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The effects and time lags of R&D spillovers in Brazil

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ABSTRACT

Government's innovation investments for science intensive sectors, such as the capital goods industry for developing countries play an important role in technology dissemination; however, few studies have addressed this issue. This study is conducted in the framework of a developing economy (Brazil), and aims to estimate the spillover effects throughout the industry resulting from public investment in innovation, as well as the spillovers of R&D and management investment performed by the capital goods industry through the rest of the industrial sector, and also the time lapse between the occurrence of innovative investment and output growth due to such expenditures. The results of the estimated econometric model exhibit significant and positive spillover effects by the government R&D expenditures for the capital goods industry with a three-year lapse, as well as a one-year lag for the occurrence of output effects on the other companies of the manufacturing sector, resulting from innovative investments by the capital goods industry.

1. Introduction

Nontraditional inputs, such as R&D, management and training, define much of the efficiency and competitiveness of companies as they directly affect the technological relationship and the ability to transform inputs into outputs described by the production function. Studies such as Khasnabis, Dhingra [1] argue, for example, that there is a direct and positive relationship between R&D expenditure and productivity gains.

The product life cycle shrinkage in the past decade emphasizes the need for reducing costs and improving efficiency, which increased the importance of R&D departments [2]. Thus, since R&D helps to bring about the company's revenue structure by creating or improving products and processes, R&D expenditures should not be disregarded, as well as its influence on improving production processes.

According to Griliches [3], it is well known that part of the output is explained by several nontraditional inputs, with R&D investment acknowledged in the literature as one of these factors, noting that their social returns characterize a considerable impact. Thus, R&D accumulation is an important economic growth driver in the theoretical models at a micro and macro level [4,5].

Therefore, it is in the government's interest to promote collaboration between academic scientists and private sector companies to extract social and economic benefits, and associated spillovers, even though the dynamics of innovative investment does not guarantee such effects [6].

According to Gittelman [7] new ideas are more rapidly absorbed and applied by companies within a specific set of conditions. Such conditions may include, for example, an industry that belongs to a science-intensive sector such as biotechnology, pharmaceutical, and capital goods. Such science-intensive sectors are intermediaries between research institutions and the rest of the industry, as they are the underlying basis for the development of other areas, due to the added knowledge on universal scientific principles [8,9].

In emerging countries such as the BRICs group, the capital goods sector plays this technology disseminator role; given that it is usually the first science-intensive sector to expand in such realities.

Therefore, in view of the government's desire to promote the socioeconomic outputs resulting from technological innovation, as well as competitive and profitability advantages resulting from R&D and management investment by the capital goods industry, the aim of this study is to calculate the spillover effects throughout the industry that result from public investment in innovation, and also the R&D and management investment spillovers of the capital

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goods industry for the rest of the manufacturing sector. Here, along with R&D investments, the management expenditures are added, since achieving technological excellence is not related only to R&D, but also to organizational and managerial skills [10].

This study will also measure the time lapse between the innovative investments and the occurrence of output growth due to such expenditures, as this issue is rarely addressed in the literature.

The research includes a sample of Brazilian capital goods companies, representing 60% of the sector, and a similar sample size of companies in the rest of the manufacturing segment, as well as national innovation expenditure data. Thus, the spillover effect will be measured in the context of an emerging economy.

2. Related literature

Since Doll [11], management issues in the production function are considered as a real "plague", because like technology, management cannot be considered as a conventional input; however, it has considerable impact on output. Furthermore, both vary among companies and are difficult to quantify. Similarly, O'Mahony and Vecchi [12] also argue that intangible assets such as R&D, human capital and marketing are difficult to quantify, and most studies tend to consider R&D alone.

Thus, Mefford [13] argues that many authors use proxy variables to measure management, such as the managers' experience and education, which although related to management, do not capture its actual effect. However, he finds that even stringent specifications such as Cobb-Douglas were as good as other specifications, adding that the management variable inclusion is desirable in the study of production functions. The author also states that omitting the management variable would leave much of the product without explanation, as well as it could result in specification bias in the estimated parameters of the other variables. Following the same logic, Mundlak [14] also considers the omission of the "management" variable as a source of bias in the estimated parameters.

