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R&D Policies and Economic Growth

The design of optimal innovation policy should focus relatively more on the selection of firms which may be more or less R&D intensive and feature higher and lower growth potential. It should also focus more on the complementary roles of basic and applied research. Basic research is an essential responsibility of government. At the same time, it occurs in the private sector and sometimes creates unexpected applications in other sectors different from original intentions. Large firms which are active in many different industries, invest relatively more since they can better exploit the general nature of basic research.

CEPR

University of St.Gallen

Moving to the Innovation Frontier

Edited by Christian Keuschnigg

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2.1 Introduction

How should the optimal R&D policy be designed? This question is at the heart of any policy debate which targets technological progress through R&D and innovation. Many governments are providing massive subsidies to foster innovation. As an example, the United States spends more than $130 billion per year at the federal level to support innovation (NSF + NIH + Army Research Office + R&D tax credit).[1] The proponents of R&D subsidies have argued that R&D has spillovers that are not internalised by the innovating firms. The opponents claim that product market competition already provides sufficient incentives to firms and that any additional subsidy would be wasteful.

In this chapter, summarising the findings from recent research, I argue that there are at least two more dimensions that the design of optimal R&D policy should consider. First, R&D support could distort the selection mechanism among firms and may be welfare reducing. Second, there are different types of research investments – for instance, basic and applied – and the spillovers associated with each type of research could be very different. Identifying these two margins and incorporating them into the current policy debate is an important step forward. Below I describe two recent studies that take important steps in this direction.

2.2 R&D policies and firm selection

The goal of R&D policies is to incentivise firms to undertake greater R&D investment, produce more innovations, increase productivity, and create more jobs. However, these policies do not affect every firm in the economy in the same way. For instance, Criscuolo et al. (2012) have shown that large incumbents are better at obtaining government subsidies. One can therefore argue that R&D subsidies to incumbents might be preventing the entry of new firms, and thus slowing down the replacement of inefficient incumbents by more productive new entrants. The turnover and factor reallocation between incumbents and entrants is an important source of productivity growth. Foster et al. (2000, 2006) have shown empirically that the reallocation of factors across firms accounts for more than 50% of productivity growth in the United States. Given the importance

1 http://www.whitehouse.gov/sites/default/files/microsites/ostp/Fy%202015%20R&D.pdf

of this reallocation margin, it is necessary for R&D policy to take into account the interaction between innovation and factor reallocation. This is our focus in Acemoglu et al. (2013).

A recent literature has emphasised the importance of firm size and age for the firm-level heterogeneity that is observed in the data (Haltiwanger et al., 2013; Akcigit and Kerr, 2015). In Acemoglu et al. (2013), we use data from the US Census Bureau's Longitudinal Business Database and Census of Manufacturers, the National Science Foundation's Survey of Industrial Research and Development, and the NBER Patent Database. Our analysis focuses on innovative firms that were in operation during the period 1987-1997,[2] and our sample covers over 98% of the industrial R&D conducted in the United States during this period. The empirical heterogeneities are summarised in Figures 2.1 to 2.4.

Figure 2.1 Transition rates

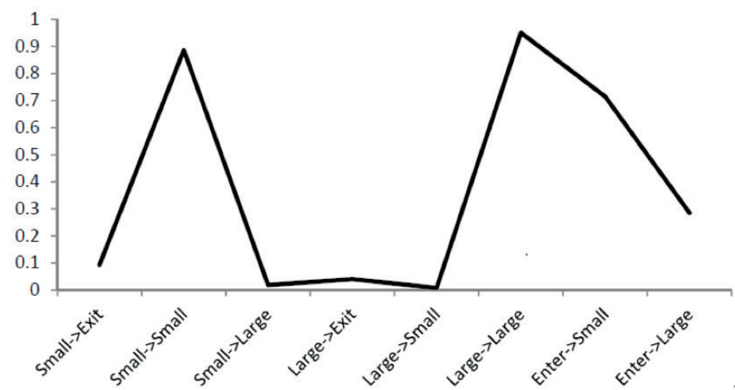
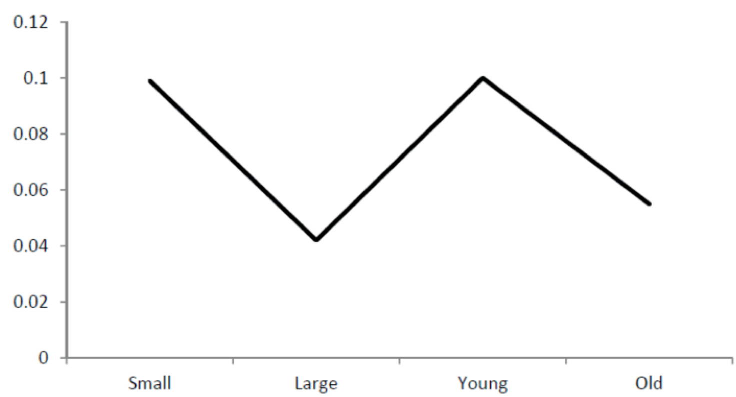


