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IMPACT OF INNOVATION ON PRODUCTIVITY AND EFFICIENCY: EVIDENCE FROM THE TEXTILE INDUSTRY OF PAKISTAN

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ABSTRACT

Being ranked 4th in the production of cotton, Pakistan's Textile industry makes up one-fourth of industrial output and generates employment for about 40 percent of the industrial labor force. Having 60 percent of total export, textile export has been declining in Pakistan since 2013-14. Therefore, this study explored the impact of innovation on productivity and efficiency in the textile industry in Faisalabad and Lahore, Pakistan. These two districts together contribute 47.8 % of the total textile firms of Punjab, Pakistan. The Stochastic Frontier Analysis has been used on data taken from 193 textile firms by random sampling. The ownership of the firms has key importance in reducing the firms' inefficiency. The lesser the liabilities, the more likely it is for the firm to take the risk, apply new ideas, and adopt innovation. Employing skilled labor in their work facility increases the likelihood of efficiency. The results show a positive relationship between efficiency and all types of innovation. While Research and development expenditure also has a positive effect on productivity as well as efficiency. Workers' training also enhances the productivity of firms, so government should facilitate the firms for workers' training and R&D expenditure.

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INTRODUCTION

The United Nations proposed the "Agenda for Sustainable Development 2030", including 17 Sustainable Development Goals (SDGs). SDG-12 refers to sustainable production and consumption. It implies a reduction in the use of scarce resources or better use of inputs. The textile industry has become a vital component of daily life and the global economy (Gabriel and Luque, 2020). Thus, it is required to examine the utilization of inputs considering innovation, technology, and efficiency. In the modern age of technology, innovation leads the economy to go forward and increase the firm's productivity by enhancing the performance of the factors of production. Firms need innovation to be competitive across the globe. It is beneficial to reduce the cost of production and increase the efficiency of labor. In this way, the firm can compete with the firms (Boso et al., 2013). Acquiring state-of-the-art technology and innovation provides a competitive edge to the countries in improving their material well-being (Kafouros et al., 2018). Enterprises feel that investment in innovation is an expensive project to incorporate innovation in their organization. In the changing world, the survival of the firms is to adopt the art of state technology which needs investment. But, the textile sector in Pakistan faces a problem and cannot attract investment in Research and Development (R&D) to a large extent. Consequently, it failed to compete international competitors like China and Bangladesh in the global market. In addition, the machinery used in textile sector are old fashioned and lack of latest technology result in low production and high cost of production and make the firm unable to compete international market (Aamar, 2012). Market innovation's contribution have significant competitive advantage whereas the organizational administration played mediating role to achieve the competitive advantage (Anning-Dorson, 2018). The innovation input plays important role to enhance labor productivity and provide foundation for welfare by accumulating wealth and making firms competitive at international market while the innovation output efficiency increases due to exports (Mairesse et al., 2012).

The first measure to attain the effect of innovation on productivity is through R&D, mostly known as innovation input which has a significant impact on innovation output and contributes to labor productivity. Some researchers argued that innovation output is more important for productivity than innovation input (Aldieri et al., 2019; Marques et al., 2015). Therefore, R&D expenditures result in reducing production costs, and product innovation limit its substitutability by doing more expenditure on skilled labor (Braun, 2008). Green technological innovation helps enhance the expected output level (Wang et al., 2021). The productivity of enterprises increases due to R&D investment. It is evident that the size of the firms also contributes to the productivity growth of the firms (Huergo and Jaumandreu, 2004). Technological innovation is helpful in raising the input-output ratio, resource utilization, and total productivity. Removal of resource constraints and increase in productivity jointly leads to economic efficiency (Raymond and Raymond, 2019).

Under rapidly changing market conditions, advancement in information technology, and increasing trends of globalization, firms are forced and need to introduce and invest in new technology to produce a variety of products, so they can compete with other firms in an ever-changing market. The economic impact of innovation in developing countries is ambiguous and needs to understand its economic implication (Wadho and Chaudhry, 2018). To be specific, Crépon, Duguet, and Mairesse (CDM) model provides the basis for investigating the link between productivity and innovation (Crepon et al., 1998). Many studies differentiate between process innovation and product innovation, while some researchers mention some other types of innovation, like incremental and radical innovation (Fu et al., 2013). So, the minimum criterion for the firm to be innovative is to produce goods at least new to the firm. The logic behind the minimum requirement is to persuade the firm to adopt innovation. Thus, firms may gain the encouragement of innovation adoption, and the process of adopting innovation could start in the economy. The process would encourage economic activities when innovation diffusion takes place in the economy and result in high productivity and export performance (Raymond and Raymond, 2019).

Although firms in developing countries recognize little about the role of exports in the way of growth, the reason behind this might be the lack of opportunities and small firms could not channel the multidimensional export market. Market-based resources and capitalization are also major difficulties in this regard (Boso et al., 2013). The world has become a global village, and globalization has compelled countries to boost economic development through exports. However, consideration of international standards is required by local firms and manufacturers to compete in the world (Adhikari and Weeratunge, 2007). Exports are a source of foreign exchange and investment, thus, showing unintended positive externalities. It creates income-generating employment opportunities (Iqbal et al., 2012; Jimoh Babalola et al., 2012). It leads to an increase in production, the adoption of modern technology, and attaining maximum production levels. Thus, it increases the national income and profits. The increase in market share and foreign earnings can help the economies to meet their necessary import bill and investment target, which in turn accelerates the development process (Chang and Chen, 2012).

