On the economic effects of research and development

– Executive summary

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“There is nothing a government hates more than being well-informed; for it makes the process of arriving at decisions much more complicated and difficult.”

– John Maynard Keynes

The report is commissioned by the Ministry of Higher Education and Science.

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Introduction

It is important for a government to be well informed when it comes to prioritizing limited resources. For example, what is the best way to subsidize private research and development (R&D)? What is the effect of research-based education? Good decision-making is based on evidence, but it is unusual for policy questions to be informed by a single study. Solving complex real-life issues typically requires a huge volume of published research. This literature review summarizes the most recent high-quality research on the effect of public R&D investment and R&D policies on firm performance to help in decision-making and focus future research policies.

The private sector plays an important role in the discovery and diffusion of new knowledge and technologies. R&D and innovation create a competitive advantage; however, due to the risky and uncertain nature of R&D projects and the public good characteristics of knowledge, firms tend to underinvest in R&D activities (Arrow, 1962; Nelson, 1959), because the private returns to R&D are below the social ones.

Governments therefore seek to correct for this market failure by balancing the public and private returns of R&D via subsidies, public research and other policy measures. These measures may lead to free-riding behavior on the part of the corporate sector; government subsidies may, however, also increase private R&D, if public and private R&D are complementary rather than substitutes. Our review covers the most commonly applied policy measures to promote research and innovative activity: university research and education, technology transfer, R&D collaboration, tax subsidies, and direct R&D subsidies. We also review the latest literature on the private and social returns of private investment in R&D. Most policy measures have been well analyzed in previous work, which forms the fundament of our present analysis. We complement that work with the most recent studies and, in particular, review papers dealing with Denmark.

Even though the literature on the relationship between R&D policy measures and R&D outcomes is vast, most studies measure correlations rather than causal effects. The existing evidence does generally suggest positive relationships between corporate R&D and the set of policy measures at governments' disposal. Apart from the need for better identification strategies, possibly through field experiments (List and Rasul, 2011), researchers would need to have more comprehensive data on the entire set of national and international policy measures. This would make it possible to analyze the efficacy of individual policy measures and investigate possible additionalities between R&D support programs.

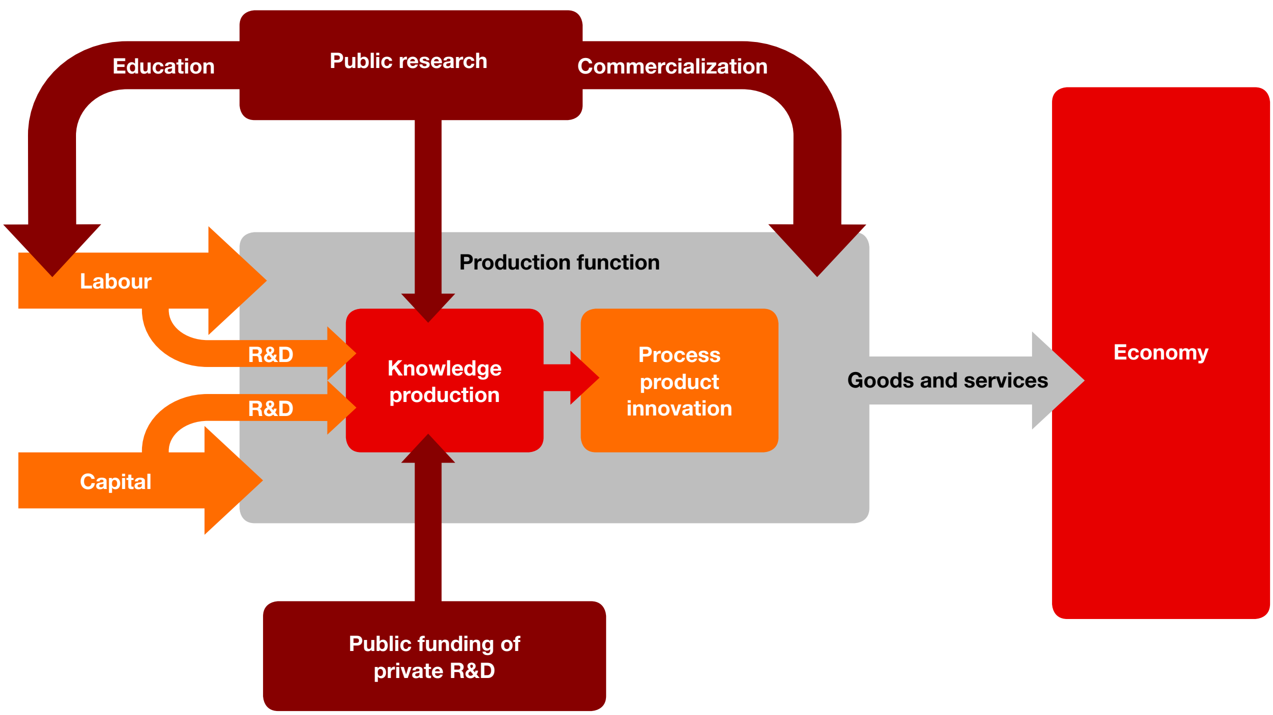
Our review focuses mainly on the short-run economic effect of R&D investment because, in fact, there is not much research on the long-run economic effects of R&D policies. The sparse literature on long-run effects arrives at very large effects, in particular for technology adoption. Due to the complexity of general equilibrium effects that would also take into account changes in competitive advantage (Acemoglu et al., 2013), we focus on partial equilibrium models.