Figure 2.2 R&D intensity



2 Non-innovative firms, by definition, do not participate in this process and nor do they compete for these resources; hence, including firms that do not conduct innovation in the sample would create a mismatch between both our focus and our model and the data. Though it would be possible to add another selection margin to the model whereby non-innovative firms choose to transition into innovation, this appears fairly orthogonal to our focus, and we view it as an area for future work.

Figure 2.3 Sales growth

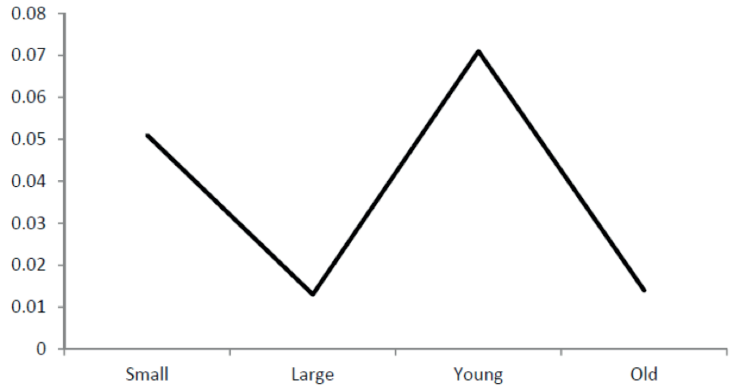
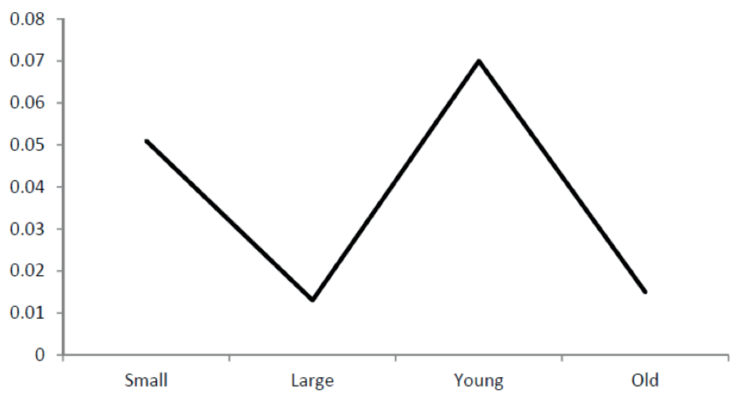


Figure 2.4 Employment growth



Source: Acemoglu et al. (2013).

Figures 1 to 4 show R&D expenditures by shipments, employment growth and exit rates between small, large, young and old firms. A firm is "small" or "large" depending on its size relative to the median employment in the sample by year; a firm is "young" or "old" depending on whether or not it is older than ten years. The figures clearly indicate that in this sample, small and young firms are more R&D intensive and grow faster.[3] Thus, industrial policies that discourage the reallocation of resources towards younger firms might indeed be costly in that they slow the movement of R&D resources from less efficient innovators (struggling incumbents) towards more efficient innovators (new firms).

In Acemoglu et al. (2013), we estimate our model by matching empirical moments capturing key features of firm-level R&D behaviour, shipments growth, employment growth and exit, and the variation of these moments with size and

3 Likewise, in Akcigit and Kerr (2015) we regress firm growth on log firm size and find an estimate of -0.04; and innovation intensity (number of innovations relative to the firm size) on log firm size and find an estimate of -0.18.

age (including those that are plotted in Figures 1-4). We then use the estimated model as a lab to run counterfactual experiments and test the impacts of various R&D policy designs on economic growth and welfare. The policies that we consider include a subsidy to new entrants, a subsidy to R&D by incumbents, and a subsidy for the continued operation of incumbents.

Our main results can be summarised as follows. Interestingly, all the policies that we consider have small effects, and some of them even reduce welfare in the economy. When incumbents are subsidised, both the equilibrium growth rate and welfare decrease. This result might suggest that the decentralised equilibrium is already efficient, and any subsidy in this environment makes the economy move away from its efficient level. To the contrary, the decentralised equilibrium is highly inefficient due to the usual intertemporal R&D spillovers and (Schumpeterian) competition effects. However, in this model there is another important margin: firm selection.

