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Innovation and firm performance in developing countries: The case of Pakistani textile and apparel manufacturers☆

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ABSTRACT

Using unique innovation survey data collected from a homogenous sample of firms in Pakistan, this paper presents an analysis of the firm level determinants of product innovation and its impact on firm performance. We employ a multi-stage structural model linking the decision of a firm to innovate, its innovation investment, product innovation, and firm performance using primary data from the textile and wearing apparel sector, which is the largest export sector of Pakistan. We find that product innovation leads to increased labor productivity as well as higher labor productivity growth. A 10 percent increase in innovative sales per worker is associated with a greater than 10 percent increase in labor productivity and labor productivity growth. On the determinants of innovation, we find that vertical knowledge flows from foreign clients and suppliers are important determinants of a firm's decision to innovate. Larger firms are more likely to engage in innovation, however, there is no significant evidence that they invest more in innovation. Exporting is positively associated with innovation performance and firms exporting to Europe and America are more likely to engage in innovation. There is mixed evidence on the impact of competition: foreign competition adversely affects a firm’s decision to innovate, whereas, local competition increases investment in innovation. Subsidies seem to have a crowding out effect since firms receiving national subsides invest less in innovation. Furthermore, firms that have higher investment in innovation, that are more productive, and that introduce organizational innovations have higher innovative sales per worker.

1. Introduction

The availability of firm level data and recent developments in economic growth theory highlight the importance of innovation for sustained output and productivity growth. In recent years, firm level survey based data on innovation, especially, from various waves of the harmonized Community Innovation Surveys (CIS) in Europe, has helped in advancing our understanding of innovation processes, strategies, mechanisms and their impact on firm performance. Consequently, a growing body of literature has evaluated the impact of innovation on firm performance. A large number of these studies report a positive impact of technological innovation on labor productivity (Crépon et al., 1998; Lööf et al., 2003; Janz et al., 2004; Criscuolo, 2009; Mairesse et al., 2012; Hashi and Stojcic, 2013), profitability (Jefferson et al., 2006; Lööf and Heshmati, 2006), firm growth (Coad and Rao, 2008), openness (Kleinknecht and Oostendorp, 2002; Lachenmaier and Woessmann, 2006) and other firm level outcomes.[1]

In the wake of an extraordinary increase in access to information and new markets in recent years (primarily due to advances in information technology and globalization), firms in developing countries are experiencing a constantly changing landscape in the market for their products. This on one hand is providing much needed knowledge flows into developing economies, while also forcing firms to improve their competitiveness on the other. In such a situation, one would expect firms (especially those which export) to invest in new technology and also introduce new and improved products in their markets. However, our understanding of innovation and its economic impact is still limited when it comes to developing countries; most mainstream economists tend to assume that openness and easy access to foreign technology is all that matters in improving firms' productivity in the

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[1] See Mohnen and Hall (2013), Hall (2011), and Mairesse and Mohnen (2010) for a detailed review of the literature.

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context of developing countries (Chudnovsky et al., 2006). Of course much of this lack of depth could be attributed to the limited availability of detailed firm level data on innovation processes in developing countries.

The main purpose of this paper is to contribute to the thin developing country literature by using firm level data from a key export oriented manufacturing sector (textiles and apparel) in Pakistan. The contribution of this paper is twofold: first, by using the primary data from a manufacturing sector of a developing country, the paper contributes to the understanding of firm level innovation outcomes in developing countries and their implications for firm performance. Second, the paper builds on a multi-stage structural model proposed by Crépon et al. (1998) by extending the model in two important aspects by taking into account the fact that: (i) a firm's decision to engage in innovation activities and committing resources to them depends on the competitive environment of the sector, and (ii) the innovative firms follow multiple innovation strategies to maximize their innovation related outcomes. In order to cater for the role of competition, we introduce competition variables (local and foreign) signaling the extent of local and foreign competition in the decision to innovate and innovation investment intensity equations. We also incorporate the role of non-technological innovations in the implementation of product innovations by including organizational and marketing innovation in the knowledge production and labor productivity equations (see Hashi and Stojcic, 2013). We believe that by focusing on two very similar sub-sectors (textiles and apparels), we get greater homogeneity in the types of product innovation and the propensity of firms to substitute their existing products. This enables us to get more accurate estimates of innovative sales per worker as well as labor productivity.

In the case of Pakistan, like that of many developing countries, there is no firm level innovation data available. In 2015, we conducted a survey of a representative random sample of 614 manufacturers of textiles and apparels in twelve different districts across Pakistan to understand the innovation system and processes of these two sectors. The choice of the textile sector in Pakistan is based on the very nature of the sector and its significance in the local economy: Textiles have the longest production chain, with inherent potential for value addition at each stage of processing, from cotton to ginning, spinning, fabric production, dyeing and finishing, made-ups and garments. Additionally, textiles are one of the very few success stories (probably the only) of the manufacturing sector in Pakistan. The sector contributes approximately one-fourth of the industrial value added, is very labor intensive and employs around 40 percent of the industrial labor force. The textile sector in Pakistan is also very export oriented and has consistently been one of the main sources of foreign exchange earnings. On average it constitutes 55–60 percent of national exports.[2] Apart from a large domestic market, especially in the high thread count plain weave cloth used in Pakistani clothing, the textile sector also competes in international markets.

Our survey results find that firms in these two sectors are engaged in a variety of innovation activities. They invest resources in innovation, and they introduce both technological as well as non-technological innovations. The total amount of investment on innovation in the surveyed firms was around 9 percent of their total turnover in 2015. A number of firms report investing in internal as well as external R&D, but investing in R&D is not the most dominant innovation activity. Rather, the acquisition of machinery (mainly in the form of imported capital) seems to be the dominant innovation activity and our data shows that more than half of the innovation investment was in the form of acquisition of machinery, hardware and software. Around one-third of total investment was in R&D (both internal and external), and around 13 percent of investment on innovation was related to the training of workers. There are noticeable differences in investment behavior among firms: Firms exporting to Europe invested more than firms with any other sales market. Firms located in the export oriented city of Sialkot[3] had exceptionally high levels of investment in innovation. Overall, surveyed firms in Sialkot spent 27 percent of their turnover in 2015 on innovation. In terms of other firm characteristics, the medium sized firms and manufacturers of apparel spent more on innovations (around 18 and 22 percent of turnover in 2015, respectively).

Apart from investing in innovations, firms were also very active in introducing technological as well as non-technological innovations. Overall, 56 percent of the surveyed enterprises introduced either technological or/and non-technological innovations during the three years, 2013-15. Forty eight percent of enterprises introduced technological innovations (new products and/or new processes) while thirty one percent of enterprises introduced new or significantly improved products in their market. In terms of their degree of novelty, the majority of these innovative products were incremental in nature. Seventy nine percent of these innovative products were only new to the firm, 21 percent of the products were new to the firm's market, and 2.6 percent of products were first in the world.

Firms were also asked about the sources of knowledge spillovers and their significance in the firm's decision to introduce technological innovations. One of the interesting deviations from the existing literature found in our analysis is that surveyed firms do not consider universities and public research institutions as highly important sources of information and cooperation. In fact, only 3 percent (2 percent) of firms consider universities (public research institutions) as important sources of information and cooperation. Firms rank market sources, especially clients and suppliers as the most important source of information and cooperation. There were also noticeable differences within clients and suppliers: foreign clients and foreign suppliers were highly ranked when firm were asked about important sources of information and cooperation.

