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How to do public R&D spending in times of budgetary austerity

Some insights from SIMPATIC analysis

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SIMPATIC Policy Contribution

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How to do public R&D spending in times of budgetary austerity: some lessons from SIMPATIC analysis

Reinhilde Veugelers

The high debt and deficit burden in some EU countries leaves no choice but to continue the course of fiscal consolidation. At the same time, the growth performance in the EU remains subdued. The dangerous cocktail of high debt and low growth calls for *smart* means of public investment. The search is for public investment that fosters long-term growth while at the same time minimise the potentially negative short-term effect on public finances and economic activity. R&D is an area typically identified as a candidate for smart spending, because of its growth effects. What is the case to be made for public expenditures on R&D? Is this an area of smart spending in times of low growth-weak public deficit?

Identifying R&D spending as an area of smart government spending requires several issues to be cleared. A first question is: does R&D contribute to growth? At present, it is widely acknowledged that innovation is an important force behind long-run economic growth. Particularly the models using an endogeneous growth framework make a strong case for the growth power from R&D and innovation (eg Aghion (2006), Conte (2006)). But this does not yet make the case for public R&D investments. Will public R&D lead to innovation and growth, sufficiently to cover the opportunity costs of using public funds for R&D? To address these questions, we review the evidence and analysis 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 special focus on the latest results from cross-country micro-research performed within SIMPATIC[1]. To analyse the impact from public R&D on growth, we need to take 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 programs.

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

The fundamental justification for government support of research is the classic market failure argument: markets do not provide sufficient incentives for private investment in research owing to 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” which the market would not supply on its own, such as defence, public health, 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”, which include pure knowledge spillovers as well as pecuniary spillovers, that lead to

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[1] SIMPATIC is a Bruegel coordinated FP7 project financed by the EC on impact assessment of RTD policies. More info on the project can be found at www.SIMPATIC.eu. In this contribution, the discussion of SIMPATIC research results is reported in dedicated Boxes which includes the references to the respective SIMPATIC Working Papers, to be found on the SIMPATIC website.

social rates of return above private rates of return, and private investment levels chosen below the socially optimal levels. This divergence between social and private rates of return, calls for government intervention to stimulate private R&D investment to the higher socially optimal level[2].

Beyond the spillover case, another market failure follows from the highly risky and uncertain nature of the outcomes of R&D. This uncertainty coupled with asymmetries in information between capital markets and R&D investors causes financial market imperfections, impeding access to finance for risky innovation projects. This will hold particularly for small young risky innovators.

These specific characteristics of R&D which give rise to market failures and call for government intervention vary for different types of R&D. The more basic, early stage the R&D, the more non-proprietary and the higher the scope for spillovers. In addition, basic research usually has a much more uncertain and unpredictable spectrum of applicability, acerbating the financial market imperfections. Moreover, the time lag between research and innovation may be extremely long. As the risks associated to basic research as well as the potentials for positive spillovers are usually higher, basic early stage R&D investments are a much bigger candidate for market failure and thus government support, compared to the more applied R&D which can be kept more proprietary. As a consequence, basic research is often carried out in publicly funded institutions, such as universities.

In sum, the wide scope for market failure in the case of R&D investments for growth, makes a theoretical case for government intervention. Important to note is that the aim of the government intervention is to bring the private R&D investments to the higher socially optimal investment levels.

In crisis times, there is the extra case for public spending to operate counter-cyclically. How apt are public R&D interventions as counter-cyclical tool? A specific characteristic from investments in R&D is that these are longer-term investments, requiring specific know-how that take time to develop. This explains why R&D investments are less procyclical than other firm investments, at least for non-credit constrained firms (Aghion et al (2005)). Attracting and training researchers in developing specific complex know how is a long term endeavour. A temporary on-off type of R&D policy support would not have an impact on the longer-term R&D strategies of the private sector and is more likely to influence already decided upon R&D projects. Hence on-off support for R&D as part of a temporary stimulus package is likely to have lower additionality and will be more likely to be absorbed in higher wages for the stock of existing researchers (E.g. Wolff et al (2008)). At the same time as temporary increases are suboptimal, temporary cuts may have long lasting negative effects when R&D staff with accumulated specific expertise needs to be laid off. Any negative effects from cuts in R&D policy support cannot be easily reversed by later increases in R&D policy support. In sum, public R&D budgets are a poor cyclical policy tool. It should be long-term consistent.

