Innovation Performance of Chilean SMEs: A Bivariate Probit Analysis

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Abstract

The purpose of this paper is to investigate the innovation activities of Chilean firms' by using micro level data. Previous studies showed research gap related to micro level analysis of the Chilean SMEs. For the first time, multiple proxies have been used as dependent variables (product/process innovations and patent application/spending), which is neglected by the past studies. A micro level data has been obtained from the World Bank, Enterprise Survey on 696 Chilean SMEs. Bivariate probit estimation method has been used. The results showed that SMEs are less likely to apply for patents and introduce product innovations. This outcome indicates that Chilean SMEs face resource constraint in terms of introducing product innovations and applying for patents. In addition, SMEs undertaking R&D and making network ties with other research institutions are more likely to introduce patents and product innovations. Similarly, SMEs that are engage in quality programs are more likely to spend on patents. Lastly, SMEs with public support for innovation activities positively influence the patent application. Findings imply that SMEs investment in knowledge based assets (e.g., R&D, networks and quality methods) accelerate their innovation output. Policy makers should not only provide financial incentives (R&D subsidies) to SMEs but also encourage their strong ties with research institutions for higher innovation output.

Keywords: Innovation, R&D, SMEs

1. Introduction

Numerous researchers emphasized the knowledge based resources (intangibles) as determinants of firms' innovation performance (*e.g.,* Bozic and Radas, 2009). These knowledge based resources are the internal characteristics of the firm and facilitate its sustained competitive advantage. Studies (Wang *et al.* 2014; Peter *et al.* 2013;) on innovation suggest that firms' can maximize their innovation activities through investment in knowledge based resources. These knowledge based resources which are mostly intangibles such as investment in R&D, business improvement methods, patents and network relations have a significant impact on the firms' innovation output (Fabrizio, 2009; Berk and Johansson, 2014). Likewise, Innovation increases the firms' internal stock of knowledge (Gloet and Samson, 2012) and this stock of knowledge improve the firms' ability to internalize the

external knowledge, which is called absorptive capacity (Cohen and Levinthal, 1990; Harris and Reid, 2010). In particular, this empirical study is more focused on the analysis of innovation activities of small and medium enterprises (SMEs) because these are the cornerstone for most of the economies in the world. In Europe, 99% of the Industry is comprises SMEs (<250 employees) and provides 70% of the employment opportunities (Neito and Santamaria, 2010). More specifically, in Chile more than 90% of enterprises are SMEs and approximately 60% of the workforce is employed in the business sector. This indicates that SMEs in developed and developing countries provide a major source of workforce in the country.

On the one hand, in the developing countries where poverty, unemployment, low income per capita, low literacy, high inflation and interest rates hinder the economic growth, SMEs contribute significantly to the national income and provide employment opportunities (Ghoneim, 2003; Moktan, 2007; Drnovsek, 2004). On the other hand, SMEs have lower survival rates than large firms because of their resource constraints (financial and non-financial) (Beck *et al.* 2005). This indicates that SMEs are less innovative than large firms. Specifically, the aim of this study is to provide the key determinants of innovation performance (as output) which is derived from the knowledge-based view of the firm's. Moreover, this study has formed a basic research question which is as follows: Why are SMEs less innovative? To answer this research question this study has identified the important knowledge based resources (i.e., R&D, networks, quality programs) to analyze the Chilean SMEs innovation performance. While, product and process innovation, patent application and patent spending are the proxies of measuring SMEs innovation performance.

Regarding the contribution, this research study has contributed to the existing knowledge in two different ways. First, the study has used multiple dependent variables (patent application/spending, and product and process innovations) to analyze the innovation performance of Chilean firms. Previous studies have neglected this research gap. Second, up till now any empirical study is hardly available on the analysis of Chilean SMEs using micro level data. For analysis, this study has used cross sectional data from Enterprise Survey-2010 (World Bank) on Chilean firms. In estimation, bivariate probit models have been used to analyze their innovation performance. The results showed that Chilean SMEs have less probability to apply for patents and with lower product innovations. However, firms engaged in R&D, networks and with quality programs have more probability to apply for patents and

introduce product innovations. Likewise, public support programs (subsidy or tax incentive) related to innovation activities has a positive impact on the firms' innovation performance.

The present study is structured as follows: section 2 discusses the literature review and section 3 present the methodology, Chilean firms as research context and data sources with descriptive analysis. Estimation of hypotheses has been provided in section 4. Section 5 concludes the major findings with policy implications.

2. Theoratical Background

Rangone (1999) argued that SMEs lack innovative capabilities due to a critical shortage of resources. For instance, small firms are reluctant to invest in R&D and have low human capital as compared to large firms, which may affect the former's innovation performance (Saleh and Ndubisi, 2006). Similarly, SMEs have few opportunities to exploit economies of scale because of high financial barriers and intense technological competition (Friestsch *et al.* 2013; Belitz and Lejpas, 2014; Adam, 1982; Ying, 2009). Furthermore, Ortiz *et al.* (2013) examined the innovation performance of Latin American countries (Argentina, Brazil, Chile, Columbia, Peru, Mexico and the Caribbean) using firm level data. Their study revealed that large firms are more innovative than SMEs in terms of R&D, product and process innovation. Moreover, they discussed that informal organizational structure and poor marketing abilities significantly reduce the innovation performance of SMEs. In addition, Radas and Bozic (2009) investigated the barriers to innovation for Croatian SMEs. They identified that lack of qualified staff, lack of information concerning technology and lack of information concerning market; high innovation cost and insufficient government support reduce the innovation performance of SMEs.