Pakistan is an agricultural country, having an agro-based industry and export of cotton products (i.e., cotton yarn, clothes, and fabrics). Other exports include sports goods and surgical items. The manufacturing sector is not developed yet and faces low exports and high imports. Consequently, the country faces budget deficits, an imbalance in international trade, and low levels of foreign exchange. Semi-manufactured output is another reason for low export, which has low demand in the international market. Old-fashioned ways of production and the usage of outdated machinery in the production process affect not only productivity but also affect the quality of the product. Thus, it leads to low demand for export. The aim is to enhance export share in the world but fail to achieve this target (Aamar, 2012).

Pakistan ranked 4th in terms of the maker of apparel commodities, sharing 52% of total trade (US$12.36 billion), 8.5% of total GDP, 46% of total production, and 40% of whole work power. The textile industry in Pakistan has serious issues such as oscillating yarn rates, power shortage, shading of the business for many days, shortage of oil supplies, rupee inflation, and the rule of martial law. The absence of R&D organizations is a barrier to enhancing resource value (Atkar et al., 2021). Textile is the major manufacturing sector in Pakistan. It has the potential for value addition and encompasses a long chain of products, including cotton, ginning, spinning, fabrics, dyeing process, finishing process, and garments. It claims the 25% value addition of industrial sectors in Pakistan and engages nearly 40% industrial labor force. It sustained its share in export by about 59% despite seasonal and cyclical ups and downs during the period. However, the textile sector did not perform better during the period of 2018-19 as it is reported in the previous year. It shows negative growth and falls to 0.3% as it was 0.5% in the last year, even though it has a high weight in the Quantum Index Manufacturing index (QIM). The textile industry of Pakistan is small, medium, and large-scale manufacturing and producing a variety of products like yarn, fabrics, knitwear, hosiery, towel, and readymade garments. Large-scale manufacturing is organized, while small and medium-sized firms are unorganized. (GOP, 2019). Textile export has been declining in Pakistan since 2013-14 (GOP, 2018). The falling trend of textile sector exports implies the need to explore the factors behind this decrease.

Pakistan's government took initiatives to increase the export-to-GDP ratio, but it has remained stagnant over the years, and its share in world export is very meager. Pakistan's economy indulges in many economic issues, and there might be many solutions to existing issues, but the best choice for Pakistan to address the issues of low economic growth is the export-led growth strategy. Pakistan secures its 4th position in ranking the production of cotton in the world. It has the potential to increase crop output, which is possible if the raw material is available at the domestic level to the firm (Ahmad and Afzal, 2020). The textile value chain starts from cotton picking to finished goods like garments. As it consists of a process, the output of one subsector is the input for the other. Consequently, each subsector leads to value addition and the generation of employment. Production of the Textile sector depends on different stages and goes through the process of cotton, ginning, spinning, fabric, dyeing, made-ups, and garments. The sector facilitates industrial value added and accounts for one-fourth of industrial output, and generates job opportunities. Employment in the textile sector is about 40% of the industrial labor force in Pakistan (GOP, 2018).

Firms in developing countries operate on traditional ways of the production process instead of adopting innovation. Therefore, it provides the opportunity to study the gap and boost entrepreneurial activities in the region. A comprehensive study is necessary for a better understanding of innovation and its interaction with R&D and other important agents as well. So far, many works have been done on the link between innovation and productivity, but limited studies have focused on the innovation types and their role in the determination of the firm's efficiency.

Thus, this study contributes to the literature in many ways. Firstly, this study uses the translog production function to estimate the production function of textile firms. Most studies used Cobb Douglas production function for the purpose. The Translog function is more flexible than Cobb Douglas's production. Secondly, this study uses four types of innovation to find out their impact on the efficiency of textile firms in Pakistan. Thirdly, it accounts for the role of export in determining the efficiency of the firms. Fourthly, it also discusses the impact of R&D expenditure on the efficiency of the firms by controlling the size of the firms.

Literature Review

The first measure to attain the effect of innovation on productivity is the introduction of R&D, mostly known as innovation input which has a significant effect on innovation output which contributes to labor productivity (Crepon et al., 1998). Product innovation refers to improving the characteristics of a product or service or delivering a new product or service to the consumer, whereas process innovation describes the adoption of a new or improved method of production. However, access to new market changes in an industrial organization is also a dimension of innovation (OECD, 2005). Kalantaridis (1999) found that the size of firms has a relationship with innovation in manufacturing firms. He concluded that there is evidence that innovative activities do not create job opportunities at the micro level. The incremental types of product innovation affect the propensity of export; however, the impact of a new product on the export propensity is not evident. It may affect a time lag (Dohse and Niebuhr, 2018). Innovation, creativity, and technology transfer positively affect a country's export (DiPietro and Anoruo, 2006). Innovation has a positive impact on a firm's labor productivity; however, technology contributes more to productivity than managerial innovation (Fu et al., 2018). Productivity and innovation, and financial services score are positively affected by the size of the (De Jong and Vermeulen, 2006; Mairesse et al., 2012). Wagner (2007) found that exporter firms in Germany perform more than those non-exporter. The firms that export produce more than the firms that do not export. Azar (2017) showed the direct and indirect positive relationship between organizational innovation and export performance by sustaining technological innovation. Abdu and Jibir (2018) revealed that R&D investment, proper training, size of the firm, firm status in exporting, opponents, location, firm type, and components, or firm's activity had a positive impact on the firm propensity to innovate. The firms that engage globally in business are characterized by high productivity, R&D efforts and innovating performance (Castellani and Zanfei, 2007).

