Determinants of innovation in SMEs:
An empirical analysis of South Korea

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Abstract: This paper examines the effects of four determinants of innovation (profit, export, foreign-ownership and inter-firm cooperation) on small and medium-sized firms (SMEs) in South Korea. It also discusses the different implications which these determinants have on innovation in low-tech and high-tech industries. Data for this paper are collected from the Survey of Business Activities in South Korea for the period of 2014 and 2015. A negative binomial model is applied to deal with the over-dispersed dependent variable. In the full sample, export, foreign-ownership and inter-firm cooperation had significant positive influences on innovation output, whereas profit had no significant influence in the full sample. In the sample of high-tech industries, export was the only significant factor for innovation output, whereas export and foreign-ownership had positive influences on innovation output in low-tech industries. Limitations and the further research areas are discussed.
Key words: Innovation, SMEs, South Korea, patent, negative binomial model

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1. Introduction

In today's competitive and globalised environment, the world needs a new driver of growth to create a more inclusive and sustainable path. Innovation has been considered one of the critical solutions for long-term economic growth (Schumpeter, 1943). According to the Organisation for Economic Co-operation and Development (2010), at present time, innovation and setting up new business ventures in existing small and medium-sized enterprises (SMEs) is vital to achieve innovation progress. However, backing SMEs and entrepreneurship is not sufficiently implanted in innovation policies, and the preconditions for efficient policies are still not fully formed (OECD, 2010).

Innovation policy has targeted at investing in research and development (R&D), however, now a broader view is required for where innovation takes place and what conditions needed to support it (OECD, 2008). The main purpose of this study is to investigate which determinants are significant to achieve successful innovation outcomes for Korean manufacturing SMEs. Considering the available dataset from the Survey of Business Activities in South Korea[1], the determinants in this analysis are narrowed down to the following four: profit, export, foreign ownership and inter-firm cooperation. The negative binomial model is conducted for the full sample and the sub-samples of high-tech and low-tech industries.

This paper is structured as follows. Section 1 introduces the motivation and theoretical framework. Section 2 explores the literature related to the determinants of product innovation in SMEs and develops testable hypotheses. Section 3 explains the data and the empirical strategy used. Section 4 provides the results from the negative binomial analysis. Discussion and further areas of research will be covered in Section 5. Finally, Section 6 concludes this paper.

1.1. Motivation

Innovation has been central to South Korea's efforts in their pursuit of catching up with the developed OECD economies (OECD, 2008). As a result of these efforts, South Korea has the highest R&D intensity in the world with GERD (gross expenditure on R&D) at 4.29 percent of GDP in 2014 (OECD, 2016a). Nonetheless, South Korea faces several challenges: "slowing growth, rising inequality and unemployment, a rapidly ageing society and emerging

[1] Survey of Business Activities is researched by Korea Statistics (KOSTAT) which is an official national statistical organisation in South Korea.

environmental problems (OECD, 2016a)". These challenges stem from South Korea's economic structure.

South Korea has a clear dual economy (OECD, 2016b), with this economic success mostly achieved by manufacturers, namely giant enterprises that consumed labour, fuel, and materials as well as produced products such as steel, ships, buildings, cars, TVs, and mobile phones. These giant enterprises have become known as *chaebol*.[2] With the success of *chaebol*, the South Korean economy has also enjoyed economic growth. However, the gaps between manufacturing and services, income gaps between employees from *chaebol* companies and SMEs and regular and non-regular workers have been increasing over time (OECD, 2016b). This labour market dualism has led to high wage inequality and a relative poverty rate.

According to the National Statistical Office (as cited in Ministry of SMEs and Startups (MSS), 2014)[3], South Korean SMEs comprise 99.9 percent of all South Korean firms and provide 87.9 percent of employment in the whole economy. Despite the importance of SMEs for their job creation power, they fail to create long-term and high-paying jobs. Instead, they generally offer irregular and low-paying jobs because of specific weakness in South Korean SMEs, such as their inability to access similar resources as *chaebol*. For example, aside from financial resources, South Korean SMEs have a difficulty in attracting young or high-skilled workers as they want to work for high-paid giant conglomerates. Therefore, the South Korean government has been making efforts on solving a shortage in the high-skilled workers in SMEs. One of the efforts is providing the high-skilled workers to SMEs for three years by exempting obligatory army service at the army camp if a graduated Master's student applies for this system and gets accepted by the companies. Another rising issue in SMEs can be seen in the effects *chaebol's* far reaching powers can have on the ability of SMEs to get their new ideas developed, in spite of governmental efforts to foster SMEs. For instance, a survey by Small and Medium Business Administration (SMBA) in 2010 found that of 27,532 manufacturing SMEs surveyed, 6.2 percent had experienced pressure from giant conglomerates to provide SMEs' core technology. In particular, young and high-technological firms (1-10 years) experienced more of these cases compared to their counterparts.

[2] *Chaebols* are generally conglomerates of affiliated companies such as Hyundai, LG and Samsung, which are characterized by family-run management.

[3] Status of Korean SMEs - Korean SMEs - Ministry of SMEs and Startups (2014). Retrieved August 13, 2017, from http://www.smba.go.kr/site/eng/02/10202000000002016111504.jsp

In order to fully understand the role of SMEs in South Korea it is necessary to provide a brief explanation about the changes in South Korean SMEs after the Korean War (1950 – 1953). In the 1960s and 1970s, the government policy for SMEs was to support the development of SMEs via five-year economic development plans, which were concentrated on encouraging the heavy and chemical industries. In 1980s and 1990s, many SMEs became key suppliers of different parts and components in the emerging automobile and electronics industries. This meant SMEs were involved in labour-intensive light industry. In the 2000s, many policies and initiatives for SMEs brought out a surge in growth of venture businesses. Then, in the 2010s, a win-win growth strategy between large companies and SMEs was pursued by promoting different business-friendly policies (Sung et al., 2016).

In recent years the South Korean government has been making public efforts to reform *chaebols*, however, these tries have met with varying degrees of success. Accordingly, the government by the President Moon Jae-in (2017 – 2022) prioritises to realise chaebol reform as well as promote SMEs. For example, formerly called Small and Medium Business Administration (SMBA) became Ministry of SMEs and Startups (MSS) as of July 26, 2017 to handle increasing gap between SMEs and chaebols. All things considered, understanding the determinants for the successful performance of SMEs is important as these enterprises are crucial for both developed and developing countries (Radas & Božić, 2009). As the OECD (2016b) pointed out, South Korea needs to enhance the capability of low-productivity services and SMEs. Innovation will play an important role to achieve higher efficiency of services and SMEs. By doing so, innovation by SMEs can attribute to long-term economic growth and can be a solution to overcome heavy dependency on giant conglomerates.

1.2. Theoretical framework and research questions

Schumpeter's hypothesis in *Capitalism, Socialism and Democracy* (1943) – innovation and the firm size are positively related – triggered a debate on innovation of firms based on the firm size. By the early 1940s, Schumpeter (1943) had assumed the role of large firms as a driver of economic growth by accumulating knowledge in particular technological areas and markets (as cited in Ughetto, 2008). In other words, it is believed from the Schumpeterian hypothesis that larger firms are more innovative than smaller firms. However, this traditional understanding of innovation has been challenged by a new point of view. Some researchers have suggested that small firms in the particular industries are likely to be more innovative than large firms.

