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You can't manage right what you can't measure well: Technological innovation efficiency☆

Claudio Cruz-Cázares[a,*], Cristina Bayona-Sáez[b], Teresa García-Marco[b]

[a] University of Barcelona, Diagonal Avenue 690, Tower 2, 3rd Floor, 08034 Barcelona, Spain
[b] Public University of Navarra, Edificio Departamental de los Madroños, 31006 Pamplona, Spain

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ABSTRACT

This paper proposes a new approach to tackle the innovation–performance relationship. It addresses the, so far, mixed and inconclusive results of studies analyzing this relationship. We argue that the undifferentiated use of innovation inputs and outputs to measure firm innovativeness is not without problems, and that, from a productive perspective, they should be simultaneously analyzed. This study follows a two-stage empirical analysis using a sample of Spanish manufacturing firms for the period 1992–2005. By examining two inputs and two outputs of the innovation process in the first stage, we estimate technological innovation efficiency by means of an intertemporal data envelopment analysis (DEA) bootstrap and also observe the yearly efficiency changes based on a global Malmquist index. In the second stage we analyze the effect of technological innovation efficiency on firm performance through a generalized method of moments (GMM) system. The results support our arguments that the best measurement of outcomes of technological innovations is through the efficiency with which they are developed. In addition, we test the moderating effect of technological intensity level and firm size on the efficiency–performance relationship.

1. Introduction

While most of the literature in the innovation field argues that technological innovations are central to business success, empirical results are inconclusive as they have reported positive, negative or no effects of innovations on firm performance. We believe that this controversy might have its origins in the measurement of innovation. Thus far, it has variously been measured as innovation inputs (O'Regan et al., 2006) or as innovation outputs (Akgün et al., 2009). Additionally, there is a lack of agreement among authors about how to measure the effect of innovation on firm performance.

This paper differs from previous studies and proposes a new approach to measuring the effects of technological innovation activities on firm performance. Tidd and Bessant (2009) stress that innovation is a complex process and that it should be evaluated as such, not as a single input or output activity. Therefore, we defend the idea that innovation inputs produce innovation outputs and the key to increasing firm performance is the efficiency with which the technological innovation process is undertaken. Moreover, we argue that directly linking innovation inputs to firm performance would generate misleading results since innovation inputs (e.g. R&D expenditure) could not improve firm performance by themselves because they involve short-term costs and those investments that do not result in innovations are sunk costs that will not improve firm performance (Koellinger, 2008). Finally, linking innovation outputs to firm performance without considering the effort – innovation inputs – needed to achieve those innovation outputs leads to a skewed perspective.

Based on the previous discussion, this paper aims to contribute to the innovation–performance literature by proposing a new approach to measuring the effect of the technological innovation process on firm performance. Moreover, we assess the moderating effect of technological intensity level and firm size on the relationship between technological innovation efficiency and firm performance.

The methodological strategy is executed in two stages. In the first stage, taking into account the causal and lagged effect of innovation inputs upon innovation outputs, we estimate technological innovation efficiency for each firm based on an intertemporal output-oriented data envelopment analysis (DEA) bootstrap.

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* Corresponding author. Tel.: +34 934 02 90 41; fax: +34 934 02 45 80.
E-mail addresses: claudio.cruz@ub.edu (C. Cruz-Cázares), bayona@unavarra.es (C. Bayona-Sáez), tgmarco@unavarra.es (T. García-Marco).

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Looking for more robust results we estimate the global Malmquist index in order to observe the dynamics of the technological innovation efficiency. In the second stage, we take the estimated technological innovation efficiency as the explanatory variable of firm performance through the estimation of a dynamic panel data model. To verify the consistency of our arguments, we also estimate two models that include innovation inputs and innovation outputs instead of technological innovation efficiency as explanatory variables of firm performance. In order to achieve the second objective, we also test for the moderating effect of technological intensity level and firm size in these models.

Few studies have endeavored to measure technological innovation efficiency and most of them have mixed innovation inputs or outputs beyond the innovation process (Zhong et al., 2011) while others have disregarded the lag effect of R&D on innovation outputs (Guan et al., 2006) or have used macro-level data (Lee et al., 2010). Moreover, the linkage between technological innovation efficiency and firm performance is almost non-existent in the literature. In this context, this paper contributes to the literature by estimating a technological innovation efficiency measure using only innovation inputs and outputs in the analysis, which allows an objective evaluation of the technological innovation process and by linking the estimated efficiency with firm performance. In addition, the nature of our sample allows us to obtain more robust results since we are able to correct for endogeneity and autocorrelation at the second stage of the analysis.

