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JaeBin Ahn
International Monetary Fund

Hyoungmin Han
The Graduate Institute Geneva

Yi Huang
The Graduate Institute Geneva

Chemin Eugène-Rigot 2
P.O. Box 136
CH - 1211 Geneva 21
Switzerland

Trade with Benefits: New Insights on Competition and Innovation *

JaeBin AHN† Hyoungmin HAN ‡ Yi HUANG §

Abstract

This paper examines how Korea's import and export linkages with China affect the innovation outcomes of Korean manufacturing firms. Using our automated algorithm, we match Korean patent data to KIS-Value firm data from 1996 to 2015. We find that rising import and export with China lead to more patent applications by Korean manufacturing firms, with the positive impact particularly driven by large or public firms compared to SMEs or private firms. Most importantly, all of these results hold only in those sectors with higher quality products than Chinese products, shedding lights on reconciling recent empirical studies that found conflicting evidence on 'Schumpeterian force' and 'escaping competition.'

Keywords: Competition, Innovation, China Shock, Schumpeterian Force, Escaping Competition

JEL Classification: F14, F16, O34

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†Economist, Research Department, International Monetary Fund

‡Corresponding Author, Ph.D. Candidate, Department of Economics, The Graduate Institute Geneva

§Assistant Professor, Department of Economics, The Graduate Institute Geneva

1 Introduction

The rise of China in international trade induced a significant competition shock to many countries (Figure 1). As innovation is one of the critical components in the competitive business environment (Atalay et al., 2013; Tavassoli and Karlsson, 2016), we raise a question how the Chinese competition affects an innovation outcome of a firm. However, it is not easy to analyze the relationship because firms may react differently to import and export competition. Some firms are discouraged from the competition so that they produce fewer innovation outcomes. On the contrary, other firms try to escape the competition through the innovation. In this paper, we aim to understand the complex nature of innovation and competition nexus using a case of Korean manufacturing firms.

The theoretical framework on the competition and innovation is pioneered by Schumpeter (1943) and Agion et al. (2005). Schumpeter (1943) address the negative relationship between innovation and competition based on the linear model while Aghion et al. (2005) present evidence that the relationship is non-linear; rather, it is U-shaped. Specifically, the ambiguous relationship between competition and innovation comes from two conflicting effects, which are 'Schumpeterian force' and 'escaping competition' (Aghion et al., 2013). The term *'Schumpeterian force'* indicates the firm's behavior of decreasing innovation outcome when competition increases. *'Escaping competition'*, on the other hand, is the firm's behavior of increasing innovation outcome when competition increases. Due to the mixture of two motives in the relationship, import and export competitions may boost or dampen innovation outcomes of firms (Schumpeter,1943; Coe and Helpman, 1995; Nikell, 1996; Aghion et al., 2001; Aghion et al., 2005; Darai et al. 2010; Lileeva and Trefler, 2010; Aghion et al., 2017).

Among many linkages between competition and innovation, we focus on import and export channels in international trade. First, many firms in the world experience competition from imported Chinese goods in their domestic markets (Scherer and Huh, 1992; Alvarez and Claro, 2009; Icovone et al., 2011; Ashournia et al., 2014; Altomonte, 2015; Autor et al., 2016a[1]; Bloom et al., 2016; Chen and Steinwender, 2017; Dang, 2017). Second, the expansion of the Chinese market attracts many firms from around the world, and such firms wish to enter the Chinese market with their export goods. So, the export channels is also closely related to the competition[2] (Clerides et al.,1998; Bernard and Jenson, 1999;

[1] Autor, D., Dorn, D., Hanson, G. H., Shu, P., & Pisano, G. (2016). Foreign Competition and Domestic Innovation: Evidence from U.S. Patents. National Bureau of Economic Research.

[2] Entering the export market requires high productivity and investment (Melitz, 2003). Moreover, if firms decide to export their products to China, they need to export their products with a comparative advantage over Chinese products.

Aghion et al., 2017).

A case of Korean manufacturing firms is suitable for the research question. Over the years, Korea's trade with China has significantly increased, so that the manufacturing firms in Korea experience significant import and export competition with China. In 2015, 31% of imports in the Korean manufacturing sector were from China, and 36% of imports in the high-technology sector came from China. Also, 27% of manufacturing exports and 40% of Korean high-technology exports go to China (see Figure 2-3 and Table A1-A3 in Appendix A).

In this paper, we examine three hypotheses. We first test how import and export competition with China affects the innovation outcomes of a Korean firm. Then, we test whether this relationship is different according to the firm's characteristics. The status of publicly listed in the market, size, age, and market orientation are closely related to the innovation capacity of a firm. So, the analysis captures how the impacts of trade with China are different by the firm's capacities. Depending on the direction of the results, we can identify how the firm's characteristics correspond to the 'Schumpeterian force' or 'escaping competition force'. Lastly, we examine which sectors are more affected by the trade with China. We calculate the export unit price of both Korea and China based on the 1995 BACI trade data. By the comparison of the export unit price, we classify the sectors into 'high-quality' sectors and 'low-quality' sectors. So, this exercise traces the direction of China shock on the innovation outcomes between the sectors, such as the sector in 'Schumpeterian force' or 'escaping competition.'