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[2] Note that the case of 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 on reducing the private R&D investments.

2. The evidence on the gap between private and social rates of return;

2.1. The evidence on private rates of return.

The rate of return to R&D for a private investor is not an invariant parameter, but the outcome of a complex system of interactions between the private investor and his environment. It follows that the private rates of return are bound to vary across firms, industries and countries and over time.

Several empirical studies tried to assess the private rate of return to R&D using data at the plant, firm, industry or country level. Hall, Mairesse & Mohnen (2009) summarizes their results. First, the rate of return in developed countries has been strongly positive in the past 50 years, with the estimated private rate of return to R&D usually exceeding that of physical capital. Most studies obtain rates of return within the range of 10%–30%. Second, the rate of return to R&D is not a constant parameter, but varies across countries. Unfortunately, there is too much heterogeneity in the methodologies being used, to pin down the sources of these country differences. Cincera & Veugelers (2014) estimate rates of return for the set of large world leading R&D spending firms and find significant higher rates of return for US firms compared to EU, and for young firms compared to old firms in the US, but not in Europe.

2.2. The evidence on social rates of return.

The motivation for public intervention lies in the social rates of return to R&D investments in excess to the private returns. Like for private rates of return, the social rates of return, are likely to vary over countries, depending on the distributional capacity of innovation systems, capitalizing on "spillovers". Unfortunately, estimates of social rates of return using large scale econometric analysis are scare. Most of the available empirical evidence comes from selected cases, which could involve a selection bias towards more favourable cases. By and large, this empirical literature finds that the social or economy-wide returns to R&D are usually much higher than the private returns to individual firms (Hall, Mairesse & 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% against a median private rate of return of about 25%. Analogously, Tewksbury et al. (1980) looking at 20 innovations, found a social rate of return of 99% against a private rate of return of 27%. Griliches (1958) found that the social rate of return to research in hybrid corn between 1910 and 1955 was between 35% and 40%. Jones and Williams (1998) argue that even conservative estimates of R&D spillovers (i.e. the discrepancy between social and private returns to R&D) suggest that optimal R&D investment in the US is at least four times the actual investment.

2.3. The evidence on spillovers

The divergence between social and private R&D is caused by knowledge spilling over; There are various ways in which knowledge is embodied and transferred. Hence knowledge spillovers are associated with researcher mobility as well as flows of goods, services and investment. Belderbos and Mohnen (2013) review the various methodologies for measuring spillovers and the evidence (see Box 1). A challenge is the variety of potential transmission channels, all of which bring with them problems of measurements. This calls for spillover matrices that are sufficiently broad to capture correlated effects. 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

One of the challenges for assessing the country- and Europe-wide productivity and growth effects of R&D investments and R&D multipliers is to include estimates of intra-industry, inter-industry and international 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 & Mohnen, Intersectoral and international R&D spillovers, SIMPATIC Working Paper N°2, 2013.

Particularly in the area of green/clean innovations, the diffusion of clean ideas is important for a green growth agenda. Market mechanisms alone cannot provide the socially optimal amount of "green" innovations because of the well-known combination of environmental and knowledge externalities. The optimal level of subsidies for clean R&D required to address these externalities crucially depends on the magnitude of knowledge spillovers from clean technologies, relatively 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 find significantly higher spillovers for the former (Box 2). This has important implications for climate change policies. It suggests that carbon pricing should be complemented with specific support for clean innovation that goes beyond standard policies in place to internalize knowledge externalities, e.g. through dedicated R&D subsidies. Radically new 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 is used including over one million patented inventions, clearly distinguishing between clean and dirty inventions in the areas of energy production, automobiles, fuel and lighting. The dataset also includes three million citations to these patents which is used to assess knowledge spillovers.