Blyde et al. (2018) combined information on innovation activities at the firm level with a rich dataset on exports at the transaction level from 1498 exporting firms. Results indicated that innovation-related firms could expand their exports more than other firms. Yang (2018) examined the effects of heterogeneity on innovations. Innovation (i.e., R&D) was used as the dependent variable, while export, firm characteristics (i.e., firm size, age, foreign capital, capital intensity, job training expenditure, profit, and skills intensity), and knowledge spillovers were independent variables. Results showed a positive association between exports, R&D, and the sale of the new product. Altuntas et al. (2018) examined the nexus between advanced manufacturing technology, innovation, export, and firm performance using data from 310 manufacturing firms in Turkey. Results showed a strong positive link between the use of AMT and innovation; and between export and firm performance. Further, export mediated the relationship between AMT and firm performance and between innovation and firm performance. Wadho and Chaudhry (2018) studied innovation and firm performance in the textile sector in Pakistan. They found a positive relationship between export and innovation performance. Wang (2018) studied inbound open innovation and firm performance across different organizations. There was a causal relationship between the implementation of inbound open innovation and firm performance. They revealed that inbound open innovation, efficient internal R&D activities, and product newness lead to better firm performance. However, all these studies explained types of innovation and their relationships with export, economic growth, and firm performances across developed and developing countries. However, the literature failed to examine the impact of innovation export performance in the case of textile firms in Faisalabad, a renowned textile city in Pakistan.

METHODOLOGY

A conceptual framework is presented in this section, along with the empirical methodology used in the underlying study for identification and estimation to show how the innovation in Pakistan's textile industry can affect the producers' technical (efficiency).

Theoretical explanation of the model

Product innovation

How to interpret, comprehend, and explain the new environment of innovation brought about by pervasive digitalization has been a difficulty for innovation academics. Today, all industries and their business strategies are influenced by context. It is unusual in that it cannot be explained by earlier theories that helped many industrial-era businesses thrive for about a century (Lyytinen, 2022). R&D collaborations with universities are expected to improve product innovation the most among the four forms of R&D collaborations that can assist enterprises to invent goods. Universities have a deeper pool of knowledge than other potential collaborators, which helps them support product innovation better. Universities have always played the function of producing wide knowledge through study in numerous fields where the rewards are far off. Universities, in contrast to other organizations, also intentionally have a wider knowledge base. They were created so that students might pursue a variety of academic interests within the same institution. This is especially true in the United States, where students are required to take courses in a variety of subject areas before concentrating on one course. The university's multidisciplinary structure offers a depth of expertise in areas that don't frequently coexist in other institutions, creating special chances for access to and integration of knowledge. There is a widespread perception that university collaboration is primarily concentrated on basic, pre-competitive research and that university collaboration is a driving factor for basic research (Sáez et al., 2002) that might be less beneficial for industrial use right away. However, universities are gradually reorienting their attention to industry needs. The least significant effect on product innovation is expected to be had through R&D partnerships with rival companies (Un et al., 2010).

Process innovation

A model for the relationship between firm size and R&D effort put toward product and process innovation was developed by Cohen and Klepper (1996). The effect of an invention in this model is indicated as a modest rise in the price-cost margin (pc). Lower manufacturing costs in the case of a process innovation led to an increase in a company's price-cost margin. The business will profit from the increased price-cost margin as long as its rivals do not copy the innovation. It is a given that innovations are not licensed or sold to other businesses in a completely inert state. The difficulties in exchanging market-related information can be considered as the justification for this. This presumption states that a firm's innovation returns can only come from distributing the benefits of that invention throughout its output. It is assumed that an invention necessitates R&D effort and that there is a correlation between the level of R&D and the corresponding rise in the price-cost margin (pc). Considering that R&D work has a positive but declining marginal return (Fritsch and Meschede, 2001).

Organizational innovation

Innovation is crucial to the development and survival of businesses. A company's ability to collaborate with other businesses gives it access to essential information, which improves its capacity for development and innovation. Revenue growth for businesses is impacted by business networking. Successful producers may work with other firms' producers to complete cutting-edge projects. New managerial working concepts and practices and administrative procedures are part of organizational innovation (Sareen and Pandey, 2022).

Market innovation

Multinational companies (MNEs) now have significant new opportunities to interact with global partners, resources, and markets to pursue innovation in foreign markets. Even though the distinctive qualities of digital technologies and assets embody a wide-ranging and optimistic global landscape for innovation, MNEs' success in pursuing such digital innovation will also be shaped by the kind and degree of localization forces present in various foreign markets, an issue that has received scant attention in both digital innovation and international business literature. The MNEs and digital-born global, which create innovation in one region of the world and market in others, are, in fact, among the majority of the leading firms in the digital economy today (Nambisan, 2022).