There are many ways to define innovation of a firm, such as TFP (Nickell, 1996; Altomonte et al., 2015), R&D expenditures (Gong and Xu, 2017), labor productivity (Clerides et al., 1998; Aghion et al., 2017), and technology in production (Alvarez and Claro, 2009; Iacovone et al., 2011). This paper exploits the patent data to measure the innovation outcome (Acemoglu and Akcigit, 2012).

Matching patent data to firm data is a challenging task. The KIPRIS patent database does not allow people to search the data with a corporate registration number. Moreover, applicant numbers for identical applicants are not always the same unless their names are perfectly identical. To circumvent this challenge, we develop an automated algorithm based on R coding to retrieve patent data by name. Based on the data collected, we build two innovation variables; the number of patent applications and the number of patents granted. The number of patents granted is a subset of the number of patent applications, in which a small number of patent applications are endowed with an exclusive right. From these two measurements, we can deliver more precise analysis based on the quality of patents.

We identify import channel as the share of imports from China over total imports in Korea and export channel as the share of export to China over total export in Korea. However, endogeneity issues may arise as the import and export variables may correlate with unobservable technology shock or industry shock. For instance, imports from China may increase from domestic demand in low-cost Chinese products. Exports to China also vary according to the technology changes in China's domestic market. To overcome the endogeneity issues in both import and export variables, we make use of China's global exports, and China's global imports as an instrumental variable respectively. The rationale behind this instrumental variable is that the expansion of China's export supply in the world is positively correlated with Korea's imports from China, whereas China's world export supplies are not driven by the import demand of Korea, but by increasing Chinese comparative advantage from a productivity shock (Autor et al.,2013). Also, China's increasing import demand from the world is positively associated with Korea's export to China, whereas China's imports from the world are driven by domestic productivity shock in the industry rather than the export from Korea.

Our empirical analysis produces following outcomes. First, trade with China is positively associated with innovation responses of Korean firms. Second, trade with China affects the innovation responses of firms differently. Public or large firms are more innovative when they face trade with China compared to SMEs or private firms. This implies that firm's capacity is closely related to the innovation behavior of a firm and large and public firms are more likely to be facing 'escape competition' motive while small and private firms to be facing 'Schumpeterian' force. Third, Korean manufacturing firms in the high-quality sector manage to escape competition from China through innovation, and this result is more prominent in large or listed firms compared to SMEs or non-listed firms. So, the competition and innovation in high-quality sector show 'escaping competition' relationship whereas in low-quality sector present 'Schumpeterian force' relationship.

Our research relates to several strands of empirical literature such as import competition and innovation (Scherer and Huh, 1992; Alvarez and Claro, 2009; Icovone et al., 2011; Altomonte, 2015; Autor et al., 2016a; Bloom et al., 2016; Gong and Xu, 2017; Li et al.,2017; Hombert and Matray, 2017), export competition and innovation (Clerides et al., 1998; Bernard and Jenson, 1999, Aghion et al., 2017), trade liberalization and innovation (Bustos, 2011; Long et al., 2011; Coelli et al., 2016; Liu and Ma, 2016), trade and quality of product (Amiti and Khan, 2013; Martin and Mejean, 2014; Medina, 2015), and China shock (Ashournia et al., 2014; Autor et al., 2016; Hau et al., 2016; Bena and Simintzi, 2017).

To our knowledge, this paper is the first study to analyze how trade with China affects the innovation outcome of Korean firms using the patent data. Recent literature by

Bloom et al. (2016) and Autor et al. (2016a) are the closest research to ours, which use the patent information to test the relationship between import penetration from China and innovation. Using European firm-level data, the analysis of Bloom et al. (2016) shows the positive linkage between import penetration from China and the parenting activities of the firms. On the other hand, Author et al. (2016a) find a negative impact of Chinese import competition on the patent application of U.S. manufacturing firms. Compared to the literature, we expand the idea to both import and export channels with up-to-date data periods using comprehensive our matching algorithm.

Our empirical research also contributes the unique finding to the literature that the impact of competition on the innovation depends on the firm's capacity and sectoral differences, such that it relates to 'escaping competition' motive in high-quality sectors (Aghion et al. , 1997; 2005) and to 'Schumpeterian' force in low-quality sectors (Aghion and Howitt, 1992).

The structure of this paper as follows: section 2 describes the data of the paper; section 3 explains the empirical strategy for the analysis; section 4 presents the empirical results; section 5 dicusses and concludes the paper.

2 Data

2.1 Description of Data

This analysis is based on firm-level data from Korean manufacturing firms in 1996–2015. We combine datasets from various sources to answer our research questions; firm-level data is from KIS by NICE, patent data from KIPRIS, and trade data from BACI by CEPII. Each dataset follows different types of classification. Harmonization is based on ISIC Rev.3 at the four-digit level. A summary of each database is in Table 1, and Table 2 contains a summary of the data.