2.1. Spillovers

The comprehension of knowledge and technology externalities is crucial for understanding the mechanisms of innovation and the dynamics of economic growth. Thus, models such as MAR (Marshall-Arow-Romer) and Jacobs emerged, seeking to explain the diffusion forms of knowledge among companies [15].

The intercommunication between economic entities driven by globalization and IT advances resulted in spillovers with important productivity implications [16]. In fact, Griffith and Peres-Neto [17], for example, recognizes that UK companies located in the USA benefit more from spillovers than those located in the UK within the home country.

Much of the literature on endogenous growth addresses not only the R&D impact to innovative companies, but also the spillovers to the rest of the economy [12]. Thus, technological knowledge can be seen as a public good that affects all companies operating in an intensive R&D environment [18].

The spillover effects can occur in several ways; resembling human capital accumulation [19], or the acquisition of improved and high quality inputs [20], although Griliches [21] does not consider them knowledge spillover, since pure knowledge spillover is the exchange of ideas between companies in the same field. In fact, according to Verspagen [22], the acquisition of improved inputs in the production process of another company will result in the recipient receiving some spillovers. This process is also called rent-spillovers [23].

Spillovers of R&D activities occur because technological knowledge cannot be fully appropriated by companies and individuals that develop knowledge [24]. Moreover, knowledge can also be transferred via publications, reverse engineering and information exchange by scientists and collaborators [23,24]. However, there are limits to spillovers, specifically, patents, skills, or lack of tacit knowledge for knowledge absorption [24].

The first economist to estimate R&D innovation spillover was Jaffe [25], using a knowledge production function, finding an R&D local concentration effect on the productivity of patents. Jaffe [25] also remarks that the essence of the spillover effect lies in the fact that other companies R&D are able to help an individual firm to achieve results with less difficulty. However, Cohen and Levinthal [26] point out the importance of the own R&D investment for the absorption potential of existing information, since that the assimilation capacity plays a key role in constructing a virtuous cycle of technology spillovers in the market place [27].

Thereby, for the endogenous growth theory, a company can benefit from research findings from other companies [28]. Hence, innovation, knowledge externalities and diffusion are vital to a nation's economic growth dynamics. Moreover, knowledge spillovers have a positive influence on the propensity of companies to innovate [23], since innovation is highly related to a company's ability to absorb external information, knowledge, and technology [29].

Watanabe et al. [30] emphasizes that improving assimilation capacity is essential for effective utilization of spillover technology, but such capacity reacts to decreases in R&D productivity in the stage when its level is low; becoming positive when the assimilation capacity overcomes a certain threshold.

As a result of the increase in R&D intensity, after reaching a certain level of assimilation capacity, it continues to increase without depending on an ensuing R&D intensity increase. Thus, R&D intensity of the top-level firms is not necessarily high despite their high level of sales [30].

In a study on the French industry, Autant-Bernard, Guironnet [28] evaluated the clustering effects to calculate intra and inter-company spillover effects. In fact, they found that R&D investments in other industries improve the technological productivity component of individual companies, and also that human capital is the major productivity determinant.

However, some authors such as Lynne, Michael [31], actually refute and minimize the spillover effects of knowledge from universities to companies, arguing that the main determining factor of the company's technologies are in fact the "star scientists", responsible for most discoveries.

The concept of spillovers can be classified as horizontal or vertical, depending on the entity that transmits and receives knowledge. The vertical spillover occurs between the supply chain links or company partnerships, while horizontal spillover is related to universities and other research institutes that transmit knowledge to companies [23,32,33].

In the endogenous growth literature there are three ways to calculate the effects of knowledge spillover, based on the estimation of production functions. The first one shows the company's aggregated R&D values in nearby localities for the production function of firms in a particular region, such as in Ref. [34].

Another method used to calculate the spillover effects takes into account spatial effects that consider, for example, cluster-based industrial policies to improve economic performance [15]. Such studies have made use of the spatial Durbin model (SDM) to compute the spatial spillover effect [35,36].

Finally, there is the technique used by O'Mahony and Vecchi [12], and Black and Lynch [37], which use a method in which residuals from a previous production function regression of companies of a sector or locality are used to check the spillover effects. More specifically, the residuals will contain the productivity