



Learning through experience in Research & Development: An empirical analysis with Spanish firms



Pilar Beneito, María Engracia Rochina-Barrachina, Amparo Sanchis*

University of Valencia, ERI-CES, Facultad de Economía, Departamento de Estructura Económica, Avda. de los Naranjos s/n, 46022 Valencia, Spain

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ABSTRACT

In this paper we analyse the role of learning through experience in Research and Development (R&D) activities in strengthening firms' capabilities to achieve innovation outcomes and, subsequently, in obtaining rewards in terms of firms' performance. First, using an innovation production function approach, we estimate a count-data model and find that the number of years of engagement in R&D activities, or R&D experience, has a positive effect on the expected number of product innovations, although at a decreasing rate. In addition, our results suggest that, whereas large firms are more efficient than SMEs in converting R&D investment into product innovations, SMEs seem to be able to draw efficiency gains from R&D experience at least comparable, if not higher, to those obtained by large firms. Secondly, we find that not only the number of innovations but also their impact on firms' performance increase as firms accumulate R&D experience, suggesting that R&D experience helps to obtain not only more innovations but also innovations of a higher quality.

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1. Introduction

The idea that the continuous engagement in an activity generates learning about the better way to carry it out and, therefore, raises the probability to achieve increased returns from that activity, has been the subject of economic literature for many years. The concept of learning effects was first introduced by Wright [1] in a study of the airplane manufacturing industry, where he assessed the decrease in the total number of working hours as firms gained experience in production. This concept was then reproduced by Hirsch [2], Arrow [3] and Alchian [4], among others, giving raise to the concept of "learning curves" or "progress ratios", recently reconsidered in works as Linton and Walsh [5], or Pruett and Thomas [6]. In his seminal paper, Arrow [3] stated, "Learning is the product of experience. Learning can only take place through the attempt to solve a problem and therefore only takes place during activity" (p. 155). Arrow formalised this idea in a model where technological change arises from experience,

under the assumption that the solutions to the problems generated during the production process improve with the time spent in developing that process.

Following these previous works, the analysis of the processes of *learning-by-doing*, and their role in the formation of human capital and, in turn, in productivity, has been a passionate field of the economic research. Lucas [7] and Stokey [8] are two examples of the application of this concept to the theoretical literature of economic growth.

The theoretical literature on innovation and technical change has also substantiated the role of learning derived from experience as a key driver in knowledge accumulation leading to innovation. The evolutionary theory of Nelson and Winter [9], for instance, emphasised the importance of *learning-by-doing* and *learning-to-learn* effects in innovation. In particular, investing in R&D projects allows firms to develop and accumulate scientific knowledge that may be used in successive innovations. The resource-based theory [10–12] states that a firm's resources may be strengthened by the impact of time, since time provides opportunity for reflection, experimentation, analysis and synthesis. From the perspective of the dynamic capabilities approach [13], the

* Corresponding author. Tel.: +34 96 3 83 83 48.

E-mail address: amparo.sanchis@uv.es (A. Sanchis).

accumulation of experience has been pointed out as one of the learning mechanisms by which operating routines and dynamic capabilities are shaped and built [14].

Therefore, at a theoretical and conceptual level, the importance of experience is generally accepted in any production process. The process of innovation is not another of these processes. Instead it is probably one of the processes where learning and the accumulation of knowledge is more important. As emphasised by Malerba and Orsenigo [15] and Malerba [16], among others, cumulateness is a key dimension of knowledge for understanding innovative activities.

Although the role of experience in production has been extensively documented, there is a lack of empirical studies dealing with a quantitative measure of R&D experience and with its introduction in estimation models. West and Iansiti [17], for instance, in the context of the evolutionary theory of organisational competencies, provide evidence for the US semiconductor industry that experience accumulation and experimentation are two organisational tools that significantly affect firms' performance. However, their empirical analysis is limited to a reduced number of research projects in one particular industry, and their measure of experience is qualitative: they use a dummy variable indicating if at least one of the project members involved in technology selection decisions has experience in research organisation. Therefore, they are not able to quantify the effect of experience on performance, but only to indicate the sign of this effect.