In her book, *The theory of the growth of the firm,* Penrose (1995) suggests a resource-based view and explains the different position of small and large firms. Penrose's study find that large and small firms have different resources, and their internal and external environments affect their production ability (as cited in Gupta et al., 2013). This resource-based view implies that there exists differences originated from inherent resources of small and large firms. And Baumol (2004) also explains that new start-ups and SMEs perform a different role in innovation compared to large firms. He explains the different roles – but complementary relationship – in innovation process between small and large firms. Whereas the major breakthroughs that are crucial for growth have come from small or new enterprises, the incremental contributions that increase capacity have been the domain of large firms. Baumol (2004) insists that this is because new firms and SMEs often work out of mainstream without strong ties to existing products and technologies. On the other hand, large firms are constrained by the need to incrementally improve their existing products and processes, even though they spend relatively more on R&D (Baumol, 2004). Accordingly, small organisations are considered to be more innovative because they are more flexible, to have better ability to adapt and improve, and to show less difficulty in taking and performing the change (Damanpour, 1996).

In their seminar study, Acs and Audretsch (1987) state that the focal point of the Schumpeterian debate should be shifted from the relationship between firm size and innovation to which determinants have relative innovative advantages for small and large firms. Policies on innovation or SMEs need to differentiate distinctly between large and small firms, considering the different characteristics how they innovate. Thus, this paper empirically tests the determinants of innovation in the context of South Korean small and medium-sized enterprises (SMEs) by investigating the following research questions:

"To what extent do the determinants (profit, export, foreign-ownership and inter-firm cooperation*) increase innovation for South Korean manufacturing SMEs"*

Furthermore, of particular interest is:

"To what extent do these determinants differ between high-technology and low-technology manufacturing industries?"

1.3. Contributions to existing literature

This study has a few contributions to the literature on the determinants of SMEs' innovation in the context of South Korea.

First, it empirically examines the determinants of SMEs' innovation in an integrated manner. Despite a number of studies concerning the determinants of innovation, research works that include all the relevant determinants in an integrated manner remain rather limited. According to Damanpour (1996), innovation is determined by a number of factors, so innovation theories containing only two or three variables may have limited explanatory power. Thus, studying multiple factors will help to understand the innovation output better.

Second, this is one of the first studies on determinants of South Korean SMEs innovation with the latest data. This paper focuses on the case of South Korean manufacturing SMEs. Traditionally, analysis in the context of South Korea has focused on the large manufacturing firms such as Samsung, Hyundai and LG given the importance of their role in industrialisation of South Korea However, as noted by Ministry of SMEs and Startups (2014), South Korean SMEs make up of 99.9 percent of all South Korean firms and 87.9 percent of employment.[4] Therefore, there SMEs should not be ignored for the efficient innovation policies. In addition to the full sample, this paper investigates the sub-samples of the high-tech and low-tech firms to see whether there exist differences in determinants of innovation between these sub-samples.

Third, this paper uses an empirical strategy which would be suitable for treating patent data. If the dependent variable, measured by patent counts, is over-dispersed, the negative binomial model can be an appropriate model to deal with over-dispersion in count data (Hausman et al., 1984; Lawless, 1987).

[4] Status of Korean SMEs - Korean SMEs - Ministry of SMEs and Startups (2014). Retrieved August 13, 2017, from http://www.smba.go.kr/site/eng/02/10202000000002016111504.jsp

2. Literature review and hypotheses development

When asked what innovation means, people tend to give vague answers. This is because the term innovation has been used so widely and dubiously. Thus, one of the problems in performing innovation is diversity in how people perceive the term, which is often mixed up with invention (Mohr, 1969). For that reason, it is worthy to clarify what innovation means. Schumpeter is one of the first scholars who emphasised the importance of innovation and knowledge for long-term growth (Ughetto, 2008). Innovation is defined by Schumpeter in "Theorie der Wirtschaftlichen Entwicklung" (1912) as meaning (as cited by European Commission, 2013)[5]: a) "the introduction of new good", b) "the introduction of an improved or better method of production", c) "the opening of a new market that is a market" d) "the conquest of a new source of supply of raw materials or half-manufactured goods", e) "the carrying out of the better organization of any industry".

Oslo Manual (OECD, 2005) provides the definition of innovation in line with Schumpeter's: "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations." Four types of innovation including both technological and non-technological forms are demonstrated in *Oslo Manual* (OECD, 2005). Technological innovations involve product and process innovation, whereas non-technological innovations embrace changes in business practice, business re-engineering and marketing system (OECD, 2005). In this paper, product innovation will be studied.

2.1 Measurement of innovation output

Since the 1980s scholars have shown growing attention to measurement of the innovation in firms. However, there is no consensus for innovation measurement. The first edition of *Oslo Manual* in 1991 has considerably affected the development of the innovation measurement by creating worldwide guidelines in innovation survey and content (Bloch, 2007). And the newly published edition of the *Oslo Manual* (OECD, 2005) broadened the definition of innovation in order to include marketing and organisational innovations. This adjustment enabled to understand innovation in less R&D intensive industries as well.

[5] The Strategy Design. (2013). Retrieved August 01, 2017, from http://enrd.ec.europa.eu/enrd-static/leader/leader/leader-tool-kit/the-strategy-design-and-implementation/the-strategy-design/en/what-is-innovation_en.html

For empirical research, there are mainly two measurement for innovation outputs. Previous literature has focused on R&D as an input measure to the innovation process and patents as both an input and output measures, along with qualitative or subjective measures of innovation (Rogers, 2004). However, some scholars point out the drawback of these measurements. Instead, they suggest using questions from a survey which asks whether new products, services or processes have been introduced over the last year (Keizer,et al., 2002; Bhattacharya & Bloch, 2004; Rogers, 2004; De Jong & Vermeulen, 2007; Honget al., 2016). In terms of technological changes, which is a commonly used definition of innovation, firms are asked to state whether they have achieved any innovations in a particular time (Roper, 1997). Then, this answers enable to estimate the percentage of innovating firms. Yet, Roper (1997) suggests potential problems of this approach. First, the results give little evidence of the commercial or technological significance of the product change for the innovating firms. Second, for small firms where much product innovation is likely to be incremental, the standard approach will underestimate the level of innovative activity.

Although using patents as a proxy of innovation is not a perfect measurement, empirical evidence shows that patents are reasonably appropriate measure of innovative activity (Acs & Audretsch, 1989; Porter & Stern, 2000; Acs et al., 2002; Czarnitzki et al., 2007; Ghazal & Zulkhibri, 2015; Czarnitzki & Delanote, 2015). Griliches (1990) concludes in his paper that patents seem to be a good indicator of differences in inventive activities among firms. Another view stated by Porter and Stern (2000) is that they do not assume patents data to be an optimal measure of innovative outputs, but they consider it to be a helpful index of general innovative activity. Overall, previous empirical studies support the application of patent counts in analysis examining technological change.