All other things being equal, clean patented inventions receive 43% more citations (between 23% and 160%, depending on the technology) than dirty inventions. These results hold for all four technological fields and are robust to a large number of sensitivity tests. Interestingly, the gap between clean and dirty technologies has been constantly increasing during the past 50 years. Furthermore, there are also innovations that make dirty technology less dirty by improving their efficiency –so-called grey technologies. While clean technologies exhibit significantly higher levels of spillovers than these grey technologies, the latter do outperform truly dirty technologies with respect to spillovers.

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

3. Government support for R&D

The evidence on social returns well in excess of private returns and spillovers would justify public intervention to redress the market failure. This however does not yet make the case for public R&D efforts. For this, the potential benefits of government intervention, should be compared to the opportunity costs, in the form of higher taxes, higher debt and/or less government spending on other items. In addition, they also require an analysis of potential government failure, ie ineffectiveness of raising the private R&D to the socially optimal level.

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

There are several reasons why R&D policy interventions may not be effective. First, public funded R&D may directly substitute for private funding of R&D projects that would have been undertaken anyway in the absence of this public funded R&D. Second, government R&D may crowd out private R&D indirectly by increasing the demand of R&D inputs, leading to higher costs of research inputs, and hence, a lower rate of return for private investments. This crowding out effect will be more significant the more inelastic the supply of research inputs. This holds particularly for labour supply, as the stock of R&D workers is in the short run, more or less given. As the majority of R&D spending is salary payments for R&D workers, this effect may turn out to be major, as argued by Goolsbee (1998). Goolsbee states that, because of this wage effect, conventional estimates of the effectiveness of R&D policy may be 30 to 50% too high. Wolff and Reinthaler (2008) find on 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%, which is consistent with subsidies raising scientists' wages. The effect is stronger in the short run, when the increase in expenditure is 60% 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 wrong projects.

3.2. Evidence on 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. What do we know from the evidence on effectiveness of public intervention? Most of the available evaluation studies of R&D programs have not been based on microeconomic techniques, but instead on qualitative case studies, interviews and surveys. These studies are not likely to be representative, suffering from a bias in favour of more successful programs, being submitted to serious evaluation. Furthermore, all of the evaluation studies grapple with the challenge to find a proper counterfactual to compare results with. Evaluation studies based on controlled or natural experiments are scarce. In the remainder we will discuss the evidence coming from economic analysis on time series and cross section data at various levels of aggregation (firm, industry, country).

Beyond policies directed at shaping the framework conditions for R&D (e.g. education policy, competition policy, regulation, labour market policy, financial sector policy, IPR regime), public funding in support of R&D can take several types, of which the most important ones are:

- Funding of R&D performed at public institutes (e.g. public research laboratories; public university research, research at publicly funded universities);
- Public funding of private-performed R&D (e.g. public grants to private firms, government procurement contracts, loans);
- Fiscal incentives to private-performed R&D (i.e. R&D tax credits);

R&D subsidies are typically considered to be the main policy tool for RTD policies. They are one of the largest and fastest growing forms of industrial aid in developed countries. Innovation policy in industrialised as well as developing countries has also seen a rise in the use of R&D tax credits.

3.2.1. Publicly funded Universities and Research Organisations

Research carried out in public research laboratories and in universities is most often pure basic research, still far from application to commercial applications. It still needs applied research and development typically done by private firms. Conditional on effectively bridging these two worlds, public research may lower the costs and uncertainty of private applied research, by helping firms to understand the technological opportunities that are available and building further on the insights from basic research.

The returns to academic research require a longer term perspective. The effects, if any, are likely to be indirect, hinging on the complementarity between public research and applied research in the business sector. Complementarity effects require an effective linking between the public and the private sector actors and a well performing private sector, able to take up public R&D in their applied R&D. Perhaps the most important contribution of public research institutes and particularly universities in this respect is through their formation and training of researchers that subsequently move to industry, building a bridge, forming the absorptive capacity in the private sector to improve the efficiency of private R&D through their links with public R&D.

Although it is hard to precisely quantify the contribution of public science to industrial innovativeness and growth (Martin and Tang 2007), scholars have consistently found evidence of a positive effect of public research on economic growth.