In order to understand the role of selection, we first solve for the economy's allocation from the viewpoint of a social planner who internalises all the externalities of R&D spending. In particular, we assume that the social planner can observe firm types. What we find is that the social planner forces low-type firms to exit the economy much more frequently, so that all their production resources are reallocated to the high-type firms. Then we turn to the public policy experiments, in which we assume that the policymaker cannot observe firm types but has access to the usual policy tools such as an R&D subsidy, an entry subsidy and a subsidy/tax to firm operations. What we find is that the optimal policy requires a substantial tax on the operation of incumbents, combined with an R&D subsidy to incumbents. The reason for this result is that taxing operations makes it harder for low-type firms to survive and forces them to exit. This way, the freed-up factors of production are reallocated to high-type firms, which make use of them much more effectively. Our analysis also highlights the importance of the entry subsidy and the incumbent R&D subsidy – these subsidies would not be as effective if the selection margin were ignored.

Overall, our general equilibrium analysis, which incorporates both reallocation and selection effects, highlights the fact that the economy in equilibrium might contain too many low-type firms, and policies that ignore the selection effect might help these low-type firms to survive. Another point that is highlighted is the fact that intertemporal spillovers are sizable and the overall R&D investment is too little. Therefore, a combination of R&D subsidies and taxes on firm operations could be an effective way of providing innovation incentives to firms, while also leveraging the selection margin in the economy.

2.3 Basic versus applied R&D

National funds allocated to basic research have been among the top items in many governments' policy agendas. For instance, in a recent report by the US Congress Joint Economic Committee, it is argued that despite its value to society as a whole, basic research is underfunded by private firms precisely because it is performed with no specific commercial applications in mind. The level of federal funding for basic research is deemed "worrisome" and it is claimed that it must be increased in order to overcome the underinvestment in basic research (JEC, 2010). However, the report also complains about the lack of research studies that actually quantify the extent of this underinvestment and about the lack of data.[4]

For similar reasons, governments introduce programmes to promote collaboration between basic academic researchers and private firms, with the hope that synergies generated from these interactions could lead to breakthrough technological advances. For instance, the United States government has aggressively promoted collaboration between universities and industrial researchers through specific funding programmes. Among many others, the National Science Foundation (NSF) sponsors the Fundamental Research Program for Industry-University Cooperative Research (FRP), the Industry-University Cooperative Research Centers Program (I/UCRC) and Grant Opportunities for Academic Liaison with Industry (GOALI).

Although the different characteristics of basic and applied research, on the one hand, and academic and corporate research, on the other, have been widely recognised to be of first-order importance by policymakers, these issues have received insufficient attention in the economic literature on productivity and economic growth. In particular, the endogenous growth literature (e.g. Romer, 1990; Aghion and Howitt, 1992) has mainly considered a uniform type of (applied) research and has overlooked basic research investment by private firms.

What are the key roles of basic and applied research for productivity growth? How should R&D policy be geared towards basic versus applied research? What are the incentives of private firms to conduct basic research? How does academic research contribute to innovation and productivity growth? In Akcigit et al. (2014), we attempt to answer these questions. In order to understand the potential inefficiencies involved in different types of research investments and to design appropriate industrial policies to address them, it is necessary to adopt a structural framework that explicitly models the incentives for different types of research investments by private firms. In Akcigit et al. (2014) we take an important step towards developing this theoretical framework, identifying the potential spillovers, and studying their macroeconomic implications for innovation policy.

Our analysis starts with an empirical investigation. Figure 2.5 shows that countries allocate a significant share of their GDP to R&D (around 2-3%). Less well known, however, is the role the composition of this research plays in determining growth, particularly when considering the breakdown between basic and applied research.