2.2 Determinants of SMEs' innovation and comparison of the determinants

So, what are the determinants of innovation in SMEs? There is an affluent literature on the determinants of product innovation in small and medium-sized enterprises (SMEs). In this literature review, we look through the empirical studies which apply a multiple number of variables as determinants of product innovation. Among previous literature on the determinants of product innovation, particularly in terms of smaller firms, some works make comparisons across different industries, manufacturing versus non-manufacturing industries, innovative versus non-innovative industries, high-tech versus low-tech industries (see Table 1).

The important work by Acs and Audretsch (1988), *Innovation in Large and Small Firms: An Empirical Analysis*, suggest that the R&D, skilled labour, and the degree to which large firms comprise the industry positively affect the total number of innovations. Also, the findings from their paper indicate that the determinants of innovation differ between large and small firms. This ignited the further investigation in the determinants of innovation in small firms.

De Jong and Vermeulen (2006) use the data from 'SME Policy Panel' in the Netherlands and make comparison across seven industries (manufacturing, construction, wholesale and transport, retail services, hotel and catering services, knowledge-intensive services and financial services). They find that the determinants of product innovation in small firms differ across industries. In addition, since large variation exist across the different service sectors in their sample, De Jong and Vermeulen (2006) suggest that it seems to be hard to treat the service industry the same as studying the determinants of product innovation. Therefore, this paper will investigate product innovation focusing on manufacturing firms.

2.3. Selecting determinants and hypotheses development

There is no consensus on a definite set of determinants for innovation. Considering the vast amount of variables (see Table 1) and the available dataset, the determinants in this analysis will be narrowed down to the following four: profit, export, foreign ownership and inter-firm cooperation.

2.3.1. Profit and innovation

Innovation is one of the important strategies of business, so high profit of the company will be invested for more innovative activities and outputs. In particular, internal funding seems to play a more important role in innovation for smaller firms compared to larger counterparts (Love & Roper, 2015). According to Ughetto (2008), large firms are less constrained for external finance, whereas small firms have a difficulty in accessing external finance for innovation. Audretsch (1995) finds empirically a positive effect of profitability on innovative activity only in high-tech industries. Himmelberg and Petersen (1994) also find that internal finance is an influential factor for R&D investment in the context of the small firms in high-tech industries. Overall, it is suggested that internal funding is more important for innovation in smaller firms than for larger counterparts, so this leads to the following hypothesis:

Hypothesis 1: The profits of firms have a positive effect on the innovation outputs of SMEs.

Table 1. Previous empirical studies on determinants of SMEs innovation

Source: Adapted from "Determinants of Product Innovation in Small Firms", by De Jong and Vermeulen (2007)

Author(s)	Innovation determinants and control variables	Sample	Methodology	Comparison
Acs and Audretsch (1987; 1988)	R&D expenditure, capital intensity, employee-union membership, four-firm concentration ratio, advertising expenditures, skilled labour, large-firm industry employment, value-of-shipments	247 manufacturing firms	OLS regression	Large vs small firms and highly innovative vs innovative industries
Kim et al. (1993)	Environment (dynamism, complexity), strategy (scanning, internal control, R&D intensity, external technology linkages), structure (formalization, centralization, professionalization, administrative intensity)	49 small manufacturing firms	Multiple discriminant analysis	Innovative vs non-innovative firms
Bhattacharya and Bloch (2004)	Size, profit, growth, R&D intensity, four-firm concentration ratio, export and import	1213 manufacturing SMEs	Probit and Tobit regression	Low tech vs high tech
Rogers (2004)	Employment, age, profit, margin, training intensity, management training, foreign-ownership, employee union-membership, business comparison, networking, export, R&D activity, patent intensity in industry, market share, four-firm concentration ratio	4314 firms	Probit regression	Manufacturing vs non-manufacturing
De Jong and Vermeulen (2007)	Managerial focus, documented innovation plans, use of external networks, market research, inter-firm cooperation, involvement of frontline employees, training and education programs, age, size	1250 small firms	Analysis of covariance and logistic regression	A comparison across 7 industries

2.3.2. Export and innovation

Internationalisation is considered an important means of enhancing SMEs' long-term growth and survival. Considering the lower business risk and resource responsibility contrary to joint ventures and foreign direct investment, SMEs generally enter foreign markets through exporting (Cerrato & Piva, 2012). A positive relationship between exporting and innovation activity in SMEs is found in empirical research. Love and Ganotakis (2013) find the positive effect of exporting on high-tech SMEs' innovation based in U.K. They suggest that consistent exposure to export markets encourages firms to get the better of innovation obstacles. After studying Australian SMEs, Bhattacharya and Bloch (2002) find that openness through import or export stimulate innovation, possibly as a chance of entering foreign markets or competing effectively with imports at home. Also, Golovko and Valentini (2011) suggest that export and innovation are complementary strategies for SMEs' growth. They insist that innovation and export positively boost each other in a dynamic virtuous circle.

Economic success of South Korea after the Korean War (1950 – 1953) reflects the government's strategy to stimulate the development of low-cost manufacturing exports. Since then, the exporting products have changed, still exporting has been an important strategy for South Korean firms (Westphal, 1978). Therefore, South Korean firms are expected to profit more when they export their goods and services rather than only focusing on domestic market. So, this leads to the following hypothesis:

Hypothesis 2: Exporting activities of firms have a positive effect on the innovation outputs of SMEs.

2.3.3. Foreign ownership and innovation

Foreign ownership can be financial resources or access to knowledge and technology for SMEs. Love et al. (2009) find that externally-owned enterprises generally perform better than domestically-owned counterparts, even if this is not the case all the time. Falk (2008) empirically shows that foreign-owned firms are more innovative in terms of share of new products or market novelties for the Eastern European states, while he finds that foreign-ownership is not an important determinant of innovation output for the group of Western European countries[6]. After examining Spanish firms, Guadalupe et al. (2010) show that foreign

[6] Falk (2008) states that this result should be treated carefully since the number of Western European countries included in the study is quite limited.

firms pick up the best firms within industries, or invest more in various innovation activities after acquisition.

Hobday et al. (2004) find that formerly South Korean firms were rather closed to foreign direct investment and considerably depended on locally-owned firms within South Korea. However, Erdal and Göçer (2015) state that foreign direct investment (FDI)[7] inflows have markedly influenced high economic growth accomplished by South Korea, China, India, Malaysia and Singapore. Ghazal and Zulkhibri (2015) argue that research on FDI in developed countries generally shows a positive relationship between FDI and innovation in the host economy (Ghazal & Zulkhibri, 2015). So, this leads to the following hypothesis:

Hypothesis 3: Foreign-ownership of firms has a positive effect on the innovation outputs of SMEs.