Mansfield (1991) found that approximately 10% of innovations could not have happened, at least without a significant delay, without the previous academic research. He estimated the social rate of return from academic research to be 28%. The same author (Mansfield 1998) also found that the importance of academic research for industrial innovation was increasing through time: the proportion of innovations that depended on the results of basic research was growing and the time lag from basic research to innovation was decreasing. Studying the pharmaceutical industry, Toole (2008) estimated that a 10% increase in public investment in basic research ultimately leads to a 6.4% increase in the number of new drugs on the market.

3.2.2. R&D tax credits

R&D tax credits are conceived to help financing private R&D projects and thus generate the socially optimal amount of R&D. A big virtue of R&D tax credits relative to R&D subsidies is that it lets the firms choose the projects and lets it foot part of the bill. It is also a more predictable, reliable scheme, as all firms qualifying for the criteria, can use it, thus economizing on bureaucratic decision making. A wide variety of R&D tax credit schemes abound, ranging from volume based to increment based, for R&D employment costs only, tax credits vs tax allowances etc.(OECD 2010). Although mostly hailed for its generality, tax credits can be specifically targeted towards sectors, firms (like 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 so-called tax price elasticity: 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. 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.” The tax price elasticity is somewhat higher for incremental than for level based R&D schemes. The power 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 directing towards low additionality is the bias in favour of large persistent R&D firms, even if small firms are often given higher rates of R&D tax credits (Mohnen (2013)). Big firms have a higher incentive to apply for R&D tax credits. Unless tax credit rates are much more generous for SMEs or that 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 in view of the too high fixed cost of applying, lacking information and experience. This is particularly unfortunate, not only because small firms have a higher tax elasticity than large firms, but also because these firms are also more likely to face financial constraints. In this respect, the R&D tax credit being too general, misses its objective of alleviating the financial market failure. To reach this objective, a more targeted R&D tax credit approach is needed, with more generous tax credits to firms facing financial constraints such as small, starting, and first-time-R&D-performing firms.

It is actually not enough to look at the additionality of tax money spent on R&D support in terms of R&D expenditure. A full cost-benefit analysis would also need to look at administration and

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[3] A first exercise to do when evaluating R&D credits is assessing 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 incentives scheme is estimated at 0.1 in the short run and 0.13 in the long run.

compliance costs, the marginal excess burden of taxation. And it also requires assessing the social rates of return, the ultimate target of policy intervention. It might still make economic sense to have a policy where the additional private R&D is totally supported by the government, as long as there is a high social rate of return. Unfortunately, little assessment of the social returns to tax credit schemes is done. In view of the high heterogeneity in social rates of return (as discussed supra), the neutral tax credit system is not likely to favor projects with higher social returns. For this, again a more tailored policy would be needed identifying areas with high social rates of return. A potential candidate would be tax credits for firms engaged in R&D collaboration for more basic R&D projects with universities or public research institutes.

3.2.3. *Subsidies to private R&D*

A growing body of econometric work has been produced, evaluating 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 & 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 incorporating the preferences of the firms as well as government agencies to allocate subsidies, thus correcting for the methodological problems characterizing previous studies. SIMPATIC does this on a comparable cross-country basis (currently for 5 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 with the traditional methods. First, incorporating insights from behavioural economics, it produces information on the preferences of firms and governments. Second, it allows the study of counterfactual policy questions. Counterfactual analyses concentrate on comparing the efficiency and distributional effects of R&D tax credits and R&D subsidies, analysing how behaviour of firms and agents and outcomes change if a country adopted a specific R&D policy. Third, the structural approach facilitates discovering 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 to estimate 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, SIMPATIC e-book.

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 programs for firms in the various countries studied, although quite similar in set-up[5]*, have nevertheless different features, introducing already one dimension of country heterogeneity. For instance, while most governments provide subsidies both through thematic programs and through unsolicited applications, the Netherlands only has targeted programs.*

The first important finding, common to all the 5 countries, is that a very small fraction of firms applies for subsidies. This is true not only of the whole firm population, but also 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 per cent or lower. This underemphasized empirical regularity is the single biggest obstacle for R&D subsidies to have an effect on the scale that they could have. This finding urges to understand better the decision of why firms (not) apply for subsidies.