Study Area and Sampling Procedure

This study is based on primary data, which were collected through a simple random sampling technique. Simple random sampling, a type of probability sampling, is a technique in which each individual has an equal probability of being selected, which is the main advantage of this technique. The whole sampling procedure is performed in one step, with each individual selected independently of the others in the population (Sharma, 2017). In this study, we included manufacturing industries from the textile sector belonging to the Faisalabad and Lahore Districts of Punjab province, Pakistan, in 2018. These two districts together contribute 47.8 % of the total textile firms of Punjab, Pakistan (CMI, 2013). As per the Federal Bureau of Statistics Pakistan, CMI textile has been defined in section 17, which is equivalent to sections 17 and 18 of the International Standard Industrial Classification (ISIC). CMI report indicates that there are 385 textile firms in the region of Faisalabad and Lahore. There are 254 firms and 131 firms in Faisalabad and Lahore, respectively. The criterion we use to sample the firms is based on small, medium and large enterprises. The sample size is calculated using a 95% confidence level with a 5% margin of error out of 385 textile firms in the study region (Faisalabad and Lahore); the appropriate sample size is 193. We collected information from 193 firms via structured questionnaires and their annual reports published on the Securities and Exchange Commission of Pakistan website for the year 2018. The questionnaire was developed as per the Community Innovation Survey (CIS) Europe, and all the standards were followed in collecting the data.

Product innovation means the implementation or commercialization of a new product or new services provided to the consumer. It does not include the changes in products or services which have gone through subjective changes or changes made for the satisfaction of the consumer's taste or judgment. However, changes in design and marketing can be included in separate types of innovation, i.e., marketing innovation. Therefore, technological product innovation can be categorized into two categories, i.e., technologically new products and improved products. Process innovation includes equipment replacement in existing machinery or using new ideas or knowledge in the firm's production method. It may also involve improved techniques that are used in the production process instead of conventional production methods. Organizational innovation, in its nature, is different from that of product or process innovation. It includes the change in the structure of the organization, introduction of the latest managerial techniques, and adoption of new corporate strategies to achieve its goal. In market innovation, new customers can be accessed using advertising leaflets and using a different database as well (OECD, 2005). In our research, we focused on product innovation if firms introduce new products to themselves or improve the product and process innovation if any new techniques regarding the production process are introduced in the firm. The firm's new techniques to market its product are considered market innovation, and any change in the organization's environment is considered organizational innovation.

Econometric Techniques

Stochastic Frontier Analysis (SFA) in the context of innovation(s)

Lovell (1993) defined productivity as the ratio of output to input, which is susceptible to change with innovation in production techniques (Zhangqi et al., 2022). If firms use certain technology to produce the most with the scarce feasible inputs, they are efficient firms. According to Farrell (1957), efficiency is a comparison between the maximum and existing productivity of a firm (Ali et al., 2016). Efficiency has to do with managing resources to get the most output out of limited resources. The proportion of observed output to maximum output is known as technical efficiency. There are two popular approaches to estimating the production frontier such as parametric (i.e., SFA) and non-parametric (i.e., data envelopment analysis) (Khan et al., 2016). Literature (Aigner et al., 1977; Meeusen and van den Broeck, 1977) gave the idea of SFA. The basic model has various additions. The one-step strategy is recommended by Battese and Coelli (1995). It allows for the testing of hypotheses considering production structure and inefficiency (Hossain et al., 2012). The contradiction between the main idea of the one-step approach and the assumption that u_i have an identical distribution that is technical inefficiency and u_i given in the second step as a function of explanatory variables whose distributions are assumed to be identical in the first step (Abdulai and Eberlin, 2001). Utilizing a specific set of inputs and technological tools to create an output is what is meant by production. Technical efficiency is the ratio of output to input. Technical efficiency is the ability of a producer to create the most output with a given set of inputs and technologies in the case when the output is a firm's production. The efficacy with which inputs are converted into outputs is revealed by the efficiency analysis. An inefficient use of resources by a producer who is using the right inputs and technologies but isn't achieving the maximum output will result in lower output and higher costs (Abdulai and Tietje, 2007).

It is assumed that production technologies employed in the textile sector in Pakistan are homogeneous. Let Y_i represent the output of a single firm and X_i represent a vector of different production factors, mathematically represented in Eq. (1) as:

$$Y_i = \ln\big(f(X_i;\beta_i)\big) + v_i - u_i \tag{1}$$

Where

Y_i = vector of firms' log outputs (sales in Rs.)

X_i= vector of production factors of the i^th^ firm

β_i= vector of the parameters of interest

v_i = random error term, assumed to be normally distributed

u_i = inefficiency term.

The error term, v_i is supposed to be independent and has identical distribution, fulfilling the 'iid' assumption (Pfeifer, 2021). Eq. (1) can be used to estimate the performance of a firm using the given technology without exogenous influences on technical skills. However, when a firm brings innovation, there is a greater chance that the technological expertise of the company will be influenced by informational deficiencies from the productivity of the firm with whom they communicate information. Due to unobserved informational inadequacies, studying the productivity of a firm under any technology that disregards the influence of other producers' inadequacies in the firm's production function may be biased (Horrace and Jung, 2018).

The inefficiency terms u_i that can be explained in Eq. (2):

$$u_i = z_i\delta + W_i \tag{2}$$

Where the random variable, W_i, refers to the truncated normal distribution having zero mean and variance constant, such that the truncation point is $-z_i\delta$, which means $W_{it} \geq -z_i\delta$. These assumptions are in line with the non-negative truncation of the $N(z_i\delta, \sigma^2)$ distribution. It is assumed that u_i and v_i are identically distributed for the firms (i = 1, 2,..., N), if they are correlated, then alternative models are needed to explain the technical inefficiency effect and the random errors included in the frontier model (Battese and Coelli, 1995).