Firm-level Variables

We acquire Korean firm-level data from NICE Korea Information Service, Inc., which is one of the data providers of financial and corporate data for Korean firms. The KISVALUEdata is collected annually from all Korean companies with assets over 7 billion won (7 million USD). The system offers data on 27,000 firms, of which 2,200 are listed firms on the KOSPI, KOSDAQ, and KONEX exchanges. The advantage of KISVALUE for this analysis is the scope of the period, which is from 1980 to the present. The vast time span allowed us to select the period of interest and to include various controls, such as the pre-WTO accession of China variable. We restrict the samples to the manufacturing sector, which consists of about 10,000 firms from 1996 to 2015; specific firm control variables are age, number of the employees, sales, and capital of a firm.

Patent

We retrieve patent data from KIPRIS(Korea Intellectual Property Rights Information Service), which is an official provider of firm-level patent information in Korea. Matching between patent applicants and a firm is quite a complicated process, as the code for the same applicant in the KIPRIS dataset is coded differently by the location of "Inc." or "Corp" (주 in Korean) in its name. For example, "Inc., Samsung Electronics" and "Samsung Electronics, Inc." are classified as different firms in the KIPRIS dataset. So, we collect the patent data of the different combination of names.

There are more than 10,000 firms in NICE KIS-Value dataset during the period of 1996-2015. We build an automated algorithm to retrieve the patent information of a firm. We acquire OPEN-API[3] access to the KIPRIS patent database. Through the access, we devise an automated search algorithm using R. The coding is devised to search each name of a firm from the database and to save the data in Excel.[4] From the extensive raw dataset, we extract and allocate patent information to each firm. [5]

There are three types of patents in Korea: patents, utility patents, and design patents. The patent and the utility patent are almost identical, except that the object of a utility patent is confined to a tangible good. We collect information for design patents. However, we do not include design patents in our analysis, as the design itself is closer to the invention of appearance or color than new technology. So, "patents" in this paper refer to the patents and utility patents.

Table A-4 shows the information related to the patent data. The number of patent applications and patents granted fluctuated over the years, whereas the number of patenting firms gradually increased over the years.

We notice that there is a difference among the firms with no innovation output. Depending on their business, some firms do not need to engage in innovation for their products. If we had included all firms with zero patent applications, the estimation would be biased, as the analysis captures the effects on firms that are not innovation responsive. We

[3] Open API is the interface to develop an application or software program through a web database.

[4] KIPRIS OPEN-API access allows users to search the patents of a firm, but the result of patent data is limited to 5,000 patents per search. So, we include additional coding to indicate the number of results, and we manually retrieve the patent data through web searches.

[5] We explain the specific rule of matching in Appendix B.

assign a dummy variable for each firm that indicates whether the firm had engaged any innovation activity over the previous 20 years (1995–2015). If a firm has not applied for any patents during this period, we classify the firm as a no-innovation-needed firm, and we exclude these firms from the sample of the analysis. The logic behind this treatment is to reduce the bias. Zero values come from two different sources. Some firms may not file any patent application solely because they have no need to innovate. Other firms may not file any patent applications even though they invest in innovation. By controlling for the outliers of the firms with non-innovative firms, we can reduce the bias in the patent variable.

We also find that few firms have a remarkably higher number of patents than other firms. The number of patent application for some firms is more than 10,000, whereas the average number of patent applications is roughly seven. Figure 4 is the scatter plot of the number of patent applications of all firms across all data periods. The plot shows that some firms apply for patents more aggressively than other firms (Figure 4a). The patent data from these firms may cause an estimation bias. So, we need to restrict the sample to have a better fit for the model. For this paper, we restrict our sample in terms of firms fewer than 100 patent applications, which accounts for 1% of our sample. After limiting the samples, we find far less extreme values in the scatter plot (Figure 4b).

Trade Variables

We construct the trade variables from BACI trade data. BACI trade data is constructed based on the United Nations COMTRADE database, provided by CEPII. Compared to raw data from COMTRADE, BACI data has an advantage because it resolves the issue of mismatching value between imports with CIF (cost, insurance, and freight) and exports with FOB (free on board) value. We use the HS-92 version, which contains the commodity information at the HS six-digit product disaggregation, for more than 200 countries since 1995.

2.2 A Preliminary Look at the Data

We report several interesting patterns of the data. Figure 5 depicts the trend of patent applications and competition shock from China in the period of 1996- 2015. The number of patents represents the overall stock of patent application in each year. Import share indicates the share of import from China over total imports of Korea, and export share shows the share of export to China over the total export of Korea. Except for the period of the Asian crisis in 1997 and banking crisis in 2008, the patent applications by Korean manufacturing firms are slightly increasing, along with growing import and export shares of China.

Table A-5 shows information of an average number of patent application, import and export exposure with China by 2-digit sector level. It presents additional evidence that the trend is different across the sector. For instance, The 'leather' and 'office computing' sector have a high level of import and export penetration. However, innovation outcomes are significantly different. The evidence suggests that the firm characteristics may affect the relationship between innovation and competition.

Table A-6 and Table A-7 compare the innovation outcomes of SMEs versus large firms and private firm versus public firm. The evidence suggests that large or public firms are more active in parenting compared to SMEs or private firm. So, the impact of import competition on innovation response may differ according to a firm's characteristics.

