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Innovation and Productivity: A Review in Literature

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Abstract:
Innovation plays a crucial role in improving a firm's performance. The relationship between innovation and productivity has been widely analysed during this decade across countries and industries, generating important new findings. This study aims to provide an overall literature review on the relationship between innovation and the productivity of firms to obtain a comprehensive overview of the role innovation plays in changing productivity. By reviewing existing empirical evidence, one can better understand the different measurements of innovation and productivity. This study also provides a discussion on methods adopted to quantify the relationship between innovation and productivity: CDM model, IV regression, and system-GMM approach.
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1. Introduction

Innovation and technology improvement has been widely known as key drivers of a firm's productivity (Bartelsman & Doms, 2000). There are two things that could affect productivity: through the availability of input resources and through value-adding to the products in producing process. How can innovation affect productivity? What evidences suggest that innovation can have a great impact on productivity? This paper will provide some ideas for those questions.

This study aims to provide a brief review of recent studies on the link between innovation and a firm's productivity. Different measurements of innovation and productivity and several models to quantify this relationship will be discussed in this paper.

The study is organised as follows: Sections 2 and 3 provide theoretical studies on innovation and productivity and how they are measured, respectively. Section 4 presents empirical studies on the relationship between innovation and productivity.

2. Productivity: Concept and Measurements

Productivity is the efficiency of the process in which a firm, an industry, and a country convert input factors into output. Therefore, productivity is generally defined as the ratio between output and input in the manufacturing process. Productivity is a good indicator of the economic performance of a firm, industry, or country as a whole.

There are many ways to measure productivity, but they could be classified into two groups: single-factor productivity measures (in which productivity is the ratio of output over single input) and multifactor productivity/total factor productivity measures (a measure of output to several inputs).

In the group of single-factor productivity, there are two ways to measure productivity: labor productivity and capital productivity. These measures are easy to calculate, but they only reflect the partial productivity of workers' capacity or capital intensity and their efficiency in combination with other input factors in the production process. To have a better index of productivity that takes into account the contribution of more than an input, multifactor productivity/total factor productivity turns out to be a more efficient measure.

Mainly there are two trends of approach of research in how to calculate total factor productivity: non-parametric and parametric. With the non-parametric technique, growth accounting is the most used based on a paper by Robert Solow in 1957 about technical changes and production function. Although the growth accounting technique is well–established and consistent, it cannot address the problem of causality, which is an investment in technological changes that can be driven and result in productivity growth at the same time. With the parametric technique, the econometric method has been applied to estimate total factor productivity in the relationship between production inputs and output (production function estimators). There are several benefits of using econometric techniques: the parameters can be checked for statistical significance, solving the problem of endogeneity.

As mentioned above, there could be the problem of endogeneity caused by a possible relationship between input decisions and productivity shocks (unobserved productivity - w_{jt}), which means firms might adjust their input level according to productivity shocks. Therefore, the result of input coefficients in the OLS regression might be biased and inconsistent (Eberhardt & Helmers, 2010).

After the problem of endogeneity arises in production function estimation, several solutions have been developed and applied in the literature: Instrumental Variables (IV) regression, dynamic panel estimators – developed by Arellano and Bond (1991) and Blundell and Bond (1998), commonly known as Generalized Method of Moment (GMM) approach and the works of Olley and Pakes (1996) which is categorized as 'structural estimators,' and further developed by Levinsohn and Petrin (2003). In 2011, De Loecker introduced some extensions to Levinsohn and Petrin model to estimate total factor productivity.

In the standard IV regression, independent variables that cause endogeneity (in this case, input quantities - K and L) need to be instrumented to generate consistent and unbiased coefficients. With the assumption of perfectly competitive input and output markets, input prices (*r, w)* have been introduced as instruments for input quantities. However, input prices seem not to be good instruments, as summary by Eberhardt and Helmers (2010) and Van Beveren (2012), for the following reasons:

- Lack of information about input prices in most of the dataset. Even though those information exist, they do not vary across firms enough to estimate the production function.
- The assumption of a perfectly competitive inputs market seems hard to hold because of the argument that productivity shocks might create market power for firms and then, in turn, affect input prices, causing the relationship between instrument variables and the error term.
- Even if the perfectly competitive inputs market assumption is strictly held, input prices might correlate with unobserved productivity in other ways. That is, the changes in 'input price' wages may be because of the unobserved labor quality, and this unobserved labor quality becomes a part of unobserved productivity, and then wages cannot act as a valid instrument for labor input in production function estimation—similar mechanism with rental rate and capital stock and unobserved productivity. Because of the above reasons, standard IV regression using input prices as instruments for input quantity could not yield consistent results.