A number of interesting issues arise from our survey that we try to address in this paper. First, which factors affect a firm's decision to engage in innovation? Which attributes of a firm (size, age, type, main market, export intensity, competition, sources of information and cooperation for innovation, etc.) make it more liable to invest in innovation? Do these or a different set of attributes determine the amount a firm decides to invest in innovation? Second, do the firms that invest in innovation experience higher commercial success—a higher percentage of turnover from these innovations? And which attributes affect the commercial success of these innovations? Third, do the firms with higher innovation rates and higher commercial success of innovations also perform better? We analyze these issues in a multi-stage structural model and we find that there are substantial rewards for product innovators in the Pakistani textile and apparel sector.

The remainder of the paper is organized as follows: we begin by a review of the literature. We then discuss our data and present some descriptive statistics in Section 3. In Section 4, we present our model and define the variables. In Section 5, we present our results and in Section 6, we compare our results to those found in the previous literature. In Section 7, we conclude.

2. Review of literature

2.1. Link between innovation and productivity

There are two widely used approaches to measuring innovation in empirical studies. The first approach uses patents as a proxy for innovation output where a patent is defined as a formal means of protecting intellectual property rights associated with invention. However,

[2] Economic Survey of Pakistan 2015–2016.

[3] The city of Sialkot is known for its entrepreneurial skills and is hub of two other export oriented clusters, i.e. sports goods manufacturers and surgical instruments manufacturers.

there are generally two problems associated with this approach. First, not all innovations are patented and firms, depending on their type of business and innovations, have different propensities to patent. Second, not all patents have the same practical implementation in the production of goods and processes, i.e. they do not reflect commercial success of innovation. Furthermore, in the context of developing countries with weak intellectual property rights, firms tend to avoid filing patents for innovations. The alternative approach to measuring innovation is to use R&D expenditure as a proxy for innovation. There are several problem associated with this approach as well: first, even when well codified, R&D is the measurement of input into the innovation process rather than the output. Second, performing R&D might not be enough to introduce new products into the market, especially in developing countries where firms generally generate technological advances outside the formal R&D process, i.e. many firms can acquire embedded technology through the purchase of machinery, hardware, licensing/purchase of patents etc. In such cases, formal R&D will not capture the true extent of innovative efforts.

A more recent approach is to use direct information from firms through innovation surveys on innovation inputs, outputs, and modalities. Innovation input is broadly defined as investment in formal R&D and innovation related non-R&D activities such as the acquisition of machinery, hardware and software, purchase/licensing of patents, workers' training related to innovations, etc. Innovation output is defined as the market introduction of new products and processes, as well as implementation of new organizational and marketing strategies. Since not all product innovations carry equal importance, product innovations are further differentiated in terms of their degree of novelty, i.e. new to market or only new to firm, and their intensity or commercial success, i.e. share of innovative products in total turnover. These innovation surveys are based on the Oslo manual (OECD, 2005), which sets guidelines for collecting data on innovation inputs, outputs, sources of knowledge flows and cooperation, constraints, as well as objectives of innovation.

Most of the literature using data from innovation surveys frames the relationship between innovation, its determinants, and its impact on firm performance in two production functions as proposed by Griliches (1979), and Pakes and Griliches (1984). First, innovation and its determinants are modeled in a knowledge production function which assumes that the production of new knowledge depends on investment in new knowledge (innovation input) and other factors such as firm and market characteristics, knowledge flows and cooperation, and constraints etc. Then innovation and firm performance are modeled in an output production function where innovation output affects firm's performance. The crucial assumption in this stage is that the innovation output (not innovation input) directly affects firm's performance. So R&D and non-R&D innovation inputs only indirectly affect performance through their impact on innovation output. Crépon et al. (1998) (CDM henceforth) are considered pioneers in developing a full structural model that links innovation to productivity. The CDM approach uses a four-equation structural model that includes three relationships: the innovation investment equation linking expenditure on innovation to its determinants, the knowledge production function linking innovation output to investment in innovation and other determinants, and the productivity equation relating productivity to innovation output. In order to control for the selection bias, an additional selection equation related to the decision to invest in innovation is added. The CDM approach has been the workhorse model in most of the firm level innovation studies.

2.2. Literature on innovation and firm performance

The existing literature offers a variety of factors affecting a firm's decision to engage in innovative activities and innovation outcome. A large number of studies have tested the Schumpeterian hypothesis of firm size positively affecting innovation efforts. In an earlier work, Acs and Audretsch (1987) report that larger firms are more likely to innovate in industries which are highly concentrated and have entry barriers. Similarly, Cohen and Klepper (1996) find that the probability of innovation increases with firm size, and within industries, firm size and innovation efforts are positively associated across all firm size groups. In more recent research within the CDM literature, most of the studies find a positive impact of firm size (measured as total employment) on the probability of a firm engaging in innovation as well as on its investment in innovation (Lööf and Heshmati, 2002, 2006; Janz et al., 2004; Criscuolo, 2009; Hashi and Stojcic, 2013).[4] Overall, this literature, mainly from advanced economies, supports the Schumpeterian hypothesis that large firms are more likely to engage in innovation.

Another common factor associated with a firm's decision to innovate and the amount of resources devoted to innovation is export orientation. The literature linking innovation to exports generally relies on the 'learning by exporting' hypothesis which refers to the mechanism where a firm's performance improves after entering export markets. Many recent studies using data from innovation surveys show the positive impact of export orientation on a firm's decision to innovate as well as on resources devoted to innovation (Lööf and Heshmati, 2002; Criscuolo, 2009; Kemp et al., 2003; Janz et al., 2004). However, this literature also identifies reverse causation from innovation (especially product innovation) to exports. The potential explanation for this reverse causation is attributed to the self-selection of more productive firms into exporting. The idea is that successful innovation (especially product innovation) improves firm productivity, and more productive firms self-select into the export market which is more competitive (Kleinknecht and Oostendorp, 2002; Lachenmaier and Woessmann, 2006).

Knowledge spillover are also considered to be important for firm level innovation behavior. Both vertical and horizontal flows of knowledge related to innovation provide information about new technologies, new markets, as well as new vintages of capital that are crucial for innovation. Many studies find a positive and significant impact of sources of information and cooperation on both the decision to innovate as well as on innovation investment. Criscuolo (2009) reports a strong positive correlation between what firms consider as important sources of cooperation and innovation expenditure. Hashi and Stojcic (2013) find a positive impact of internal, market, and institutional sources of information on innovation investment. Janz et al. (2004) report a positive impact of cooperation, and Kemp et al. (2003) find contacts and cooperation with research institutes to have a positive impact on innovation input. Another strand of literature focuses on the positive vertical spillovers from larger firms, especially multinational companies. Greenaway et al. (2004) and Gashi et al. (2014) report a positive impact of vertical spillovers on exporting.

Another factor that has received much attention in the innovation literature in recent years is the relationship between innovation and competition. Built on the theoretical foundations of the Schumpeterian paradigm, competition is shown to have a negative impact on innovation and R&D activities. The reasoning behind this is that competition is thought to reduce monopoly rents stemming from innovation, hence reducing incentives to innovate–a mechanism known as the 'Schumpeterian effect' (Aghion and Howitt, 1992; Nickell, 1996). More recently, models incorporating a distance to the frontier approach propose that competition has a positive impact on innovation as well. A mechanism known as the 'escape-competition effect' shows that competition increases innovation, especially in industries with neck-and-neck competition (Aghion et al., 1997; Aghion et al., 2009). Aghion et al. (2005) consider both these mechanisms and propose an inverted-U shaped relationship between competition and innovation. They

[4] Janz et al., 2004 find a negative and significant impact of size on investment on innovation though.

empirically show the existence of an inverted-U shaped relationship between competition and innovation in which competition discourages laggard firms from innovating whereas it encourages neck-and-neck firms to innovate. Castellacci (2011), using a CDM model for Norway, also reports this non-monotonic relationship between the two. He finds that firms in an oligopolistic industry have a greater propensity to innovate as well as having greater investment in innovation. However, firms in competitive industries are better at converting innovation input into output, and also benefit from a greater impact of innovation output on firm performance.