Overall, this casual inspection provides suggestive evidence that firm heterogeneity and the sectoral difference may play a role in the relationship between competition and innovation.

3 Empirical Strategy

The empirical analysis is based on a panel regression with fixed effects. The panel is constructed in a firm i, corresponding to a sector j in four digits, and a year t (Eq 1).

$$INNV_{ijt} = \beta_0 + \beta_1 IMP^{CHN}_{jt-1} + \beta_2 EXP^{CHN}_{jt-1} + \beta_3 X_{ijt} + Trends_j + FE_i + FE_t + \epsilon_{ijt} \qquad (1)$$

The dependent variable ($INNV_{ijt}$) is innovation output measured by the number of patent applications in log. [6] For the explanatory variables, we include the lagged import share of China ($IMPC^{CHN}_{jt-1}$) and the lagged export share of China (EXP^{CHN}_{jt-1}) in a four-digit sector, as well as firm-level characteristics (age, labor, capital, and sales). All of these variables are also in logarithm. Included in the fixed effects are firm FE (FE_i), and year FE (FE_t), and we control for the industry trends of the ISIC Rev.3 at the four-digit level ($Trends_j$).[7]

[6] Although we restrict the baseline sample to those firms that have applied the patents at least once over the sample period (1996-2015), since there are many firm-year observations without any patent applications (or granted patents) even in this restricted sample, we actually take log (1+n), where n is the number of patent applications (or granted patents).

[7] We include the term 'industry trend' ($Trends_j$) to absorb time-variant components of the innovation variable at the sector level. Controlling the industry trends is crucially important in the specification. Autor et al. (2016a) point out that there is a significant difference in the sectoral trends of innovation behavior between Chemical and computer sectors. In our sample, we also find evidence that innovation outcome

The variable of interest is $\beta 1$ and $\beta 2$. $\beta 1 > 0$ implies that imports from China affect positively on innovation, and $\beta 2 > 0$ means that exports to China boost innovation of firms. The firm fixed effects (FE_i) absorb all time-invariant components of the innovation variable at the firm level. The year fixed effects (FE_t) absorb all time-invariant components of the innovation variable at the year level. We specify the industry trends ($Trends_j$) to ensure $\beta 1$ and $\beta 2$ is correctly identified as those dummies absorb time-variant components of the innovation variable at the sector level, such as technology shock. To reduce the potential bias in the analysis, the empirical strategy is based on a restricted sample. Specifically, we exclude the sample to those who applied the patents at least once in sample period (1996-2015) and drops the outlying firms who applied more than 100 patents.

3.1 Measurement on Innovation

There are many ways to define firm-level innovation. For instance, Altomonte et al. (2015) used TFP as a proxy for innovation, whereas Iacovone et al. (2011) and Alvarez and Claro (2009) employed the production of the item based on technology classification. Based on our empirical exercise[8], we employ the number of patent application as a measurement of the innovation outcome of a firm.[9] [10]

There is a concern that some firms file patent applications to protect their current technology from Chinese competition, and this type of patent application does not have new technology. Bloom et al. (2016) use the citation per patent to reconcile this concern. The authors assume that the quality of a patent is low if the number of citations is small. Also,

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and trade exposure among sectors are different (Table A-5). So, we explicitly add the term to reduce the bias in $\beta 1$ and $\beta 2$.

[8] Innovation is also one of the sources of firm's productivity (TFP). We analyze the impacts of innovation outcome on productivity. For this, we incorporate innovation activity directly into the production estimation process, which the method is similar to Kasahara and Rodrigue (2008). We add "innovation" (the number of patents) explicitly as an additional state variable in the production estimation process of Olley and Pakes. The regression is defined as $Y_{ijt} = \beta_0 + \beta_1 INNV_{ijt} + \beta_2 LABOR_{ijt} + \beta_3 CAPITAL_{ijt} + \beta_4 INTERM_{ijt} + FE_j + FE_t + \varepsilon_{ijt}$ Dependent variable is the sales of a firm (Y_{ijt}), and the explanatory variables are the number of (granted) patent plus 1 ($INNV_{ijt}$), number of employees ($LABOR_{ijt}$), capital ($CAPITAL_{ijt}$), and intermediate input cost ($INTERM_{ijt}$). All the variables are in logarithm. Included FE are 2-digit sector FE(FE_j), and year FE (FE_t). Table A-10 shows that both the number of patent applications and the patents granted are positively associated with the sales of a firm. This result suggests that the technology and innovation are significant factors of the firm's productivity.

[9] Acemoglu and Akcigit (2012) also points out that innovation outcomes are closely related to the level of intellectual property rights (IPR).

[10] Alternative measurement for innovation is a R&D expenditure by the firms. We do not exploit the R&D data in this paper as follow. First, there is a fundamental difference between patent and R&D. The former is the outcome of the innovation while the latter is the input of the innovation. In this paper, we choose the output to measure the innovation. Second, a significant share of R&D data is missing from KIS-Value. Third, firm-level R&D data is not reliable, especially for SMEs due to the government subsidy (Cin et al., 2017).

they assert that these types of patents are merely filed from the "fear of being copied by Chinese firms (-97p)" so that the patent itself has no innovation.

