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Does Internal and External R&D Affect SMEs Innovation Performance? Micro Level Evidence from India and Pakistan

Dr.Naqeeb Ur Rehman¹

Preliminary draft, please, do not quote anything from here!

Abstract

The purpose of this study is to investigate the impact of internal and external R&D on SMEs innovation performance. Micro level data was obtained from Enterprise Survey. For analysis, bivariate models have been used. The results show that internal and external R&D positively affects the product and process innovations. However, this effect is stronger for Indian SMEs. In comparison, only external R&D showed positive association to product and process innovation for Pakistani SMEs. Similarly, Pakistani SMEs are externally constrained (lack of access to credit) than Indian SMEs. Moreover, Indian SMEs are dominant in terms of undertaking internal R&D, generating product and process innovations than Pakistani SMEs. Lastly, the complementary relationship has been examined between internal and external R&D for both countries. Regarding contribution, this research study for the first time has examined the Indian and Pakistani SMEs innovation activities. The implication of this study suggests that business managers can utilize the balance combination of internal and external R&D to accelerate the SMEs innovation performance.

Keywords: Internal and External R&D, SMEs

1. Introduction

Innovation is expensive and ambivalent activity. From a firm perspective, innovation can be originated as complex process involving new ideas; their development; transformation and application; using knowledge technologies; capabilities and resources (Karlsson and Tavassoli, 2015; Artz *et al.* 2010). Similarly, a firm's engaged in innovation activities involves many complex strategies (*e.g.*, product, process, marketing and organizational innovation) because innovation plays key role in the evolution of industries. Studies single out innovation as a primary driver of firms' competitiveness and the ultimate source of productivity and growth (Karlsson and Tavassoli, 2015; Subrahmanya, 2012). Not surprisingly, firms' carried out innovation by internal (internal R&D) and external efforts (collaboration) and have better technological strength to produce product and process

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innovations because investment in innovation enhance the technological advancement and minimizes the firms' marginal cost of production (Ganotakis and Love, 2011).

Small and medium enterprises (SMEs) have been examined one of the major driving force for advance economies to their multi functional contributions in terms of employment, exports and technological innovation. SMEs flexibility, adaptability, effective internal communication and quick decision making provides them competitive edge over large firms. However, several quantitative and qualitative studies (Conte and Vivarelli, 2013; Love and Ropper, 1999; Subrahmanya, 2012) have found that SMEs are more financially and non-financially constrained than large firms. For example, lack of financial assets, weaker competencies and absorptive capacity and the absence of economies of scale force SMEs to under-invest in R&D. Likewise, Demirbas *et al.* (2011) argued that SMEs operating in developing countries often face extra barriers such as lack of technological investment, low level of R&D and skills shortage. Presently, the global challenges for SMEs survival are related to promoting the innovative culture, improving the quality of innovation *i.e.*, radical innovations which is supported by R&D activities and encouraging patenting culture for superior SMEs performance. Empirical studies (e.g., Ceccagnoli *et al.* 2013) SMEs can use internal R&D which is coupled with external R&D activities significantly improve the innovation performance.

Especially, open innovation models (see *e.g.*, Spithoven, Vanhaverbeke and Roijackers, 2013) suggest that SMEs innovation can be achieved through internal or external knowledge and technologies. This point out that only internal R&D is not sufficient, SMEs reliance on external R&D is equally important for innovation performance. Numerous empirical studies emphasized the importance of internal and external R&D for product and process innovation output (Cohen and Levinthal, 1989; Stam and Wennberg, 2009; Higon *et al.* 2014; Hagedoorn and Wang, 2012). Additionally, the two faces of R&D based on a Cohen and Levinthal (1989) study suggested that internal R&D not only generate product and process innovation but also improve the firms' absorptive capacity (learning effect). Similarly, Lane and Lubatkin (1998) argued that external R&D (R&D alliances) will increase the firm's innovative output and absorptive capacity, if these small firms are reluctant to invest alone in R&D.

The major contribution of this paper lies in the dataset used: to obtain cross sectional data and firm level analysis of Indian and Pakistani SMEs, which is very rare to analyze from other sources. In other words, there is still scarcity of empirical research related to the impact internal and external R&D on SMEs innovation performance with reference to South Asian economies. To the best of my knowledge, to date, hardly any empirical study is available related to the comparison of innovation performance of Indian and Pakistani SMEs. In addition, the complementary relationship has been investigated between internal and external R&D for the first time for Indian and Pakistani SMEs. To conclude, the aim of this research paper is to address the following research questions. Does internal and external R&D affect SMEs innovation performance? Is internal and external R&D complementary related?

The results showed that SMEs engaged in internal and external R&D is more likely to introduce product and process innovations. However, this effect is found stronger for Indian SMEs. Findings from figure 1 and 2 suggest that Pakistani SMEs are less innovative in terms of undertaking R&D, generating product and process innovation than Indian SMEs. In addition, the probit models showed that internal and external R&D has complementary relationship. The remainder of this paper is organized as follows. The next section details the theoretical background with hypotheses. Section 3 discusses the methodology and section 4 presents the empirical results. While, section 5 concludes and suggests the policy implications.

2. Theory and Hypotheses

Internal R&D

A well known used antecedent for innovation is research and development (R&D). Innovation results from investment in R&D (Czarnitzki and Hottenroh, 2011) because R&D increases the firms' stock of knowledge and firms' can utilize that knowledge to introduce new products (Artz *et al.* 2010). Similarly, several researchers (Conte and Vivarelli, 2013; Pellegrino *et al.* 2014; Karlsson and Tavassoli, 2015; Hall and Bagchi-Sen, 2002) identified R&D as a major innovation input for increasing the firms' innovation performance. Regarding the R&D role, numerous studies (*e.g.*, Cohen and Levinthal, 1989; Stam and Wennberg, 2009; Gallie and Legros, 2012; Ceccagnoli *et al.* 2013) stated that R&D performs two major functions: first it generates new knowledge through product/process innovation and secondly it increases the firms' absorptive capacity (a firms' ability to internalize the

external knowledge).² In other words, R&D not only introduces the technological competencies but also absorb the knowledge spillovers from external sources. This suggests that R&D is an important indicator for measuring the firms' absorptive capacity (Gallie and Legros, 2012). However, R&D is a costly and risky investment and requires a long term commitment to improve the firms' competitiveness and innovation performance (Pradhan, 2011; Ortega-Argiles, Vivarelli and Voigt, 2009). Studies shows that SMEs normally carry out informal R&D (non-permanent R&D) by using resources from different departments due to lack of financial and technological competencies.