SIMPATIC analysis further finds that there is considerable heterogeneity in 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.

When looking at the decision by the government agencies whether or not to grant a subsidy and with which subsidy rate, SIMPATIC again finds a high heterogeneity across firms. SMEs seem to be granted subsidies that are five percentage points higher in Germany and seven percentage points higher in the Netherlands. In the other countries there is no significant higher subsidy rate for SMEs. These are unexpected results, showing much smaller differences in the actual SME favorable treatment than compared with the announced benefit.

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

Furthermore, in Germany, governmental agencies grant three percentage points higher subsidies to firms from disadvantaged regions. On the contrary, in Spain, they grant ten percentage points lower subsidies to firms in these areas.

Overall, the firm characteristics included in the analysis (age, size, SME status, productivity) have no big impact on the subsidy rate decisions of the government agency. But perhaps they also should not. What should matter most for the subsidy rate is the quality of the project identifying the divergence between social and private rates of return of the project. All of the countries studied use grading systems of 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 where the social rates of return to R&D are the highest. SIMPATIC finds for Finland, where information on grading was available for the researchers, that these grades are indeed significantly correlated with the subsidy rate.

On the additionality effect, ie how subsidies affect the firm's decision to invest in R&D, i.e. whether subsidies crowd in or out private R&D investments, the results show again a large 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, SIMPATIC e-book.

BOX 5: Results from SIMPATIC's structural modelling

The benefits of estimating a structural model is that one can uncover information which is typically hard to assess by researchers. Three dimensions 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 who end up doing R&D have very high perceived costs of applying for subsidies.*
- *A comparison across countries suggest large 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 to identify welfare (social value), as revealed by the government agencies' choice to fund which projects at with rate. Welfare is the sum of profits, spillovers and the government cost of support to 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 as to maximize these social values.

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

Social returns (Welfare) relative to Private returns (Profits)

BELGIUM	*1,22*
FINLAND	*1,11*
GERMANY	*1,21*

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 credit. Following results are obtained:

- *Compared to laissez-faire, current policies yield large gains in R&D among firms who would do R&D anyways, 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: less than 1% for Finland and Germany; almost 1% for Belgium/Flanders.*
    - *Firms that would invest in R&D even without current policies already spend so much that the marginal returns to 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 are in enticing new firms to start investing in R&D, but this is where policies fail.*
- *Optimal R&D policies would require large public investments to induce the private sector to spend the required higher investment levels. Also optimal R&D tax credits should be high and would imply large budgetary costs. These large budgetary costs may constrain governments from reaching full social 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: 2% in Finland, 3% in Belgium/Flanders and 4% in Germany.*
- *Because an R&D grant system allows to target better 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 among firms, leaving 1,6% higher welfare in Finland, 2.3% higher welfare in Belgium and 2,5% higher welfare in Belgium.*

The counterfactual of an EU agency is also considered. Assuming that national agencies ignore 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). As 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, SIMPATIC e-book.

An important results from the cross-country analysis is the large heterogeneity in characteristics of programs, firms, their ideas and their environment and the consequent large heterogeneity in effects of R&D subsidies program. Thus, copying policies without adapting them to local circumstances is likely to be a bad idea.

Another important and robust SIMPATIC result is that public R&D programs are impeded in their effectiveness by low application rate. 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

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[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 induced by higher subsidy rates. But these welfare gains are at the European level. If the Belgian tax payer 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 optimizing on international spillovers, this also requires an EU wide financing of such coordinated policy making.*

begin with. The most obvious but in no way simple way to improve the effectiveness of public R&D programs is therefore to help firms to get R&D projects with higher returns. This calls for other policies than R&D support, namely policies targeting for instance at improving access to markets, skills and knowledge access, also ensuring intellectual property protection. In order for R&D subsidies to have a larger effect on the economy, governments should redesign their schemes so as 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 subsidize, i.e. with the highest social rates of return, if these are not likely to apply on their own.

