



Productivity effects of basic research in low-tech and high-tech industries[☆]

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ABSTRACT

R&D encompasses plenty of activities which are usually summarized under the terms of basic research, applied research and development. Although basic research is often associated with low appropriability it provides the fundamental basis for subsequent applied research and development. Especially in the high-tech sector basic research capabilities are an essential component for a firm's success. We use firm-level panel data stemming from Belgian R&D surveys and apply a production function approach which shows that basic research exhibits a premium on a firm's output when compared to applied research and development. When we split the sample into high-tech and low-tech companies, we find a large premium of basic research for firms in high-tech industries, but no premium in low-tech sectors.

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"The important thing is not to stop questioning. Curiosity has its own reason for existing."

Albert Einstein

1. Introduction

It has been widely acknowledged by the literature that research and development have positive effects on firm performance (see [Hall et al., 2010](#) for a recent survey). However, the term R&D is a rather complex construct, since R&D encompasses plenty of activities. According to the definition of the [Frascati Manual \(1993\)](#) which frames the methodology for collecting and using statistics about R&D in OECD countries, the term R&D covers three activities: basic research, applied research and experimental development.

Basic research can be understood as very early stage research which is designed to build a knowledge base in order to understand fundamental principles. It is driven by a scientist's curiosity

or interest in a scientific question. Contrary to applied research and experimental development which are more commercially orientated, basic research is phenomena oriented, that is, it barely helps practitioners with their everyday concern. Nevertheless, it stimulates new ways of thinking which may lead to generation of pioneering and revolutionary ideas, concepts and applications. For instance, modern computer technology could not exist without pure mathematical research, at that point of time undertaken without any ulterior motive of practical applications in computer science. Firms conducting basic research broaden their knowledge base that provides the fundamental basis for subsequent applied research and development. Thus basic research enables a firm to exploit rapidly useful scientific and technological knowledge through their own innovations ([Cohen and Levinthal, 1989, 1990](#); [Rosenberg, 1990](#)). There are several studies (e.g. [Mansfield, 1980](#); [Griliches, 1986](#)) which have already demonstrated that corporate basic research is important for a firm's performance.

[Rosenberg \(1990\)](#) has pointed out that there are a number of activities that are essential to the success of firms located in the high-tech industries that depend heavily upon basic research capability. Therefore, an interesting question arising within this context is how basic research contributes to firms located in different industries. To be more precise, do firms operating in the low-tech sector benefit as much as companies from the high-tech sector by conducting basic research?

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The conventional view of basic research also rests on the assumption that basic research is relatively difficult to appropriate. Basic research is thought to be of riskier nature and also have longer lead times than applied research and development which coincides with lower appropriability (Trajtenberg et al., 1992). As high-tech companies are characterized by investing a larger fraction of their budget in R&D activities they may be more likely to appropriate a larger fraction of the benefits than firms operating in low-tech sectors.

This paper addresses this question by estimating an augmented Cobb–Douglas production function with Flemish firm level data. Our results indicate that basic research exhibits a productivity premium when compared to applied research and development in high-tech sectors. In low-tech sectors, however, we do not find evidence for a premium of basic research.

2. Conceptual framework

2.1. Basic research and the low vs. high tech industry

Early work (Nelson, 1959; Arrow, 1962) has already stressed that knowledge once produced has the characteristics of a public good since it may easily spill over from the innovating firm to its rivals allowing them to free ride on its innovative efforts. These outgoing spillovers make it impossible for firms to fully appropriate the economic benefits from their R&D activities. Nevertheless, there is a vast body of literature which deals with the relationship of R&D and productivity (see e.g. Mairesse and Sassenou, 1991 for a survey and Griliches, 1979, 1986; Cuneo and Mairesse, 1984; Griliches and Mairesse, 1984; Hall and Mairesse, 1995, to name only some of the authors who conducted studies at the firm-level). They all provide evidence that a firm's productivity is positively related to research and development.

Especially for firms located in the high-tech industries R&D activities are crucial to maintain their competitiveness since products and processes are frequently changing in this industry segment. Additionally, within high-tech sectors corporate R&D investment may be more fruitful in terms of achieving productivity gains. Usually most of the R&D activities are conducted in the sectors labeled as "high-tech" industries, e.g. around 80% of Flanders' total R&D expenditures have been conducted by firms located in the high-tech segment (Andries et al., 2009).