Overview of the review

Our review falls into four core chapters: the effects of private R&D on firm performance and economic growth; public funding of R&D investment; public research education and the R&D labor market; and the effect of knowledge transfers on firms. Figure 1 shows how these four elements relate to one another.

FIGURE 1.

A simple model of R&D investment



The cornerstone of the figure is the knowledge production function of private firms. Chapter three of our review deals with the private incentives to invest in R&D and knowledge spillovers to other firms.

The remaining three chapters deal with the environment outside of the private-sector R&D box and primarily study the role of the public sector. In chapter four, we review the effect of direct public funding for private R&D investment, specifically discussing direct subsidies and tax incentives. In chapter five, we analyze the role of public research as a knowledge supplier and producer of skilled labor. Our sixth chapter is concerned with knowledge transfer between the public and private sector, like commercialization of research or collaboration between public research and private research.

We have covered the most important channels from R&D investment to the market economy in the review. However, there remain a few other channels that we do not cover. First, we have not touched upon innovation that is directly not related to R&D, like organizational and marketing innovations. Research-based education, in particular in the social sciences and humanities, is important for these types of innovation. Second, we do not deal with rent spillovers, which occur when firms purchase products with embodied R&D and where the product price may not fully cover the value of the product. This channel seems to be important in the long run, when new technologies are adopted. Third, public research does not only benefit the economy indirectly through the private sector, e.g., research on health and health-related questions improve the hospitals' treatment of diseases and improve longevity; this could increase the labor supply and improve the economy.

Results

Summary table 1 summarizes the main findings. Most of the investigated policy measures positively affect the economy. It is not possible to present a number or range of numbers due to the substantial heterogeneity between the studies. This also means it is impossible to compare the size of the effect across the different measures. The evidence is strongest for R&D subsidies and R&D taxes, which is due to the larger number of studies with good quality and clear transmission paths, compared to the other policy measures.

We also summarize the results for private and social returns on private R&D investment. We find, in line with other reviews, that the private rate of return is high, reflecting a substantial risk premium. Knowledge spillovers are positive, which means that the social rate of return is higher than the private rate of return.

The evidence in the table is likely to hold for Denmark because we focus mostly on economies that are broadly similar to the Danish. Moreover, studies exist for Denmark on all policy measures with the exception of R&D taxes.

SUMMARY TABLE 1.

Effect of policy measures and R&D investment on the economy and the level of evidence

Note: As no general agreement exists on classifying evidence, summary table 1 is based on the authors own classification. Authors hierarchy of evidence (highest first): Strong, indication, modest

Policy measure	Expected effect	Evidence
R&D subsidies	Positive	Strong
R&D taxes	Positive	Strong
Public research and education	Positive	Indication
Knowledge transfer	Positive	Modest
Private sector	**Expected effect**	**Evidence**
Private R&D investment	20%-30% p.a.	Indication
Private R&D knowledge spillovers	Positive	Indication

Evidence can be strong or less strong. For example, if many studies point in the same direction and none or only a few point in different directions, this would indicate an effect. If some of the studies are high quality,[1] we will say that the evidence is strong. If a large number of studies exist and the majority point in one direction, but some studies point in other directions, we will say that the evidence is modest.