Likewise, SMEs generally tend to under-invest in R&D projects because of higher uncertainty in succeeding the innovative project and the lack of information between firms' and external suppliers of finance. Further, small firms have limited access to internal and external finance as they cannot even use their initial money/profits to invest in risky projects (Czarnitzki and Delanote, 2015). Sometime, it is less expensive to imitate than to innovate because firms' size is correlated with availability and stability of internally generated funds (Ortega-Argiles, Vivarelli and Voigt, 2009). It is argued that investment in R&D below the optimal level is very expensive; however, R&D subsidies/grants could alleviate the underinvestment in innovation activities (Meuleman and Maeseneire, 2012). Czarnitzki and Delanote (2015) conducted a study on 3272 German SMEs and suggested that R&D subsidies (from government) significantly boost the innovation performance of small firms. Likewise, Hottenrott and Lopes-Bento (2012) study on 1973 Belgian SMEs has found that R&D subsidies accelerate R&D spending in SMEs and has a significant impact on the firms' innovation performance. In support of Hottenrott and Lopes-Bento (2012), Orteg-Argiles, Vivarelli and Voigt (2009) suggested that fiscal incentives and subsidies for SMEs may overcome the problems of weaker competencies, absorptive capacity and absence of scale and scope of economies. In comparison, Demirbas *et al.* (2011) analyzed the barriers to innovation for 224 Turkish SMEs using logit model. They found that lack of government support for R&D significantly reduces the SMEs innovation performance. This apparently indicates that that R&D is essential input for SMEs innovation success because small firms can benefits from scientific knowledge activities (R&D) and may increase their innovation

² Similarly, Ornaghi (2006) states that R&D generates two types of externalities, first it generates rent spillovers (*e.g.*, investment in goods, patent licensing and quality improvements), and second it generates knowledge spillovers (exchange of information at conferences and reverse engineering).

output (Parrilli and Elola, 2012). Especially, R&D subsidies and grants can accelerate R&D in SMEs.

Furthermore, Artz *et al.* (2010) conducted a panel study of US firms and found that R&D has a positive and significant impact on the firms' invention (patents) and innovation (new products). This apparently indicates that R&D is directed both at firms' invention and innovation. Mairesse and Mohnen (2005) examined the positive relationship between R&D and product/process innovation using Tobit regression analysis on 2253 French firms. Similarly, Ganotakis and Love (2011) conducted a study on 412 UK SMEs. They revealed that internal R&D has a strong and positive impact on the firms' product innovation. Gallie and Legros (2012) analyzed the French firms by using the unbalance panel data and found that R&D has significant and positive impact on the firms' innovation output. Further, Fritsch and Meschede (2001) examined the positive relationship between process R&D expenditure and firms' size. This indicates that large firms devote significant portion of their R&D on process innovation because process innovation improve the quality of their new products or to introduce completely new products. Likewise, Ornaghi (2006) investigated the Spanish manufacturing firms. Ornaghi results suggested that knowledge spillovers through R&D improve the firms' innovation performance (product and process innovation). Pradhan (2011) conducted a firms' level study on Indian manufacturing firms. Pradhan study revealed that R&D is an important determinant of SMEs performance. Interestingly, a reasonable amount of researchers (Hagedoorn and Wang, 2012; Berchicci, 2013) categorized R&D into internal and external R&D and their impact on the firms' innovation performance. The next sub section provides the discussion on the role of external R&D.

External R&D

Firms' reliance on internal R&D activities and other internal capabilities (e.g., skills) is no longer enough to cope with the higher cost of innovation, shorter product lifecycles and higher technological complexities (Berchicci, 2013; Bergman, 2010). This recent shift from closed to open innovation models has emphasized the role of external R&D activities. Through such network activities (*i.e.*, R&D alliances with universities, suppliers and other research organizations) firms' may increase their competitiveness and superior performance (Minarelli *et al.* 2013; Ahuja, 2000; Cantner *et al.* 2010; Annique, Cuervo-Cazurra and Asakawa, 2010). The common goal of external R&D is to develop new products and processes by saving costs. Moreover, the potential benefits of such external networks are

sharing risks and costs, shortening innovation cycles and exploiting economies of scale (Hagedoorn, 1990; Peltier and Naidu, 2012; Colombo *et al.* 2011; Neito and Santamaria, 2010; Pullen *et al.* 2012).) In addition, external R&D cooperation provide access to intangible knowledge (non-codified) by means of people-to-people contacts and increases the market power of each cooperating partner (Teirlink and Spithoven, 2013; Kinkel and Som, 2010). Specifically, SMEs can overcome the challenges of resource constraint through R&D cooperation. Interestingly, the study of Teirlink and Spithoven (2013) based on 140 Belgium SMEs found that micro enterprises rely more on a R&D cooperation than any other type of firms' size.

Additionally, several studies concerning the SMEs financial resources suggests that SMEs are more financially constrained than large firms (Abor and Biekpi, 2007; Beck and Kunt, 2006). In fact, SMEs internal source of finance is not sufficient to undertake R&D projects directly. This indicates that lack of financial resources reduce the SMEs innovation activities (Dundas, 2006). One way is to overcome this problem is through R&D collaboration with competitors, suppliers and universities which increases the R&D spending and firms' competitiveness (Hottenrott and Lopes-Bento, 2012; Jong and Vermeulan, 2006). The lack of resources is barrier to SMEs innovation performance, but at the same time it is the primary motive for SMEs to search beyond the boundaries for required knowledge and innovative ideas. In particular, R&D alliances allow firms' to internalize more technology spillovers, exploit economies of scale, combining complementary technological skills and minimize the free riding on R&D outputs (Hottenrott and Lopes-Bento, 2012). Moreover, SMEs can enhance the innovation performance from external knowledge sources *e.g.*, through R&D cooperation with other firms and research institutions (Chun and Mun, 2012). Cooperative R&D agreements provide SMEs with opportunities to increase their absorptive capacity, because such collaborative innovative efforts maximize the firms' internal stock of knowledge.