2.3.4. Inter-firm cooperation and innovation

Innovation cannot happen solely through an internal process. Firms should be informed about customers, outer ideas and economic trends (Rogers, 2004). Edwards et al. (2005) argue that knowledge of innovation in SMEs can be enhanced by examining the intra- and inter-organisational firm relationship. SMEs seem to rely more heavily on external knowledge networking as an input of innovation compared to large firms (Rogers, 2004). With the help of networking, firms can share resources with other organisations and utilise resources possessed by others (Srholec, 2009). In particular, science-intensive sectors need resources for innovation process such as scientific knowledge, state-of-the-art technology and equipment which are scattered among organisations (Kang & Park, 2012). Accordingly, as stated by Edwards et al. (2005), it has been viewed as an important factor for SMEs innovation that SMEs associate for other organisations for technological development in today's knowledge-based economy. However, some scholars suggest that alliances can also create challenges for SMEs. For instance, after analysing a Canadian biotech start-up, Baum et al. (2000) argue that companies working with different-type partners seem to be better off rather than working with same-type partners as same-type alliances bring less diversified information.

Within South Korea, some South Korean firms have shaped joint technology partnerships with leading foreign firms to offset their weaknesses in technology and to enter

[7] Foreign Direct Investments (FDI) means "a form of inter-firm cooperation that involves a significant equity stake in, or effective management control of foreign enterprise (Erdal & Göçer, 2015)."

markets through foreign distribution channels (Hobday et al., 2004). These partnerships happen remarkably active in electronics, semiconductors and automobiles sectors. Lee et al. (2012) find that South Korean SMEs get benefited from the external relationship for facing inherent risks in new and small firms. Besides, the small-sized countries like South Korea generally have limited domestic markets, so forming international alliances enable to access to the external markets and a wider source of knowledge and ideas (Lee et al., 2012). Considering the relative advantages of alliance activities, especially R&D alliances, could provide resources and reduce risk. Therefore, this leads to the following hypothesis:

Hypothesis 4: Inter-firm cooperation has a positive effect on the innovation outputs of SMEs.

3. Data and methodology

3.1. Data and sample

Data for this paper are collected from the Survey of Business Activities in South Korea for the period of 2014 and 2015. This microdata is provided by Microdata Integrated Service (MDIS)[8]. This survey is based on annual statistics to provide basic data required for making economic policies as well as for studying management strategies by grasping the various kinds of business activities. It targets all industries and the corporations that are doing business activities in South Korea who have at least 50 full-time employees and KRW 300 million turnover, which can be converted to USD 262,500 following the exchange rate as of August 13, 2017. The survey response rate was 99.10 percent in 2014 and 99.79 percent in 2015. These data includes the four dependent variables (profit, export, foreign ownership (foreign shares) and inter-firm cooperation activities), two control variables (firm size and region) and an outcome variable (innovation measured by the patent counts).

According to the criteria of European Commission, SMEs are defined as enterprises having less than 250 staff headcount. This is generally used criteria, however, in the case of South Korea, the SMEs criteria is more specific considering the different industries. Thus, I sorted out SMEs from large enterprises following the South Korean criteria. Then, to separate the sample into the high-tech and the low-tech industries, Korean Standard Industrial Classification (KSIC) is used (see Appendix A). High-tech and low-tech industries are divided following the classification of manufacturing industries based on R&D intensities (OECD, 2011). Also, subsidiaries are excluded from the data. Lastly, lagged values are matched by the company code from survey data. All of these process created a final sample of 3,737 South Korean manufacturing SMEs covering 22 sub-sectors.

3.2. Empirical strategy

In order to find out the effects of determinants of innovation in South Korean SMEs, this paper uses a negative binomial model as shown in equation (1) below. The dependent variable of the model, patent counts, is count data characterized by over-dispersion. The characteristic of industrial research and development (R&D) activity shows that patent counts are assumed to

[8] Microdata Integrated Service (MDIS) provides microdata to public since 2014 within boundary of protecting information of the survey respondents.

follow a Poisson distribution.[9] In consequence, econometricians have investigated the relationship between R&D and patenting by using Poisson regression (Wang et al., 1998). In the Poisson distribution, the variance equals the mean. Empirically, however, data often shows over-dispersion, with a variance larger than the mean (See Appendix D for more in detail). When the outcome count variable is over-dispersed, the negative binomial model is applied to deal with over-dispersion in the Poisson model (Hausman et al., 1984; Lawless, 1987). Therefore, negative binomial regression is appropriate for this model in equation (1).

$$Innovation = \beta_0 + \beta_1 Profit + \beta_2 Export + \beta_3 Foreign + \beta_4 Alliance + \beta_5 Size + \beta_6 Region + \epsilon \quad (1)$$

where *Innovation* represents the dependent variable and *Profit*, *Export*, *Foreign* and *Alliance* represent the independent variables. Control variables such as *Size* and *Region* are also included in the model. These variables will be further illustrated in the following sections. In addition, we are also interested as to which channel of inter-firm cooperation is more influential to the model. Therefore, *Alliance* is decomposed by marketing and R&D alliances in equation (2).

$$Innovation = \beta_0 + \beta_1 Profit + \beta_2 Export + \beta_3 Foreign + \beta_4 Marketing\_alli + \beta_5 Rnd\_alli + \beta_6 Size + \beta_7 Region + \epsilon \quad (2)$$

3.2.1. Dependent variable

This paper uses the number of patents for measuring innovation performance. The empirical evidence shows that patents can be used for measuring innovative activity (Acs & Audretsch, 1989; Porter & Stern, 2000; Acs et al., 2002; Czarnitzki et al., 2007; Ghazal & Zulkhibri, 2015; Czarnitzki & Delanote, 2015). According to the Patent System Administration Division at KIPO (Korean Intellectual Property Office, 2016), to acquire the patent rights, a patent must have industrial applicability. That is, it needs to be applicable in the industry. And technology must have novelty, which is not known to the public before an application is submitted. Also, technology must have an inventive step, which should not be easily obtained from prior art. Therefore, the idea of patentability can capture the innovative outcome of the firm.

[9] According to Wang et al. (1998), patent application would measure the number of successful outcomes among a large (but unobserved) number of projects within a firm's R&D lab, which has a little chance of success.

3.2.2. Independent variables

The independent variables for the regression are: (1) *Profit*, (2) *Export*, (3) *Foreign* and (4) *Alliance*; (4.1) *Marketing_alli* and (4.2) *Rnd_alli*.

Profit denotes the profit of firm measured by Earnings Before Tax (EBT) using income and loss before income taxes data. EBT is used because of lack of corporate tax data. Still, it has an advantage to use EBT data. Some industries have tax benefits, while others may not have. Therefore, using EBT will allow for a comparison between companies without regard to how taxation policies influence them. In an attempt to circumvent the potential reverse causality problem between profit and patents, one-year lagged profit is used in the model. The variable of *Profit* shows skewed distributions, so log transformation is conducted.

Export denotes the exporting activities measured by export earnings. As noted by Golovko and Valentini (2011), there is a possibility that innovation and export positively boost each other in a dynamic virtuous circle. Thus, to reduce the potential reverse causality between export and patents, one-year lagged export is used in the model. Also, log transformation is conducted to change into normally distributed data.

Foreign denotes the dummy variable indicating foreign-ownership whether the firm is wholly or partially foreign-owned. Otherwise, it means wholly Korean-owned firms. That is, *Foreign* shows the presence of foreign shareholders in SMEs. Among 3,737 firms, 46 firms have foreign shares higher than 49 percent and 250 firms have foreign shares between 1 percent and 48 percent.