Besides these factors, subsidies, financial and market constraints may also impact a firm's level of investment on innovation. Subsidies are generally considered to have a positive impact on private R&D (Busom, 2000; Klomp and Van Leeuwen, 2001; Almus and Czarnitzki, 2003; Hall and Maffioli, 2008; Criscuolo, 2009).[5] Many studies find a counter intuitive positive impact of constraints on innovation and one example of this is Criscuolo (2009) who found a positive impact for almost all countries. Mairesse and Mohnen (2010), however, suggested that once these constraints are treated as endogenous, their effect can become negative.

An important stage in the innovation process is the transformation of innovation input into output. The most essential input into the production of innovation is investment in innovation (R&D as well as non-R&D). The underlying theory suggests a positive impact of innovation effort on innovation output. This theorized positive impact of innovation effort on innovation output has been found in the majority of the empirical studies (Crépon et al., 1998; Mohnen and Dagenais, 2002; Lööf and Heshmati, 2002; Janz et al., 2004; Criscuolo, 2009; Hashi and Stojcic, 2013). Apart from innovation effort, a firm's technology of converting innovation effort into innovation output is proposed to depend on its size. Firm size is significant and negative in most of the studies, suggesting that smaller firms are more efficient in converting innovation input into output (Brouwer and Kleinknecht, 1999; Janz et al., 2004; Hashi and Stojcic, 2013). However, Lööf and Heshmati, (2002) find a positive impact for the services sector, and Criscuolo (2009) finds mixed results in which firm size is positively correlated, negatively correlated or not correlated with innovation output depending on the country. Others have included financial constraints along with innovation input and firm size. Overall, there is variation in the direction of their impact with evidence of both a positive and negative impact (Klomp and van Leeuwen, 2001; Lööf and Heshmati, 2002; Kleincknecht and Oostendorp, 2002; Kemp et al., 2003; Hashi and Stojcic, 2013).

Innovative firms are believed to follow more than one strategy to achieve their objectives. For example, producing a new product may require a new way of production, and/or a new arrangement for workplace management or external relations, and/or a new marketing strategy to introduce these new products. Generally, it is shown that the use of two or more innovation strategies leads to better performance. Martinez-Ros and Labeaga (2009), and Miravete and Pernías (2006) report a complementarity between product and process innovation. Polder et al. (2009), and Ballot et al. (2011) find a pair-wise complementarity between product, process and organizational innovations. Within the CDM framework, Janz et al. (2004) find a positive impact of process innovation on innovative sales intensity. Hashi and Stojcic (2013) report a positive and significant impact of marketing innovation for both Western Europe and Central and Eastern Europe, and a positive and significant impact of organizational innovation for Western Europe.

Does innovation improve firm performance? Mohnen and Hall (2013) provide a comprehensive survey of the literature using variants of the CDM model.[6] They report a positive and significant elasticity of firm productivity with respect to the intensity of innovative sales in all but one study. There is, however, significant variation in the size of the elasticity depending on the proxy for innovation output, the type of sector (i.e. manufacturing vs services sector), and the use of various controls including other forms of capital such as physical and human capital, and other innovations such as process, organizational and marketing. They report an elasticity of labor productivity with respect to innovative sales up to 0.5 implying that if innovative sales per worker go up by 10 percent, labor productivity rises by 5 percent. Their conclusions are: (i) elasticities are lower and more volatile when elasticity concerns the share of new products instead of share of new products per worker, and (ii) elasticities also tend to be lower when human capital is controlled for. Hashi and Stojcic (2013) find exceptionally high elasticities of 1.46 and 0.64 for Western Europe and Central and Eastern Europe, respectively. Criscuolo (2009) finds relatively high elasticities for another set of countries, i.e. 0.69 for Korea, 0.68 for New Zealand, and 0.65 for Brazil. In an extended model, she also reports a higher elasticity for the manufacturing than the services sector, and overall elasticity is smaller when human capital is controlled for. Janz et al. (2004) also report a slightly higher elasticity for the manufacturing sector as compared to the services sector. The CDM model has also been extended to study developing countries and countries in transition. Chudnovsky et al. (2006) has performed the analysis for Argentina, Benavente (2006) for Chile, Jefferson et al. (2006) and Mairesse et al. (2012) for China, and they all report a positive and significant impact of innovation on firm performance.

3. Data and descriptive statistics

In 2015, we surveyed 614 textile and wearing apparel manufacturers from the Punjab and Sindh provinces of Pakistan.[7] Textiles and wearing apparel sector is defined as all manufacturing firms classified under Sections 13 and 14 of the Pakistan Standard Industrial Classification, PSIC 2010 (International Standard Industrial Classification − ISIC 17 and 18). We used the Directory of Industries (official business book) as the main sampling frame which the same as that used in the Pakistani Census of Manufacturing Industries (CMI). All firms with a minimum 10 employees are included in the frame. The frame was then cleaned/updated with the support of the Bureaus of Statistics of Sindh and Punjab.[8] For this type of survey, the Oslo manual (OECD, 2005) recommends stratified random sampling where the strata can be based on the size of firm, principal activity of the business, geographic location of the firms etc. Due to the limited information available in our frame, we could only stratify our sample based on the geographic location of firms. We drew a stratified random sample which was representative firstly at the provincial level and then at the district/regional level. The total population of the textiles and wearing apparel manufacturers in Punjab and Sindh provinces is 4205 units, and our sample size of 614 is around 15 percent of the population.

The survey questionnaire was designed on the basis of the Oslo manual (OECD, 2005) and its recommendations for developing countries. The core questionnaire related to innovation was similar to the Community Innovation Surveys (CIS) of Europe. Apart from the standard modules on technological (product and process) innovation, the questionnaire included modules on non-technological (organizational and marketing) innovation, competition, and information communication and technologies. The survey was conducted in August-October 2015 and innovation related questions were for the previous three

[5] See Arundel and Hollanders, 2008 for survey of the studies.

[6] See Table 1 for continuous variable (innovative sales), and Table 2 for dichotomous variable.

[7] Total population of the manufacturers of textiles and wearing apparel in Pakistan is approximately 4380 units, of which 96 percent (4205 units) are located in two provinces, Punjab and Sindh.

[8] The frame was updated by cross comparing information with the ministry of textiles Pakistan, various chambers of commerce and industries, all Pakistan textiles mills association (APTMA), Pakistan readymade garments manufacturers and exporters association (PRGMEA), and the Karachi stock exchange.

years, 2013–2015. The survey response rate was 70 percent and a total of 431 firms voluntarily participated in the survey. The majority of the non-respondents were firms which did not exist or were permanently closed at the time of survey (139 firms out of a total 183 non-respondents). Out of the 431 respondents, there were firms who did not report their annual turnover due to confidentiality issues; however, we did not find systematic refusal based on firm characteristics or geographic location. In order to ensure that the data is suitable for estimations, we remove all firms not reporting turnover in 2015 and this reduced our sample to 377 firms.[9]

3.1. Product innovation and innovative firms

The Oslo manual (OECD, 2005) defines product innovation as the implementation of a new or significantly improved product with respect to its characteristics or intended uses. This includes not only the products that are first in the market but also the products that are only new to the firm. The idea of considering imitators as innovators is in line with the observation by Hall (1994) who suggested that the distinction between Schmookler's innovator and the imitating enterprises is often unclear.[10] Imitating enterprises in their process of implementation often do things differently from the way they were done by the first enterprise (be it by design or unintentionally), which makes them innovators in their own way. We follow the same approach and define product innovation as the market introduction of goods that includes both: (i) new or significantly improved to the market, and (ii) new or significantly improved to the firm only.