For instance, the empirical study of Annique, Cuervo-Cazurra and Asakawa (2010) stated that R&D collaborations with universities and suppliers positively influence the firms' product innovation. However, R&D collaborations with competitors appear to have negative impact on the product innovation. This indicates that not all R&D alliances positively influence the firms' product innovation. The disadvantages of R&D collaboration are transaction costs, especially to cooperate, manage and control R&D activities (Becker and Dietz, 2002). Nevertheless, the study of Chun and Mun (2012) on Korean SMEs suggested

that R&D cooperation significantly improve the firms' product and process innovation. A similar finding is provided by Kinkel and Som (2010) related to German mechanical engineering industry. In addition, Mukherjee *et al.* (2013) investigated the R&D alliance formation (external R&D) in 854 German SMEs. They found that in SMEs inter-firms' trust are more likely to form R&D alliances, because such R&D alliances mainly influence the product innovations. Specifically, SMEs face more environmental uncertainty (*i.e.*, uncertain costs and benefits) and trust between R&D firms' can minimize this problem. Likewise, Spithoven, Vanhaverbeke and Roijackers (2013) investigated the open innovation practices in 967 Belgium SMEs. They argued that SMEs reliance on external R&D significantly improve the innovation performance (product innovation).

On the other hand, Hagedoorn and Wang (2012) and Berchicci (2013) empirical studies suggest that internal and external R&D (R&D alliances) have complementary relationship at higher level of in-house R&D intensity. While at lower level of in-house R&D intensity both internal and external R&D has substitutability relationship. Specifically, the trade off between internal and external R&D positively influence the firms' innovation output (Berchicci, 2013). Similarly, Bergman (2010) panel study on Swedish firms discussed that internal and external R&D both have a positive impact on the firms' productivity and this may suggest the complementary relationship between the two types of R&D. Likewise, Lokshin, Belderbos and Carree (2006) investigated 304 Dutch firms by using a dynamic linear panel model. They found that internal and external R&D has complementary relationship. Additionally, Ceccagnoli *et al.* (2013) examined the complementary relationship between internal and external R&D using pharmaceutical firms. According to Ceccagnoli, external R&D promotes innovation by fostering internal R&D activities. This finding suggests that firms with external R&D must also continue to undertake internal R&D. A similar finding is suggested by Piga and Vivarelli (2004) using Italian manufacturing firms. They argued that internal and external R&D has complementary relationship which implies that doing more of one increases the return on doing more of other. Likewise, Becker and Dietz (2002) conducted a study on 2048 German manufacturing firms using simultaneous equations. They found that internal and external R&D (R&D cooperation) has complementary relationship. Their findings suggest that external R&D drives firms to invest more in the development of innovation. In other words, a firm's with sufficient internal R&D base serve as an 'absorptive capacity' to benefit from the external R&D activities. To sum up, the literature review has extracted the following main hypotheses, which are as follows;

H1: Internal R&D has positive impact on the SMEs innovation performance

H2: External R&D has positive relationship with the SMEs innovation performance

H3: Public support to innovation has positive association to SMEs innovation performance

H4: Internal and external R&D has complementary relationship.

3. Methodology towards a research

This section provides information related to the research context of this study. Further, two figures have been reported to analyze the comparison of innovation activities in Indian and Pakistani SMEs. The source of data has been discussed which is followed by an empirical analysis and results discussion.

3.1. Indian and Pakistani SMEs as Research Context

India and Pakistan are the two major economies of South Asia in terms of GDP (Gross Domestic Product). Both countries share a long border with each other and are active members of SAARC (South Asia Association for Regional Cooperation). In 2013, India total GDP valued at US\$ 1.875 trillion, and, Pakistan GDP was US\$ 232.3 billion. This suggests that Indian economy is relatively larger than Pakistan. Despite the tense diplomatic relations between the two neighbouring countries, the current trade volume between the two countries is less than \$3 billion. Moreover, SMEs in India contribute 17% in the total GDP while, SMEs in Pakistan contribute around 40% in the total national income (GDP). Indian SMEs sector employs 60 million (nearly 15% of Indian workforce) and 26 million enterprises contribute 45% of manufacturing output. In comparison, SMEs in Pakistan employ 75% of non-agriculture workforce and 3.2 million enterprises contribute 30% of manufacturing output. Similarly, India has edge over Pakistan related to the overall R&D expenditure (% of GDP). India spends approximately 1% of total GDP on R&D compared to 0.33% for Pakistan (World Bank).

In fact, R&D investment is essential to ‘absorptive capacity’ and ‘national learning’, but the poor countries tend to do very little R&D due to their low human capital, lack of research infrastructure and less technological advance private sector (Goni and Maloney, 2014). For instance, a micro study of Pradhan (2011) investigated that R&D intensity is very low among Indian SMEs than large firms and shortage of funds is one of the important barrier for their technological competitiveness. In addition, Subrahmanya (2012) investigated that most of

India SMEs carried out incremental type of innovation because these incremental innovations are largely driven by customer demands and confined to slight changes in product design/shapes to meet the customer requirements. Similarly, Subhan *et al.* (2013) study suggested that Pakistani SMEs are required to invest in knowledge based resources (*e.g.*, R&D, process innovation) for higher innovation performance. Further, Pakistan has not yet developed even effective national innovation system for improving the overall R&D spending and other technological investment especially in Biotech industry. Moreover, outdated technologies, lack of access to credit or higher interest rate on lending and the lack of government support are the major barriers to Pakistani SMEs (Berry, 1998). Overall, the facts related to Indian and Pakistani SMEs suggest that low level of R&D undertaking, less innovative products, lack of access to credit and the lack of innovative culture are the major obstacles for SMEs innovation performance.

3.2. Data Source

The data has been obtained from the World Bank Enterprise Survey. The data was collected in 2013 under the title of “World Bank Innovation Follow Up”. Fortunately, the innovation data was available for both India and Pakistan for the same year, which is very rare to access from other sources (government statistical departments). The survey has gathered information on the key innovation variables such as R&D, product/process innovation, source of financing for their innovation activities, organizational and marketing innovation. However, this study has excluded organizational and marketing innovation which is beyond the scope of this paper. For India, total 3492 firms responded to the survey compared to 696 firms for Pakistan. Mainly in both countries firms participated (over 75%) from manufacturing sector (Textile, Tobacco, Chemicals, Printing, Electronics and Machinery etc) compared to (over 15%) from the services sector (IT, wholesale, Hotel and restaurants and transport etc).