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 GDP growth and jobs. This requires also taking into account higher order effects, such as impact on demand, wages, interest rates, prices. To capture these higher order effects, we need to resort to macro models. Early macro models either had no explicit treatment of investment in knowledge capital differently from other capital investments or they treated R&D exogeneously and modelled public R&D policies as TFP shocks (eg Worldscan). These early macro-models lacked details on the process of 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). In the remainder we will look at macro-models presently in use at the European Commission for quantitative policy analysis, all of them endogeneous growth models, more particularly the model used by EC-DG Research & Innovation to assess the impact of its R&D policies: the NEMESIS model. Further development of the NEMESIS model is part of the SIMPATIC work programme.

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

The NEMESIS model has regularly been used by EC-DG for Research and Innovation for the assessment of innovation policies on competitiveness, growth and employment in Europe. The NEMESIS model is an econometric model, treating R&D endogeneously and adapted for multi-sectoral and cross-country analysis of innovation. Box 5 details how R&D is modelled in NEMESIS.

Box 6: The NEMESIS model specifications for R&D

The NEMESIS model includes endogenous technical change mechanisms, which link innovations realized by sectors to knowledge accumulation and diffusion between production sectors and countries, and to the profit maximization 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 coming from other sectors and other countries flow into the knowledge stock of the sector. An increase in this stock boosts Total Factor Productivity (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 those allocated to product innovations. Process innovation leads to productivity gains with unfavorable effects on the labor market (at least in the short-term), whereas product innovation leads to quality product improvements which directly favor employment (higher demand for the products). The efficiency of increased knowledge is calibrated on past econometric work. The knowledge stock depreciates at a constant rate over time. (iv) ***The intersectoral and macroeconomic feedbacks*** :The NEMESIS model is 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 R&D modelling of NEMESIS 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 to properly take into account the General Purpose or Key Enabling Technology characteristic of ICT. This is an important modification as the volume of investments in these intangibles is orders of magnitude larger 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 the supra described 4 phase impact pattern for all innovation inputs, be it that the short term negative effects on employment from increased productivity is more pronounced for ICT investments.

The support to different innovation inputs may have different impact in the long-run, depending on the degree of complementarity between the innovation inputs. The more innovation inputs are complementary, the more support for ICT investment impacts long term economic performance compared to the other innovation inputs. But 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: Reference scenario of the European Economy from NEMESIS

The new improved version of the NEMESIS model provides a scenario describing the European economies performance up to 2050. This scenario is used as the reference for any innovation policy 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 both very high levels of unemployment and of public debt, which requires a long recovery time. The Eastern countries show also high levels of unemployment but with less debt constraints, 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.

Important to note is 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 ageing demography. 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 the Southern Europe, growth needs both investments in ICT and complementary intangible investments. In the reference scenario, insufficient investments in R&D and other intangibles impede growth. These investments are all the more important given that this lack of intangible assets increased their weakness during the economic crisis. Nevertheless, the model shows that, after the crisis, labour productivity growth overall in the EU reaches 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 FP7 2013 budget allocation of Euro 8 billion and the 2014 call for Horizon 2020. Box 9 details the results of this exercise.

BOX 9: EU RTD policy assessment with NEMESIS

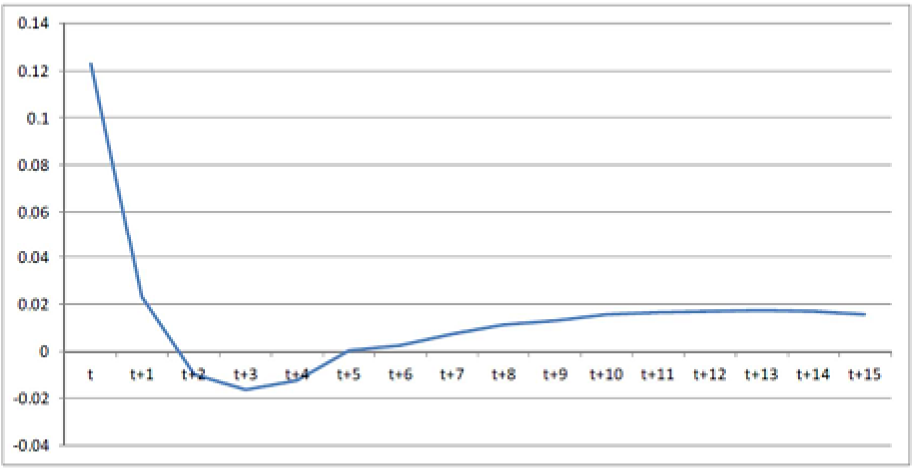
The NEMESIS model has been used to provide an ex ante-assessment of two EU innovation policy scenarios i) the impact on GDP and employment of the FP7 2013 budget of € 8 billion; and ii) the 2014 call for proposals of Horizon 2020. We discuss the first exercise in somewhat more detail to explain the methodology.