On the other hand, Lane and Lubatkin (1998) suggested that small firms usually comprise family members and these small family owned businesses are less innovative because of centralized decision making and use of informal procedures. Weeks (2003) stated that SMEs are less efficient than large firms because small firms provide low quality jobs and may produce incremental innovation by utilizing less economies of scale. Further, the workers in small firms receive less fringe benefits and occupy less secure jobs because SMEs adopt more informal recruitment and selection procedure (through friends and family member contacts) in order to avoid a high cost of recruitment (Vinten, 1998). In contrast, several studies (Friestsch *et al.* 2013; Smallbone and Welter, 2001; Terziovski, 2010) argued that

SMEs have certain advantages over large firms such as their organizational flexibility with less bureaucratic control, quick in decision making, flexibility to market needs, informal strategies and greater responsiveness to changing environment. In short, this interesting and distinctive debate in the literature motivated the researcher to investigate why SMEs are less innovative by using knowledge based resources.

A number of researchers have divided resources into two broad categories *i.e.,* tangible and intangible, which are heterogeneous in nature (Penrose, 1995; Dundas, 2006; Walker, 2010). These tangible (people, machinery, financial capital) and intangible (R&D, skills and process) resources perform productive tasks for the firm **(**Galunic and Rodan, 1998). These tangible and intangible resources significantly improve the firm's innovation output. However, this study is mainly focused on role of intangible assets or knowledge based assets (KBA) for a number of reasons. First, KBA provides the firm's sustained competitive advantage and second KBA positively influence the firm's productivity (Harris, 2008). These KBA are defined as knowledge embodied in intellectual assets, such as R&D and proprietary know how, intellectual property, workforce skills, world class supply networks and brands (Harris, 2008). These KBA have a significant impact on the SMEs innovation performance (Zahra and George, 2002; Harris, 2008). In other words, this study has examined the relationship between KBA (*i.e.,* R&D, networks, quality methods) and innovation output (product and process innovation, patent application and patent spending) by using a micro level data on Chilean SMEs.[1]

2.1. Research & Development (R&D)

From the perspective of input resources, one of the most common indicators used to measure firm innovation is R&D expenditure (Karlsson and Olsson, 1998). Consequently, innovative firms are strongly R&D oriented (Gatignon and Xuereb, 1997). Concerning R&D function, it performs two major functions: R&D generates new knowledge through product/process innovation and increases the firm absorptive capacity, and hence innovative performance (Cohen and Levinthal, 1989; Stamm and Wennberg, 2009). According to Cohen and Levinthal (1989), a firm must invest its own R&D in order to obtain benefits from output of its competitors. In support of Cohen and Levinthal's (1989) argument about the two faces of

[1] There are a large number of empirical studies investigating the relationship between proxies of innovation and productivity. However, this study is not considering the literature on the relationship between antecedents of innovation and productivity. This study only reviews literature that explicitly examines the key determinants of innovation performance.

R&D, Kinoshita's (2001) panel data analysis of Czech manufacturing firms found that the learning effect of R&D (absorptive capacity) is more important than the innovative effect of R&D in explaining the firms' performance. Similar evidence is provided by Kinoshita's (2001) empirical study which states that firms should engage in R&D for higher absorptive capacity and innovation performance.

Likewise, the study by Wang *et al.* (2014) on 279 Chinese firms investigated the impact of R&D strategies on firms' performance using Structural Equation Model (SEM). R&D novelty (technological newness in product/process innovation) and R&D openness (external technology acquisition) has a significant impact on the firms' innovation performance. On the one hand, a considerable internal R&D investment is required to generate radical product and process innovation. And on the other hand, greater technological acquisition from external sources (external R&D) positively contributes to the firms' performance (Wang *et al.* 2014). This study suggests that firms' can adopt balance R&D strategy related to the novelty and openness which may result in higher firms' performance. Moreover, incurring R&D cost allows firms' to enhance technology and minimizes the marginal cost of production (Peter *et al.* 2013). Further, Harris and Moffat (2012) study on UK firms identified that R&D not only support innovation but also increase the knowledge based asset through improving the absorptive capacity of the firms'. However, R&D is a risky adventure and it is not necessary that always R&D lead to successful innovation. Sometime for product and process innovation firms' do not require formal R&D and can develop outside the firm (Harris and Moffat, 2012; Jong and Vermeulen, 2006).

Additionally, Peter *et al.* (2013) investigated the German SMEs from manufacturing and services sector. Their findings suggest that R&D positively contribute to the firms' product and process innovation.[2] Further this product and process innovation will raise the productivity of SMEs in the long run. Mairesse and Mohnen (2005) examined the positive relationship between R&D and product/process innovation using Tobit regression analysis of 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. Additionally, a number of empirical studies (Adam, 1982; Harris and

[2] Product innovation is defined as new or significantly improved good/services and process innovation defined as new or significantly improved methods of production, logistics etc. For instance, the study of Podler *et al.* (2010) suggests that R&D has a strong effect on the product innovation. In other words, R&D is a measure of innovation input and product/process innovations are output.