An innovative firm engages in a variety of innovation activities that serve as an input for its innovation output such as product innovation. We define innovation input as expenditure on five different innovation activities including: (i) in-house R&D, (ii) external R&D, (iii) acquisition of machinery, equipment and software (including lease or rental of machinery or equipment), (iv) acquisition of external knowledge, (v) training for innovative activities. Whereas, we proxy product innovation as the innovative sales, which refers to the sales revenues of a firm in 2015 attributed to products that are either new to market or new to the firm and are the result of innovation during the three years 2013-15.

We then define an innovative firm as a firm that has reported a non-zero innovative sales in 2015. This condition results in a sub-sample of 120 firms (31.8 percent) that were innovative as per our definition.

3.2. Descriptive statistics

Table 1 reports summary statistics of the general information on observations, distribution of industry groups, firm size, innovation expenditures, innovative sales, and innovative firms.

On average, firms in the apparel sector are larger than firms in the textile sector, they spend more on innovation, have a higher percentage of innovative sales, and are more innovative. On average firms spent 3.6 percent of turnover in 2015 on innovation, and approximately one-third of turnover in 2015 is attributed to innovative products.

Another, important observation to notice from Table 1 is that the standard deviations are quite large, and in fact are larger for the apparel sector. This shows a greater dispersion in the distribution of firms in terms of their size, innovation expenditure, and innovative sales. Based on our definition of innovative firms, around one third of all firms are innovative. However, there is a striking difference between the textile and apparel sectors: The percentage of innovative firms in the apparel sector is more than two times greater than the textile sector.

Table 2 reports the distribution of innovation investment in various activities for the sub-sample of innovative firms.

On average innovative firms spent more than 7 percent of their turnover in 2015 on innovation, of which around two-thirds of the expenditure was on the acquisition of machinery, equipment, and software. This finding is in line with the idea that in developing countries, acquisition of machinery is the most dominant innovation strategy. In-house R&D is the second most important activity followed by the expenditure on training related to innovative activities.

4. Model specification

We apply a modified version of the Crépon et al. (1998) (CDM) structural model as in Lööf and Heshmati (2002, 2006). The CDM model builds on three equation system proposed by Pakes and Griliches (1984) that links innovation input to innovation output, and innovation output to firm performance. The CDM approach comprising of a four equation system basically attempts to correct two major problems associated with the econometric estimations of the relationship between innovation and firm performance, namely selection bias and endogeneity bias. Selection bias arises since only a subset of firms engage in innovation activity i.e. invest resources in innovation, and many survey questions are directed to only this subset of firms. If the econometric analysis is restricted to this non-random subset of innovation active firms then the approach must correct for the selection bias. Also, in a four equation system, innovation input is an explanatory variable in the innovation output equation and innovation output is an explanatory variable in the productivity equation, which generates an endogeneity problem where the explanatory variables and the disturbance terms might be correlated. The CDM model handles some of the endogeneity by using a reduced form model to derive consistent estimators, and it explicitly models the selection of innovation input by adding a selection equation to overcome selection bias.

4.1. General specification of the model

Let g_i^*be an unobserved decision variable for a firm's innovation effort and $k_i^*$the unobserved level of a firm's investment in innovation, with g_i and k_i being their observable counterparts. The first two equations of the system can be defined as follows:

$$g_i = \beta_0 x_{0i} + \mu_{0i}$$
$$g_i = 1, \text{ if } g_i^* > 0, \text{ otherwise } g_i = 0 \tag{1}$$

and

$$k_i | g_i > 0 = \beta_1 x_{1i} + \mu_{1i}$$
$$k_i = k_i, \text{ if } k_i^* > 0 \text{ otherwise } k_i = 0 \tag{2}$$

where x_{0i} and x_{1i} are vectors of independent variables. β_o and β_1 are vectors of unknown parameters to be estimated reflecting the impact of various factors on the probability of investing in innovation and the level of innovation investment, respectively. μ_{0i} and μ_{1i} are random error terms with mean zero, constant variances and are uncorrelated with the explanatory variables. However, the two error terms are correlated with each other.

The third equation of the system is the knowledge production function in which innovation output depends on innovation input and other independent variables including the inverse Mill's ratio calculated from the first step to control for selection bias.

$$t_i = \alpha_k \hat{k}_i + \beta_{MR} MR + \beta_2 x_{2i} + \mu_{2i} \tag{3}$$

where, t_i is the observed innovation output, $\hat{k}_i$ is the latent innovation effort proxied by the predicted values of innovation investment from the first step and α_k is its coefficient. By including the predicted values of innovation investment, we take into account the fact that all firms may make some kind of innovative effort, although, only some of them

[9] Since the truncation due to lack of reporting of turnover is not systematic, we believe that the randomness of sample is intact.

[10] See Schmookler (1966).

Table 1
Summary statistics

	Obs	Size[a]			Innovation Expenditure[b]		Innovative Sales[b]		Innovative Firms[c]
		Mean	SD	Median	Mean	SD	Mean	SD	
Total	377	348	1067	50	3.6	9.8	29.6	43.7	32
Textile	306	311	1016	40	2.9	7.9	26.1	42.9	26
Apparel	71	509	1257	80	6.7	15	44.8	44.2	56

Note:
[a] Number of employees in 2015.
[b] as a percentage share of total turnover in 2015.
[c] as a percentage of total number of firms.

Table 2
Distribution of innovation expenditure in innovative sample.

	Mean[a]	Std. Dev	Max[a]
Total	7.18	12.22	79.5
Internal R&D	1.68	3.60	30
External R&D	0.18	0.43	2
Acquisition of machinery, equipment, and software	4.65	9.50	64
Acquisition of other external knowledge	0.09	0.31	2.5
Trainings for innovative activities	0.58	2.18	20

Note:
[a] as a share of total turnover in 2015.

invest in innovation and report it. Furthermore, it is also a way to instrument for simultaneity between innovation effort and knowledge production (Hall, 2011). MR is the inverse Mill's ratio calculated from the first step that accounts for selection bias, and β_{MR} is its coefficient. x_{2i} is a vector of other explanatory variables and β_2 their corresponding coefficient vector, and μ_{2i} is the random error term with mean zero and constant variance and not correlated with the explanatory variables.

The final equation of the system corresponds to firm performance.[11]

$$q_i = \alpha_t t_i + \beta_3 x_{3i} + \mu_{3i} \tag{4}$$

where q_i is the indicator of firm performance, α_t is the elasticity of firm performance with respect to innovation output, x_{3i} is a vector of other explanatory variables and controls with β_3 their corresponding coefficient vector, and μ_{3i} is the random error term with mean zero and constant variance not correlated with the explanatory variables.

The main difference between the CDM approach and the approach of Lööf and Heshmati (2006) lies in the assumption about the correlation between the error terms of the four equations. The CDM model assumes a full correlation structure of the error terms. Lööf and Heshmati (2006), on the other hand, assume a partial correlation by allowing a full correlation of the error terms of Eqs. (1) and (2), and similarly a full correlation of the error terms of Eqs. (3) and (4), but assume no correlation in error terms of the two stages. The idea is that with cross-sectional data, the assumption that unobservable forces that have an impact on the estimated probability of engaging in innovation also impact the elasticity of productivity, might not be true.