This paper proceeds as follows. Section two presents the theoretical framework the hypotheses. Data and methods used are described in the third section. Results from the first- and second-stage estimations are shown in the fourth section, while the fifth is reserved for discussion and conclusions.

2. Theoretical framework

2.1. Technological innovation efficiency concept

When evaluating the performance implications of innovation activities, some studies have focused on the short-term direct effect of innovation inputs on firm performance (George et al., 2002), while others seek the long-term indirect effect through the innovations achieved (Balkin et al., 2000) and a third strand disregards innovation inputs and links innovation outputs directly to firm performance (Weerawardena et al., 2006). Furthermore, different types of innovation inputs have been used, such as R&D expenditures (O'Regan et al., 2006), R&D intensity (Hitt et al., 1997) and R&D manpower (Wang and Huang, 2007), and a variety of innovation outputs like product innovations (Li, 2000), process innovations (Akgün et al., 2009) and patents (Zahra and Nielsen, 2002). This use of a wide range of measurements and effects has led to results that are often inconclusive and ambiguous, highlighting the need for further examination of the innovation–performance relationship.

In this study we propose a new approach to measuring the effects of technological innovation activities on firm performance considering both innovation inputs and outputs. We argue that the new approach presented here overcomes some limitation of previous studies.[1]

Technological innovations are achieved through a long and complex process, involving the phases of searching for, selecting, implementing and capturing value (Tidd and Bessant, 2009) and a realistic evaluation of the effects of technological innovation activities on firm performance should encompass the innovation process as a whole. We defend the idea that the key to increasing such performance is through the efficiency with which the innovation process is undertaken. The resource-based view (RBV) gives us support for considering innovation as a process and for evaluating it from an efficiency perspective; RBV supports the concept of the transformation of firm resources – R&D – into desirable outputs – innovations – through the use of the internal capabilities – efficiency. Furthermore, without these capabilities – efficiency – the mere possession of a large quantity of resources – R&D – does not guarantee the creation of a competitive advantage – innovations – or superior performance (Song et al., 2007). Chiesa and Frattini (2009: 2) took the view that "... a larger availability of higher level resources does not necessarily lead to superior performance in R&D". As previously mentioned, we define technological innovation efficiency as the relative capability of a firm to maximize innovation outputs given a certain quantity of innovation inputs.

Measuring efficiency of innovation activities from the technical efficiency perspective (Farrell, 1957) is not new in the literature but the relevant empirical evidence is limited. In Table 1 we list some studies applying this efficiency measurement at a micro- and macro-level. China, Japan and Spain are the countries in which the micro-level analyses have been performed. Divergences can be observed in these studies as some included inputs and outputs beyond the technological innovation process (e.g. Guan et al., 2006; Hashimoto and Haneda, 2008) and some did not take into consideration the time lag required before R&D projects are completed and innovation outputs are achieved (e.g. Revilla et al., 2003; Díaz-Blateiro et al., 2006; Guan et al., 2006). Finally, those papers which at a micro-level only considered inputs and outputs of the technological innovation process and controlled for the lagged effects (e.g. Wang and Huang, 2007; Guan and Chen, 2010) did not link efficiency to firm performance.

As the discussion above indicates, this study makes three important contributions. First, it estimates a technological innovation efficiency measure using only innovation inputs and outputs in the analysis and compares efficiency scores across industries. Second, it takes into consideration the lagged effects of innovation inputs in producing the desired outputs while estimating efficiency. Finally, it links the efficiency of the technological innovation process to firm performance.

We expect that efficiency with which the technological process is achieved will produce a positive and significant effect on firm performance. In other words, firms able to transform their limited innovation resources efficiently through the use of their internal capabilities into the desired innovation outputs will perform better.

The conceptual framework for the research model is presented in Fig. 1. As mentioned earlier, in the first stage we estimate technological innovation efficiency by means of an intertemporal DEA bootstrap and in the second stage we link the efficiency score obtained to firm performance. In order to corroborate our hypotheses, we additionally link innovation inputs and outputs to firm performance and expect a negative effect for the former and a positive effect for the latter.

Based on the RBV, which argues that firms might transform their resources in an efficient way in order to achieve the needed outputs to obtain a competitive advantage, we propose the following hypothesis.

Hypothesis 1. Technological innovation efficiency will have a positive effect on firm performance.

[1] For example, linking innovation inputs to firm performance could lead to misleading results, for various reasons: (a) R&D expenditure is a measure disconnected from the requirements of competitive advantages since it makes no reference to potential customer demand (Liao and Rice, 2010) and (b) R&D activities cannot improve firm performance by themselves, since they are simply an input that involves short-term costs and those investments that do not result in innovations are sunk costs that will not improve firm performance (Koellinger, 2008).

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