Trainor, 1995) emphasized the role of R&D subsidies/grants to support innovation in SMEs. They argued that R&D grants from government agencies are more beneficial in increasing R&D spending and innovation output than R&D financing (through external sources), as it is difficult to obtain R&D finance due to its risky nature (*e.g.* R&D takes a long time to generate results). In other words, R&D grants/subsidies could alleviate underinvestment in firms' innovation activities. Meuleman and Maeseneire (2012) conducted a study on 1107 Belgian SMEs. They found that R&D subsidy has positive impact on the SMEs innovation quality and access to long term debt. This indicates that government intervention through R&D subsidies may reduce the SMEs financial constraint because investment in R&D below optimal level is very expensive for the firms. More specifically, SMEs require government help in approving new products, granting patents and awarding subsidies and grants.

To sum up, SMEs that are engaged in R&D would likely to have higher innovation output than non-R&D SMEs. However, SMEs financial constraint suggests that R&D subsidies/grants could alleviate their underinvestment in innovation activities. Two hypotheses have been drawn from the above theoretical evidences which are as follows:

H1: *A firms' engaged in R&D has a positive impact on the firms' product and process innovations and applies for patents.*
H2: *Public support to innovation activities (e.g. R&D subsidies/grants) has a positive impact on the firms' product and process innovation and applies for patents.*

2.2. Networks and Quality Methods

The lack of resources in SMEs is barrier to its innovation performance, but at the same time it is the main motive of SMEs to search beyond the organizational boundaries for required knowledge and technological ideas (Subrahmanya, 2012; Spithoven *et al.* 2013). Subrahmanya's (2012) study on Indian SMEs suggests that SMEs with external support have better technological competence in the form of a large number of innovated products. In other words, networks allow firms' to cope with rising demand for human and technological dependence on others and without network relations it is difficult for a firm's to coordinate its diversified resources with heterogeneous economic agents *i.e.,* competitors, customers, suppliers, public and private research institutions (Cantner *et al.* 2010; Gebreeyesus *et al.* 2013). Specifically, SMEs lack of resources and reluctant to invest on R&D and networks

may encourage small firms to improve their innovation performance through such linkages with other firms and research institutions (Jong and Vermeulen, 2006). Staveren and Knorringa (2007) defined social networks (social capital) in a broader way as "social relations matter" and examined their impact on the economy. Their study measured firm social networks through inter-and intra-firm relationships, clusters, value chains, business association and business systems. They argued that the economic impacts of social relations are to reduce the transaction cost, enabling collective action and improve learning through knowledge spillovers (Staveren and Knorringa, 2007). Similarly, Gebreeysus *et al.* (2013) conducted a study on 153 Ethiopian footwear micro enterprises. Their results revealed that firms with networks are more likely to engage in innovation activities (product/process innovation).

Firms can reduce their innovation cost and minimize the risk of innovation failure by using inter-firm networks and linkages with research organizations (Narula, 2004; Fukugama, 2006). In addition, Fukugama (2006) conducted a case study on Japanese small firms from cross industrial groups (*i.e.* manufacturing, services, wholesale, retail, finance and insurance) and analyse that the firm cooperative activities[3] leads to innovation. Fukugawa suggested that network relationship based on shared knowledge among members would increase the absorptive capacity at network level (Fukugama, 2006). Similarly, Gronum *et al.* (2012) conducted a longitudinal study on 1435 Australian SMEs and investigated the relationship between networking (*e.g.,* frequency of firm inter-intra interaction) and firms' performance. They found that firm networking has a positive impact on its productivity and innovation performance. This suggests that network provides SMEs with more access to external sources such as complementary skills, knowledge, capabilities which are important factors for higher firms' performance (Gronum *et al.* 2012). Further, Spithoven et al. (2013) investigated the open innovation practices in 967 Belgium SMEs. They found that SMEs linkages with research organizations (R&D cooperation) significantly improve the innovation performance (product innovation). Moreover, their findings suggested that SMEs rely heavily on external sources of information along with the internal ones because cooperation broadens SMEs technical competencies (skilled workers).

[3] These cooperative activities are sharing knowledge through joint product developments, R&D alliances, linkages to public research institutions.

In contrast, Chapman and Khawaldeh (2002) examined the link between total quality management (business improvement methods) and labour productivity for Jordanian manufacturing firms. They developed a conceptual framework which measured elements of total quality management: (i) employees participation; (ii) education and training; (iii) organisational communication; (iv) customer focus; (v) scientific approaches to decision making; (vi) scientific methods for quality control; (vii) organisational commitment to quality and continuous improvement; (viii) statistical methods for quality control and; viii) unity of purpose. Using multiple regression analysis by Chapman and Khawaldeh (2002) stated that the elements of business improvement methods were shown to have a positive impact on firm labour productivity for high TQM firms. In addition, Harris *et al.* (2012) discuss the effects of business improvement methods on innovation in SMEs. Business improvement methods (BIM) include the following processes (or elements) such as 'to focus customer needs', 'management involvement', 'continuous improvement', and 'employee involvement' (Harris *et al.* 2012). They suggest that business improvement methods improve the firm efficiency and innovativeness.[4]

Similarly, Hoang and Igel *et al.* (2010) and Koberg *et al.* (2012) emphasized the importance of total quality management practices (*e.g,* customer focus, employees' involvement, education and training) for higher firm innovation performance. Their study[5] suggested that TQM-practices large firms have higher quality implementation programs as compared to small firms due to their resource constraint. Concerning quality programs, the International Standard Organization (ISO) has certain criteria for quality management for use by small or large firms. The standard is based on several quality control principles such as customer focus, the motivation of leadership, process approaches and the involvement of people in the firm's continuous improvement programs. For example, Malik *et al.* (2010) assert that ISO-certified SMEs are higher performer than non ISO certified SMEs. This apparently indicates that quality improvement methods (customer focus, management commitment, employees'