A first step to assess the impact of this shock in public R&D expenditures is to assess its impact on overall R&D investments. The allocation of the extra FP7 funding between Member States is assumed to be as observed at the beginning of the FP7. The allocation of research and innovation funding between economic sectors in each country is based on the 'grandfathering' principle, i.e. proportionate to the level of R&D expenditure in each sector. This does not necessarily accord with the actual funds allocation. The exercise furthermore takes as 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 likely to be violated, in view of the heterogeneity across countries in effects from public R&D funding, cf 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 Euro 8 billion of FP7-2013.

A next step in the analysis is to estimate with NEMESIS the impact of this extra R&D on GDP and employment. The total cumulative extra GDP estimated from the Euro 8 billion shock amounts to Euro 75 billion after 15 years, 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 patience to enjoy it. The effect is cumulated over time where 4 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 materialize. 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 where 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, being replaced by other newer innovations. In a fourth stage this depreciation effects start to become more powerful, slowly dying out the positive effect on GDP and jobs of the shock.

Figure B. 1: 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 euro. 49.000 extra jobs are created each year in average in 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 for GDP growth and jobs in Europe, shows the potential for a considerable impact, which could reach a multiplier of around 10. But these positive effects require a long time to realize, with initially the stimulus effects being absorbed in higher wages for researchers and resulting in job destructions from increased labour productivity. Only in the longer term, the endogeneous growth power of the additional private investments in R&D are leveraged into positive competitiveness, growth and job effects.

An important point 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 across countries, types of firms and for different types of R&D. The R&D module of NEMESIS will be modified, taking on board the inputs from SIMPATIC's micro works (cf supra).

3.3.2. R&D policies assessed in other EC macro-models

Within the European Commission there are other macro-models at use for policy simulation. Most notable is the QUEST model III, a global Dynamic Stochastic General Equilibrium (DGSE) model employed by EC Directorate-General Economic and Financial Affairs. QUEST III is an extension of

QUEST incorporating R&D as an 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 at the European Commission is *RHOMOLO*, a Dynamic General Equilibrium model covering the EU at the regional level. It is developed by the Joint Research Centre (JRC-IPTS) together with DG REGIO 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 as a tool to assess concrete policy initiatives and reform proposals on their short and long run growth and employment impacts. For R&D policies, two types of interventions are looked at: a tax credit to private R&D and a subsidy on 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. An important obstacle for leveraging R&D into growth and jobs are the entry barriers and market power in the intermediate and final goods sectors.

Overall, the QUEST III model generates 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, tax credits or wage subsidies to private R&D offer limited growth potentials 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 a production sector for high skilled talents. Furthermore, the results from R&D serves 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 hold particularly for the effect on jobs. This is because in the QUEST III model the support to 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

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[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 currently being extended by developing an endogenous R&D module.

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

using the R&D lowers the efficiency of the R&D policy instrument. The QUESTIII 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 larger positive effects from final product innovations for employment compared to process innovations (see Box 10)

Box 10: 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, being product or process innovations. While the effects of product innovations are typically found to have more positive effects, while 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 2004-2010 for 28 EU countries, confirms that product innovation has a consistent positive effect on employment growth. This effect is larger for manufacturing industries compared to services. While organizational 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 endogeneous growth model for RTD in NEMESIS, the semi-endogeneous growth model for RTD in QUEST III gives less scope for positive effects from RTD policies on growth and jobs in Europe. It is hard to say which of the models are 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 for instance SIMPATIC. These calibrated numbers should be as country specific as possible. Transferring results obtained from other countries is not recommended in view of the important heterogeneity across countries in effects from R&D (policies) 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 which can enhance the effectiveness of RTD policies. The results confirm the complementarity of RTD policies with particularly product market reforms and labour market & education reforms. A more competitive intermediate goods sector and a policy increasing 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

Reviewing the evidence on whether public R&D can be part of smart fiscal consolidation leaves a positive answer 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. Although these spillover can potentially be substantial, including international spillovers, they cannot be taken for granted and require that these projects are embedded in an innovation system that has a strong distributional power.