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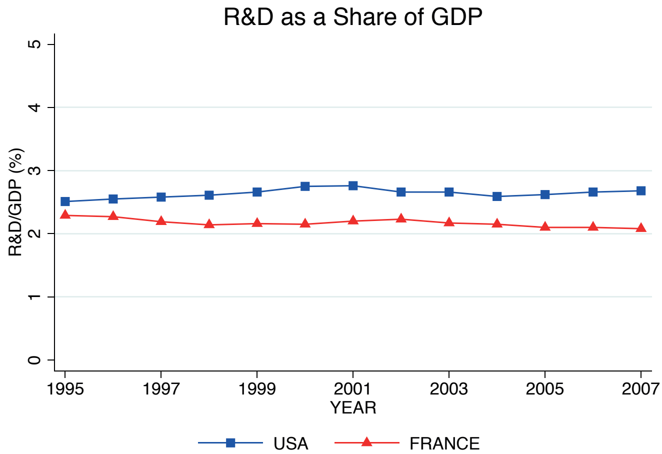
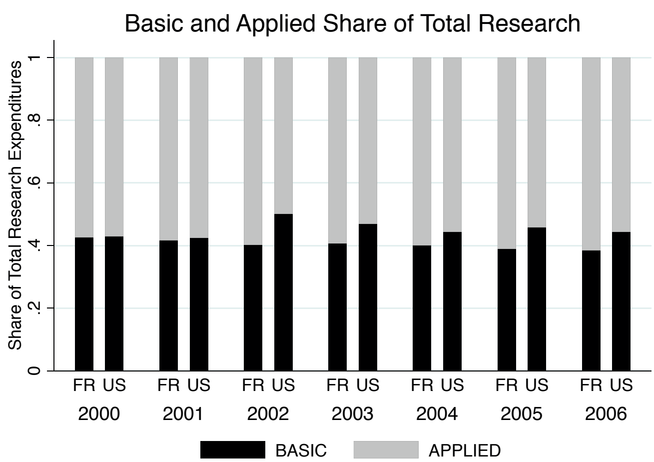
4 http://jec.senate.gov/public/?a=Files.Serve&File_id=29aac456-fce3-4d69-956f-4add06f111c1

Figure 2.5 R&D as a share of GDP



Source: Akcigit et al. (2014).

Figure 2.6 Basic and applied share of total research



Source: Akcigit et al. (2014).

Before we proceed further, it might be helpful to provide the relevant definitions. According to the NSF, basic research investment refers to a "systematic study to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind"; applied research is defined as a "systematic study to gain knowledge or understanding to meet a specific, recognized need". Figure 2.6 shows the composition of the overall R&D spending in the United States and in France. The interesting result is that almost half of overall spending goes into basic research.

What kind of spillovers does basic research generate? In our analysis, we follow the influential literature on basic science and consider the possibility that basic research not only generates large spillovers within an industry, but it can also be applicable to many different industries. The historical example of Du Pont de Nemours' financing of William Carothers' research serves as a fine showcase of these spillovers. As Nelson (1959) describes it:

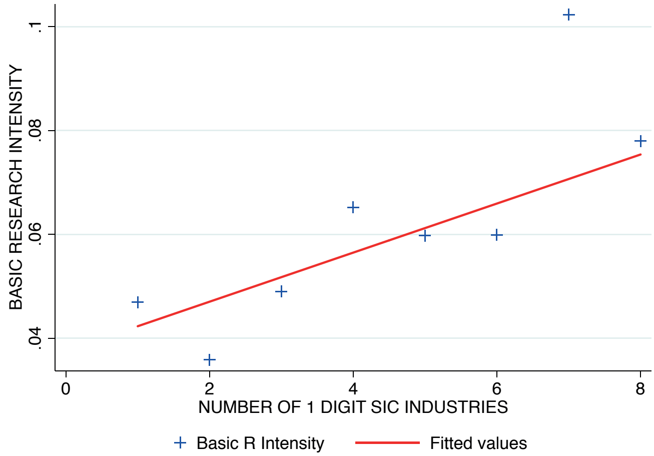
> Carothers' work in linear super-polymers began as an unrestricted foray into the unknown, with no practical objective in mind. But the research was in a new field in chemistry and Du Pont believed that any new chemical breakthrough would likely be of value to the company. In the course of research Carothers obtained some super-polymers that became viscous solids at high temperatures, and the observation was made that filaments could be made from this material if a rod were dipped in the molten polymer and withdrawn. At this discovery the focus of the project shifted to these filaments and Nylon was the result.

Nylon is now used in many industries including textiles, automobiles and military hardware, three industries in which Du Pont had operations.

Ideally, in order to capture the full return to new scientific knowledge in industries where it could have an application but in which the innovating firm is not present, the innovator would first patent and then license or sell the innovation to other firms in those industries. However, the applications of basic scientific advances are often not immediate and firms are often only able to transform them into patentable applications in their own industries. This is the well-known appropriability problem of basic research that has been discussed in a vast literature. It follows that firms operating in more industries will be able to utilise more facets of a given basic innovation. As Nelson hypothesised it, "[i]t is for this reason that firms which support research toward the basic-science end of the spectrum are firms that have fingers in many pies". Note that the key concept that is being emphasised here is not the size of the firm per se, but the diversity of its operations. This interesting argument (which we will refer to as "Nelson's hypothesis") will be the central building block of our analysis in this chapter.