The aim of this paper is threefold. First, we are interested in providing empirical evidence on the role of R&D experience as a factor driving the achievement of innovation outcomes by firms. In order to do so, our approach will be the estimation, using count data models, of an augmented *innovation production function* that includes R&D experience as an additional innovative factor. Our point is that experience in R&D must be considered as an additional source in the process of innovation, that is, that the usual factors traditionally included in the estimation of innovation production functions are not sufficient to explain the outcomes of the innovation process. Secondly, we investigate the ultimate effects of R&D experience on firms' performance, measured as firms' productivity and sales. For this purpose, we analyse whether firms' innovation outcomes allow firms to enjoy higher productivity levels and sales, and, also, whether as firms accumulate R&D experience, innovation outcomes obtained produce greater rewards in terms of firms' productivity and firms' sales. Finally, we aim at investigating whether the returns to R&D experience, both in terms of expected innovation outcomes and in terms of their final effects on firms' performance indicators, differ between large firms and SMEs.

Using panel data for Spanish manufacturing firms provided by the 'Survey of Business Strategies' (*Encuesta sobre Estrategias Empresariales*, ESEE henceforth) for the period 1990–2006, we construct a measure of R&D experience based on the number of years the firm has been carrying out R&D activities. This way of measuring R&D experience is based on the idea that time devoted to R&D activities provides learning about how to increase the effectiveness in achieving innovation outcomes, independently on whether the firm has obtained an innovation outcome in a particular year. Previous experience helps to identify those problems more relevant to

be solved, improves the understanding of the searching process and its instrumentation, and provides more information about the best potential solutions. This measure of experience is then consistent with the sequential process of development and assimilation of knowledge that takes place with the passing of time.¹ Additionally, we also consider as an indicator of R&D experience the information available in the ESEE from 1998 onwards about the hiring of personnel with experience in corporate R&D. Although this information is qualitative, we find interesting to include it in estimation of our innovation production function because it may reinforce a basic idea of this paper: that R&D experience, in this case embodied in hired R&D personnel, contributes noticeably to the achievement of innovation outcomes. In estimation, we distinguish two subsamples of firms in the ESEE according to their size: the subsample of large firms (those with more than 200 employees) and SMEs (those with 200 employees or less). We proceed in this way both because of the different sampling criteria followed in the ESEE for these two size groups (described below) and because of the possible differences of innovative behaviour and performance between them.

To anticipate our results, from our first estimation step, i.e., the estimation of the innovation production function, we obtain that controlling for the firms' volume of R&D investment and other factors, firms' innovation outcomes, measured in terms of the number of product innovations, increase as the firm accumulates experience in conducting R&D activities. Our findings also indicate that the relationship between R&D experience and product innovations is non-linear, that is, that experience has a positive effect on the expected number of product innovations, but at a decreasing rate. In addition, our results point out that, although SMEs are less efficient than large firms converting R&D investment into innovations, their gains from R&D experience in terms of innovations may be, at least, as relevant as for large firms. Therefore, the R&D-experience-elasticity relatively to the traditional R&D-spending-elasticity is larger for SMEs. Moreover, the estimated effect of the variable accounting for the hiring of experienced R&D personnel is positive and highly significant in estimation. This effect is even statistically stronger for SMEs, reinforcing the idea of higher efficiency gains obtained by SMEs from R&D experience.

From our second estimation step, i.e., from the estimation of the effects of innovations on firms' performance indicators, our results shed light into a completely new issue of research, since we obtain that not only firms are able to achieve more innovations as they accumulate R&D experience, but also, and perhaps more importantly, they also improve the level of quality embodied in their innovations. Our results indicate that this latter result may be particularly relevant in the case of SMEs.

Our findings have a number of implications for policy makers and business managers. First, if learning effects exist

¹ In the labour economics literature, where information regarding the number of years the individual has been working is usually available, labour experience measured in this way is considered to be a key factor determining human capital and, thus, salaries or the duration of unemployment (see, e.g., the seminal work of Mincer [18] and the recent revision of the issue by Baffoe-Bonnie and Ezeala-Harrison [19], and references therein).

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