In the first stage, the decision to innovate and innovation investment intensity Eqs. (1) and (2) equations are jointly estimated in a Heckman two-step sample selection model. This stage includes both innovative as well as non-innovative firms. In the second stage, we follow two different approaches to modelling innovation output and firm performance Eqs. (3) and (4). In both approaches, predicted values of the inverse Mills ratio and innovation investment intensity are used to account for selection bias and the endogeneity of innovation investment in innovation output, respectively. In the first setting (Model 1), innovation output and firm performance equations are jointly estimated as a system using the three-stage least squares, (3SLS) method. This model assumes a one way causation in which innovation output affects labor productivity. The model allows for the correlation of the error terms of the two equations, and accounts for some of the endogeneity including the simultaneity bias. However, it does not take into account the feedback effect from labor productivity to innovation output, and the endogeneity of innovation output and labor productivity. In the second setting (Model 2), the innovation output and firm performance equations are modelled as a simultaneous system which allows for the feedback effect from labor productivity to innovation output. The model is estimated using instrumental variables two-stage least squares (IV 2SLS), in which predicted labor productivity is used as an explanatory variable in the innovation output equation to account for the feedback effect, and the predicted innovation output is used as an explanatory variable in the labor productivity equation. This model accounts for the endogeneity of innovation output and labor productivity, but does not allow for the correlation between the two error terms.

In Eq. (1), the decision to engage in innovation is modelled as a function of a set of firm characteristics: firm size, legal form of company (partnership, private limited, and public limited); market orientation: exporting to Europe and USA, local and foreign competition; factors hampering innovation: cost factors, knowledge factors, and other factors; sources of information and cooperation: internal sources, foreign suppliers, local suppliers, foreign clients, local clients, and active cooperation; and innovation objectives: product outcomes, and process outcomes.

In Eq. (2), the dependent variable is innovation input measured as the natural logarithm of total expenditure per worker on innovation activities in 2015. Innovation input is also modelled as a function of as set of firm characteristics: firm size, legal form of company: partnership, private limited, and public limited); market orientation: exporting to Europe and USA, local and foreign competition, and export intensity; factors hampering innovation: cost factors, knowledge factors, and other factors; innovation objectives: product outcomes, and process outcomes; and receiving a national subsidy. For the correct identification of the Heckman model, an exclusion restriction is imposed: The variables in our model that are included in the first equation and excluded from the second are sources of information and cooperation.[12]

In Eq. (3), the dependent variable is innovation output measured as the natural logarithm of total turnover per worker generated from the sales of innovative products (new to firm, and new to market) in 2015. In Model 1, innovation output is modelled as a function of: innovation input (predicted),[13] export intensity, process innovation, organizational innovation, marketing innovation, innovation objectives (product and

[11] Since we do not model a direct link between innovation input and firm productivity, the inverse Mill's ratio is not included in this equation.

[12] The exclusion decision is primarily driven by our data in which sources of information and cooperation do not have any significant impact on innovation expenditure.

[13] A number of other studies have used predicted innovation investment from the Heckman model (see Hashi and Stojcic, 2013; Criscuolo, 2009; Lööf and Heshmati, 2006, 2002 for example). This is a way to instrument for simultaneity between innovation effort and knowledge production as discussed in Hall (2011).

process outcomes), legal form of company (partnership, private limited, public limited, and part of a group), sources of information and co-operation (internal sources, foreign suppliers, local suppliers, foreign clients, local clients, and active cooperation), sectoral and location dummies, and the inverse Mill's ratio.[14] In Model 2, apart from the explanatory variables included in Model 1, labor productivity (predicted) is also used as an explanatory variable.

In Eq. (4), the dependent variable is labor productivity measured as the natural logarithm of output per worker in 2015 (level), and growth in labor productivity between 2013 and 2015 (growth-rate). Labor productivity is modelled as a function of: innovative sales per worker (innovation output), firm size, process innovation, organizational innovation, marketing innovation, human capital, sources of information and cooperation (internal sources, foreign suppliers, local suppliers, foreign clients, local clients, and active cooperation), sectorial and location dummies, and labor productivity in 2013 as a control in the growth equation only.[15]

A detailed description and the measurement of all variables used in estimations is provided in the Appendix A.

Table 3 reports the mean and standard deviation of explanatory variables used in estimations for both the total sample as well as the innovative sample.

In the total sample, 28 percent of firms export to the European market, and 20 percent to the US market. The percentage of firms exporting to these two markets is higher in the innovative sample where one in every two innovative firms export to the European market and one in every three firms to the US market. This suggests a positive correlation between exporting to these two destinations and innovation. A very high percentage of firms reported facing competition from medium to large size local firms, and this is slightly higher for the sample of innovative firms.

Innovative firms consider foreign market sources (both suppliers and clients) as a very important source of information and cooperation for technological innovation. In our sample, 23 percent of innovative firms reported having active cooperation on innovation with other enterprises and institutions. Sixty four percent of firms in the total sample, and 56 percent of innovative firms consider cost factors a highly important constraint to technological innovation.

The percentage of innovative firms reporting product and process outcomes as their main objective for technological innovation is quite similar (31 and 37 percent, respectively). There is a high correlation between process innovation as well as non-technological innovations with innovative firms. Seventy three percent of innovative firms report a process innovation, fifty three percent report an organizational innovation, and seventy four percent report a marketing innovation.

5. Results

In this section, we present the results of our estimations. In the first stage, the decision to innovate and innovation investment intensity (Eqs. 1 and 2) equations are jointly estimated in a Heckman two-step sample selection model. This stage includes both innovative as well as non-innovative firms.

Table 3
Summary statistics of variables.

	Total sample		Innovative sample	
	Mean	*Std. Dev*	*Mean*	*Std. Dev*
Decision to innovate	0.45	0.50	0.91	0.29
R&D intensity (in log)	5.81	7.45	12.1	6.38
Inn sales per worker (in log)	4.12	6.14	12.9	1.98
Productivity (in log)	13.4	1.90	13.7	1.59
USA	0.20	0.40	0.35	0.48
Europe	0.28	0.45	0.51	0.50
Local competition	0.85	0.36	0.88	0.33
Foreign competition	0.27	0.44	0.41	0.49
Cost factors	0.64	0.48	0.56	0.49
Knowledge factors	0.19	0.39	0.21	0.40
Other factors	0.42	0.49	0.23	0.42
Internal sources	0.22	0.42	0.48	0.50
Market sources: Foreign suppliers	0.17	0.38	0.44	0.50
Market sources: Local suppliers	0.16	0.31	0.31	0.46
Market sources: Foreign clients	0.26	0.44	0.55	0.50
Market sources: Local clients	0.20	0.40	0.31	0.47
Active cooperation	0.13	0.33	0.23	0.42
Product outcomes	0.16	0.36	0.31	0.46
Process outcomes	0.19	0.40	0.37	0.49
National subsidy	0.03	0.17	0.07	0.26
Process Innovation	0.41	0.49	0.73	0.45
Organizational Innovation	0.30	0.46	0.53	0.50
Marketing Innovation	0.39	0.49	0.74	0.44
Export intensity (in Log)	5.81	7.45	11.99	6.45
Human capital (in Log)	1.76	2.23	2.80	2.35

Table 4
Heckman two-step results.

	Decision to innovate	R&D intensity
Firm characteristics		
Firm size	0.27*** (0.098)	0.07 (0.306)
Partnership	0.59** (0.266)	2.89*** (1.158)
Private Ltd	0.25 (0.288)	1.40 (1.104)
Public Ltd	0.77 (0.592)	3.65** (1.696)
Market orientation		
USA	0.68** (0.344)	−1.68 (1.035)
Europe	0.66* (0.348)	−1.76 (1.210)
Local competition	−0.42 (0.297)	1.89* (1.162)
Foreign competition	−0.52* (0.308)	0.11 (1.050)
Export intensity	–	0.20***(0.074)
Factors hampering innovation		
Cost factors	−0.44* (0.242)	2.11** (0.891)
Knowledge factors	0.37 (0.285)	−0.84 (1.050)
Other factors	−0.61*** (0.237)	0.22 (0.931)
Sources of information and cooperation		
Internal sources	0.93*** (0.299)	–
Market sources: Foreign suppliers	1.63*** (0.577)	–
Market sources: Local suppliers	0.47 (0.345)	–
Market sources: Foreign clients	1.12*** (0.433)	–
Market sources: Local clients	0.41 (0.317)	–
Active cooperation	1.20*** (0.416)	−2.02** (1.027)
Innovation objectives		
Product outcomes	1.10*** (0.283)	−2.51** (0.980)
Process outcomes	0.90*** (0.281)	0.88 (0.876)
National subsidy	–	−3.62** (1.666)
Lambda	–	−2.62**(1.149)
Rho	–	−0.49726
Sigma	–	5.2758747
No. of observations	377	377

Note: The parentheses contain standard errors. ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively. Wald Chi2 (16) = 38.09, Prob > chi2 = 0.00.