For this paper, we use the number of patent applications and "granted" patents. Both dependent variables are our proxy for innovation. The number of patent applications represents the effort of innovation in a firm. The number of patents granted is a subset of the number of patent applications, in which a small number of patent applications are endowed with an exclusive right. There are three criteria to determine the granted status of a patent under the patent law in Korea: (i) novelty, (ii) creativity, and (iii) utility in industry. So, the number of patents granted can be a good proxy for innovation, as patents with industrial usage, novelty, and technology advancement can obtain the "granted" status. So, using both dependent variables may rule out concerns about the patent variable.

3.2 Measurement on Trade

For the import variable, we use the import share of Chinese products as a measurement of the competition level in each 4-digit sector.[11] Specifically, we define the import variable in the sector j and time t-1 (${IMP_{jt-1}}^{CHN}$) as equation 2 where M_{jt-1}^{CHN} is the imports from China and M_{jt-1} is the overall imports of Korea. Since we use the sector-level variable, we explicitly assume that the firms face the level of competition in the sector to which they belong.

$$IMP_{jt-1}^{CHN} = 100 * (\frac{M_{jt-1}^{CHN}}{M_{jt-1}}) \tag{2}$$

With the same analogy, we define the export variable ${EXP_{jt-1}}^{CHN}$ as the export values of Korean firms in China in the sector j and time t-1 (Eq 3). For each j sector and time t-1, X_{jt-1}^{CHN} represents Korea's export value to China, and X_{jt-1} is the overall export value of

[11] There are many ways to define import penetration in previous studies in the literature. One method is to use the share of imports over domestic demand (D). In this definition, import penetration can be expressed by equation 2: P, X, and M correspond to a country's production, import, and export in j sector in year t, respectively $IMP_{jt}^{CHN} = 100 * (\frac{M_{jt}^{CHN}}{D_{jt}}) = 100 * (\frac{M_{jt}^{CHN}}{P_{jt}+M_{jt}-X_{jt}})$. However, the problem with this identification is that we can only analyze at the restricted two-digit level of sectors due to the data availability. Firm datasets from KIS do not provide the origins of the imports, and production data is not available at the four-digit level. The two-digit level is highly aggregated, so the analysis might not capture the difference between the sectors. Within the same communication equipment sector in the two-digit sector, for instance, an individual firm may not innovate when there is a high level of competition from China, as they are domestically oriented firms; or, a firm's productions are overseas, so competition might not be a significant factor for its innovations. On the contrary, some firms in this sector may need to innovate as they face direct competition. So, the definition based on the 4-digits sector can deliver better estimation as it controls more variations among the industries.

Korea.

$$EXP_{jt-1}^{CHN} = 100 * (\frac{X_{jt-1}^{CHN}}{X_{jt-1}}) \tag{3}$$

We notice that endogeneity issues may arise as the import penetration variable may correlate with unobservable technology shock or industry shock. Imports from China can be correlated to time-varying factors in the error term. Imports from China may increase from domestic demand in low-cost Chinese products or technology shock. We make use of China's global exports as an instrumental variable to overcome this endogeneity issue (Autor et al. 2013), as well as several other papers have implemented in their specifications (Ashournia et al., 2014; Autor et al., 2016a; Dang, 2017).

The definition of an instrumental variable is China's total supply to the entire world minus China's exports to Korea in j sector at time t-1, which we denote as (SUP_{jt-1}^{CHN}). The rationale behind this instrumental variable is that the expansion of China's export supply in the world is positively correlated with Korea's imports from China, whereas China's world export supplies are not driven by the import demand of Korea, but by increasing Chinese comparative advantage from a productivity shock.

We construct the instrumental variable for an export variable by reversing the instrumental variable of the import channel, which is China's import demand from the world (except Korea), which we denote as (DEM_{jt-1}^{CHN}).

3.3 Measurment on Quality in Sectors

There are few ways to define the quality of the sectors in the previous literature.[12] First, following the work of Schott (2004) and Hallak (2006), we classify the product quality by the export unit price of the sector. We divide the export value (thousand USD) by sectoral unit (ton) to calculate the export unit price of Korea and China for each ISIC Rev.3 sector. The export unit price indicates the average value of products in each sector. We can compare the quality of a product by comparing the unit price between China and Korea based on the 1995 BACI trade data. We create a dummy variable for sectoral quality. If the export unit price from Korea is higher than one export unit price from China, we classify the sector as a high-quality sector. We classify other sectors in the opposite way. Detailed sector classifications can be found in Table A-8 and Table A-9. The differentiation allows us to unravel the ambiguous relationship in competition and innovation, such that we

[12] Additionally, we include alternative quality measure based on Lall (2000). Lall(2000) classifies manufacturing sectors based on the technology level. High-technology products require sophisticated inputs, such as infrastructures and research efforts. So, sectoral classification based on the level of technology can be an alternative measurement of the quality of the sectors. The results are as follow (Table 9).

may identify the 'Schumpeterian force' and 'escaping competition force' in each sector.