Cuneo and Mairesse (1984) used a sample of 182 R&D performing firms in the French manufacturing sector during the 1972–1977 period to examine the relationship between R&D and productivity. They distinguished between so-called scientific firms belonging to the R&D-intensive industries and other firms. The estimated elasticity between productivity and R&D capital was twice as much for the scientific firms than for firms belonging to other sectors. Griliches and Mairesse (1984) found similar results by applying the same method to a sample of 133 US R&D performing firms. Harhoff (1998) investigated the relationship between R&D and productivity in German manufacturing firms using a panel database covering the years from 1979 to 1989. His results show that the R&D elasticity differs considerably between high-technology and other firms. Furthermore, a recent study conducted by Tsai and Wang (2004) in which a sample of 156 large Taiwanese firms in the period from 1994 to 2000 is analyzed also leads to the conclusion that the R&D elasticity is remarkable higher for firms in the high-tech sector. Verspagen (1995) analyzed 15 manufacturing sectors in 9 OECD countries by applying a translog production function. His findings suggest that R&D only has a positive and significant effect on productivity in high-tech industries, but plays no role in the medium and low-tech sectors. Similar to the last study, Kafourous (2005) also used firm-level data of the UK

manufacturing sector and found that R&D investment only has a positive and significant effect in high-tech sectors, whereas it shows no impact in low-tech industries.

2.2. Why basic research?

According to the Frascati Manual (1993) which is used to create the questionnaire for the OECD R&D surveys basic research is defined as "[...] experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view." This forms a contrast to applied research which focuses on the use of existing scientific principles with the intention to improve existing or create new products and processes and experimental development which draws on existing knowledge gained through research. Since basic research is conducted with no specific application or use in view, the generated knowledge and technologies are potentially applicable elsewhere. The researcher himself may not be able to think about possible applications and may thus miss opportunities to appropriate the potential benefits of the generated knowledge. Due to this vague nature basic research is characterized by a higher degree of risk and uncertainty compared to applied research and development and more likely to spill over to competitors. Hence, a profit seeking firm may not capture all of the benefits of basic research which it sponsors leading to an under invest in this type of research, i.e. less than socially desirable (see e.g. Nelson, 1959; Pavitt, 1991). But what actually makes basic research economically useful? Why is it in the interest of society to support basic research?

As already pointed out above the outputs generated by basic research do barely possess any intrinsic economic value, nevertheless basic research is often considered as the 'fuel that powers innovation'. Its research outputs are considered as key inputs for further investments in the R&D process which lead to additional research findings and in the optimal case to technological innovations, i.e. new products or processes (David et al., 2000).

Furthermore, investment in basic research can yield technology that can be profitably sold or licensed to others. Secondly, basic science has an impact on technology not just through direct knowledge transfers, but also through access to skills, methods and instruments (1991). As a result, basic research generates the capability to absorb external information and improve the productivity of applied R&D (Cassiman et al., 2002). It contributes to and enhances the stock of knowledge applied research initiatives build on (Henard and McFadyen, 2005). In addition, the very fact that basic research does not have specific goals or applications in mind, permits the direction of a basic research project to change over time, which can lead to significant breakthroughs that are seldom discovered in applied research projects, e.g. a famous example is the case of Pasteur who found the anthrax vaccine by coincidence while actually studying chicken cholera (Nelson, 1959). As a result, basic research can – even in the short-term – lead to breakthrough applications (Pavitt, 1991).

There are some authors who have already advocated that a firm's investment in basic research has a positive impact on its overall performance: in his seminal work Mansfield (1980) using a dataset of 119 US manufacturing firms during the 1970s found a significant and direct relationship between the amount of basic research carried out by an industry or firm and its rate of increase of total factor productivity. These results were confirmed by Link (1981) who not only found that privately financed basic research increases a firm's productivity, but also basic research which is financed by the government. Based on the work of Mansfield (1980), Griliches (1986) provided further evidence that basic research appeared to be more important for productivity growth than other types of R&D. To be more precise, he found a several hundred percent premium

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