5.1. First stage (Decision to innovate and innovation investment intensity)

Table 4 reports the estimation results from the first stage-Heckman two-step model. In line with the existing literature based on the

[14] Apart from these variables, we also included factors hampering innovation as explanatory variables. However, all of these were insignificant. For the sack of brevity, we exclude them from the final regression. We also assume that the legal form of companies and competition impact the decision to innovate and the amount of investment in innovation made by the firm managers and then the amount of investment affects the innovation output directly while the legal form and competition only affect innovation output indirectly.

[15] Unfortunately, we do not have a good proxy for physical capital. We did ask information about physical capital in our survey, but the number of responding firms to this question was small.

Schumpeterian hypothesis, larger firms have a higher probability of engaging in innovation. However, contrary to the existing evidence (mainly from developed economies), firm size has no significant impact on R&D intensity.

The market for a firm's product plays an important role in its innovation decision as well as its R&D intensity. The existing literature suggests exporting to foreign markets increases a firm's innovativeness. Our results support this literature: firms exporting to Europe and the US have higher probabilities of engaging in innovation, while a firm's R&D investment also increases with export intensity measured as the share of exports in total turnover.

Firms were also asked whether they face competition from medium or large sized local firms and foreign firms in their main market. Competition seems to have a different impact depending on the location of the competitor. Our results suggest the presence of a Schumpeterian negative impact of competition on the decision to innovate. Firms with medium or large sized foreign competitors are less likely to engage in innovation. However, the results for the impact of having medium or large sized local competitors are not significant. There is, however, a positive impact of competition on R&D intensity: Firms with medium or large sized local competitors have higher R&D intensity. Foreign competition on the other hand has no significant impact on R&D intensity.

On the constraints side, firms reporting cost factors as a highly important constraint to innovation are less likely to engage in innovation, but they invest more in R&D. Surprisingly, contrary to the common belief about developing countries, knowledge factors are not found to have a significant impact on the probability of being innovative or R&D intensity. Also, if firms listed 'other' as a factor that was highly important in hampering innovation, they had a lower probability of engaging in innovation. One component of this 'other' variable was an open ended question on factors hampering innovation, and many firms reported the energy crisis as a problem.[16]

Our results suggest a positive impact of information and cooperation for both within and outside the enterprise on a firm's decision to innovate. An interesting finding is on the role of vertical linkages where firms that considered foreign suppliers and foreign clients as highly important source of information and cooperation have a higher probability of engaging in innovation. However, there is no significant impact of local suppliers and local clients on a firm's probability of engaging in innovation. Firms reporting active cooperation for innovation activities with other enterprises or institutions are more likely to engage in innovation, however, they invest less in R&D. Furthermore, partnerships are more likely to engage in innovation and have higher R&D intensity. Public limited companies also invest more in R&D, however, they do not have a significantly higher probability of engaging in innovation.

Firms reporting product outcomes or process outcomes as the objective for technological innovation are more likely to engage in innovation. However, firms with product outcomes as the main objective invest less in R&D. National subsidies seem to have a crowding-out effect on a firm's R&D investment. Firms that receive any national financial support for innovation activities invest less in innovation. This apparently looks counterintuitive, since public financial support has been found leading to additional private R&D (Busom, 2000; Klomp and Van Leeuwen, 2001; Almus and Czarnitzki, 2003; Hall et al., 2009; Criscuolo, 2009). Even in the case of developing economies (Latin America), Crespi and Zuniga (2012) show a positive impact of public subsidies on R&D investment. Unfortunately, we do not have detailed information about the nature of public support in the sectors and its conditionalities. We suspect that in the absence of effective monitoring that ensures the use of subsidies for its intended purpose, firms might be directing subsidies to other purposes. Rodrik (2004) discusses the failure of similar first best R&D subsidies for the subsidization of new and non-traditional industries.

5.2. Second stage (Innovation output and firm performance)

This stage consists of only the sub-sample of innovative firms, i.e. firms that have a positive amount of innovation output, and the inverse Mill's ratio from the first stage is included to control for the selection bias. In Model 1, innovation output and firm performance equations are estimated as a system using three-stage least squares (3SLS). Labor productivity level in 2015 (level), and labor productivity growth between 2013 and 2015 (growth-rate) are used as proxies for firm performance. Model 2 is estimated using instrumental variables two-stage least squares (IV 2SLS), in which labor productivity (predicted) is used as an explanatory variable in the innovation output equation, and innovation output (predicted) is used as an explanatory variable in the labor productivity equation. For clarity purposes, the estimation results for innovation output and labor productivity equations from both models (Model 1 and Model 2) are presented in separate tables.

5.3. Innovation output equation

Table 5 reports the results from the innovation output Eq. (3) where the dependent variable is the log of innovative sales per worker.

The results of innovation output equation from Model 1 are almost identical for the productivity level and growth rate. There is a positive and significant impact of R&D intensity on innovative sales per worker, suggesting a positive impact of innovation effort on innovation outcome. We do not find any direct significant impact of export intensity suggesting that it only affects innovation output indirectly through its impact on innovation input.

We also find complementarity between product innovations and organizational innovations. Firms are able to achieve higher sales per worker from new products by introducing organizational innovations. However, there is no significant impact of marketing innovation. A somewhat unexpected finding is the negative and significant coefficient of process innovation meaning that process innovators have lower innovative sales per worker. One possible explanation for this might be that the introduction of process innovation involves changes in the production processes and needs adjustments that temporarily reduce the production especially of new products. Another possible explanation is that efficiency improvements from process innovations may result in lower prices and may not show up in the revenue figures (Hall, 2011).

Firms for whom product outcomes are a highly important objective for technological innovation are found to achieve higher innovative sales per worker. These are the firms who target the expansion of the range of goods that they produce, and/or entering new markets or increasing market share in the existing market, and/or improving quality of goods. The results also show that innovation output is higher in firms that classify internal ideas as a highly important source of knowledge for innovation. Further, the firms reporting foreign clients as a highly important source of information and cooperation are able to achieve higher innovative sales per worker. Out of the other controls, only the location dummy is significant with firms located in the province of Sindh having lower innovative sales per worker. This could be explained by the incremental nature of new products. In our sample, survey results showed that the percentage of 'new to the firm' products was higher in Sindh than in Punjab.

The results from Model 2 also confirm that innovation output depends on innovation effort. However, the coefficients for both the level and growth rate specifications are smaller and less significant than in Model 1, partially because some of the variation is now explained by the feedback effect. In terms of the feedback effect, the results show significant evidence of more productive firms achieving higher innovative sales per worker. There seems to be strategic behavior on the

[16] Electricity shortages were quite intense in 2013–15, and electricity breakdowns of 10 h per day on average were reported for many months.

Table 5
Knowledge production (Innovation output): The simultaneous knowledge capital (innovation output) equation estimated under the assumption that productivity is measured both in level and growth-rate terms.