Second, the definition of quality based on the export unit price follows the assumption that the price reflects the quality of a product. However, assigning the quality based on the price may face the issue as the price may relate to the input prices, such as labor or capital factor prices. So, we include additional test by using alternative measurements of the quality of sectors, followed by Khandelwal et al. (2013)[13]. The approach to measuring the quality by Khandelwal et al. (2013) is summarized as the following equation.

$$ln(q_{ijst}) + \sigma ln(p_{ijst}) = FE_s + FE_{jt} + \epsilon_{ijst} \tag{4}$$

The equation is constructed in exporter i, an importer j, a sector s, and a year t. The sigma represents import demand elasticity, which we take the mean value for each industry from Broda et al.(2006). FE_s represents the sector fixed effects, which control sector-specific characteristics of the demand function. $FE_j t$ is importer-time fixed effects, which absorb the importer country's income and price level of the function. The intuition of the equation is that quality of the products determines the quantity conditional on price. After we estimate the quality for both Korea and China, we compare the estimates for each industry. We classify the high-quality sector if the quality estimate of Korea is higher than the one of China.

3.4 Heterogenous Firm Characteristics

One of the testable hypotheses is how firm heterogeneity relates to the relationship between competition and innovation. Specifically, we test which types of firms are more likely to be facing 'escaping competition' motive or 'Schumpeterian force.' We find the evidence in our dataset that the impact of import competition on innovation response may differ according to a firm's characteristics such as the public market status of a firm or the size (Table A-6 and Table A-7).

Another testable hypothesis is whether age and export status matter for the relationship between competition and innovation. The reason behind this test is that age represents the accumulated technology. Aged firms have a better understanding of the market and more prolonged periods of exposure to the industry technology needs compared to young firms. The export status of a firm may matter for this relationship. Melitz (2003) asserted that productive firms can enter the export market due to the high cost of the knowledge of productivity. To enter the export market, a firm may need to invest in a

[13] The demand is based on CES utility function with a quality parameter.

product.

We construct the following regressions (Eq 4) to test this hypothesis.

$$INNV_{ijt} = \beta_0 + \beta_1 IMP_{jt-1}^{CHN} + \beta_2 EXP_{jt-1}^{CHN} + \beta_3 D\_FIRM_{ijt} + \beta_4 IMP_{jt-1}^{CHN} * D\_FIRM_{ijt} + \beta_5 EXP_{jt-1}^{CHN} * D\_FIRM_{ijt} + \beta_6 X_{ijt} + Trends_j + FE_i + FE_t + \epsilon_{ijt} \quad (5)$$

The characteristics included (D_FIRM_{ijt}) are as follows. (i) Public: If a firm was in the public trading market, we classify the firm as "listed," and we assign 1 to the dummy variable (Autor et al 2016a). (ii) Size: If the number of employees is greater than 100, we classify the firm as a large-sized firm, and we assign 1 to the dummy variable (Ayyagari et al. 2014; Aga et al. 2015). (iii) Age: If the age of a firm is less than five years, we classify the firm as a young firm, and we assign 1 to the dummy (Roob, 2002). (iv) Domestic: If a firm do not report a cost of export within the entire data period, we classify the firm as a domestic firm, and we assign 1 to the dummy variable.[14]

4 Results

4.1 Baseline: Ordinary Least Squares

In this section, we explain how trade with China affects the innovation outcomes of Korean manufacturing firms. We present baseline OLS results in Table 3. There are two dependent variables: the number of patent applications (from column 1 to column 3) and the number of patent applications granted (from column 4 to column 6). The baseline OLS estimations show that imports from China do not have a significant effect on innovation outcomes of firms, whereas exports to China affect the innovation outcomes positively. Specifically, a 10% increase of export share to China will boost the number of patent applications by 0.22% and the number of patents granted by 0.17%. The OLS estimation suggests that the primary channel in trade for innovation is from exports.

[14] We retrieve data on the export value of the firms. However, we notice that there are many missing values of export data. Alternately, for the classification, we use information on the cost of export. It has more data compared to the export value and makes a valid distinction between domestic and export-oriented firm.

4.2 Baseline: Instrumental Variable

The baseline with OLS estimation suffers from the endogeneity issue. Time-varying factors, such as demand for Chinese products in a firm or technology shocks in the industry, can be correlated to Chinese imports. The omitted variable bias exists in the baseline since we could include all the relevant variables in the estimation. To control the bias, we introduce an instrumental variable to the estimation. China's global exports are highly correlated with the imports of Chinese goods in Korea, but it is not associated with technology shocks in Korean industries. This identification strategy is similar to that in the work of Autor et al. (2013) and Ashournia et al. (2014).