Alliance denotes the dummy variable indicating strategic inter-firm cooperation whether any following strategic inter-firm cooperation was made: marketing, R&D, technology, investment, co-production, co-branding and share-exchange agreement. *Alliance* is decomposed into *Marketing_alli* and *Rnd_alli*, which denote marketing alliances and R&D alliances respectively.

3.2.3. Control variables

The control variables for the regression are: (1) *Size* and (2) *Region*.

Size denoted the firm size and is measured by the number of employees. Previous studies imply that firm size and innovation have a positive relation (Bhattacharya & Bloch, 2004; De Jong & Vermeulen, 2007). Therefore, to control for the effect of firm size, it is included in the model as a control variable. To handle skewed distribution, the variable is transformed to a natural logarithm scale.

Region denotes the categorical variable of South Korean administrative division. South Korea is divided into 9 provinces, 6 metropolitan cities, and 2 special cities (see Appendix B). In order to handle an issue of a severe development imbalance among cities, the South Korean government has been trying to promote different fields of innovation by forming the regional clusters. To control for the regional effects, categorical variable *Region* is included in the model (see Appendix C for the mean innovation output in the different regions).

Table 2. Variable description

Variable name	Description	Year	Source
Innovation	Innovation measured by patent counts	2015	MDIS
Ln(Profit)	Natural logarithm of lagged profit measured by Earnings Before Tax (EBT) using income and loss before income taxes	2014	MDIS
Ln(Export)	Natural logarithm of exports measured by lagged export earnings	2014	MDIS
Foreign	Foreign-ownership dummy indicated by 1 if the firm is wholly or partially foreign-owned, otherwise 0; 0 means 100 percent South Korean owned firms	2015	MDIS
Alliance	Dummy of inter-firm cooperation indicated by 1 if firm has an inter-firm cooperation activity domestically and globally	2015	MDIS
Marketing_alli	Decomposed from *Alliance*, showing marketing alliance activities domestically and globally	2015	MDIS
Rnd_alli	Decomposed from *Alliance*, showing R&D alliance activities domestically and globally	2015	MDIS
Ln(Size)	Natural logarithm of firm size measured by the number of employees	2015	MDIS
Region	South Korean administrative divisions	2015	MDIS

4. Empirical Results and Findings

4.1. Descriptive statistics

Table 3 below shows the descriptive statistics on the variables measuring South Korean SMEs' innovation. All variance inflation factors (VIFs) show within acceptable limits between 1 and 2. Only one region dummy, Gyeonggi-do, shows VIFs higher than 2 (VIFs = 2.56). And the mean value of *Innovation* is 9.65 (*SD* = 27.00), which implies over-dispersion in patent data. Also, South Korean manufacturing SMEs having wholly or partially foreign-ownership make up 7 percent of the full sample, indicating most of the SMEs are South Korean-owned firms. Approximately 6 percent of SMEs cooperate with other firms domestically and globally. In addition, frequency of the regions shows that most of SMEs are located inside or nearby a capital city, Seoul, such as Incheon and Gyeonggi-do. This implies that the location matters for SMEs innovation.

Table 3. Descriptive statistics and VIF

	VIF	Mean	SD	Min	Max
Innovation		9.65	27.00	0	873
Ln(Profit)	1.00	11.94	0.20	0	12.39
Ln(Export)	1.08	4.93	4.41	0	14.07
Foreign-ownership	1.03	0.07	0.25	0	1
Alliance	1.01	0.06	0.24	0	1
Ln(Firm size)	1.06	4.67	0.45	3.91	5.69
Region	VIF	Frequency	Percent	Cum.	
Seoul (capital)		434	11.61	11.61	
Busan	1.46	236	6.32	17.93	
Daegu	1.35	177	4.74	22.67	
Incheon	1.47	246	6.58	29.25	
Gwangju	1.14	67	1.79	31.04	
Daejeon	1.12	57	1.53	32.57	
Ulsan	1.15	73	1.95	34.52	
Sejong-si	1.02	9	0.24	34.76	
Gyeonggi-do	2.56	1,181	31.60	66.36	
Gangwon-do	1.08	38	1.02	67.38	
Chungcheongbuk-do	1.38	198	5.30	72.68	
Chungcheongnam-do	1.47	251	6.72	69.40	
Jeollabuk-do	1.17	86	2.30	81.70	
Jeollanam-do	1.15	68	1.81	83.52	
Gyeongsangbuk-do	1.44	229	6.13	89.64	
Gyeongsangnam-do	1.70	387	10.36	100.00	

In Table 4, a Pearson correlation matrix is presented to test for the multicollinearity. From correlation matrix, little correlation between the variables are found, all falling between 0.1< | r | <0.3. *Export* shows the strongest Pearson product-moment correlation coefficient with the innovation outcome: r=0.14, p<.001.

Table 4. Correlation matrix

	Profit	Export	Foreign ownership	Alliance	Size	Region
Profit	1.00					
Export	0.02	1.00				
Foreign ownership	0.00	0.12	1.00			
Alliance	0.01	0.05	0.07	1.00		
Size	0.05	0.20	0.08	0.08	1.00	
Region	-0.01	-0.03	-0.02	-0.03	-0.03	1.00

In addition, the Model fit was investigated by using criteria of the AIC (Akaike information criterion) and BIC (Bayesian information criterion) to determine negative binomial regression is suitable for the model. A lower AIC and BIC mean that a model is closer to the truth. Results are shown in Table 5. Both AIC and BIC show the negative binomial model suits better than the Poisson model.

Table 5. AIC and BIC

Model	observations	df	AIC	BIC
Poisson	3,737	21	82386.22	82516.96
NB	3,737	22	21669.2	21806.17

4.2. Empirical results

Negative binomial regressions were run on South Korean SMEs in manufacturing industry. Along with the full sample, additional regressions were run for the sub-samples based on high-tech and low-tech industries. The high-tech and low-tech industries are classified by the degree of technology intensities (OECD, 2011). Models were estimated by the maximum-likelihood estimates (MLE) and were tested by likelihood-ratio tests for the model fit. Table 6 presents the estimates of negative binomial regressions. All the models have the value of $\alpha>0$ with likelihood-ratio tests of $p<.05$, indicating that a negative binomial regression is more suitable than Poisson regression.

From the regression results in the full sample, presented in Model 1, the coefficient of *Profit* shows negative and insignificant impact on patent application. This means that higher profit did not lead to a higher innovative performance, holding other factors constant, which is inconsistent with hypothesis 1. On the other hand, consistent with hypothesis 2, exporting increased the innovation outcome which is significant at the 1 percent level. The coefficient of foreign-ownership, as expected, is positive and statistically significant at the 10 percent level. Inter-firm cooperation activity, *Alliance*, has the positive effects on the patent outputs as significant at the 5 percent level, which is consistent with hypothesis 4.

In high-tech industries, shown in Model 2, no significant relationship was found between the profit and the patent outputs. The results also show, as expected, export activities increased the innovation outcome. Both coefficients of *Foreign-ownership* and *Alliance* have positive effects on the patent output, as in the full sample, but the coefficients are much smaller and not statistically significant at the conventional significance level.