[4] Harris et al. (2012) conducted a study on 606 SMEs from Republic of Ireland, Northern Ireland, and West of Scotland. They used multinomial logit model to investigate the relationship between business improvement methods (BIM) and firm innovation (*e.g.,* undertaking R&D). Further, Harris *et al.* (2012) classified firm responses into successful innovators (introduced a major product innovation in the last 3 years), unsuccessful innovators (engaged in innovation activities but had not introduced a major product innovation) and non-innovators (did not innovate or spend on innovation related capabilties).

[5] This study showed the relationship between implementing total quality management (TQM) and organisation characteristics (size, industry type, type of ownership, and degree of innovation). The structural equation modelling (SEM) was used to investigate the 204 Vietnamese firms; results showed that manufacturing and large firms had higher TQM abilities compared to firm from services sector.

involvement) have a positive impact on the firm's performance. In short, literature on network and quality methods derived the next hypotheses as follows;

H3: *SMEs networks with research institutions are more likely to introduce product and process innovation and apply for patents.*
H4: *Firms' with quality methods have positive association to the firms' product and process innovation and apply for patents.*

.*3. Methodology*

This section first explains why Chilean firms have been selected for empirical analysis as research context. Second, it discusses the data sources and firms' characteristics before informing about the operationlization of variables (factor analysis) and econometric models.

3.1. Chilean SMEs as Research Context

Chile is the first country in South America to have joined the OECD, in 2010. According to the World Bank, the country has the highest GDP per capita (approximately US$ 15000) in Latin America with lower inflation rate (3.2%) in the last 4 years. Chile's major exports are copper, sea products, minerals, chemicals and agriculture goods. The government's robust business-friendly policies welcomed the investment of foreign firms which resulted in a more competitive business environment. In Chile, more than 99% of all enterprises are SMEs and nearly 57% of the workforce is employed in the business sector. Of these 99%, 77% are micro enterprises, 19% are small and 3% are medium sized firms. Alternatively, Chilean SMEs are the major source of employment in the country. There are a number of public support programs to support firms' innovation activities. For instance, FONTEC (National Productivity & Technological Development Fund) and FONDEF (Science & Technology Development Fund) are specifically designed to encourage innovative business culture in the country. These two organizations provide subsidies (contribution up to 55% of total cost) in product/process innovation, R&D projects with universities and science & technology institutions. The main aim of such public support program is to improve SMEs innovation performance. Despite the public support programs, Chilean firms are facing many challenges to their innovation performance such as high cost of innovation, limited access to credit, low human capital and overall lack of innovative culture (Lussier and Halabi, 2008; Amoros *et al.* 2008).). In addition, there is a research gap in terms of analysis of Chilean SMEs innovation

performance. To fill that gap, this empirical study provides contribution to the existing knowledge.

3.2. Data Source

The data on Chilean firms has been obtained from the World Bank Enterprise Survey-2010. An enterprise survey is firm-level survey which is representative sample of a Chilean economy private sector. The survey covers a broad range of information related to the business environment such as innovation capacity, financial performance, infrastructure facilities and so forth. Usually Enterprise Survey carried out these micro level surveys in cooperation with business organizations and government agencies promoting job creation and economic growth, but confidentiality is strictly followed. Moreover, Enterprise Surveys used stratified random sampling methodology. In this method, all population units are grouped within homogenous groups and simple random samples are selected within each group.

The manufacturing and services sectors are main business sectors of interest. The data comprises 1033 manufacturing firms formally registered. Of the total, approximately 78% of firms are from the manufacturing sector (food, textile, machinery and equipment) and only 22% from the services sector (retail, wholesale, hotel and restaurants). The majority of these firms (88%) are local based with only 12% having foreign ownership. In addition, the information was mainly collected from four regions of the country (Santiago, Antofagasta, Los Lagos and Valparaiso) using a structured questionnaire. Firms were predominantly interviewed in Santiago (68%), 8% in Antofagasta, 10% in Los Lagos and nearly 14% in Valparaiso. The survey asked detailed questions from the owner-managers related to firm size, age, sales, exports and their innovation activities such as product/process innovation, R&D, patents and networks. The average age of a firm is approximately 32 years. However, this data has certain limitations related to measuring innovation activities. For example, the data has not provided any information related to the patent citation (measure of quality), R&D employees, nature & types of linkages with other firms, science & technology institutions and with universities.

3.3. Dependent Variable

A number of studies (*e.g.,* Hogedoorn and Cloodt, 2003; Katila, 2003; Holgersson, 2013; Ying, 2009) have used multiple indicators to measure the firms' innovation performance.

This empirical study has used four proxies of measuring the firms' innovation performance such as i) patent application[6], ii) patent spending[7], iii) product innovation and, iv) process innovation. Patent applied is a more appropriate indicator than patents granted because usually the time interval is long between patent applied and granted which results in underestimation of measuring innovation performance (Ying, 2009). Similarly, product and process innovation are innovation output (see Podler *et al.* 2010).