The main concern in this study is the interaction between technical efficiency and innovation in the firm's output of producer investment. Assume that producers use a set of inputs to maximize their output. So,

$$Y = f(x_1, x_2, x_3, \dots, x_N) + \epsilon \tag{3}$$

Where Y denotes output, $x_1, x_2, x_3, \dots, x_N$ are the different inputs, and ϵ is the error term. The production function in the stochastic frontier model has an error term, also known as a composite error term, which is made up of two components: noise and inefficiency.

$$\epsilon = v - u \tag{4}$$

where v is the noise, called statistical or white noise. It considers the random effects, while the inefficiency term, u, includes systematic effects that are not explained by the production function but contribute to technical inefficiency. Eq. (3) therefore, takes on the form:

$$Y = f(x_1, x_2, x_3, \dots, x_N) + v - u \tag{5}$$

The production frontier model is characterized as follows:

$$Y_i = Exp(\beta X_i)\exp(v_i - u_i) \tag{6}$$

Where

Y_i = Total sale as production ith firm

$X_i = (n+1)$ row vector where the first element represents the intercept, and the remaining elements represent quantities of inputs employed to produce Y.

$\beta = (n+1)$ a column vector of technology parameters to be estimated.

v_i = random error term assumed to be independently and identically distributed $N(0, \sigma_v^2)$.

u_i = Non-negative error term ($u_i \geq 0$) representing technical inefficiency of firm i.

The stochastic production frontier consists of three components:

1. $Y_i = F(X_i\ ;\ \beta)$, being the deterministic production frontier.
2. $\exp(v_i)$, noise
3. $\exp(-u_i)$, inefficiency

The value of the inefficiency term is $0 \geq 1$. The technical efficiency of a process is measured by the ratio of the observed output to the stochastic output, as discussed earlier.

$$TE_i = \frac{Y_i}{Exp(X_i\beta + V_i)} \tag{7}$$

Y_i is calculated by solving Eq. (7)

$$TE_i = \frac{Exp(\beta Xi)\exp(vi - ui)}{Exp(X_i\beta + V_i)} \tag{8}$$

$$TE_i = \text{Exp}(-u_i) \tag{9}$$

Stochastic frontier models have the following functional form:

$$lneff_i = \alpha + \sum_{d=1}^{N}\beta_1\, lnPInv_i + \sum_{e=1}^{N}\beta_2\, lnPrInv_i + \sum_{f=1}^{N}\beta_3\, lnOrgInv_i + \sum_{g=1}^{N}\beta_4\, lnMktInv_i + \sum_{h=1}^{N}\beta_5\, lnR\&Dexp_i + \sum_{i=1}^{N}\beta_6\, lnExpD_i + \sum_{j=1}^{N}\beta_7\, lnFS_i + \sum_{k=1}^{N}\beta_8\, lnFOwn_i + \sum_{l=1}^{N}\beta_9\, lnFTF_i + v_i - u_i \tag{10}$$

ln = natural log

eff = efficiency

$PInv$ = product innovation

$PrInv$ = process innovation

$OrgInv$ = Organizational innovation

$MktInv$ = Market Innovation

$R\&Dexp$ = R&D expenditures

$ExpD$ = Dummy for exports

FS = Firm size

$FOwn$ = Firm Ownership

FTF = Firm training facility

v_is = Assumed to be independently and identically distributed normal, random errors, having zero means and unknown variance σ_v^2.

u_is = Technical efficiency, which is assumed to be independent of v_is.

The stochastic frontier model has been employed in several studies; however, some studies utilized Cobb-Douglas and translog models. Translog form does not necessitate making any assumptions regarding the elasticity of the production constant or the elasticity of input substitution. Translog form allows data to indicate the function's true curve without imposing a priori assumptions. The functional form of translog can be written as:

$$lnTS_i = \alpha + \beta_1 lnLC_i + \beta_2 lnKC_i + \beta_3\, lnMC_i + v_i - u_i \tag{11}$$

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ln= Natural log

TS= Total sale

LC = Labor cost

KC = Capital cost

MC = Material cost

$\beta's$ = coefficients to be estimated.

And the technical inefficiency can be estimated by the following equation:

$$u_i = \delta_0 + \delta_1 x_1 + \dots + \delta_N x_n + W_i \tag{12}$$

RESULTS AND DISCUSSION

Descriptive Analysis

Table 1 indicates the summary statistics of the variable included in the study. Most of the textile firms earn around 1.78 billion rupees, with a minimum of 31 million rupees, and the maximum sales among the firms are about 3.7 billion rupees. However, there is considerable variation in sales among the firms. It ranges from thirty-one million to about 3.7 billion rupees. The material cost of firms is approximately four times more than that of the labor cost and capital cost of firms. The variation in labor cost is considerable, accounting for twenty-four million to one hundred forty-five million rupees. There is less variation in capital cost than labor cost. Material cost expresses more variation than both labor and capital cost. It ranges from eleven million to more than half a billion. On average, the amount spent on R&D is about thirteen million rupees. There is also substantial variation in R&D expenditure as well. It varies from zero expenditure to thirty-five million rupees. The firm not engaging in innovation do not spend on R&D, while firms engaged in innovation spend considerable amounts on R&D. Majority of the textile firms export their goods while some do not export. Therefore, the export ranges from zero to more than one and a half billion rupees. The type of innovation indicates firms are divided into innovative and non-innovative firms. The innovative firms are further grouped into four groups, i.e., product, process, organizational, and market innovation. Ownership of the firms shows three categories of the firm one is the firm run by an individual, and the second is run by a partnership and a private limited company. Firms are also divided into small, medium, and large firms in terms of labor. Firms having less than twenty laborers are considered small, while firms having more than equal twenty to less than ninety-nine are regarded as medium, and the firm engaging more than ninety-nine firms are included in large firms. The training facility is a dichotomous variable reflecting the proportion of the firms that provide the facility of training to their workers. About 59 percent of the firm provide the services of training to their workers.

Table 2 discusses the average sales of the firms in terms of different groups. Non-innovative firms have lower sales than those innovative firms. The minimum sales of non-innovative firms are thirty-one million, while the maximum average sale is more than three billion. Among innovative firms, the firm involved in product innovation has more average sales than the firms engaged in organizational and process innovation. The second in terms of sales is market innovative firms; they earn approximately two and a half billion rupees. The firms doing organization innovation have more variation in their sales than that product and process innovative firms. There is considerable variation in market-innovative firms. Although the average sale of sole proprietor firms is double that of partnership and private limited companies, there is substantial variation in their sales. The size of the firms also reflects differences in sales. The larger firms have nineteen times more sales than the small firms and about three times more than medium firms. Medium firms claim six times more sales than small firms as well, but it varies from more than three hundred million to more than two billion rupees. Table 2 indicates that the export firms earn five times more than non-exporter firms. However, the variation in their distribution is obvious. The sales of firms that provide facilities for training their workers earn around four times more than the firm that do not provide the facility.

Table 1. Descriptive Summary.

Variable	Obs	Mean	Std. Dev.	Min	Max
Sales	193	1773.933	1186.844	31	3704
Labor cost	193	82.793	64.806	10	288
Capital cost	193	88.285	36.032	24	145
Material cost	193	334.876	193.886	11	670
R & D expenditure	193	0.294	0.295	0	35
Export	193	666.943	590.058	0	1595
Types of Innovation	193	0.684	0.466	0	5
Ownership	193	2.782	1.539	1	3
Training facility	193	0.710	0.455	0	1
Firm size	193	2.005	0.807	1	3

Table 2. Average sales by groups.

Group	Obs.	Mean Sales	Standard deviation	Min	Max
Non-innovative	61	476.131	506.412	31	3459
Product innovation	32	2214.313	919.628	592	3637
Process innovation	26	2495.539	669.475	962	3704
Organization innovation	36	2502.500	933.409	583	3691
Market innovation	38	2302.447	971.739	638	3649
Sole Proprietor	62	761.500	862.398	31	2635
Partnership	68	1595.382	871.599	412	3525
Private Ltd	63	2963.016	559.214	445	3704
Small firms	60	375.633	209.224	31	729
Medium firms	70	1779.686	640.405	608	2741
Large firms	63	3099.254	432.460	1782	3704
Non-Exporter	56	952.821	903.746	31	2818
Exporter	137	2109.569	1125.701	330	3704
No training facility	80	666.338	619.803	31	2929
Training facility	113	2558.071	804.456	583	3704

Table 3. R&D, Exports, and other costs by groups.

Group	R&D expenditure	Exports	Labor cost	Capital cost	Material cost
Non innovative	0	74.607	32.902	47.410	124.820
Product innovation	0.371	829.094	96.938	104.625	417.219
Process innovation	0.400	1050.308	102.231	107.500	435.423
Organization innovation	0.465	1011.389	117.639	111.028	450.306
Market innovation	0.467	892.632	104.658	105.447	424.579
Sole Proprietor	0.084	212.290	38.306	55.758	167.855
Partnership	0.244	534.382	69.794	85.956	314.941
Private Ltd	0.555	1257.460	140.603	122.810	520.762
Small firms	0.033	0	30.183	46.167	120.583
Medium firms	0.250	667.514	62.371	88.400	321.714
large firms	0.592	1301.492	155.587	128.270	553.587
No training facility	0.076	130.988	37.650	55.500	162.887
Training facility	0.448	1046.380	114.752	111.496	456.637

Table 3 reflects the variety of expenses that take place in the process of production. Primary costs include expenditures on labor, capital, and material. Irrespective of what sort of activities firms perform, the material cost of firms is higher than the cost of labor and capital. The material cost of firms is more than double the capital cost and nearly four times greater than the labor cost in non-innovative firms. In the case of firms engaged in product innovation and process innovation, their material cost is four times greater than the cost of labor and capital. When we analyze the material cost over innovation types of the firm, we find that firms those busy with product innovation face higher material costs than the rest of the firms. Process and market innovative firms spend approximately the same on material costs. Market innovative firms have four hundred twenty million rupees in material cost. R&D expenditure is crucial to involve in innovation activities. It provides the base to way upward. In table 3, firms that adopt market innovation have more R&D expenditure than the rest of the innovative firms. There is a slight difference in R&D expenditure in the firms taking an interest in the product, process, and organizational innovation. Organizational innovation firms have less R&D expenditure than those of others participating in innovation activities. R&D cost also differs in terms of ownership; sole proprietors spend more than partnership firms and private limited companies. Partnership firms and private limited companies are almost on the same page in R&D expenditure. A firm's size is one of the most important factors involved in R&D activities. Small firms spend the least on R&D, and large firms have the maximum R&D expenditure when it comes to R&D expenditure. Large firms also spend more than medium firms. They account for double to medium firms and nine times more than small firms.