Moreover, majority of these firms who participated in the survey are SMEs. This study has used two dummy variables to define SMEs. The definition has followed the guidelines from the World Bank, Enterprise Survey instead of country specific SMEs definition. In the case of India, approximately 28% are small firms (5-19, employees), 45.50% are medium sized firms (20-99, employees) and large firms (over 100 employees) are nearly 27%. For Pakistan, 44% are small firms, 35% medium firms and 21% are large firms. However, none of firm's is comprised from micro enterprises (≤ 5 employees) in the Indian dataset, so it is dropped from the analysis. Further, this study has also dropped large firms (as dummy variable) for

two reasons. First, large firms caused multicollinearity with other size bands. Second, this study specifically presents the analysis of SMEs.

The data was gathered from Indian regions such as Maharashtra (6.87%), Karnataka (6.47%), Andra Pradesh (6.27%), West Bengal (5.84%), Delhi (5.7%), Gujarat (5.01%), Haryana (4.47%) and so forth. While in Pakistan data was collected from Punjab (53.59%), KPK (20.26%), Sindh (13.36%) and Islamabad (12.79%). Of the total 1613 R&D firms, India has higher internal R&D investment in industries such as plastics and rubber (10.04%), machinery (9.98%), Chemicals (9.73%), electronics (9.86%), basic metal (8.25%) and so forth. While, of the total 65 Pakistani R&D firms, Pakistan has higher internal R&D investment in industries such as food (13.85%), textile (13%), chemicals (10.77%), vehicles (9.23%), retail (9.23) and so forth. For comparative analysis, two figures provide the innovation activities of Indian and Pakistani SMEs.

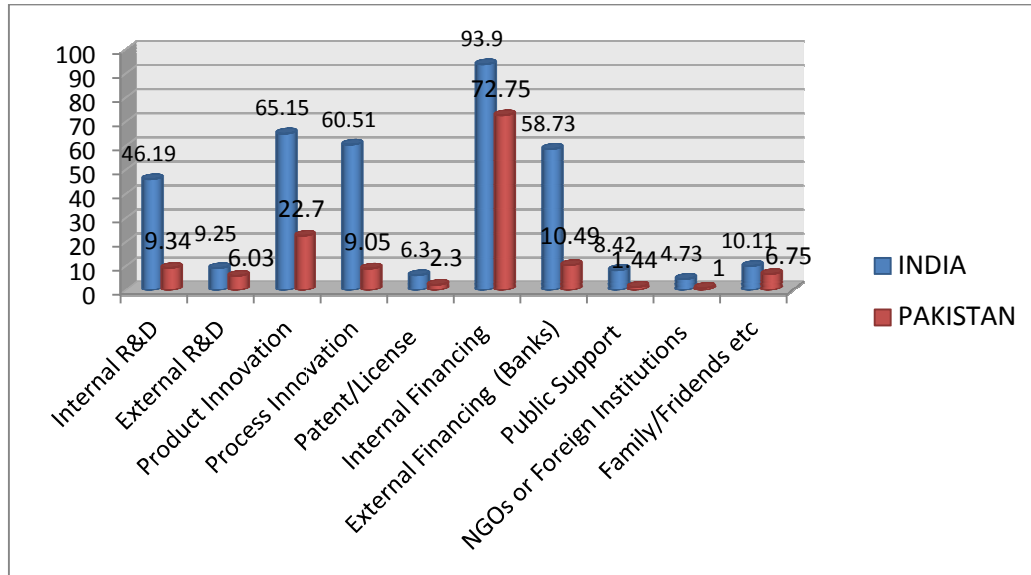
3.3. A Comparison of Innovation Activities

Figure 1 present's information related to the innovation activities in Indian and Pakistani SMEs such as internal and external R&D undertaking, product/process innovation and their source of financing for innovation activities. Of the total (n=3492), approximately 46% of Indian SMEs undertook internal R&D compared to just over 9% for 696 Pakistani SMEs (see Figure 1). This suggests that Pakistani SMEs are less engaged in internal R&D. In addition, the level of external R&D undertaking is very low in proportion for both Indian and Pakistani SMEs. Further, most of the Indian SMEs are engaged in product innovation (65%) while only 22.17% of Pakistani SMEs produced product innovation. In comparison, nearly 61% of Indian SMEs introduced process innovation compared to 9% for Pakistani SMEs. However, the patent and licence as output is lower in percentage for both countries. Perhaps, this outcome indicates that SMEs in both countries predominantly introduced incremental type of innovations. Overall, figure 1 suggests that Indian SMEs are dominant in terms of carrying out internal R&D and product/process innovation than Pakistani SMEs. In other words, Pakistani SMEs are less involved in innovation activities (internal R&D, product innovation).

Additionally, SMEs in both countries are mainly (over 70%) relying on internal source of financing for their innovation activities (see Figure 1). Interestingly, nearly 59% of Indian SMEs also financed their innovation activities through external borrowing (banks). However, only 10.49% of Pakistani SMEs funded their innovation activities through external finance.

This apparently indicates that Pakistani SMEs are more externally constrained than Indian SMEs. Similarly, public support (subsidy or tax credit) is higher (8.42%) for Indian SMEs compared to Pakistani SMEs which is 1.44% of total firms (n=696).

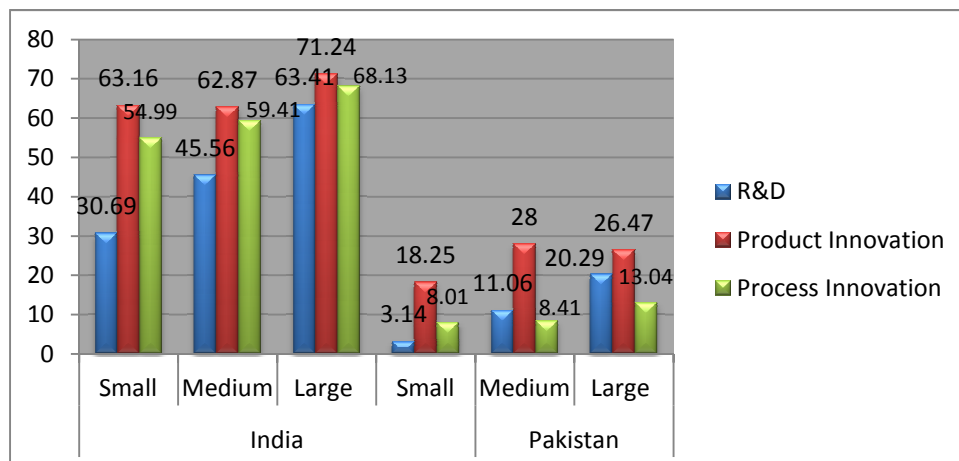
Figure 1: Innovation Activities across Indian and Pakistani SMEs (figures are in %)



Source: Author own calculations

In addition, Figure 2 provides information on R&D undertaking, product and process innovation by firms’ size across Indian and Pakistani SMEs.