3.4. Independent Variables

The literature examples suggest that firms' with R&D, networks and quality standards are important innovation input variables. In addition, this paper has used exports as independent variable in the empirical analysis for the following reasons. First, in foreign markets, firms get access to the diversified knowledge, gain cross country income and acquire patents, which increase the likelihood of innovativeness of exporters (Bratti and Felice, 2012). Second, exporting firms broadens the international customer base, specifically when foreign markets are more competitive and innovative than the domestic ones (Lu and Beamish, 2006; Castellani, 2002). On the other hand, studies (*e.g.* Bratti and Felice, 2012; Anh *et al*. 2008; Harris and Li, 2009) examined the causal link between export and innovation performance using instrumental variable approach. However, this study does not focus on the causal link between export and innovation performance which is beyond the scope of this paper. Lastly, a number of studies (*e.g.* Harris and Trainor. 1995; Kim, 2000) stated that SMEs required greater R&D incentives (*e.g.* grants/subsidies) from government agencies to improve their firms' performance. This paper expects the positive relationship between public support for innovation and innovation output.

3.5. Descriptive Analysis

Table 1 provides information on the firms' characteristics. Of the 771 firms, approximately 43% firms are engaged in R&D. Similarly, a significant proportion (57.6%, 50%) of firms introduced product and process innovation in the last 3 years.[8] This suggests that firms that

[6] Firm apply or file for any patent, trademark, industrial design or copy right registration with its products and process innovation.

[7] Patent spending is defined as spending on purchases of licenses to use intellectual property such as patent, trademark, industrial design copy rights or specialized consultancy services.

[8] Of the total 446, 55% of firms introduced product innovation new to the market; and of the 237 firms, 61% of firms introduced process innovation new to the industry in the last 3 years. The rest of the firms did not answer the question. However, most of these firms are selling their main innovative products just locally (34%), 58% at national level and only 7% are selling to the international market. This indicates that Chilean firms' are not serving the highly innovative international markets.

are engaged in R&D are more likely to introduce innovation output. Size of the firm is measured by creating four dummy variables (size-1 to size-4) to analyze the innovation performance of micro, small, medium and large firms. It is observed that most of the firms (56%) are small size (11-100 employees) in our sample with a low percentage (nearly 14%) of large firms. In comparison, a low percentage (23%) of firms applied for patent registration in the last 3 years. Likewise, a low proportion of firms (31%) are spending on patent registration of their products and services (See Table 1). Further, these firms have a low level (nearly 14%) of public support (assuming FONTEC and FONDEF) related to their innovation activities and with weak networks with other firms and science & technology (S&T) institutions. Only 38% of firms are ISO (International Standard Organization) certified which means that firms are pursuing total quality standards.

Table 1: Firms characteristics (figures are in percentages)

Variables	N	Yes	No
Dependent Variables			
Patent Applied	768	22.92	77.08
Patent Spending	767	31.42	68.58
Product Innovation	775	57.68	42.32
Process Innovation	774	49.74	50.26
Independent Variables			
Firm Undertaking R&D	771	42.67	57.33
Size-1 (1-10) employees (Micro)	1033	13.94	86.06
Size-2 (11-100) employees (Small)	1033	55.95	44.04
Size-3 (101-250) employees (Medium)	1033	16.17	83.83
Size-4 >250 employees (Large)	1033	13.94	86.04
Public Support (Innovation)	775	13.81	86.19
ISO-Quality Standards	1028	38.42	61.58
Networks (Inter-firm, S&T)	770	24.03	75.97

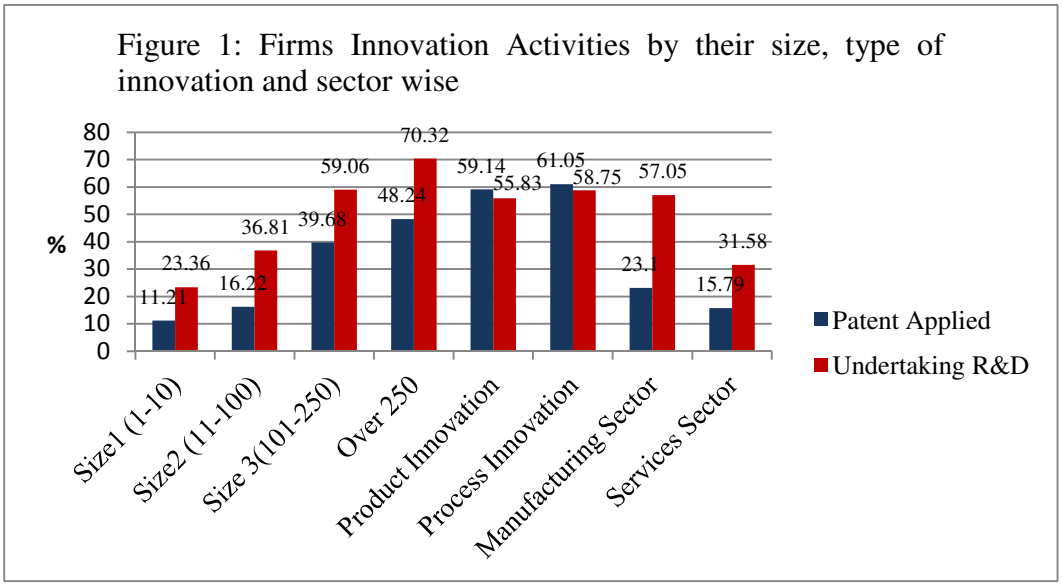
Source: Author own calculation

Table 2 presents the region wise innovation activities (R&D, Patent applied) in Chile. Of the total 771 R&D firms, R&D undertaking activities are higher in Santiago and Antofagasta as compared to Los Lagos and Valparaiso regions. Surprisingly, overall a low proportion of firms (less than 30%) have applied for patents in the last 3 years. This indicates that firms' across all four regions of Chile have low tendency towards patenting their products and processes.