Exporter firms involve more R&D activities than non-exporter firms. On average, non-exporter firms spend nearly five million rupees on R&D activities, while exporter firms have eighteen million rupees on R&D activities, which is more than double. The exports of innovative firms are more than the exports of non-innovative firms. Among innovative firms, the export of products and market innovation are approximately the same. Process innovative firms have more exports than firms engaged in organizational innovation, which have fewer sales than those of other innovative firms. Sole proprietary firms export more than partnership and private limited firms; however, private limited companies export more than partnership firms. In the case of the size of firms, large firms export more than medium and small-sized firms. Larger firms' exports are around five times more than medium-sized firms. Firms providing training facilities to workers have eight times more export than those firms not providing training facilities to their workers.

Empirical Analysis

Table 4 reflects the translog stochastic frontier production for textile firms in Pakistan. The types of innovation are considered indicator variables in the inefficiency model, and textile firms with no innovation are the base category. In general, all types of firms have negative estimates and significance. As the firms adopt any sort of innovation, it contributes to the efficiency of the firms. The estimate of the product innovation parameter is negative and statistically significant, which indicates that firms engaged in the product are more efficient than those that have no innovation. So, innovation adoption results in the efficiency of the firms. In the same fashion, the parameter estimates of process, organizational, and market innovation are also negative and statistically significant, arguing that those firms engaged in the process or organizational or market innovation is more efficient than the firm that does not innovate. The results are consistent with Crowley and McCann (2018), who stated that during development and moving towards an efficiency-driven stage production process improves, and the quality of the product improves. The size of the firms plays an important role in reducing inefficiency of the firms. The bigger the size of the firms, the more likely the firm appears to be efficient. The sign of a firm's size is negative for the estimated parameter of medium and large firms, indicating reducing the inefficiency of firms. The estimate of parameters for medium firms is insignificant, so there is statistically no evidence for its impact on efficiency. It may be the sample size as the maximum likelihood method require asymptotic properties. On the other hand, the estimate of parameter large firms is negative and significant at 5%, focusing on the reduction of the inefficiency of large firms compared to small firms as they are big in size. The bigger the size of the firms, the more likely it is to reduce inefficiency.

The negative value of exporting firm's coefficient is negative and significant near to 5% level of significance. Thus, the exporting firms are likely more efficient than those not exporting. The coefficient of skilled labor is negative and highly significant, reflecting the more firms have skilled labor, the more it is efficient. Worker's training has negative estimates with low p-value arguing that firms providing training to their workers are more likely to be efficient. Ownership was used as an indicator variable, and sole proprietary firms were taken base category in the analysis. Although the sign of partnership is negative but insignificant, meaning that it may reduce the inefficiency of the firms, there is no statistical evidence for this assertion. It may be due to the small sample taken in the study as maximum likelihood assume the asymptotic property of data. Whereas private limited companies are more efficient than sole proprietary firms because the estimate of its parameter is negative and significantly different from zero.

Table 4. Maximum likelihood estimates for parameters of the translog stochastic frontier production function for textile firms in Pakistan (Innovation types).

Variables	Parameter	Coef.	SE	t-value	Prob.	[95% Conf. Interval]		Sig.
Constant	β_0	7.305	.013	576.32	0.000	7.280	7.329	***
Ln(labor)	β_1	.692	.079	8.710	0.000	0.536	0.848	***
Ln(capital)	β_2	.205	.1	2.050	0.040	0.009	0.400	**
Ln(material)	β_3	-.225	.051	-4.380	0.000	-0.326	-0.125	***
0.5(ln(labor))^2	β_{11}	1.405	.466	3.010	0.003	0.491	2.318	***
0.5(ln(capital))^2	β_{22}	1.48	.695	2.130	0.033	0.118	2.842	**
0.5(ln(material))^2	β_{33}	.219	.107	2.040	0.042	0.008	0.429	**
0.5(ln(labor) x ln(capital))	β_{12}	-3.195	1.148	-2.780	0.005	-5.444	-0.946	***
0.5(ln(labor) x ln(material))	β_{13}	-.642	.762	-0.840	0.399	-2.136	0.852	
0.5(ln(capital) x ln(material))	β_{23}	-.384	.751	-0.510	0.610	-1.856	1.089	
Inefficiency model								
Constant	δ_0	-8.493	0.186	-45.740	0.000	-8.856	-8.129	***
1. No innovation			.	.	.	.	.	
2. Product innovation	δ_2	-1.458	0.491	-2.970	0.003	-2.42	-0.497	***
3. Process innovation	δ_3	-1.554	0.853	-1.820	0.069	-3.226	0.118	*
4.Organisational innovation	δ_4	-0.951	0.540	-1.760	0.078	-2.009	0.107	*
5.Market innovation	δ_5	-1.332	0.472	-2.820	0.005	-2.257	-0.408	***
1b. Small firms			.	.	.	.	.	
2. Medium firms	δ_6	-3.195	0.419	-7.63	0.000	-4.015	-2.374	***
3. Large firms	δ_7	-5.264	1.146	-4.59	0.000	-7.511	-3.017	***
Exporting firms	δ_8	-2.502	0.282	-8.88	0.000	-3.055	-1.950	***
1b. Sole proprietorship			.	.	.	.	.	
2. Partnership	δ_{10}	-0.398	0.401	-0.990	0.321	-1.185	.389	
3. Pvt. Ltd. companies	δ_{11}	-0.321	0.834	-0.380	0.700	-1.955	1.313	
Workers Training	δ_{13}	-1.264	0.481	-2.630	0.009	-2.208	-.321	***
Mean dependent var	6.741			SD dependent var			0.883	
Number of obs	193.000			Chi-square			44696.804	
Prob > chi2	0.000			Akaike crit. (AIC)			-671.651	