In Model 3, the sub-sample of low-tech industry, the variable *Profit* again indicates a negative and insignificant relationship with the patent output. Like the full and high-tech samples, export activities has a positive effect on innovation outcome in the low-tech industries, which is statistically significant at the 1 percent level. The coefficient of *Foreign-ownership* is positive and significant at the 5 percent level, which was not significant in the high-tech sectors. That is, foreign shares had a positive impact on the patents output in low-tech industry. Although alliance has a positive relationship with the innovation output, it is not statistically significant at the conventional level of confidence.

Having shown different results in *Alliance* in the full and sub-samples, we want to further investigate which channel of alliance made this difference. Therefore, *Alliance* is decomposed

by marketing and R&D alliances in equation (2).[10] Model 4 reports the results of the full sample and the coefficient of R&D alliance is significant at the 5 percent level, whereas marketing alliance is not statistically significant at the conventional level. In Model 5, both alliance activities do not have effects on innovation performance in high-tech industries as shown in Model 2. Again R&D alliance activities in Model 6 increased the innovation outcome, while marketing alliance does not have a significant relationship with innovation performance.

In summary, these regression results suggest that South Korean manufacturing SMEs react to the different determinants of innovation based on high-tech and low-tech industries. Export played an important role in all sectors, while foreign-ownership significantly affected the low-tech industries. Besides, the results suggest that R&D alliance would be an influential determinant of alliance activities of firms which develop patent output.

[10] The variable *Alliance* includes various inter-firm cooperation activities. However, only cooperation in marketing and R&D is included in the model. For example, technology cooperation is not included for the further investigation. In this survey, technology alliance means that firms answering the survey provide their technology to the partners. Therefore, technology alliance would be more influential for innovation outcome of partner firm, rather than the company providing their technologies.

Table 6. Negative binomial models

	(1) Full sample	(2) High-tech	(3) Low-tech	(4) Full-sample	(5) High-tech	(6) Low-tech
Ln(Profit)	-0.80	-0.19	-1.27	-0.74	0.18	-1.34
	(0.50)	(0.28)	(1.02)	(0.50)	(0.27)	(1.01)
Ln(Export)	0.07***	-0.06***	0.07***	0.07***	0.06***	0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Foreign-ownership	0.20*	0.00	0.63**	0.20*	0.00	0.64**
	(0.11)	(0.11)	(0.24)	(0.11)	(0.11)	(0.24)
Alliance	0.22**	0.11	0.37	-	-	-
	(0.11)	(0.12)	(0.23)			
Marketing_alli	-	-	-	0.04	0.86	-0.68
				(0.245)	(0.17)	(0.54)
Rnd_alli	-	-	-	0.33**	0.16	0.85**
				(0.16)	(0.17)	(0.39)
Size	0.85***	0.90***	0.33**	0.85***	0.90***	0.33**
	(0.06)	(0.07)	(0.11)	(0.06)	(0.07)	(0.11)
Region	included	included	included	included	included	included
Observations	3,737	2,150	1,587	3,737	2,150	1,587
Dispersion parameter (α)	2.59	1.98	3.14	2.59	1.98	3.12
Log-likelihood	-10812.60	-7101.58	-3523.59	-10812.04	-7101.30	-3522.13
χ^2	631.23	483.30	109.40	632.34	483.87	112.30

Dependent variable is innovation measured by the patent counts.

* significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard deviations are in parentheses.

4.3. Robustness check: specific sub-sector regression

As De Jong and Vermeulen (2006) stated, some previous works have suggested that sectors are different in respect of the sources, paces, and rates of technological changes. Even though such different patterns are expected, they are not fully investigated due to the lack of data. Therefore, in this robustness check, to determine whether the results show the real characteristics of high-tech and low-tech industries, reflected in specific sub-sectors, the additional models are run by restricting our attention to firms within a single sub-sector. By doing so, it prevents the difficulties originated from inter-sector variance in other influencing elements such as technological needs and effectiveness of patents as a way of returns on R&D activities. Model 7 and Model 8 present the sub-sectors in high-tech manufacturing firms and Model 9 and Model 10 present the low-tech sub-sectors.[11]

Model 7 shows the sample of 460 SMEs in the computer, electronic and communication equipment manufacturing sector. Unlike the results from other models, *Profit* became significant at the 5 percent level, remaining a negative effect on innovation. As expected, *Export* remains significant and has positive effects on the patent outcome. Foreign-ownership and alliance activities have positive and statistically insignificant relationship with innovation performance. Model 8 shows the estimates of 451 manufacturing SMEs in motor vehicles, trailers and semi-trailers sub-sectors. *Profit* is significant at the 5 percent level in this sub-sector as well, but also turned to have a positive effect on innovation performance. As expected, *Export* has statistically significant and positive relationship with innovation outcome. Like other high-tech firms, foreign-ownership and alliance activities do not have an impact on the patent counts.

Model 9 shows the regression estimates of the textiles manufacturing sector. As the full sample of low-tech industries showed, foreign-ownership increased the patents outcome and is statistically significant at the 10 percent level. However, other determinants - *Profit*, *Export* and alliance - are not statistically significant at the conventional level of confidence. In Model 10, estimates from fabricated metal products sub-sector show that *Profit* is statistically significant at the 5 percent level, showing a negative effect on the patent outcome. Again, foreign-ownership increased the innovation outcome, which is significant at the 10 percent level. *Export* does not have effects on innovation performance in sub-sector of fabricated metal

[11] See Appendix E for the other sub-sector regressions.

products, while still having a positive coefficient. Also, the coefficient of alliance became negative value but it is not statistically significant at the conventional level.

Some results are consistent with the full-sector samples, but also different results are found. These results imply that the sector differences seem to exist in determinants of innovative performance. To control the effects of sectoral differences, additional regressions were run. However, no big differences were found in significance and the sign of coefficients after adding sector dummies.

Table 7. Negative binomial regressions for the sub-sectors

	(7) High-tech Computer	(8) High-tech Motor vehicles	(9) Low-tech Textiles	(10) Low-tech Fabricated metal
Ln(Profit)	-2.80**	8.86**	-5.00	-4.55**
	(1.1)	(3.20)	(6.51)	(2.06)
Ln(Export)	0.04**	0.05**	0.02	0.01
	(0.01)	(0.02)	(0.42)	(0.03)
Foreign	0.18	-1.22	1.74*	1.32*
	(0.23)	(0.37)	(0.92)	(0.70)
Alliance	0.09	-0.389	0.62	-0.12
	(0.25)	(0.342)	(0.95)	(0.60)
Size	0.90***	0.89***	0.86**	0.77**
	(0.15)	(0.21)	(0.41)	(0.29)
Region	included	included	included	included
Observations	460	451	160	243
Dispersion parameter (α)	1.88	2.46	2.67	2.54
Log-likelihood	-1688.24	-1082.687	-266.75	-644.62
χ^2	87.63	94.62	23.60	43.63

Dependent variable is innovation measured by the patent counts.
* significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard deviations are in parentheses.