Figure 2: R&D, Product/Process Innovation by Firm Size across India and Pakistan



Source: Author own calculations

In India, of the total 3492 firms, approximately 31% of small firms (employees: 5-19) are engaged in R&D. Similarly, nearly 46% of medium sized firms (employees: 20-99) have undertaken R&D. However, large firms (employees over 100) have higher (63%) R&D undertaking compared to other size bands. In Pakistan, of the total 696 firms, only 3% of small firms are engaged in R&D compared to 11% for medium sized firms. The R&D undertaking is higher (20.29%) for large firms in the case of Pakistan. Overall, figure 2 suggest that large firms have higher R&D undertaking than small and medium sized enterprises for both countries. However, the level of R&D investment is very low for Pakistani SMEs than Indian SMEs.

Furthermore, almost a similar proportion (63%) of small and medium firms has produced product innovations in the case of India. However, 71% of large firms have introduced product innovations and 68% for process innovations. In the case of Pakistan, 18% of small firms have introduced product innovation compared to 28% for medium size firms. Large firms have generated 26% product innovations. While, process innovation is overall very low for Pakistani SMEs. Overall, figure 2 shows that large firms are more engaged in innovation activities such as R&D and product innovation for both countries. This suggests that large firms have better financial and knowledge resources than SMEs. Another finding from Figure 2 is that, Pakistani SMEs have low innovation abilities than Indian SMEs.

3.4. Dependent Variable (Innovation Performance)

This empirical study has used two dependent variables *i.e.*, product and process innovation because to remain a successful firms' in the highly innovative markets, product and process innovation are important innovation outputs which are driven by R&D and technological acquisition (*e.g.*, investment in advance machinery) (Conte and Vivarelli, 2013; Fritsch and Meschede, 2001). Likewise, Pellegrino *et al.* (2014) argued that product and process innovation are essential innovation output. This apparently indicates that product innovation provides firms' market leadership, broader its customer base and increases the price buyers, while process innovation reduce the firms' average cost of production (Wolff and Pett, 2006; Cohen and Klepper, 1996; Jong and Vermeulan, 2006). However, some studies (*e.g.*, Hagedoorn and Cloudt, 2003; Katila, 2000; Ying, 2009) use patent counts/applications as a proxy of innovation output, but this study preferred product/process innovation over patents as dependent variables for a number of reasons. First, it is not necessary that every innovation is patented and secondly, many firms do not patent their products and processes because of

their reluctance to disclose the strategic information related to innovation and secrecy may be considered as effective way of protection of their innovation. Moreover, in developing countries patents usage is not very common due to financial constraint and lower quality of innovation output (Ghoneim, 2003).

3.5. Independent Variables

The major variables of interest of this study are internal and external R&D. These two variables has been analyzed *vis-a-vis* innovation output *i.e.*, product and process innovation. Similarly, two additional innovation input variables has been used related to firms' technological acquisition. Specifically, firms' investment in internal technology acquisition (investment in machinery, equipment and software) and external technology acquisition (patents/licence) have a significant impact on the firms' innovation performance (Silva *et al.* 2012; Crespi and Zuniga, 2012). Moreover, firms' financial resources have been measured through internal funds, external finance (bank credit) and public support (subsidy on R&D/tax incentive). These three explanatory variables would investigate the impact of source of finance on the firms' innovation output.

3.6. Control Variables

Previous studies indicate that there are certain factors that influence the innovation performance of a firm which needs to be controlled. For instance, firms' size and age are important variables which affect the firms' innovation output. Firms' size is included as in dummy form while firms' age is included in logarithmic form.

4. Econometric Model

A bivariate probit model has been used to estimate the relationship between R&D and product/process innovations. This estimation method removes the sample selection bias and also presents more accurate parameters through the inclusion of non-innovative firms (Chun and Mun, 2012). For instance, Heckman suggested Heckit-procedure for continuous dependent variables for sample selection bias. However, in this case the dependent variables are discrete and the use of Inverse Mills Ratio (IMR) is not an appropriate choice. This study has used bivariate probit model to correct the sample selection bias. Moreover, the correlation coefficient between the two unobserved factors (residuals) from the two equations indicates the possible complementarities between the dependent variables. The model is as follows

$$y_{1i} = \begin{cases} 1 & \text{if } x_{1i}\beta_1 + e_{1i} > 0 \\ 0 & \text{otherwise} \end{cases} \quad (a)$$

$$y_{2i} = \begin{cases} 1 & \text{if } x_{2i}\beta_2 + e_{2i} > 0 \\ 0 & \text{otherwise} \end{cases}$$

y_{1i} and y_{2i} are product and process innovations while, e_{1i} and e_{2i} are error which are jointly normally distributed with correlation coefficient $\rho = \text{Corr}(e_{1i}, e_{2i})$. In other words, when $\rho \neq 0$ indicates that the null hypothesis is rejected and bivariate probit model is the correct choice of estimation.

4.1. Empirical Results

Before estimation, Table 1 provides summary statistics of all variables used in the estimation. Means, standard deviations and definition of each variable is provided in Table 1 for both countries. In addition, the correlation matrix is used to detect the problem of multicollinearity. Multicollinearity arises when some or all explanatory variables are highly correlated with each other and it is difficult to tell which variable is influencing the predicted variable (Koop, 2004). However, in majority the correlation between variables are lower than 0.5 (Tables can be provided upon request).