Table 2: Innovation activities region wise (figures are presented row wise in percentages)

	R&D Undertaking				Patent(s) Applied			
Regions	n=771	Yes	No	Total	n=768	Yes	No	Total
Santiago	542	42.25	57.75	100	540	22.92	77.08	100
Antofagasta	50	42.00	58.00	100	50	12.00	88.00	100
Los Lagos	77	37.95	48.05	100	75	29.33	70.67	100
Valparaiso	102	38.24	61.76	100	102	23.53	76.47	100

Figure 1: shows the firms' innovation activities (R&D, Patents) distributed by their respective size, type of innovation and sector wise R&D and patent application. The figure clearly indicates that large firms (over 250 employees) are more engaged in R&D and applied for more patent registrations compared to other size bands (size1 to size 3). However, the product and process innovation shows almost similar trend for undertaking R&D and patent applications. This apparently suggests that firms with product and process innovation have significant association to patents and R&D.



Source: Author own calculation

In addition, in manufacturing sector the R&D proportion (57%) is higher than the services sector. While 23% manufacturing firms applied for patent compared to nearly 16% in the services sector.

4. Estimation Analysis

Table 3 provides information on the definitions of variables and their means and standard deviations. Firms' financial information (export sales, innovative product sales) has been

converted into single international currency (US$). The average exchange rate has been calculated *i.e., US$ 1 = 559.6126* (*Chilean Peso*) in the year 2009. Before estimation, correlation matrix is used to investigate the multi-collinearity problem (see Table 4). Overall, most of the correlation values are lower than 0.5. This indicates that multi-collinearity is not a problem.

Table 3: Definitions of variables and descriptive statistics

Variable Name	***n***	***Definition***	***Mean***	***Std. Dev.***
R&D undertaking	771	Dummy coded 1 if firm is engaged in R&D within enterprise, otherwise 0	0.4267	0.4949
Age ***(ln)***	1032	Year of firm beginning operation. ***log***(2010-Age)	3.2164	0.7222
Product Innovation	775	Dummy coded 1 if firm with new or significantly improved products/services over the last 3 years	0.5767	0.4943
Process Innovation	774	Dummy coded 1 if firm with new or significantly improved processes (production/supplying)	0.4974	0.5003
Networks	770	Dummy coded 1 if firm cooperate innovation activities with other firms or science and technology institutions.	0.2402	0.4275
ISO-Quality Standards	1028	Dummy coded 1 if firm with internationalized quality certification	0.3842	0.4866
Patent Applied	768	Dummy coded 1 if firm applied for IPRs related to product/process innovations in the past 3 years	0.2291	0.4205
Export Intensity ***(ln)***	1031	***log***(export sales in US$) divided by overall sales in fiscal year (2009)	0.0833	0.2037
Patent Spending	767	Dummy coded if firm spend on IPRs, otherwise 0	0.3142	0.4645
Public Support -Innovation	775	Dummy coded 1 if firm received public support related to innovation	0.1380	0.3451
Micro (1-10) employees	1033	Dummy coded if firm employees are between 1-10	0.1393	0.3465
Small (11-100) employees	1033	Dummy coded 1 if firm employees are between 11-100	0.5767	0.4943
Medium (101-250) employees	1033	Dummy coded 1 if firm employees are between 101-250	0.1616	0.3683
Large >250 employees	1033	Dummy coded 1 if firm employees are over 250	0.1393	0.3465

Source: Author own calculations

Table 4: Correlation matrix of all variables

		1	2	3	4	5	6	7	8	9	10	11	12
1	R&D	1											
2	Age ***(ln)***	0.0305	1										
3	Micro	-0.1528	0.0160	1									
4	Small	-0.1414	-0.1816	*-0.4966*	1								
5	Medium	0.1639	0.0628	-0.1790	*-0.5316*	1							
6	Product Innovation	0.3224	0.0236	-0.1176	-0.0394	0.0625	1						
7	Process Innovation	0.3258	-0.0298	-0.0849	-0.0523	0.0625	0.1081	1					
8	Networks	0.2574	0.0535	-0.1316	-0.0937	0.1020	0.1820	0.1795	1				
9	ISO-Quality	0.1750	0.0592	-0.1186	-0.2317	0.2000	0.2727	0.0844	0.0996	1			
10	Patent Applied	0.2574	0.1251	-0.1245	-0.2054	0.1946	0.2432	0.2491	0.1920	0.2014	1		
11	Exports Int. ***(ln)***	0.2210	0.0778	-0.0874	-0.2765	0.1524	0.3205	-0.0116	0.0604	0.1161	0.3358	1	
12	Patent Spending	0.0276	0.026	-0.0209	0.0856	0.0860	0.0122	0.0014	0.080	0.0489	0.1578	0.0053	1