As many studies do not focus on employment or productivity, "economy" must be understood broadly. Instead, the studies focus mainly on much narrower measures, like the level of private R&D investment and innovation. Increasing R&D investment and innovation are likely to create positive effects on the economy. Due to the very long time lag between research and research-produced innovations becoming a part of the market, focusing on these earlier effects is the best that can be done.

R&D subsidies and R&D taxes

Generally, studies conducted over the last two decades on the empirical evaluation of direct public R&D support clearly lead to the conclusion that there is substantial empirical evidence that public R&D subsidies stimulate private R&D investment, and some empirical evidence that direct R&D support can enhance innovation outcomes, such as patents, innovative sales, and R&D employment, as well as productivity.

The current understanding in empirical research on the effects of tax credits leads to the conclusion that tax credits can stimulate private R&D investments on a level roughly equivalent to the foregone taxes. Tax credits increase the amount of corporate R&D efforts and lower its marginal costs.

1. High-quality studies have a good research design (i.e., RCT-study or MRA-study) and are executed well.

Both policy instruments are able to stimulate R&D in the private sector. Empirical studies suggest that tax incentive schemes are effective in the short-run and constitute an effective means to increase R&D efforts, particularly in SMEs, low-tech sectors, and countries with incremental incentive schemes. Notably, the tax incentive schemes need to be designed in accordance with the general tax scheme; direct public R&D subsidies require a minimum grant size and time in order to create additionalities. Empirical evidence shows that direct subsidies are especially effective for stimulating innovation in areas with higher degrees of innovation novelty.

From a policy perspective, building on Guellec and Van Pottelsberghe (2003), we would like to draw some general policy recommendations. First, any type of policy instrument is more likely to show the desired effects if the policy is integrated in a long-term policy framework and is somehow stable over time. The positive effects might be related to the decrease in uncertainty for firms, and hence enable better strategic planning and coordination. Second, there should be consistency between the different policy instruments, which requires coordination and management between the agencies involved. Third, positive effects from public funding for R&D in the private sector require a certain amount of governmental support; hence the subsidy should neither not be too low nor too high. Fourth, the policies' instruments and schemes (e.g., awarding criteria, level of grants) should be designed in alignment with the national innovation system and the national or regional industry structure.

Public research and education

The literature on the direct link between public and corporate research is vast and shows that public research institutions have a significant economic impact on industrial research. To study these direct relations, scholars have mostly used patent citations and survey data. These data show that public research crowds in, rather than crowds out, private R&D.

Scholars have recently begun to use register data, coupled with patent and patent citation data as well as surveys, which allows them to track the entire working history of individuals. The corresponding studies show that there is a statistically significant and economically positive link between public research and private sector innovations. Most studies do, however, focus on a few high-technology sectors, while little is known about public research effects on low-tech industries. Existing research has so far ignored the reverse relationships from industry to university (e.g. whether private funding effects public research).

The training of qualified research workers constitutes an important mechanism through which university research affects industry. Studies have shown that these movements constitute an important mechanism through which academic knowledge disseminates. Another mechanism of knowledge transfer is the startup activity of graduates and post-graduates; the evidence on their importance is scant, in contrast to the research literature on direct university spinoffs. Existing research does, however, show that the number of startups founded by (post-) graduates is rising and that these startups do at least as well as other startups.

A key problem with the literature on the effects of universities on industry is that causal effects are inherently hard to identify, as the sorting and matching of workers is non-random, knowledge flows between university and industry may be bi-directional, and international mobility is characterized by self-selection. Quasi-experiments of the type conducted by Christensen et al. (2016) would constitute an important step towards a more proper assessment of university-industry interactions.

Apart from educating labor, a second key purpose of universities is the generation of knowledge, of course often indirectly transmitted through qualified academic labor. There exists a vast body of evidence showing that proximity to universities increases industrial innovation. This is because universities constitute an important source of information for industrial innovation and universities not only increase innovation, but also enable firms to tap into new technology fields. These studies are empirically often not particularly well identified and solid evidence for Denmark is lacking. The existing evidence does, however, indicate that universities constitute important contributors to industrial innovation not only through education, but through knowledge generation as well. University-based research has a very long tail and may affect industry with a delay of up to 20 years. It hence seems advisable to maintain basic "blue sky" funding to universities to lay the fundament for future industrial innovations by encouraging basic science.