Table 4 shows the baseline results with instrumental variable (IV) estimations. Columns 1 and 2 demonstrate how our IV relates to Chinese imports as well as exports to China. The high number of first-stage F statistics suggests that our instrument (China's global supply) is strongly correlated with the variable of imports from China. Columns 3 and 8 show that both imports from China and exports are positively associated with the innovation outputs in a firm. With a 10% increase in import share (percent) of Chinese products, a firm is expected to produce 1.58% more patent applications and 1.76% more patents granted. With a 10% increase in export share (percent) to China, a firm is expected to produce 1.17% more patent applications and 1.29% more patents granted. The results suggest that trade with China benefits the innovation outcomes of Korean manufacturing firms, and these positive impacts are more prominent by the import channel.[15] [16]

4.3 Heterogeneous Impacts According to Firms' Characteristics

For this section, we test how the impacts of trade with China are different according to firms' characteristics. First, we conduct the OLS analysis (Table 5). The results show that trade with China affects the innovation response differently according to a firm's status in the public market and the size of a firm. Columns 1 and 5 show that imports from China affect listed firms more positively compared to unlisted firms. Regarding the size of a firm, both imports from China and exports to China result in more innovation at large firms compared to small firms (column 2 and column 6). Age and export status of a firm is not a factor in trade with China and innovation.

[15] We check whether the result holds for other innovation measurements. We conduct the same analysis with labor productivity and TFP as the dependent variable. We find the same positive association between trade with China and innovation outcome of firms. (see Appendix C)

[16] We investigate whether the competition impact on innovation persists. We find that the competition in imports and export channels with China increase the innovation response of a firm in a short period, and have lesser or no long-run effects over time. (see Appendix D)

We also conduct an IV estimation (Table 6). As with the OLS analysis, we find that the impacts of Chinese imports are different according to a firm's status in the public market and the size of a firm. Listed or large firms would experience higher innovation outputs from the Chinese import exposure and Chinese export market penetration, compared to the non-listed companies and SMEs. With a 10% increase in Chinese imports in a sector, listed and large firms have 1.15% and 0.47% more patent applications, respectively, compared to the opposite types firms. From the analysis of Chinese imports and patents granted, we found that listed and large firms would produce more innovation responses—about 1% and 0.33%, respectively—compared to the opposite types of firms. When we focus on the export channel, we find that listed or large firms have 0.68% and 1.06% more patent applications, respectively, compared to the opposite types of firms, with a 10% increase of export share to China. Also, a 10% increase of export share to China will boost the innovation outcomes of large firms by 0.91%. Regarding the age and export status, we do not find any evidence to support the idea of there being different impacts from trade on innovation. The results imply that the capacity of firms may determine the innovation responses towards import and export competition.

The implication of the results are the followings. First, the capacity of firms may determine the innovation responses towards import and export competition. The evidence suggests that public or large firms are prone to have a more positive impact from import and export competition with China on their innovation than private or SMEs. In return, the better capacity of firms is one of the factors of innovation when it comes to the competition. Second, we find the larger and better firms are more likely to face 'escape competition' motive whereas smaller and worse firms are prone to be facing 'Schumpeterian force.' The results are closely related to the prediction of Aghion et al. (2013), which 'Schumpeterian effects' dominates in many sectors by default except the 'neck-and-neck' sectors. For the neck-and-neck firms, the firms try to escape from a situation of constraining profits. So, more competition drives the firms to innovate. Our results suggest that import and export competition with China push the large or public firm to innovate.

4.4 Heterogeneous Impacts According to Sector Quality

Up to this point, we discuss how trade with China boosts the innovation outcomes of Korean manufacturing firm, and we have noted that large or publicly listed firms benefit more from trade with China compared to SMEs or non-listed firms. In this section, we ask whether the findings are different by sectors.

We divide the sector by comparing the unit price of Korea's exports to the world and

China's exports to the world. We define the unit price of Korean exports by dividing export value (thousands) over tons in 1995 for each ISIC Rev.3 sector. The same calculation is applied to the unit price of Chinese export goods. If the unit price of Korean goods is higher than the one-unit price of Chinese goods, we classify the sector as a "high-quality" sector. If the unit price of Korean goods is less than the one-unit price of Chinese goods, we assign the sector as "other" sectors.

First, we test how the impact of trade with China on innovation outputs affects the high-quality sector and other sectors differently. Table 7 shows that Korean sectors that have higher unit prices than those from the Chinese sector have positive impacts on innovation outcomes from trade with China. A 10% increase in imports from China boosts patent applications by 4.81% and patents granted by 4.52%. Also, the number of patent applications is expected to increase by 2.36% and the number of the patents granted by 2.24% if a firm faces 10% more export share to China. Other sectors show no significant relationship between trade with China and innovation outcomes. The result holds when we switch the quality measurements to Khandeiwai et al. (2013) (Table 8). These results imply that Korean manufacturing firms in the high-quality sector may escape competition from China by upgrading the product. This suggests the 'escape competition force' of the firms in the high-quality sector when it comes to the import and export competitions.