Table 1: Variable definitions and descriptive statistics

	India		Pakistan		Definition
	\bar{x}	σ	\bar{x}	σ	
Product Innovation	0.6518	0.4764	0.2286	0.4202	Dummy coded 1 if firm introduce any innovative products or services in the last two years
Process Innovation	0.6050	0.4888	0.0905	0.2871	Dummy coded 1 if firm introduce any innovative method of manufacturing processes or offering services
Internal R&D	0.4619	0.4986	0.0933	0.2911	Dummy coded 1 if firm conduct internal R&D for developing innovative products or services
External R&D	0.0924	0.2897	0.0603	0.2382	Dummy coded 1 if firm conduct external R&D undertaken by other firms, public or private research organization
Log Age	2.7430	0.7458	2.9406	0.6279	Log (2014-Age)
Small	0.2780	0.4481	0.4408	0.4968	Dummy coded if firm employees are between (5-19)
Medium	0.4550	0.4980	0.3471	0.4764	Dummy coded if firm employees are between (20-99)
Technology-acquisition1	0.6331	0.4820	0.1781	0.3829	Dummy coded 1 if firm spends on purchase of new equipment, software to develop innovative products or services
Technology-acquisition2	0.0630	0.2429	0.0229	0.1499	Dummy coded 1 if firm spends on license/patents or other type of knowledge
Internal Finance	0.9380	0.2393	0.7270	0.4458	Dummy coded 1 if firm finance innovative activities from internal funds
External Finance	0.5873	0.4923	0.1048	0.3066	Dummy coded 1 if firm finance innovative activities from banks
Public Support	0.0841	0.2777	0.0143	0.1190	Dummy coded 1 if firm finance innovative activities through public support
Sector	0.7800	0.4142	0.8376	0.3690	Dummy coded 1 if firm is from manufacturing sector otherwise zero

Means and standard deviations are reported.

(a) R&D (Internal and External) and Product/Process Innovation

Table 2 provide information on the relationship between R&D (internal and external) and product/process innovation using bivariate probit analysis for India. A firm's probability to introduce product innovation is higher when it is engaged in internal and external R&D. This suggests that internal and external R&D increases the firms' innovation output. This outcome is in line with the previous findings of Stam and Wennberg (2009), Gallie and Legros (2012). This finding confirms the hypothesis which is drawn from the literature. However, this relationship is found weaker *vis-a-vis* process innovation. Only internal R&D showed statistical association with process innovation. One possibility of this outcome is that Indian SMEs are more inclined towards undertaking internal R&D related to the process innovation. This apparently implies that internal R&D undertaking would likely to reduce the marginal cost of production. The coefficients of technological acquisition 1 and 2 showed positive association to product innovation. This finding indicates that firms' decision to spend on

machinery and equipments, licensing, software would likely to introduce more product and process innovation (see Table 2). This outcome confirms the finding of Silva *et al* (2012) which states that innovation expenditure increases the probability of introducing product and process innovations.

The coefficient of age showed negative association to product innovation. This outcome suggests that younger firms are more likely to generate product innovations than older firms. In addition, firms' size (small and medium) showed negative relationship with product and process innovation. This indicates that Indian SMEs are less likely to engage in product and process innovation compared to large firms. This finding supported the Schumpeterian hypothesis (Conte and Vivarelli, 2013; Love and Ropper, 1999) that is large firms are more innovative than small firms because large firms have better knowledge and financial resources (See Table 2). Further, the parameter of external finance suggests that 1% increase in the external finance (borrowing from banks) would likely to increase the process innovation by 21%. This outcome implied that access to formal credit (banks loan) is important resource for firms' process innovation. Lending to SMEs through commercial banks would generate more intensified competition in the local market because their internal source of finance is not sufficient to undertake highly risky innovative projects. Similarly, public support for innovation activities (R&D subsidy or tax credit) has a positive impact on the firms' product innovation. Such support scheme would accelerate their innovation spending. This implies that government intervention through R&D subsidy/grant could improve the innovation performance. This outcome has confirmed the findings of Hottenrott and Lopes-Bento (2012) that is public support to R&D increases the firms' innovation performance. Lastly, manufacturing sector is more likely to introduce product innovation than services sector and this results that manufacturing sector is more likely to undertake innovation projects.

Table 2: Bivariate probit estimation analysis

	India			
	<i>Product Innovation</i>		<i>Process Innovation</i>	
	<i>Coeff.</i>	<i>Z-value</i>	<i>Coeff.</i>	<i>Z-value</i>
Internal R&D	0.3718*** (0.0485)	7.65	0.1045** (0.0489)	2.14
External R&D	0.2144** (0.0841)	2.55	-0.0867 (0.0789)	-1.10
Technology Aquisition-1	0.3675*** (0.0499)	7.38	1.0328*** (0.0487)	21.20
Technology Acquisition-2	0.1685* (0.0936)	1.80	0.1184 (0.0961)	1.23
Log Age	-0.0639** (0.0307)	-2.08	-0.0397 (0.0311)	-1.28
Small Firms	-0.1239* (0.0642)	-1.93	-0.1575** (0.0647)	-2.43
Medium Firms	-0.2008*** (0.0559)	-3.59	-0.1313** (0.0569)	-2.31
Internal Finance	0.0299 (0.0947)	0.28	-0.0494 (0.0985)	-0.51
External Finance	0.0299 (0.0947)	0.64	0.2147*** (0.0476)	4.51
Public Support	0.6522*** (0.0985)	6.62	-0.1073 (0.0817)	-1.31
Sector	0.3912*** (0.0555)	7.04	0.0774 (0.0574)	1.35
Constant	0.3484** (0.1422)	2.45	-0.3249** (0.1447)	-2.24
<i>Rho</i> (ρ)	-0.3075*** (0.0286)	10.75	-	-
<i>Wald Chi2</i>	819.14***			

***p<0.01; **p<0.05; *p<0.10.

Robust standard errors are in parentheses

N=3486

Table 3 showed the bivariate probit estimation analysis between R&D and product/process innovation for Pakistani SMEs. Internal R&D has no statistical association with product and process innovation. However, external R&D has significant impact on the firms' product and process innovation. There are two main possibilities of this outcome. First, this outcome indicates that Pakistani SMEs are reluctant to engage directly in R&D due to risk and higher cost of innovation. Second, Pakistani SMEs do not have the sufficient capacity (R&D related skills) to undertake internal R&D. External R&D provides shared cost and risk and also expertise in undertaking joint R&D programs with other organizations. This finding confirms the second hypothesis.

Overall, technological acquisition has a positive and significant impact on the product and process innovation. This suggests that innovation expenditure on machinery, equipment and gaining intellectual property rights (patents) would likely to introduce more product and process innovation. This outcome is in line with the findings of Crespi and Zuniga (2012). Only medium size firms' has positive relationship with product innovation. The coefficient of age showed positive association with product innovation. This implies that older firms are more likely to introduce product innovation because of their experience. However, small firms showed no association at all. Further, the negative signs of coefficients for small and medium size firms without statistical association to process innovation suggest the weak outcome (see Table 3). Regarding the source of financing for their innovation activities, 1% increase in the internal finance would likely to increase the product innovation by 89%. This is very strong outcome and suggests that internal finance is the major source of financing for Pakistani SMEs. However, the parameter of external finance showed no association. This indicates that Pakistani SMEs are more externally constrained than Indian SMEs. Overall, manufacturing sector is more likely to introduce product innovations.