It seems hard to find a strong instrument for input quantity in production function regression to yield satisfactory results. Arellano and Bond (1991) and Blundell and Bond (1998) have contributed to the literature by proposing Generalized Method of Moment (GMM) estimator. In this approach, past values of dependent and independent variables have been used as instruments to correct endogeneity problems. These instruments also are valid with the argument that input choices before time *t* are uncorrelated with productivity shock at time *t* - w_{jt}.

Although GMM approach was an efficient tool in addressing the endogeneity problem and yielding satisfying results, this approach is not constructed from a structural model based on the firm's behaviors (Eberhardt & Helmers, 2010). Olley and Pakes (1996) (OP) have developed a new approach that explains a firm's production function using observed firm's behaviors. Put in a simpler explanation, OP solved the problem of endogeneity in the production function by using the observed *firm's investment decision* to proxy for unobserved productivity - w_{jt}.

'Structural estimator' has been further developed from the OP method by Levinsohn and Petrin (2003) (LP). Instead of using investment as a proxy for productivity - w_{jt}, Levinsohn and Pertrin proposed to use intermediate inputs. They have proved that using the suggested proxy would generate more consistent results in the coefficients estimated.

It is important to know about the sources and determinants of productivity. From the definition of productivity, inputs of production (such as capital, labor, material, energy, etc.) are generally well-known as direct factors affecting a firm's productivity. In addition, other factors also have a significant effect on productivity, such as: firm age, firm size, ownership status, credit accessibility, export intensity, etc. These factors could be allocated into two groups:

- Exogenous factors, and
- Endogenous factors

Exogenous factors which are related to firm characteristics are reviewed in this section as: firm age, firm size, and ownership status. Cucculelli et al. (2014) have applied a two-stage approach to determine the sources of productivity in Italia using data from manufacturing firms. In the first stage, they estimated the firm's total factor productivity by applying Levinsohn and Petrin's (2003) approach. In the next stage, other variables (such as firm age, firm size, family-managed status, ownership concentration, and capital intensity) are included in the regression of TFP obtained from the first stage to examine the impact of these factors on firm productivity. They have concluded that family-managed firms are less productive than non-family-managed firms. In addition, they have found evidence for the increasing relationship between firm age and family-managed firm productivity but no relationship between age and non-family firm productivity. Ding and Harris (2016) studied nearly 600-thousand Chinese firms from 1998 to 2007 and concluded that firms with state ownership have lower TFP, which supports their argument that state-owned enterprises remain the least efficient group in the economy. Furthermore, they also found that younger firms are producing more efficiently than older firms.

In terms of firm size, Dhawan (2001), while studying US firms from 1970 to 1989, found that small firms are more productive than large firms. However, Margaritis and Psillaki (2010) suggested that bigger firms are more productive than smaller firms. The positive relationship between firm size and productivity is then confirmed by Cucculelli et al. (2014) and Camino-Mogro and Bermudez-Barrezueta (2021). Tovar et al. (2011) analysed the data of 17 Brazilian electricity distribution firms from 1998 to 2005 to examine the effect of firm size on the productivity of the Brazilian Electricity Industry. They determined productivity using Stochastic Frontier Analysis and found evidence that firm size differences can explain productivity differential.

The relationship between firm capital structure and productivity has been analysed carefully in both theories and empirical studies. The theory of agency suggests the negative effect of debt on firm performance. On the other hand, *free cash flow* theory suggests that debt has a positive influence on a firm's performance. Margaritis and Psillaki (2010), using data from three industries in France: chemicals, computers, and textiles from 2002 to 2005, have found that a firm's capital structure is positively correlated with its efficiency. They proposed a two-stage approach to estimate this relationship. First, Data Envelopment Analysis and distance function approach is applied to estimate firm efficiency. In the next stage, the firm's efficiency obtained from the first stage is regressed against leverage and other control variables using dynamic OLS estimation to examine the impact of leverage on the firm's efficiency. In contrast, studying Korean manufacturing firms, Kim (2006) found a significant negative effect of debt ratio on firm productivity. However, they also found the positive impact of debt ratio in Chaebols firms (which are defined as family-managed, debt-dependent, diverse business activities firms). A study by Le and Phan (2017) using data from Vietnam non–financial listed firms from 2007 to 2012 pointed out the significant negative relationship between debt ratio and firm performance.