Knowledge transfer

In addition to public support mechanisms, such as subsidies and tax incentives, which are designed to increase input additionalities, such as R&D investments in the private sector, additional policy measures support the commercialization and diffusion of technological knowledge from universities and other research institutes.

To review the effects of knowledge and technology transfer from academia to the private sector, we account for policy instruments, such as: research partnerships; research services, including academic consulting; technology transfer offices; academic entrepreneurship (i.e., academic spin-offs); intellectual property rights; and further entrepreneurship and technology policies. Taking all this together, these public support policies address market failures in R&D and innovation and aim to contribute to increasing innovation in the private sector.

Importantly, our review finds that broadly-accepted empirical evidence on transfer mechanisms is lacking. Hence, we focus on individual studies that address the specific policy measures indicated above.

First, the university-industry partnership constitutes a very commonly practiced policy measure to increase industrial as well as academic innovation. We find that these research partnerships have a positive effect on innovation; however, there is a lot of heterogeneity. In particular, large firms can benefit when opening-up towards science partners for radical and incremental innovations. Small firms have more difficulties in collaborations with science partners (i.e., with respect to incremental innovations). Notably, the effects of research partnerships should retain a lot of attention by policy makers, as it constitutes a very important and frequently used policy measure and receives a lot of public funding.

Second, research services, in the form of academic consulting, constitute a very important means of technology and knowledge transfer for R&D executives in industry. Empirical evidence on academic consulting is, however, missing, with one exception that indicates no significant effect.

Third, there are many studies on technology transfer offices (TTOs) that highlight appropriate TTO configurations, but there is very little robust evidence regarding the outcomes of TTOs.

Fourth, an increasingly popular policy instrument is academic entrepreneurship, in terms of academic spin-offs, science parks, and academic clusters and incubators. Our reviews find that the results on the effects of incubators are mixed, and science parks obviously increase collaboration, particularly industry-science collaboration. With respect to the outcome effects of clusters, there are only a few empirical studies; these studies report an increased likelihood of cluster participants to become innovators due to collaboration. In particular, collaboration with public research institutes is promoted within clusters. In addition, clusters lead to an increased availability of suitable R&D labor. Importantly, the results on clusters show that distance matters: being located in a cluster has positive effects, and these effects are strongest for biotech firms.

Fifth, there is not much empirical literature on the outcome effects of intellectual property rights. Our review points out that licensing has large effects on GDP, industry output, and employment.

Private and social return on private R&D investment

The literature shows that the private rate of return of R&D is positive, significant, and higher than the rate of return of other types of capital.[2] Most of the studies find that the annual rate of return is between 20% and 30%; however, the effect ranges from 3% to 66% in the review, and different data, different definitions, etc., drive some of the differences in results.

Most of the available papers apply data on firms in the manufacturing sector; however, increasingly more studies are analyzing the service sector, and the results are comparable in magnitude with the manufacturing sector with respect to the rate of return. Across industries, high-tech sectors have better technological opportunities and invest more in R&D. There is no systematic evidence that some industries have higher returns than others.

A number of papers utilize multi-country datasets to investigate the difference in the rate of return between countries. This type of study is interesting from a policy perspective, because they provide evidence of the importance of innovation systems. The evidence shows that EU countries have lower investment in R&D than in the US, but the EU also has a lower return on R&D investment. This points to a superior US innovation system, compared with the EU.

There is some evidence that investment in R&D has a diminishing rate of return as investment in R&D-intensity increases within the firm; however, there are no signs in our literature review that the rate of return of private R&D investment drops over time, despite an overall increase in global research intensity.

The results for Denmark are in line with the literature and we find that the annual rate of return is in the range of 20% to 30%. One must be careful in comparing the rate of return with other types of capital; for the return to be as high as 20%-30%, the investment must be productive immediately, and R&D projects sometimes take years to complete and become productive. The remaining difference in the return, compared to other types of investment, may be attributed to the risk premium.