*** p<0.01, ** p<0.05, * p<0.10

Table 5. Maximum likelihood estimates for parameters of the translog stochastic frontier production function for textile firms in Pakistan (R&D expenditure).

Variables	Parameter	Coef.	SE	t-value	p-value	[95% Conf. Interval]		Sig.
Constant	β_0	7.300	0.014	516.64	0.000	7.273	7.328	***
Ln(labor)	β_1	0.683	0.085	8.05	0.000	0.517	0.850	***
Ln(capital)	β_2	0.199	0.100	2.00	0.045	0.004	0.394	**
Ln(material)	β_3	-0.209	0.059	-3.56	0.000	-0.324	-0.094	***
0.5(ln(labor))^2	β_{11}	1.407	0.479	2.94	0.003	0.468	2.346	***
0.5(ln(capital))^2	β_{22}	1.499	0.715	2.10	0.036	0.098	2.901	**
0.5(ln(material))^2	β_{33}	0.231	0.127	1.82	0.069	-0.018	0.479	*
0.5(ln(labor) x ln(capital))	β_{12}	-3.195	1.192	-2.68	0.007	-5.531	-0.859	***
0.5(ln(labor) x ln(material))	β_{13}	-0.657	0.777	-0.85	0.398	-2.180	0.867	
0.5(ln(capital) x ln(material))	β_{23}	-0.392	0.751	-0.52	0.601	-1.863	1.079	
Inefficiency model								
Constant	δ_0	-8.495	0.178	-47.820	0.000	-8.843	-8.147	***
R & D exp.	δ_1	-4.903	1.336	-3.670	0.000	-7.522	57.596	**
1b. Small firms		0	.	.	.	.	.	
2. Medium firms	δ_6	-3.245	0.404	-8.030	0.000	-4.037	-2.374	***
3. Large firms	δ_7	-5.160	1.180	-4.370	0.000	-7.472	-3.017	***
Exporting firms	δ_8	-2.544	0.278	-9.160	0.000	-3.088	-1.950	***
1b. Sole proprietorship		0	.	.	.	.	.	
2. Partnership	δ_9	-0.394	0.394	-1.000	0.316	-1.166	0.389	
3. Pvt. Ltd. companies	δ_{10}	-0.203	0.998	-0.200	0.839	-2.160	1.313	
Workers Training	δ_{11}	-1.067	0.431	-2.470	0.013	-1.913	-0.321	***
Mean dependent var.	6.741			SD dependent var.			0.883	
Number of obs.	193.000			Chi-square			44229.328	
Prob > chi2	0.000			Akaike Crit. (AIC)			-677.968	

*** p<0.01, ** p<0.05, * p<0.10

In Table 5, the translog stochastic frontier with R&D expenditure explains that coefficient δ_1 of R&D expenditure has a negative sign indicating a reduction in the inefficiency of the firms. It is highly significant to elaborate that the firm engaging in R&D activities performs well than the firms that do not participate in research activities.

CONCLUSIONS

This study used firm-level data for a textile firm in the year 2018 in Faisalabad and Lahore region from Punjab province in Pakistan to estimate the efficiency of firms that adopt any type of innovation and compare it to the firms that do not adopt innovation. The outcome of the translog stochastic frontier function shows that innovation is the important factor determining textile firms' efficiency. The firms that engage in innovation activities have higher efficiency as we compare them with non-innovative firms. Firms' size also plays a significant role in reducing the inefficiency of textile firms. The bigger it is, the more likely it is to be efficient as it has more opportunity to the way forward. International orientation is also important in determining the efficiency of the firms, as the firms involved in exports are more efficient than those not engaged in export activities. The ownership of the firms has key importance in reducing the inefficiency of the firms. The lesser the liabilities, the more likely it is for the firm to take the risk, apply new ideas, and adopt innovation. Employing skilled labor in their work facility increases the likelihood of efficiency. The more skilled labor produces more and efficiently performs their assignments. For reducing the inefficiency of the firms, workers' training has a substantial role to play. This study suggests that innovation is an important factor in the productive efficiency of textile firms in Pakistan. It helps in enhancing the capacity of the firm to be efficient. Therefore, the productivity of the firms can be enhanced through innovation. Workers' training also enhances the productivity of firms, so Government should facilitate the firms for workers' training and R&D expenditure. This study has some limitations. It ignores the estimation of efficiency using Data Envelopment Analysis. It is also possible to add some other inputs in the production function.

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