Table 3: Bivariate probit estimation analysis

	Pakistan			
	<i>Product Innovation</i>		<i>Process Innovation</i>	
	<i>Coeff.</i>	<i>Z-value</i>	<i>Coeff.</i>	<i>Z-value</i>
Internal R&D	0.1154 (0.2574)	0.45	-0.0664 (0.3366)	-0.20
External R&D	0.1015* (0.0572)	1.77	0.4433** (0.1663)	2.66
Technology Aquisition-1	0.3395** (0.1593)	2.13	1.0154*** (0.1749)	5.80
Technology Acquisition-2	0.6580* (0.4109)	1.60	0.3973 (0.3552)	1.12
Log Age	0.4957*** (0.1104)	4.49	0.1954 (0.1267)	1.54
Small Firms	0.0359 (0.1704)	0.21	-0.0546 (0.2187)	-0.25
Medium Firms	0.3037* (0.1670)	1.82	-0.1721 (0.2091)	-0.82
Internal Finance	0.8947*** (0.1749)	5.11	0.6304*** (0.2057)	3.06
External Finance	-0.1996 (0.2055)	-0.97	0.1062 (0.225)	0.48
Public Support	0.3141 (0.4828)	0.65	0.0390 (0.5459)	0.07
Sector	0.4040** (0.1982)	7.04	0.2886 (0.2501)	1.15
Constant	-3.3600*** (0.4748)	-7.08	-2.8609*** (0.5308)	-5.39
<i>Rho</i> (ρ)	0.6107*** (0.0721)	8.47	-	-
<i>Wald Chi2</i>	121.24***			

***p<0.01; **p<0.05; *p<0.10.

Robust standard errors are in parentheses

N=648

(b) Complementary Relation between Internal and External R&D

In order to estimate the last hypothesis related to the complementary relationship between internal and external R&D. Separate probit models have been used (see Table 4). A number of researchers used R&D as dependent variable (see *e.g.*, Pradhan, 2011; Ornaghi, 2006; Piga and Vivarelli, 2004; Becker and Dietz, 2002). Specifically, Piga and Vivarelli (2004) study has found that internal and external R&D are potentially endogenous. Internal R&D is correlated with the error terms of external R&D equation. In order to avoid this endogeneity problem, this study has preferred to use separate probit models for each dependent variable (internal and external R&D). Moreover, this empirical study has followed the estimation

procedure of Becker and Dietz (2002). Becker and Dietz (2002) used internal and external R&D as dependent variables in the separate equations to estimate their complementary effect. In this research study internal and external R&D both are discrete variables so the choice of probit models is appropriate. In addition, firms' size has been introduced as continuous variable (logarithmic form) for two reasons. First, a number of researchers (e.g., Demirbas *et al.* 2011) used firms' size as continuous variable for estimation to avoid the possible multicollinearity between firms' size categories. Second, the sign of coefficient of firms' size as continuous variable provides the comparison between small and large firms for analysis.

Table 4 report the results of probit estimation for India and Pakistan. The link test has been used to see whether the model is adequately satisfied without omitted variable bias. The variable prediction hat-square indicates that the model is correctly specified (see Table 4). In model 1, 1% increase in the external R&D the probability of internal R&D is likely to rise by 53%. Similarly, in model 2, internal R&D has positive and significant impact on the external R&D. In both specifications, the parameters for internal and external R&D are highly significant (at the $p < 0.01$ level). This outcome is pointing out the complementary relationship between internal and external R&D. External R&D motivates firms to undertake more internal R&D and expand technological capabilities of SMEs. This result is in line with the findings of Ceccagnoli *et al.* (2013); Becker and Dietz (2002) and accepted the prior expectation. In addition, technology acquisition 1 and 2 showed positive association to internal R&D in the case of India (see Table 4 and model 1). This outcome indicates that firms' innovation expenditure would likely to increase the probability of undertaking internal R&D. However, in model 2 only technology acquisition-2 shows positive association to external R&D. Overall, firms' size (logged) present positive relationship with internal and external R&D. This outcome suggests Indian and Pakistani SMEs are less likely to engage in internal and external R&D compared to large firms. Alternatively, this outcome indicates that large firms are more R&D intensive than small firms. This finding accepted the Schumpeterian hypothesis which is large firm is more innovative than small firms'.

Similarly, the positive relationship is found between internal and external R&D relationship for Pakistan in model 3 and 4 (see Table 4). This relationship is much stronger for Pakistani SMEs. Overall, in Table 4 the outcome between internal and external R&D suggest that both variables have complementary relationship. Doing one internal R&D (or external R&D) increase the probability of another external R&D (or internal R&D). Furthermore, technology

acquisition 3 and 4 would likely to increase the probability of internal R&D. However, model 3 and 4 failed to show the relationship between SMEs and internal or external R&D. The coefficient of internal finance shows that 1% increase in the internal finance; internal R&D is likely to increase by 85%. This indicates that majority of Pakistani SMEs are relying on internal source finance for their innovation activities. Lastly, public support to innovation activities would likely to increase the external R&D. This suggests that R&D subsidies or grants significantly and positively influence the external R&D.

Table 4: Probit Model Estimation (Maximum Likelihood Method)