In the literature on the social rate of return of R&D, the estimate is found to be (much) larger, 2- to 3-fold, than the private rate of return of R&D, indicating that the knowledge spillover effect to other firms is potentially large. The most common transmission channels of knowledge are technological and geographical proximity, and both channels seem to be important; one does not appear to be more important than the other. The spillover effect is positive intra-industry, interindustry, and internationally. In a small open economy, the international channel plays a larger role than the other channels relative to large countries. Business stealing and product market rivalry have negative spillover effects – although not of the same magnitude as knowledge spillover.

The Danish evidence suggests lower knowledge spillover effects. One explanation is that the number of receiving domestic firms is smaller in a small country; however, the competitive advantage created by R&D investment and innovation have a negative effect on other firms, which lose market share. These effects are also more likely to hit foreign firms in small open economies and externalize some of the negative effects of innovation.

2. The high return is due to a large risk premium. Comparisons with other types of capital is not easy because, for example, a machine is almost always instantly productive, whereas R&D projects require "time to build."

Other results

The composition of public research activities, i.e., basic versus applied, competitive versus non-competitive, and research fields, was part of our study, which was commissioned by Ministry of Higher Education and Science. We did not find much literature on these subjects, and we are therefore unable to come up with results. Public research activities are such a large share of the public research budget that there is a real need for evaluation. Many public research activities are expected to have long-term impacts and it might be very important, in the long run, for the innovative competitiveness of the economy. In particular, universities are educating labor, which the literature has shown is important for innovation and growth, but we do not know much about how important research activities in universities are for this effect.

Our review also shows that there is a positive relationship between the mobility of labor and corporate innovation, as well as knowledge diffusion. In addition, mobility does not even appear to be a double-edged sword; existing studies show that both patenting and the knowledge absorption of the firm that loses a R&D worker can increase. This implies that policies restricting labor mobility may negatively affect innovative activity and knowledge diffusion. The use of register data and the identification of individual inventors in this dataset, as well as the design of an appropriate empirical identification strategy, would constitute important next steps in our understanding of the mapping between labor mobility and innovation.

Conclusion

The ambition of our literature review was to cover the most commonly applied policy measures to promote research and innovative activity: university research and education, technology transfer, R&D collaboration, tax subsidies, and direct R&D subsidies. Even though the literature is generally based on quite weak empirical identification, it generates a number of consistent findings. This is useful evidence that can guide policymakers on prioritizing limited resources; however, these findings are mainly based on correlations, so causality cannot be claimed. By the same token and given the vast amounts of money spent by governments on R&D all over the world, it seems advisable to allocate some of these funds to policy experiments, as is common practice in e.g. labor economics. Better data simply leads to better results as well as more comprehensive policy advice.

Search strategy

We were asked to conduct a broad systematic search of the most recent reports in the literature. Box 1 documents our search strategy.

BOX 1.

Overview of search strategy

Preselected literature

Initially, the authors and Ministry of Higher Education and Science compiled a list of high quality papers and other writings.

Systematic literature search on ECONLIT

- Seven research questions were formulated that covered the review
- Two-four concepts were developed for each question
- Synonyms for each concept were listed
- Search provided us with 2276 journal articles (2010-2016) and 595 working papers (2013-2016)

Grey literature

- 21 homepages of research repositories, government agencies, think tanks etc. were manually searched

Screening the literature from ECONLIT in three stages. The initial search gave a huge number of papers of little interest to the review. These were screened first by title and then by abstract. Papers with a very narrow industry focus and with a focus on transitional, emerging, or developing economies were screened away. Finally, 204 journal articles and 21 working papers were read and ranked according to methodological rigor, relevance for the review, and importance of findings.

We did not score the grey literature. Since it does not have to meet up to certain scientific standards, they are typically much harder to judge.

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VÆKST GENNEM VIDEN

DEA er en ideologisk uafhængig tænketank, der arbejder for, at Danmark øger sin værdiskabelse og vækst samt tiltrækker internationale virksomheder gennem viden om uddannelse, forskning og innovation.

Tænketanken DEA kæmper grundlæggende for, at flere unge får en uddannelse, der efterspørges; at forskning bliver omsat til innovation i private og offentlige virksomheder, og at Danmark er et attraktivt land for videnbaserede virksomheder.

DEA vil nå sine mål gennem:

- Analyser og undersøgelser, der styrker DEAs dagsorden
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