We first test Nelson's hypothesis, namely that the main investors in basic research would be those firms that have fingers in many pies. According to this argument, as the range of its products and industries becomes more diversified, a firm's incentive for investing in basic research relative to applied research should increase due to better appropriability of potential knowledge spillovers. To measure multi-industry presence, we count how many distinct SIC codes a firm is present in. Using micro-level data on French firms, Figure 2.7 plots average basic research intensity against the total number of distinct one-digit SIC codes in which the firm is present. The figure also shows a simple linear fitting line.

Figure 2.7 Average basic research intensity against total number of distinct one-digit SIC codes



Source: Akcigit et al. (2014).

Figure 2.7 shows a positive and statistically and economically significant relationship between multi-industry presence and basic research spending. A broader technological base is associated with higher investment in basic research relative to applied research. Our findings are therefore supportive of Nelsons' hypothesis on the link between multi-industry presence and relative research incentives. These correlations are robust to a large variety of potential confounding factors. This result suggests that cross-industry spillovers are sizable, and using the variation in the technology base of firms we can estimate the cross-industry spillovers associated with basic research.

In order to study the policy implications of these spillovers, we build a general equilibrium, multi-industry framework with private firms and a public research sector. Firms conduct both basic and applied research, whereas the public sector focuses exclusively on basic research. In our model, basic research generates fundamental technological innovations and generates spillovers, both within and across industries, that affect subsequent applied innovations.[5] In line with the 'ivory tower' theory of academic research, basic research by private firms in our model will turn into consumer products faster than that undertaken by public research labs. Applied research, on the other hand, will be done only by private firms and will generate follow-on innovations building on the existing basic knowledge stock.

We then undertake a quantitative investigation of the impacts of various innovation policies on the aggregate economy. We first estimate the model by targeting some of the key moments in the data, especially public and private spending on basic and applied research in France. We use the estimated model to assess the extent of inefficiencies in basic and applied research and to study the implications of several important innovation policies.

5 By fundamental innovation, we mean major technological improvements that generate larger than average contributions to the aggregate knowledge stock of society. In addition, these will have long-lasting spillover effects on the size of subsequent innovations within the same field.

Our main results can be summarised as follows. We find that a large fraction of spillovers from basic research across industries is not internalised. As a result, there is a dynamic misallocation of research efforts, which reduces welfare significantly. One striking result is that the decentralised economy and the social planner's economy use the same overall level of resources for research. However, the compositions of the total research efforts are very different. While the social planner allocates more resources to basic research, it allocates less ressources to applied research. This implies that the dominant misallocation here is not misallocation between production and research, but among the various types of research activities – in this case, applied and basic research. There is actually overinvestment in applied research in the decentralised economy because of product market competition, whereas there is underinvestment in basic research due to within-industry and cross-industry spillovers that are not internalised.

This raises an important question. To what extent can public policies address this inefficiency? The first policy we analyse is a uniform research subsidy to private firms. In this environment, subsidising overall private research is ineffective since this will over-subsidise applied research, which is already excessive due to product market competition. Therefore, the welfare improvement from such a subsidy is limited unless the policymaker is able to discriminate between types of research projects at the firm level, a difficult task in the real world.

We therefore analyse another policy tool: the level of funding for public research labs. We show that due to the ivory tower nature of public basic research, allocating more money to the academic sector without giving property rights to the researchers (i.e. ownership over their inventions) is not necessarily a good idea. To demonstrate this, we simulate a policy similar to the Bayh-Dole Act enacted in the United States in 1980. We consider alternative scenarios in which public researchers have no property rights, then 50% and 100% property rights. We find a complementarity between the level of property rights and the optimal allocation of resources to academic research. The optimal combination turns out to be granting full property rights to the academic researcher and allocating a larger fraction of GDP to public research. This reduces the welfare gap significantly.

2.4 Conclusions

In this chapter, I have summarised some recent findings from research on optimal innovation policy. The two new elements introduced were firm selection and the distinction between basic and applied research. The former implies that R&D policy could affect firm survival and resource reallocation between more productive and less productive firms, or between incumbent and entrant firms. The latter highlights the fact that different types of research – in this case, basic and applied – could have different spillovers, and R&D policy should take into account its impact on the distinct types of research.

There are still many unexplored directions for future research. One such direction is the labour market consequences of the R&D policies. While the literature typically assumes frictionless labour mobility across firms, it takes time for workers to find new jobs when a firm has to exit. It would be important to study the potential reallocation costs of such policies. Another important issue is the transitional dynamics. The current focus of the literature is typically on steady-state dynamics. Clearly any new policy is likely to entail a transition path that might generate additional costs for the economy. These are important questions that will we hope will be answered in future research.

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