5. Discussion and further areas of research

The aim of this study was to assess the effects of determinants (profit, export, foreign ownership and inter-firm cooperation) of South Korean SMEs' successful innovation outputs. Of particular interest is how much the full sample regression results are reflected in the sub-samples of the high-tech and low-tech industries. The results of this paper seem to support empirical evidence that the different determinants of innovation in South Korean SMEs exist between high-tech and low-tech industries. In this section, the following research questions will be answered based on the results: *To what extent do the determinants (profit, export, foreign ownership and inter-firm cooperation) increase innovation for South Korean manufacturing SMEs?* And *to what extent do these determinants differ between high-tech and low-tech manufacturing industries?* Yet, the results should be considered carefully for the possible limitations. Potential solutions and further research areas will be discussed in the following sections.

Profit

Previous studies suggested that internal funding seems to play a more important role for innovation in small firms (Love & Roper, 2015), at least for high-tech firms (Himmelberg & Petersen, 1994; Audretsch, 1995) due to the constrained chances to use external resources (Ughetto, 2008). However, unexpectedly, the findings show that profit affects the patent output negatively and insignificantly. Negative income means that expenses of firms were greater than their revenue. Therefore, the most likely explanation of this finding is due to the characteristics of the sample. This paper studies in the context of SMEs, which means some firms are young and small. Consequently, it takes time for these firms to get returns from investments. Owing to lack of data for firm age, the effect of firm age could not be investigated in the model. Still, exceptional cases were found from regressions of an individual sector. For instance, a sub-sector of motor vehicles, trailers and semi-trailers had a positive and significant coefficient. One possible explanation for this result could be the national advantage in this manufacturing sector and therefore they have positive profits. South Korea has a relative advantage in motor vehicles industry having large companies such as Hyundai, Kia and Ssang-young. Accordingly, South Korean SMEs work with these giant companies and get profited from relative advantage of motor industry in the global market.

Export

There is consistent evidence that exporting has a positive and significant effect on innovation outputs for both high-tech and low-tech manufacturing firms. This result is consistent with the work by Love and Ganotakis (2013). One potential explanation for this finding could be the limited domestic markets in South Korea. This explains why South Korean firms expand their activities to international markets (Lee et al., 2012). Therefore, the strong significance of exporting indicates that exporting is one of the most important factors for South Korean SMEs innovation.

Foreign ownership

It is noticeable that in the low-technology industries foreign-ownership has positive and significant influence to innovation output. That is, the existence of the foreign stakeholders matter in low-tech manufacturing industry. These results are consistent with the results of Guadalupe et al. (2010), showing that foreign firms pick up the best firms within industries, or invest more in various innovation activities after acquisition in the context of Spanish firms. Therefore, the positive effects of foreign stakeholders would be explained by their selection of the promising firms in the field, or wholly foreign-owned companies perform better (Love et al., 2009) for innovation output through their management strategies. In addition, another explanation can be higher wages in wholly foreign-owned firms (Aitken et al., 1996) which can be incentive to work for foreign companies in South Korea. Considering the low wages in South Korean SMEs, higher wages can attract more high-skilled workers.

Inter-firm cooperation (Alliance)

After decomposing inter-firm cooperation activities into R&D and marketing activities, R&D alliance showed the positive and significant effects on innovation output in the low-tech industry sample. This result is partially inconsistent with the result of Lee et al. (2012). According to Lee et al. (2012), R&D-intensive SMEs make the most of the R&D alliance by lowering risk. A potential explanation for this result would be the lack of internal resources in low-tech firms. Low-tech firms may have less R&D-related employees, so they can compensate this weakness by having R&D alliances and acquiring external knowledge.

Control variables

The estimates of the coefficients suggest a particular implication. This study controlled for the regional and sectoral effects. However, the results showed that most of the innovation determinants have negative effects on the patent outputs in the regions away from the capital city, Seoul. The over-concentration of firm activities in the capital city or Gyeonggi-do – the region next to Seoul – has created new problems such as a noticeable economic gap. In addition, sectoral differences were found in the individual sub-sector. Therefore, the South Korean government encourage SMEs innovation with different policies to help SMEs in small size, having less ability to develop or having a regional disadvantage (Doh & Kim, 2014). For example, specialised R&D fields are allocated to each region aiming for scattering the opportunities more evenly over the country and lessening over-flocking in Seoul area.

Limitations and further areas of research

First, firm age could not be controlled for lack of data. In addition, due to the nature of data, some limitations should be considered. This study was conducted in the context of South Korea. The results would not be generalised to other countries where they have different economic and innovation policies. The micro-firms having fewer than 50 employees are not included in the Survey of Business Activities in Korea. Therefore, the results cannot be generalised to micro-firms. Besides, in terms of a measurement, accumulated patent data are used as a proxy of innovation since it was cautious to simply subtract patent count from the data of a previous year to see the newly registered patent counts. In addition, there seem to expired patents. Thus, simply subtracting the patent counts would not be matched with the real data of newly registered patents.[12] Another issue is the shortcomings of using patent data for measuring innovation. According to Archibugi and Planta (1996), using patent-based indicators have following shortcomings. First, there are some cases which cannot be patentable, so not all the inventions are patented. Second, the firms have different propensity to patent in their domestic market and in foreign countries, which largely depends on their expectations for exploiting their inventions commercially. Considering drawbacks of a patent measurement, a further study using different innovation measurement (e.g. questions from survey) can be done to examine whether the results of this paper are still valid.

[12] The survey data used for this paper has the company code, however, this code can be applied only within this survey. Microdata is provided given that the information of respondents is protected.

However, the findings and limitations of this paper suggest some interesting points for the future research. First, additional research can be conducted by using data of newly registered patents to make sure the results of this study still valid in this way. The firm age can be also included to investigate whether the negative value of profit is to do with the firm age. Furthermore, a future study can analyse the model by including the political factors. For instance, the South Korean government provides subsidies or favourable policies to specific industries or regions to support SMEs. Therefore, these factors can be included in the future study.

6. Conclusion

Despite the efforts to support Korean small and medium-sized enterprises (SMEs), the focus remains on research and policy in the domain of the giant Korean conglomerates (*chaebol*) because of their influential domestic market power and quality job creation. The gap between *chaebol* companies and SMEs have been increasing over time. To resolve this gap, more focus on SMEs, especially for their survival and innovation, is required. This paper analyses the determinants of SMEs' innovation using the firm-level data for the period of 2014 − 2015 in the context of South Korea. The negative binomial model is used for the full sample as well as for the sub-samples of high-tech and low-tech industries. In the full sample, export, foreign-ownership and inter-firm cooperation had significant positive influences on innovation output, whereas profit had no significant influence. However, the sub-samples showed the different results. In the sample of high-tech industries, export was the only significant factor for innovation output, while export and foreign-ownership had positive influences on innovation output in low-tech industries. Also, inter-firm cooperation for R&D played an important role for innovation in low-tech industries when examined after decomposing inter-firm cooperation into marketing and R&D activities. Overall, innovation in South Korean manufacturing SMEs is driven by export. A noticeable implication is that low-tech SMEs are facilitated by the foreign shares for their innovation. Thus, internationalisation is an important means for innovation in South Korean low-tech SMEs. Similarly, external linkages seem to be important considering that low-tech firms react to foreign shares and R&D inter-firm cooperation. These findings suggest that innovation policies for high-tech Korean manufacturing SMEs in South Korea deserve a different approach than their low-tech counterparts.