	Model 1		Model 2	
	Level	Growth-rate	Level	Growth-rate
R&D intensity (predicted)	0.23***(0.070)	0.23***(0.074)	0.14*(0.083)	0.13*(0.788)
Export intensity	−0.13(0.095)	−0.13 (0.102)	−0.07 (0.117)	−0.08(0.111)
Types of Innovation				
Process Inn	−1.04***(0.336)	−1.03***(0.338)	0.57 (0.790)	−0.90***(0.323)
Organizational Inn	0.77***(0.319)	0.77** (0.320)	−0.96 (0.842)	0.68**(0.304)
Marketing Inn	−0.02 (0.356)	−0.02 (0.357)	−0.18(0.362)	−0.23 (0.342)
Innovation Objectives				
Product outcomes	1.04***(0.366)	1.03***(0.391)	0.57 (0.444)	0.69*(0.418)
Process outcomes	−0.36 (0.250)	−0.32 (0.270)	−0.00 (0.312)	0.19 (0.297)
Firm characteristics				
Partnership	0.26 (0.368)	0.29 (0.390)	0.42 (0.450)	0.26(0.429)
Private Ltd	0.49 (0.310)	0.51 (0.321)	0.64* (0.362)	0.28(0.350)
Public Ltd	0.79 (0.564)	0.83 (0.597)	1.19* (0.681)	0.88(0.631)
Group	−0.30 (0.298)	−0.28 (0.320)	0.32 (0.398)	0.17(0.345)
Sources of information and cooperation				
Internal sources	0.69** (0.317)	0.69** (0.30)	0.60*(0.326)	0.45(0.312)
Market sources: Foreign suppliers	−0.14 (0.340)	−0.13 (0.341)	0.02 (0.345)	−0.10(0.324)
Market sources: Local suppliers	0.16 (0.367)	0.16 (0.371)	0.24 (0.376)	0.08 (0.358)
Market sources: Foreign clients	0.89* (0.467)	0.90* (0.477)	0.82* (0.499)	0.62(0.478)
Market sources: Local clients	0.09 (0.403)	0.08 (0.407)	−0.08 (0.420)	0.16(0.394)
Active cooperation	0.54 (0.339)	0.52 (0.366)	0.13 (0.422)	0.32(0.401)
Other controls				
Apparel	0.15 (0.372)	0.13 (0.375)	−0.10 (0.382)	0.12(0.360)
Sindh	−1.76***(0.358)	−1.77*** (0.364)	0.90 (1.311)	−2.10***(0.359)
Inverse Mills Ratio	0.24 (0.442)	0.27 (0.474)	0.21 (0.555)	0.19(0.522)
Feedback effect				
$\text{Productivity}_{2015}$ (Predicted)	–	–	2.43**(1.107)	–
Productivity growth (Predicted)	–	–	–	−0.18***(0.045)
R-squared	0.44	0.44	0.46	0.52
Chi2	107	107	105	128
P	0000	0000	0000	0000
No. of observation	120	120	120	120

Note: The parentheses contain standard errors. ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

part of more productive firms who transform their higher productivity into a competitive advantage by introducing new and improved products. Also, the feedback effect on innovation output from productivity growth is negative.

Overall, the results from Model 2 with the growth-rate specification are similar to the results from Model 1 in terms of sign and significance of coefficients, however, the size of the coefficients are generally smaller. Further, there is no significant impact of the reported sources of information and cooperation in Model 2 with the growth-rate specification. The results in Table 5 also show that there is no significant direct impact of process and organizational innovation in Model 2 with the level specification. There might be an indirect impact as these innovations affect predicted labor productivity which is an explanatory variable.

5.4. Firm performance

Table 6 reports the results from the labor productivity Eq. (4) where the dependent variable is the log of sales per worker in 2015 in the level and growth rate between 2013 and 2015 in the growth-rate specification.

The existing literature suggests that labor productivity might increase due to changes in the skill composition of the workforce i.e. human capital, or due to other types of innovations including process innovation, and non-technological innovations which can result in creating more productive labor. In order to get more reliable estimate for innovation, we control for human capital, process innovation, organizational innovation, and marketing innovation in the labor productivity equations.

The results in Table 6 from both models (Model 1 and Model 2) and with both specifications (level and growth-rate) show a very strong correlation between the innovation output and productivity. The results show that both productivity levels and growth rates significantly increase with innovative sales per worker after controlling for firm size, location, sector, human capital, other innovations (process, organization, and managerial), and the initial level of productivity (for growth-rate specification only). The elasticity of labor productivity with respect to innovative sales per worker is greater than 1 in all of the specifications implying that a 10 percent increase in innovative sales per worker yields a greater than 10 percent increase in labor productivity and labor productivity growth. The elasticity is slightly higher for Model 2 which takes into account the feedback effect. The increases in labor productivity found in our results are substantially larger than those reported in the previous literature for developed economies.[17]

Process innovation positively affects labor productivity as well as its growth rate in Model 1. However, it has no significant impact in Model 2, partially because its indirect impact is coming through the predicted innovative sales per worker. The coefficient of organizational innovation is not statistically significant suggesting that it affects labor productivity indirectly through its impact on innovative sales per worker. Further, in the labor productivity growth equation, a negative and statistically significant coefficient of lagged labor productivity suggests that firms with lower initial labor productivity experience higher productivity growth, which could signal a potential catch up effect. Firms located in the province of Sindh experience higher labor productivity as well as labor productivity growth while apparel manufacturers experience lower productivity and labor productivity growth. There is no

[17] See Mohnen and Hall (2013) for the estimates of elasticities for the developed economies.

Table 6
Productivity: The simultaneous productivity equation estimated both in level and growth-rate variants.

	Model 1		Model 2	
	Level	Growth-rate	Level	Growth-rate
Innovative sales	1.07***(0.099)	1.04***(0.100)	–	–
Innovative sales (predicted)	–	–	1.11***(0.226)	1.20***(0.256)
Firm size	−0.02(0.069)	−0.01(0.068)	0.29(0.198)	−0.17(0.156)
Innovation types				
Process Inn	0.35**(0.160)	0.32**(0.146)	0.27(0.340)	0.55(0.346)
Organizational Inn	−0.18(0.147)	−0.17(0.134)	−0.19 (0.309)	−0.16(0.282)
Marketing Inn	0.05 (0.141)	0.04(0.136)	0.07(0.295)	0.09(0.283)
Sources of information and cooperation				
Internal sources	0.11(0.133)	0.12(0.123)	0.13(0.275)	0.14(0.256)
Market sources: Foreign suppliers	0.13(0.136)	0.13(0.129)	0.05(0.284)	0.21(0.271)
Market sources: Local suppliers	−0.22(0.142)	−0.21(0.134)	−0.20(0.294)	−0.21(0.277)
Market sources: Foreign clients	−0.15(0.175)	−0.14(0.162)	−0.15(0.363)	−0.09(0.333)
Market sources: Local clients	−0.09 (0.151)	−0.09(0.144)	−0.10(0.313)	−0.14(0.299)
Other controls				
Apparel	−0.27*(0.144)	−0.27**(0.137)	−0.25 (0.299)	−0.34(0.285)
Human capital	−0.07(0.046)	−0.07(0.046)	−0.28**(0.133)	−0.06(0.111)
Sindh	1.01***(0.224)	0.96***(0.218)	1.19**(0.528)	1.37**(0.558)
Productivity (lag, t-2)	–	−0.10***(0.020)	–	−1.05***(0.050)
R-squared	0.85	0.97	0.40	0.88
Chi2	384	479	79	915
P	0000	0000	0000	0000
No. of observation	120	120	120	120

Note: The parentheses contain standard errors. ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

significant impact of firm size and sources of information and cooperation on a firm's productivity or its growth.

6. Comparison with other CDM type studies

There have been quite a few recent studies using the CDM framework and estimation techniques similar to ours to test the impact of innovative sales per worker on labor productivity. A comparison between our findings and those from other studies is shown in Table 7.