N=695

4.1. Econometric Models

(a). *Bivariate Probit Models*

The bivariate probit model is used for estimation analysis. 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. 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. Further, the correlation $value\ i.e.,\ \rho = 0.4021$ between two dependent discrete variables (patent applied and patent spending) is statistically significant . This indicates that a separate probit model is not a good option for the estimation (Neito and Santamaria, 2010). Bivariate models provide two binary results. Mathematically the two outcomes are determined by the two unobserved latent variables (Cameron and Trivedi, 2009),

$$y_1^* = x_1\beta_1 + e_1 \qquad \text{(a)}$$

$$y_2^* = x_1\beta_2 + e_2 \qquad \text{(b)}$$

Both errors (e_1, e_2) are jointly normally distributed with mean of 0 and variance of 1. X_1 is a vector of explanatory variables common to both outcomes with estimators, β. It is expected to observe the two binary outcomes;

$$y_1 = \begin{cases} 1 & if \quad y_1^*>0 \\ 0 & if \quad y_1^*\leq 0 \end{cases} \qquad \text{and} \qquad y_2 = \begin{cases} 1 & if \quad y_2^*>0 \\ 0 & if \quad y_2^*\leq 0 \end{cases}$$

Table 5 reports the results of bivariate probit model. Two indicators of firms' innovation performance (patent application and patent spending) are used in the bivariate analysis. Concerning the firms' size, three size dummy variables are named as micro, small and medium enterprises. This strategy allows us to investigate the impact of SMEs on innovation performance more appropriately. Further, an additional dummy variable is introduced for sector *i.e.,* 1= manufacturing sector, 0= services for sector. A result for manufacturing sector is related to the services sector, which is our reference category. Further, the models used robust standard errors method to eliminate the heteroskedasticity.

Micro and small sized firms showed negative association to patent application (see Table 5). This suggests that SMEs has the lower probability to apply for patents. This outcome implies

that Chilean SMEs have found patents to be expensive in terms of money, time and efforts and their incremental innovation satisfy the customer demands and it is not worth patenting. Alternatively, this finding is in line with Schumpeterian hypothesis which suggest that large firms are more innovative than small firms. Previous studies of Ying (2009); Belitz and Legpas (2014) and Rangone (1999) investigated that SMEs are less innovative due to their resource constraint (financial and non-financial). Similarly, the negative relationship is stronger between micro size firms and patent spending. This indicates that Chilean SMEs are less likely to spend on patenting their products and services. There are two possible outcomes of this relationship; first, perhaps patent spending is not worth for SMEs because of incremental innovation (largely confined to changing product design/shape), second due to financial barriers Chilean SMEs are reluctant to apply or spend on patenting their products and services. In addition, the positive coefficient of age with patent applied indicates that older firms are more experience and competitive and likely to have higher innovation performance than younger firms.

The positive association between undertaking R&D and patent applied shows that 1% increase in R&D would likely to increase the patent application by 40%. Similarly, this relationship is stronger between undertaking R&D and patent spending (see Table 5). Moreover, undertaking R&D positively influence the firm's product and process innovation (see Table 6). Overall, this outcome has supported the first hypothesis and confirms the previous findings of Peter et al. (2013); Stamm and Wennberg (2009); Peter et al. (2013) and Mairesse and Mohnen (2005). This suggests that firms' undertaking R&D significantly improves the firms' innovation output in terms of taking out patent applications and/or product/process innovations. Networks with other firms' and research institutions presented positive impact on the patent application. The coefficient value of network tells that collaboration with other firms and research institutions increases the probability of SMEs patent application by 22%. This result supported the initial hypothesis and the outcome is consistent with the findings of John and Vermeulen (2006); Staveren and Knorringa (2007). However, there is no relationship is found between networks and patent spending. Similarly, firms with ISO quality standards are more likely to spend on patent registration. This suggests that firms with quality programs (e.g., customers focus, employees' participation and scientific methods for decision making) would be more likely to have higher innovation performance.

The coefficient value of exports which is 0.5071 shows that 1% increase in exports the probability of patent application is rise by 50%. This positive relationship shows that exports significantly improve the firms' innovation performance because exports provide firms more innovative opportunities to compete in the international markets. Any public support (tax incentive or subsidies) related to firm's innovation activities have positive and significant impact on the firm's patent application (See Table 5). Lastly, the sector dummy variable (*i.e.,* services sector) showed positive association to firm's patent spending. This apparently indicates that firms in the services sector are more likely to be naturally flexible and spends on patent registration. The value of *rho* is estimated at 0.41. It is positive signed and statistically significant different from zero in a *Wald* test, indicating that the two outcomes are related and some unobserved factors (*e.g.,* university-linkages, external R&D, patent citation) are positively related to both dependent variables.

Table 5: Bivariate probit regression analysis (using Maximum likelihood method)