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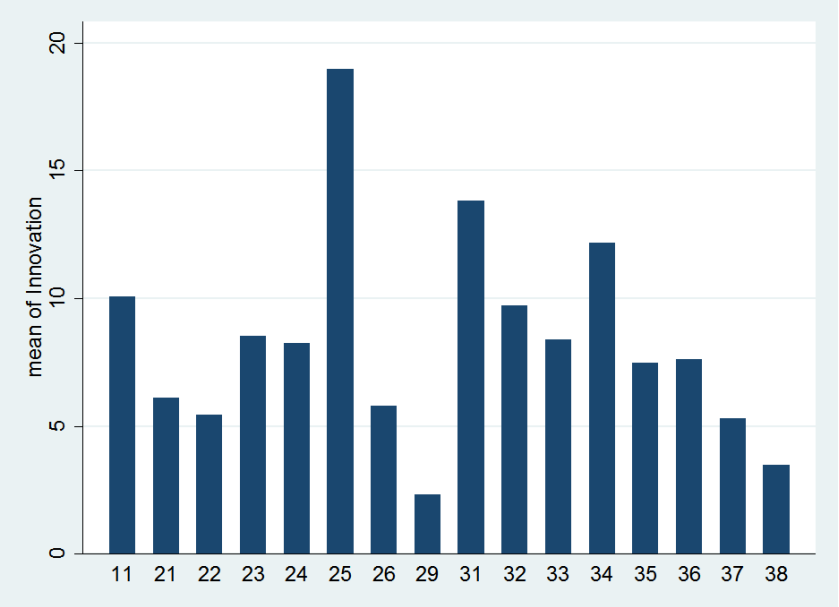
Appendix A. KSIC code for manufacturing industry

KSIC	Mid-category
10	Manufacture of food products
11	Manufacture of beverages
12	Manufacture of tobacco products
13	Manufacture of textiles
14	Manufacture of wearing apparel
15	Manufacture of leather and related products
16	Manufacture of wood and of products of wood and cork, except furniture
17	Manufacture of paper and paper products
18	Manufacture of printing and reproduction of recorded media
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of rubber and plastics products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and communication equipment
27	Manufacture of medical; measuring, testing, navigating and control equipment; optical products; watches and clocks
28	Manufacture of electrical equipment
29	Manufacture of machinery and equipment n.e.c.
30	Manufacture of motor vehicles, trailers and semi-trailers
31	Manufacture of other transport equipment
32	Manufacture of furniture
33	Other manufacturing
High-tech: 20, 21, 26, 27, 28, 29, 30, 31 Low-tech: 10, 11, 13, 14, 15, 16, 17, 18, 19, 22, 23, 24, 25, 32, 33	

Appendix B. Administrative divisions of South Korea

Administrative divisions	Name	Survey code
Special city (capital city)	Seoul	11
Metropolitan cities	Busan	21
	Daegu	22
	Incheon	23
	Gwangju	24
	Daejeon	25
	Ulsan	26
Province	Gyeonggi-do	31
	Gangwon-do	32
	Chungcheongbuk-do	33
	Chungcheongnam-do	34
	Jeollabuk-do	35
	Jeollanam-do	36
	Gyeongsangbuk-do	37
	Gyeongsangnam-do	38
Special self-governing province	Sejong-si	29
	Jeju-do (island)	39

Appendix C. Histogram of mean innovation in different regions



Appendix D. Negative Binomial Regression

A formulation of the negative binomial distribution can be applied for the model using count data with over-dispersion which is presented below. The negative binomial distribution has two parameters, namely, $\lambda \ and \ \alpha$.

$$\Pr(Y = y|\lambda, \alpha) = \frac{\Gamma(y + \alpha^{-1})}{y!\,\Gamma(\alpha^{-1})}\left[\frac{\alpha^{-1}}{\alpha^{-1} + \lambda}\right]^{\alpha^{-1}}\left[\frac{\lambda}{\alpha^{-1} + \lambda}\right]^{y}$$

where λ is the mean of the distribution, while α denotes the extent of over-dispersion. When $\alpha = 0,$ the negative binomial distribution is identical to a Poisson distribution.

Appendix E. Negative binomial models of an individual sub-sector

Since negative binomial model should be applied when having relatively big number of observation, so only sub-sector with more than 100 firms are included for the regressions.

	(1)	(2)	(3)	(4)	(5)	(6)
KSIC	10	20	22	24	25	27
Ln(Profit)	5.13	0.64	1.64	-3.42	-4.55**	-0.90
	(3.67)	(1.27)	(2.70)	(2.44)	(2.06)	(2.14)
Ln(Export)	0.13***	0.03	0.07***	0.03	0.01	0.02
	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.02)
Foreign	0.03	-0.58**	-0.52	1.31**	1.32*	-0.25
	(1.19)	(0.28)	(0.40)	(0.49)	(0.70)	(0.29)
Alliance	0.17	0.49	0.61	-0.13	-0.12	0.41
	(0.64)	(0.38)	(0.38)	(0.53)	(0.60)	(0.27)
Size	0.26	0.64**	0.67***	0.62**	0.77**	1.20***
	(0.33)	(0.25)	(0.20)	(0.31)	(0.29)	(0.20)
Region	included	included	included	included	included	included
Observations	236	198	293	225	243	161
Dispersion parameter (α)	2.87	1.66	1.75	2.35	2.54	0.95
Log-likelihood	-370.67	-593.61	-784.80	-458.37	-644.62	-642.57
χ^2	511.38	1667.05	2091.84	681.63	2636.21	2611.37

Dependent variable is innovation measured by the patent counts.

* significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard deviations are in parentheses.

KSIC: Manufacture of food products (10); chemicals and chemical products (20); rubber and plastics products (22); basic metals (24); fabricated metal products, except machinery and equipment (25); medical; measuring, testing, navigating and control equipment; optical products; watches and clocks (27)

Appendix E. Negative binomial models of an individual sub-sector

Since negative binomial model should be applied when having relatively big number of observation, so only sub-sector with more than 100 firms are included for the regressions.

	(7)	(8)
KSIC	28	29
Ln(Profit)	-0.03	-4.45***
	(0.10)	(1.28)
Ln(Export)	0.04*	0.04**
	(0.02)	(0.02)
Foreign	0.47	0.20
	(0.34)	(0.21)
Alliance	-0.26	0.14
	(0.42)	(0.22)
Size	1.20***	1.14***
	(0.20)	(0.14)
Region	included	included
Observations	222	488
Dispersion parameter (α)	1.23	1.45
Log-likelihood	-3522.13	-1674.97
χ^2	2088.76	1.1e+04

Dependent variable is innovation measured by the patent counts.

* significant at 10% level; ** significant at 5% level; *** significant at 1% level. Standard deviations are in parentheses.

KSIC: Manufacture of electrical equipment (28); machinery and equipment n.e.c. (29)