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 investments? A first important policy issue to deal with is the paucity of empirical evidence on the (relative) effectiveness of different policies based on sound evaluation studies with proper counterfactuals. Particularly missing are studies with a (quasi-) experimental design to nail down the causality effect of public funding. In any case, general conclusions will be difficult to draw from individual studies, as the effects of a particular program depend on the specific program design and management. And even for similarly designed programs, 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 in effects across countries, the practice of transferring best practice from one Member State to others should be handled with great care at this stage.

Nevertheless, the evidence as it stands now suggests that by and large R&D grants and R&D tax credits have the scope for positive effects, especially at a coordinated international level, but only if they are targeted towards firms that are impeded to develop R&D projects where social rates of return are substantially exceeding private rates of return. Interventions that are not targeted enough, like general R&D tax credits, tend to have lower effectiveness. But also for R&D grants or targeted R&D tax credits, the identification and selection of projects of higher social rates of return remains a substantial challenge. Apart from subsidies for basic research efforts 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 where the government's selection follows closely the market selection, looking at private rates of return. Public funding mostly goes to firms which are already spending on R&D. Inducing firms that are already spending on R&D to spend more, is public budgetary costly as these firms are more likely to be in the area where marginal returns to R&D are diminishing and need to be compensated 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 programs would be to entice 'new' firms to engage in innovative projects. But the evidence is not supportive that this group is being effectively reached in current standard public R&D programs.

Another important insight from the SIMPATIC evidence is the low rate with which private firms apply to government public R&D programs. This low attrition rate may seriously impede the effectiveness of government programs, particularly if those firms which may have the projects that have the highest social rates of return are not applying. The low application rate may be due to the high application costs for firms, but the evidence also indicates that firms may not be applying because they are lacking attractive innovative projects that generate high enough private rates of return even when subsidized. In order to attract more applications, public R&D programs should keep the application procedures as clear and transparent as possible to minimize 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 subsidize, i.e. with the highest social rates of return. Perhaps the most important insight from the SIMPATIC evidence is that perhaps the most potent policy avenue to get more applications and improve the effectiveness of public R&D programs is to help firms to get R&D projects with higher private returns. This calls for complementary policies addressing the framework conditions for innovation.

When looking beyond the effects of public R&D interventions on innovation, to evaluate whether they induce 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, there are few macro-models applied in policy evaluation that have an explicit modelling of the R&D growth process. Those that do, treating either R&D as semi-endogenous (like the QUESTIII 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 within these models and calibrated. Further work on testing the robustness of the results from variations in modelling is needed. Calibrations on the effectiveness of public R&D to instigate innovations should be as country specific as possible. Transferring results obtained from other countries is hazardous in view of the important heterogeneity across countries in effects from R&D (policies) 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. Particularly 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 policy instruments, particularly in Southern Europe.

So on the question 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 across 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 Communication '*Research and innovation as sources of renewed growth*' of last November 2014, 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, improving the modelling of the impact of R&D and the calibrating with parameter values for effects from R&D policies that come from state-of-the-art micro-econometric impact assessments exercise.

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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 wrt 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% 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% 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 LR 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% for Greece and 0.9% for Italy. For Spain it is even lower: 0.1%. In comparison, the structural reforms that yield the most significant results in the long run are education policies decreasing the share of low skilled workers. This gives an increase of 15% in GDP for Italy and Spain, an increase in employment with 11% for Italy, 10% 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% of GDP. Also in Spain product market reforms leave substantial LR increase in GDP: 16% of GDP.