Our findings are in line with this literature, showing a positive and significant elasticity of labor productivity with respect to innovative sales per worker. However, the size of the elasticity which we obtain, is several times greater than the original CDM paper (Crépon et al., 1998). This is not unique to our study since more recent literature, especially from less advanced countries, reports elasticities similar to what we find: Criscuolo (2009) reports an elasticity of 0.69 for Korea, Mairesse et al. (2012) find an elasticity of 0.5 for wearing apparel and 1.12 for the electronic equipment sectors for China, and Hashi and Stojcic (2013) report an elasticity of 1.15 for Western Europe.

Table 7
Comparison of findings.

Study	Country	Method	Impact of innovation
Crépon et al. (1998)	France	ALS	0.104
Lööf et al. (2003)	Sweden	3SLS	0.15
	Finland		0.09
	Norway		0.26
Janz et al. (2003)	Germany	Sequential IV	0.27
	Sweden		0.29
Lööf and Heshmati (2006)	Sweden	3SLS	0.12 (Mfg)
			0.09 (Serv)
Van Leeuwen and Klomp (2006)	Netherlands	3SLS	0.13
Criscuolo (2009)	17 OECD countries	Sequential IV	0.3–0.7
Mairesse et al. (2012)	China	Sequential IV	0.25 − 1.12
Hashi and Stojcic (2013)	CEEC	3SLS	0.64
	WE		1.15
Our study	**Pakistan**	**3SLS**	**1.04–1.07**
		Sequential IV	**1.11–1.20**

7. Conclusion

There is very little micro based literature on the relationship between innovation and labor productivity in developing countries. To this end, this paper contributes by presenting an in depth analysis of the determinants of product innovation and its impact on labor productivity in the context of a developing economy. The paper employs a multi-stage model linking the decision of firm to innovate, its innovation investment, product innovation, and labor productivity using firm level data from the highly export oriented textile and wearing apparel sectors of Pakistan. The findings reveal some interesting insights into innovation behavior at the firm level that have the potential to serve as inputs to national policy making. First, product innovation leads to increased labor productivity as well as higher labor productivity growth. The elasticity of labor productivity with respect to innovative sales per worker is larger than the estimates of elasticities reported from the advanced economies.

Second, there are interesting regularities in the innovation behavior of firms. The results show that vertical knowledge flows are very important determinants of a firm's decision to engage in innovation. In particular, firms considering foreign clients and foreign suppliers as important sources of information and cooperation have a higher probability to innovate. In line with the Schumpeterian hypothesis, larger firms are more likely to engage in innovation, however, they do not have higher investment in innovation. The impact of competition depends on the location of the competitors: foreign competition negatively affects a firm's decision to innovate, whereas, local competition positively affects a firm's level of innovation investment. The results point to learning by exporting: firms exporting to Europe and the US are more likely to engage in innovation, and the investment in innovation increases with exports intensity. There is also evidence in support of the crowding out effect of national subsidies: firms receiving national subsides invest less in innovation. Finally, higher investment in innovation, and higher labor productivity lead to higher innovative sales per worker, and there is also evidence of complementarity between product innovations and organizational innovations.

Appendix A

Description of the variables

Variable	Definition
Decision to innovate	= 1 if a firm in 2015 invested in any of the following activities: (i) in-house R&D, (ii) external R&D, (iii) acquisition of machinery, equipment and software (including lease or rental of machinery or equipment), (iv) acquisition of external knowledge, and (v) training for innovative activities.
R&D intensity	Measured as the natural logarithm of total expenditure on innovation per worker in 2015. Total expenditure is a sum of expenditure on following five activities: (i) in-house R&D, (ii) external R&D, (iii) acquisition of machinery, equipment and software (including lease or rental of machinery or equipment), (iv) acquisition of external knowledge, and (v) training for innovative activities.
Innovative Sales	Measured as the natural logarithm of total turnover per worker in 2015 generated from the sales of innovative products (new to firm, and new to market) introduced over the 2013-15.
Productivity	Measured as the natural logarithm of total turnover per worker in 2015.
Productivity growth	Natural logarithm of turnover per worker in 2015 minus natural logarithm of turnover per worker in 2013.
Process Inn	= 1 if a firm has implemented a new or/and significantly improved production process, distribution method, or/and supporting activity during 2013-15.
Organizational Inn	= 1 if a firm has implemented a new organizational method in its business practices, workplace organization, or external relations during 2013-15.
Marketing Inn	= 1 if a firm has implemented a new marketing concept or strategy during 2013-15. This includes changes to the packaging and design, new methods for product promotion, new method of product placement, and new method of pricing.
Firm size	Measured as the natural logarithm of total employment in 2015.
Europe	= 1 if a firm sold goods to European countries during 2013-15.
USA	= 1 if a firm sold goods to USA during 2013-15.
Cost factors	= 1 if a firm considered any of the following factors as highly important factor hampering innovation during 2013-15: lack of funds within enterprise or its group; lack of finances from banks; lack of finances from non-bank sources; innovation costs were too high.
Knowledge factors	= 1 if a firm considered any of the following factors as highly important factor hampering innovation during 2013-15: lack of qualified personnel; lack of information on technology; lack of information on markets; and difficulty in finding cooperation partners for innovation.
Other factors	= 1 if a firm considered any of the following factors as highly important factor hampering innovation during 2013-15: no need due to prior innovation by the enterprise; no need because of no demand for innovations; macro level uncertainties, and an open ended question where majority of the respondents mentioned energy crisis.
Internal sources	= 1 if a firm considered internal sources as highly important sources of information and cooperation for technological innovation during 2013-15.
Market sources: Foreign suppliers	= 1 if a firm considered foreign suppliers as highly important source of information and cooperation for technological innovation during 2013-15.
Market sources: Local suppliers	= 1 if a firm considered local suppliers as highly important source of information and cooperation for technological innovation during 2013-15.
Market sources: Foreign clients	= 1 if a firm considered foreign clients as highly important source of information and cooperation for technological innovation during 2013-15.
Market sources: Local clients	= 1 if a firm considered local clients as highly important source of information and cooperation for technological innovation during 2013-15.
Active cooperation	A dummy variable that equals 1 if a firm report cooperating on any of the innovation activities with other enterprises or institutions in 2013-15. Innovation cooperation is active participation with other enterprises or institutions.
Local competition	= 1 if a firm faces competition from medium to large sized local firm in the market where it sells its main product.
Foreign competition	= 1 if a firm faces competition from medium to large sized foreign firm in the market where it sells its main product.
Product outcomes	= 1 if a firm reports any of the following objectives as highly important objectives for its activities to develop product and process innovations during 2013-15: a) increase range of goods, b) enter new markets or increase market share, and c) improve quality of goods.
Process outcomes	= 1 if a firm reports any of the following objectives as highly important objectives for its activities to develop product and process innovations during 2013-15: a) improve flexibility for producing goods, b) increase capacity for producing goods, c) reduce labor costs per unit of output, and d) reduce material and energy costs per unit of output.
Export intensity	Measured as the natural logarithm of the share of exports in total turnover in 2015.
National subsidy	= 1 if a firm received financial support (subsidy) for innovation activities from the government during 2013-15. Financial support includes tax credits or deduction, grants, subsidized loan, and loan guarantees from the national government (federal).
Human Capital	Measured as the natural logarithm of total number of workers with a university degree and/or professional diploma in 2015.
Partnership	= 1 if the legal form of company is partnership.
Private Ltd	= 1 if the legal form of company is private limited.
Public Ltd	= 1 if the legal form of company is public limited.

Group	=1 if a firm is a part of an enterprise group.
Apparel	=1 for manufacturers of apparel.
Sindh	=1 if a firm is located in the province of Sindh.
Inverse Mills Ratio	The inverse Mill's ratio

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