Explanatory Variables	India				Pakistan			
	<i>Internal-R&D (Model 1)</i>		<i>External R&D(Model 2)</i>		<i>Internal-R&D (Model 3)</i>		<i>External-R&D (Model 4)</i>	
	<i>Coeff.</i>	<i>z-value</i>	<i>Coeff.</i>	<i>z-value</i>	<i>Coeff.</i>	<i>z-value</i>	<i>Coeff.</i>	<i>z-value</i>
Internal R&D	-	-	0.4606*** (0.0678)	6.79	-	-	2.4019*** (0.2677)	8.91
External R&D	0.5399*** (0.0829)	6.51	-	-	2.4239*** (0.2862)	8.46	-	-
Technology Aquisition-1	0.5013*** (0.0479)	10.45	-0.0549 (0.0689)	-0.80	0.3626* (0.1951)	1.86	0.3203*** (0.1228)	2.60
Technology Acquisition-2	0.3281*** (0.0940)	3.49	0.2849*** (0.1069)	2.66	1.2141*** (0.4174)	2.91	0.1126 (0.4392)	0.26
Log Age	0.0268 (0.0305)	0.88	-0.0458 (0.0413)	-1.11	0.06577 (0.1599)	0.41	-0.2618 (0.2130)	-1.23
Log Size	0.2571*** (0.0221)	11.61	0.2208*** (0.0805)	2.74	0.2707 (0.2102)	1.29	1.7957*** (0.4002)	4.49
Internal Finance	0.4283*** (0.0942)	4.55	-0.0370 (0.1278)	-0.29	0.8533*** (0.2148)	3.97	0.2985 (0.2904)	1.03
External Finance	0.0194 (0.0464)	0.42	0.1742*** (0.0637)	2.73	0.1149 (0.2756)	0.42	0.2345 (0.3708)	0.63
Public Support	-0.1188 (0.0833)	-1.43	0.0602 (0.1069)	0.57	0.3758 (0.7127)	0.53	0.6318* (0.3548)	1.78
Sector	0.5440*** (0.0575)	9.45	0.0727 (0.0811)	0.90	-0.0289 (0.2396)	-0.12	0.6041 (0.4252)	1.42
Constant	-1.0096*** (0.1420)	-7.11	-1.4454*** (0.1921)	-7.52	-2.6540*** (0.6191)	-4.29	-1.9740** (0.7919)	-2.49
<i>Pseudo R²</i>	0.1148		0.0468		0.1468		0.1233	
<i>Model Specification Test</i>								
<i>Predict hat</i>	1.0015***	21.19	0.8241	0.91	0.9605***	7.16	0.7357***	3.10
<i>Predict hat-Square</i>	0.0068	0.10	-0.0669	-0.19	-0.0436	0.41	-0.1942	-1.21

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

Robust standard errors are in parentheses

N=3488 (India)

N= 648 (Pakistan)

4.2. Discussion

This study provides the relationship between R&D (internal and external) and product and process innovations. SMEs are engaged in internal and external R&D is more likely to introduce product and process innovation. This outcome is stronger for Indian SMEs. While, in the case of Pakistani SMEs, only external R&D showed positive association to firms' product and process innovation. This implies that Pakistani SMEs are reluctant to engage in internal R&D due to higher cost of innovation and risks. Furthermore, Indian SMEs is found dominant in terms of undertaking R&D, product and process innovation than Pakistani SMEs. This suggests Indian SMEs are more innovative compared to Pakistani SMEs. Moreover, Indian SMEs are relying not only on internal source of financing but also external finance (from banks) as their major source of financing for innovation activities. Nonetheless, Pakistani SMEs are dependent upon only on internal source of finance which is not sufficient to undertake internal R&D activities. This indicates that Pakistani SMEs are more externally constrained than Indian SMEs.

The positive relationship between internal and external R&D shows the complementary relationship between internal and external R&D. This suggests that investing in internal R&D would likely to increase the probability of doing external R&D and *vice versa*. This outcome confirm the findings of Ceccagnoli *et al.* (2013); Piga and Vivarelli (2004); Bergman (2010). Lastly, the negative relationship between firms' size categories (SMEs) and product and process innovation shows that Indian SMEs face resource constraints. In addition, in Table 4 the positive relationship between firms' size (continuous variable) and R&D implies that large firms are likely to undertake internal and external R&D than small firms. This outcome has supported the finding of Schumpeter which argues that large firms are innovative than small firms. Going back to the initial research question, does internal and external R&D affect product and process innovation? The answer to this question is internal and external R&D significantly affects the SMEs innovation performance. However, this effect is found stronger for Indian SMEs.

5. Conclusion

This research study found that internal and external R&D positively influences the SMEs innovation performance. However, this effect was identified stronger for Indian SMEs. Similarly, Indian SMEs were dominant in terms of undertaking internal R&D, product and process innovation compared to Pakistani SMEs. Especially, in the case of Pakistani SMEs

only external R&D showed positive association to product and process innovation. This finding implied that Pakistani SMEs were reluctant to engage in internal R&D because of higher cost of innovation and risks. Moreover, majority of Pakistani SMEs relied on internal source of financing for their innovation activities. This outcome suggested that Pakistani SMEs were more externally constrained compared to Indian SMEs. The relationship between firms' size and innovation performance supported the Schumpeterian hypothesis that large firms were more innovative than small firms. Lastly, this study supported the findings of Ceccagnoli *et al.* (2013) and Becker and Dietz (2002) related to the complementary relationship between internal and external R&D. This outcome implied that external R&D encourages SMEs to undertake more internal R&D and provide technological competitiveness.

The research study provides important policy implications. The complementary relationship between internal and external R&D implies that investment in R&D is pre-requisite for SMEs innovation performance. Business managers can utilize the balance combination of internal and external R&D to increase the SMEs innovation performance. However, this study has found that R&D undertaking is higher in large firms for both countries. Therefore, policy makers should enhance the R&D culture in SMEs. Specifically, the R&D gap is wider between Indian and Pakistani SMEs. Pakistani SMEs less engage in undertaking R&D undertaking, product and process innovation compared to Indian SMEs. This requires robust policies to encourage R&D undertaking in Pakistani SMEs. For instance, public support for innovation such as R&D grants/subsidies and tax credit could encourage SMEs to undertake more radical innovation output.

The relationship between firms size and innovation performance implies that specific policy instruments are needed through the help of Small Industries Development Bank of India (SIDBI), State Financial Corporations of Indian, and Small and Medium Enterprise Development Authority (SMEDA) of Pakistan, SMEs banks in Pakistan to facilitate the financing of "Innovative Business Plans". In particular, Pakistani SMEs are externally constrained and cannot meet the innovation and marketing costs of product and process innovation. Financial assistance and financing with lower interest rates could overcome their problems.

This empirical paper has certain limitations. The non availability of financial information (R&D expenditure, technological acquisition expenditure and borrowing) for Pakistani SMEs restricted this study to use dummy variables. The use of dummy variables does not provide sufficient information on variables. For instance, if the financial data on internal and external R&D was available for Pakistani SMEs, then an interactive variable can be introduced to investigate the complementary relationship between the two variables. The future research can use patent count or patent citation as dependent variables which measure the quality of innovation. Lastly, the study can be extended to other South Asian countries (Sri Lanka, Bangladesh etc) to broaden the analysis of innovation performance of SMEs.

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