3. Innovation: Concept and Measurements

Oslo Manual (OECD, 2005) suggested the definition of innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method in business practices, workplace organization or external relations." There are four types of innovations proposed in the Oslo Manual (OECD, 2005):

- Product innovation,
- Process innovation,
- Marketing innovation, and
- Organizational innovation

Different types of innovation can be easily represented by dummy variables applied by many studies such as Hall, Lotti, & Mairesse (2008), Griffith, Huergo, Harrison, & Mairesse (2006), Mairesse, Mohnen, & Kremp (2005), Mairesse & Robin (2009), Polder, Van Leeuwen, et al. (2009), Morris (2018). However, this measurement could not adequately reflect the differential in innovation intensity among firms (Mohnen & Hall, 2013). It could generate misleading results while examining innovation activities across firms of different sizes that large firms could be more innovative than small firms. In fact, it is argued that large firms might involve in many activities. Therefore, these activities could fall into one of four innovation types. Therefore, innovation dummy variables might not be suitable to come up with the conclusion that large firms are more innovative than small firms.

Innovation can be measured in terms of both input and output approaches. Input approaches refer to a firm's effort to introduce new products, improve its production process, open new markets or raise a firm's efficiency. On the output side, innovations are reflected through new products introduced, successfully improved production process, costs deduction, or gain in efficiency (Mohnen & Hall, 2013).

With the input approach, innovation is commonly measured by Research and Development (R&D) expenditures which are involved in developing the process of introducing new products or production methods. However, there are many non-R&D activities that firms are involved in, and these activities are considered innovation. Oslo Manual (2005) has pointed down several non-R&D innovation activities that firms might have. They can buy patents, pay royalties or scientific information, and then modify them in compliance with their need. They can improve their labor knowledge and skill via internal training. They can buy new equipment and software and improve their facilities, which affects the innovative process. They can improve their current management structure or create a new method to introduce products to the market. Together with purely R&D activities, these above non-R&D activities also have the common objective of innovation to improve the firm's efficiency. Therefore, expenditures of these non-R&D activities should be taken into account in measuring innovation together with R&D expenses. Another suggestion from Oslo Manual (2005) about measuring innovation with the input approach is by the skilled employees of the firm. As skilled employees are considered key assets for innovation activities, they help to facilitate the process of adopting new technologies, manage manufacturing operations and resolve possible technological problems.

On the output side, innovation is generally measured based on its quality which can be represented through revenue. The percentage revenue share of new products or current products with added value through the innovation process is a proper indicator for showing the results of innovation in the overall firm's performance. This indicator has been used to proxy for innovation in many studies, such as Miguel Benavente (2006), Jefferson et al. (2006), and Siedschlag et al. (2010). Another measurement of the effect of innovation on a firm's performance is cost deduction due to process innovation (Peters, 2008). The number of patents resulting from the innovation process is also an indicator of innovation, and it is closer to the notion of invention. Kim and Oh (2009) found that patent applications have a significant positive effect on productivity in the Korean manufacturing industry in the period from 1981 to 1999. Mohnen (2019) argued that patents might have a significant effect on particular industries such as chemicals, pharmaceuticals, or computer. In addition, the invention is a costly process and might not be affordable for small firms.

4. How Has the Relationship between Innovation and Firms' Performance Been Analysed in the Literature?

How does innovation affect a firm's performance? Innovation in a firm's performance is argued as a process in which innovation inputs generate innovation output, and then this output contributes to the overall firm's performance (Crépon, Duguet, and Mairessec, 1998). Crépon, Duguet, and Mairessec (1998) proposed a method to estimate the relationship between innovation and performance called CDM model, which has been applied and developed by many researchers over the world, such as Miguel Benavente (2006), Janz, Lööf, and Peters (2003), Mairesse, et al. (2005), Siedschlag, Zhang, and Cahill (2010), Crespi and Zuniga (2012), Baumann and Kritikos (2016). CDM model takes into account the whole process of innovation by three equations:

- Firm's decision on innovative activities,
- The results of those activities, and

- Impact of innovation activities on productivity

In the research of Siedschlag, Zhang, and Cahill (2010), CDM model is employed with panel data of 723 firms from the Community Innovation Survey of Ireland from 2004 to 2008 and control for foreign ownership and international trade activities. They conclude that:

- Foreign-owned firms and domestic firms involved in export activities are more likely to invest in innovation than firms with domestic activities only,
- Foreign-owned firms and domestic firms involved in export activities are more likely to have innovation output. Innovation expenditure has no significant effect on innovation output, and
- Innovation outputs have a positive relationship with labor productivity

More recently, Morris (2018) analysed this relationship using data from 40,577 firms across 43 countries surveyed in the World Bank Enterprise Surveys in both manufacturing and service sectors. The study used several innovation indicators to represent whether the firm has introduced product and/or process innovation and R&D expenditure intensity. CDM model was applied to examine the relationship and confirmed that significant innovative firms have higher productivity in both manufacturing and service sectors.