	Patent Applied		***Patent Spending***	
Independent variables	Coefficients	$z-value$	Coefficients	$z-value$
Micro (1-10)	-0.8954***	-3.48	-1.1124***	-4.40
	(0.2575)		(0.2528)	
Small (11-100)	-0.6831***	-3.55	-0.5978***	-3.23
	(0.1921)		(0.1852)	
Medium (101-250)	-0.1215	-0.62	-0.2708	-1.40
	(0.1969)		(0.1941)	
Log Age	0.1714*	1.93	-0.0005	-0.01
	(0.0886)		(0.0753)	
R&D Undertaking	0.4060***	3.44	0.5905***	5.21
	(0.1180)		(0.1132)	
Networks	0.2299*	1.70	0.1344	1.06
	(0.1349)		(0.1267)	
ISO-Quality Standards	0.0488	0.36	0.2193*	1.78
	(0.1349)		(0.1231)	
Log Export Intensity (US$)	0.5071**	2.24	0.2889	1.09
	(0.2255)		(0.2647)	
Public Support (Innovation)	0.3295**	2.08	-0.1396	-0.91
	(0.1585)		(0.1535)	
Sector (dummy)	0.1449	0.40	1.1604**	2.03
	(0.3500)		(0.5727)	
Constant	-1.2923**	-2.54	-1.5032**	-2.32
	(0.5078)		(0.6467)	
Rho	0.4126***	6.31	-	-
	(0.0657)			
Wald Test rho = 0 Chi2(1) = 31.2019 p-value>Chi2 = 0.000				

*N=696. *** p<0.01, **p<0.05, *<0.10. Robust standard errors are reported in parentheses.*

Table 6 provide information on the determinants (*e.g.,* R&D, networks and quality) of product and process innovation. The coefficient of micro firms' shows negative association to product innovation. This outcome is in line with the previous finding in Table 5. This result indicates that the probability of micro firms is lower to introduce product innovation. This finding suggests that micro firms have low innovation activities. However, the parameters of other size groups present no statistical association with product and process innovations. Overall, the negatively signed coefficients of firms' size (SMEs) imply that Chilean SMEs are less innovative due to resource constraint.

Additionally, SMEs external relationship with other firms and research institutions has a significant impact on the firms' innovation performance. This result has accepted the prior expectation and supported the finding of Subrahmanya (2012) which states that SMEs external linkages has positive impact on the firms' innovation performance. Further, the coefficient of exports which shows that 1% increase in the exports the probability of product innovation is rise by 69% which is strong evidence for the positive relationship between exports and product innovation. This outcome suggests that SMEs penetration in international markets significantly boost their innovation performance.

Table 6: Bivariate probit regression analysis

	Product Innovation		***Process Innovation***	
Independent Variables	Coefficients	$z-vlaue$	Coefficients	$z-value$
Micro (1-10)	-0.5280**	-2.30	-0.2447	-1.08
	(0.2296)		(0.2275)	
Small (11-100)	-0.3044	-1.58	-0.1867	-1.01
	(0.1931)		(0.1842)	
Medium (101-250)	-0.2677	-1.28	-0.1332	-0.66
	(0.2092)		(0.2011)	
Log Age	0.0217	0.31	-0.0993	-1.38
	(0.0710)		(0.0721)	
R&D Undertaking	0.7390***	6.67	0.7814***	7.19
	(0.1107)		(0.1086)	
Networks (S&T)	0.3735***	2.83	0.2129*	1.69
	(0.1319)		(0.1269)	
ISO-Quality Standards	0.0756	0.62	0.1716	1.49
	(0.1223)		(0.1148)	
Log Export Intensity (US$)	0.6907***	2.72	0.3802*	1.80
	(0.2537)		(0.2103)	
Public Support (Innovation)	0.2326	1.42	0.0388	0.26
	(0.1637)		(0.1521)	
Sector (dummy)	0.1831	0.59	-0.0080	-0.03
	(0.3095)		(0.3157)	
Constant	-0.9931*	1.82	0.0972	0.22
	(0.5441)		(0.4451)	
Rho	0.3361***	4.86	-	-
	(0.0691)			
Wald Test rho = 0	*Chi2(1) = 20.1406*	*p-value>Chi2 = 0.000*		

*N=696. *** p<0.01, **p<0.05, * p<0.10. Robust standard errors are reported in parentheses.*

5. Conclusion

This paper had used bivariate probit models to analyze the innovation performance of Chilean SMEs. This study addressed the research question *i.e.,* why SMEs are less innovative? Specifically, SMEs investment in knowledge based assets may accelerate their innovation output. The negative association between firms' size categories and patent application/spending and product innovation suggested that Chilean SMEs had resource constraint. The cost of innovation in terms of patents and product innovation significantly reduced their innovation performance. On the other hand, knowledge based resources such as R&D, networks and quality methods showed positive association to firms' innovation performance. These results suggested that SMEs require to increasing level of investment in knowledge based assets (R&D, networks and quality methods). However, figure 1 showed that large firms were more innovative than any other size bands.

Concerning the contribution of this paper, to the best of my knowledge hardly any micro level study is available on the analysis of Chilean SMEs innovation performance. This empirical study provides contribution to the existing knowledge. Moreover, there is scarcity of empirical studies which investigates the innovation performance using multiple dependent variables (patent application, patent spending and product/process innovation). This study would fill that gap within the country specific characteristics.

In spite of the positive relationship between networks and innovation performance, Chilean firms' still have weak linkages with other firms and research institutions. They require strong linkages with research universities for joint R&D projects. Policy makers shall encourage firms' network relations. Similarly, it is investigated that only a few percent of firms are receiving public support for innovation activities. This implies that policy makers shall revisit the innovation policy to ensure that firms can maximize benefits from such public support programs. In other words, complicated and bureaucratic procedures for applying to such programs must be minimized without discrimination of firm size. Lastly, this study has certain limitations such as non availability of information on patent citations, type of linkages and specifically what type of innovation support programs firms have received. Having information on these variables may provide more appropriate ways to investigate their innovation performance. This study has not addressed the causality between exporting and innovation. It could be analysed in the future.

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