by 0.08 percentage points. About 25 percent of the total increase in R&D spending is due to higher wages in these simulations.

The alternative scenario considered is a *subsidy on the wages of researchers in the R&D sector* of 0.1 percent of GDP. The results show somewhat stronger GDP effects compared to the tax credit case: a 0.44 percent increase in GDP in the long run. Compared to R&D tax credits, this scenario gives more stimulus to the employment of researchers in the long-run: the number of researchers increases by 5.7 percent and R&D intensity rises by 0.12 percentage point. According to these model simulations wage subsidies in the R&D sector are more efficient than R&D tax credits.

In Roeger *et al* (2013), the QUEST III model is used to analyse the effects of various structural reforms in Southern European countries (Italy, Spain, Portugal and Greece). Reforms are modelled as closing the gap of the country with the average of the three best performing countries in the euro area. The use of R&D tax credits yields positive long-run effects on GDP but they are only of minor size. The long-run GDP effects are the largest for Greece and Italy, the countries with the lowest current R&D tax credits, but still are only about 1.4 percent for Greece and 0.9 percent for Italy. For Spain it is even lower: 0.1 percent. In comparison, the structural reforms that yield the most significant results in the long run are education policies that cut the share of low-skilled workers. This gives an increase of 15 percent in GDP for Italy and Spain, an increase in employment with 11 percent for Italy, 10 percent for Spain. For Greece, the highest economic gains are realised from product market reforms. Such reforms leave significant economic gains in the long-term, 39 percent of GDP. Also in Spain product market reforms leave substantial long-run increase in GDP: 16 percent of GDP.