The innovation – firm's performance relationship is argued as a causal relationship (Belderbos, Carree, and Lokshin, 2004; Lokshin, Belderbos, and Carree, 2008; Parisi, Schiantarelli, and Sembenelli, 2006; Santos, Basso, Kimura, and Kayo, 2014). On the one hand, innovation creates new products, improves production processes or business practices, and then leads to an improvement in the firm's efficiency and performance as well. On the other hand, firms with better performance tend to put more effort into innovation creation. Because of the causal relationship between innovation and a firm's performance, IV or GMM estimation has been applied in many studies to correct the endogeneity problem that arises.

Belderbos, Carree, and Lokshin (2004) have analysed the impact of innovation and firm performance in the Netherlands. They measure a firm's innovation by two sets of variables:

- Internal innovation activities represented by internal innovation expenditure per sales, and
- External innovation collaboration through R&D cooperation dummies with competitors, suppliers, customers, and universities or other research institutions.

A firm's performance is expressed in labor productivity growth and sales of products that are new to the market growth. IV regression has been applied to identify the causal relationship between innovation and productivity. Productivity in the previous period is also included in the model because of the argument that past productivity levels can impact current productivity growth. They found that different types of R&D collaboration and innovation intensity significantly and positively affect productivity growth, but there is no significant effect of innovation intensity on innovation sales growth.

Also, using internal and external innovative activities to represent innovation, Lokshin, Belderbos, and Carree (2008) found a significant positive relationship between internal innovation and labor productivity. Internal innovation is defined as the in-firm's R&D expenditure, while external innovation is the contracted R&D with other firms. They applied GMM estimation for the dynamic panel equation from augmented Cobb-Douglas production function for 304 Netherlands manufacturing firms from 1996 to 2001. The authors concluded that internal and external R&D complements the relationship with productivity with decreasing returns to scales effect. Internal R&D plays an important role in a firm's productivity, and external R&D only has a significant impact on the circumstance in which a firm has invested enough in internal R&D.

Parisi, Schiantarelli, and Sembenelli (2006) did research on 941 manufacturing firms in Italy from two surveys in 1995 and 1998 to examine the innovation – a firm's performance relationship. They used product and process dummies and R&D expenditure as a percentage of output to represent for firm's innovation effort. The study uses two approaches to identify the impact of innovation on firm performance. At first, Cobb-Douglas production function is applied against output growth and innovation variables, instrumented by a lag of ln(output/labor), ln(material/labor), ln(capital/labor), R&D intensity, and size. In the second approach, TFP (calculated using Levinsohn and Petrin (2003)) is regressed against innovation variables, instrumented by the same set of variables in the first approach. The results showed a positive impact of process and product innovation on productivity. These results are robust in both approaches: TFP growth and Cobb-Douglas production function estimation.

RL (2021) confirmed the positive relationship between investing in innovation and a firm's growth in the agriculture input industry of India. 1,320 firm-year observations have been analysed using GMM technique.

In contrast, many papers found no significant effect of innovation on productivity. Santos, Basso, Kimura, and Kayo (2014) concluded that innovation efforts from innovative investment do not significantly explain a firm's performance. In addition, Li and Atuahene-Gima (2001) explained the insignificant impact of innovation on a firm's performance through the uncertainty characteristic of innovation. Furthermore, it is required special resources and capabilities in terms of organizational structure for innovation activities to generate positive outcomes for the firms, as suggested by Branzei and Vertinsky (2006).

5. Conclusion

From the previous theoretical evidence, productivity can be calculated in two ways: single factor productivity (labor productivity and capital productivity) and total factor productivity, which can be classified into non-parametric approach (growth accounting technique) and parametric approach (OLS regression, IV regression, GMM approach, OP approach, and LP approach). In terms of innovation, there are four types of innovation which are: product innovation, process innovation, marketing innovation, and organizational innovation. Those can represent innovation in the regression as dummy variables. However, dummy variables might not be suitable to measure the innovation intensity but other indicators, such as R&D expenditure or the number of skilled employees (input approach), percentage revenue share, or cost deduction from the innovation process (output approach).

The relationship between innovation and productivity has been widely analysed. There are several techniques have been applied to quantify this relationship so far. CDM model considers the whole process of innovation to productivity via three equations. However, this relationship is argued as a causal relationship, and then IV and GMM approaches have been used by many researchers to correct the endogeneity problem that arises. From the existing empirical studies, innovation has been widely confirmed to have a positive effect on a firm's productivity. However, there are still some empirical studies that found no significant effect of innovation on productivity. It is necessary to construct a fully intensive dataset about innovation to examine the dynamic aspects of the relationship for further research.

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