Second, we examine whether there is a heterogeneous impact of trade with China on innovation by the types of firms and the sector. Based on the export unit price comparison, Table 10 shows the analysis based on the number of patent applications. The imports from China boost the number of patents more for large and listed firms in high-quality sectors. Specifically, a 10% increase in imports boosts the number of patents by 0.84% more for listed firms than for non-listed firms, and by 0.23% more for the large firms than for SMEs. Exports with China show that listed and large firms would experience more innovation than non-listed firms or SMEs. In other sectors, Chinese imports may boost innovation outcomes of the listed or large firms more than for non-listed companies or SMEs. We conduct the same analysis with the number of the patents granted (Table 11). The direction of the results is identical, except that we do not find the heterogeneous impact of Chinese imports to innovation according to the size of a firm. We also conduct the analysis based on the quality comparison based on Khandeiwai et al. (2013) (Table 12, Table 13). The results shows indicate the similar heterogeneous results.

All the results suggest that Korean manufacturing firms in the high-quality sector can manage to escape competition from China through innovation, and this result is more prominent in large or listed firms compared to SMEs or non-listed firms due to the capacity difference. So, our finding of firm heterogeneity does hold in sectoral comparison, such that the import and export competitions drive the ‘better’ firms in the high-quality sector to innovate ‘escaping competition force’.

5 Discussion

China’s economy has grown significantly over the years. Based on its strong manufacturing sector, China exports many products to the world, and many countries face competition from Chinese goods in their domestic markets. Trade with China brings competition in the market, and it changes the various aspects of a country.

Among many aspects, this paper asks how the trade shock from China affects the innovation response of a firm. We choose the case of Korea because the manufacturing firms in Korea experience significant import and export competition with China over the years. However, the question is not easy to answer. Some firms show the relationship of ’Schumpeterian force’ when they face competition, whereas other firms show ’escaping competition’ relationship.

Based on the novel patent data, we test the causal relationship between innovation and competition in trade. Then, we examine how the relationship is different by the capacities and sectors of firms to identify the motive between ’Schumpeterian force’ and ’escaping competition.’ Our empirical approaches reveal that trade with China is positively associated with innovation outcomes of Korean manufacturing firms, and the impact is different according to firms’ characteristics. Large and public firms are more prone to produce innovation when they face competition from China than SMEs and private firms. This result implies that ‘larger and better’ firms are more likely to be facing the ‘escape competition’ motive while ‘smaller and worst’ firms are more likely to be facing ‘Schumpeterian force.’ We also study the quality of sectors by comparing unit prices in Korea and China. We find that the positive association between trade with China and innovation outcomes is in high-quality sectors, and low-quality sector does not present any significant relationship. It implies that Korean firms in the high-quality sector can escape from the import and export competition through innovation, which shows the ‘escaping competition’ relationship, whereas the low-quality sectors have ‘Schumpeterian force’ relationship.

Many theories in international economics have shown that trade between countries inevitably transforms the allocation of the production inputs. Our research shows that trade integration between Korea and China may benefit Korean firms in terms of innovation outcomes. However, such benefit needs to be understood under the complex mechanism between competition and innovation.

We note that our finding needs to be carefully interpreted. Due to the availability of the data, we construct the import and export competition variable at the sector level. Although we build the variables in the most disaggregated level of the industry, which is a four-digit level of ISIC Rev.3, however, our identification strategy may suffer from measurement error.

There are several expansions of this research that could be taken. First, we plan to explore possible trade channels on the labor side, such as potential skill mismatches due to Chinese import competition. Second, we would like to trace the transfer of technology through the global value-chain connection. We have identified these topics as our future research agenda.

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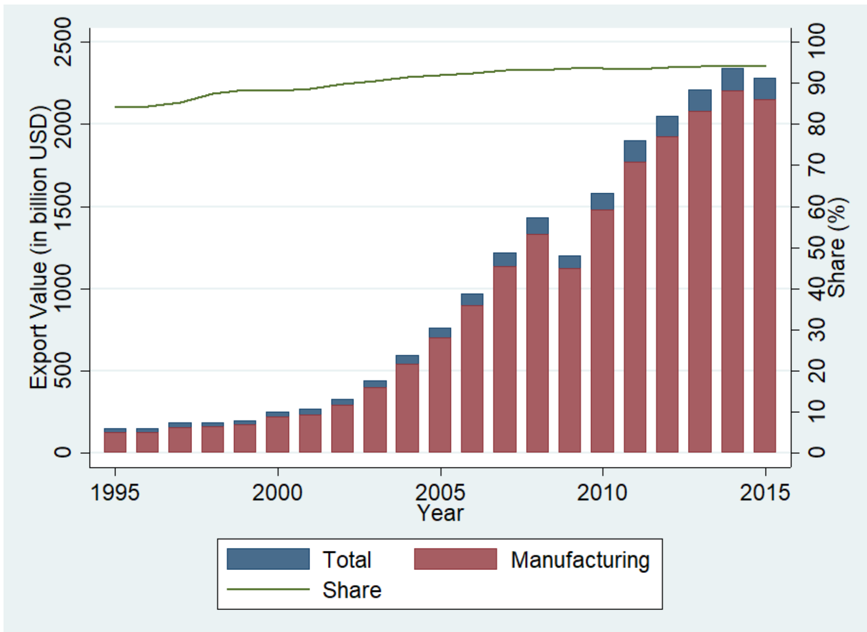
Appendix A. Figures and Tables

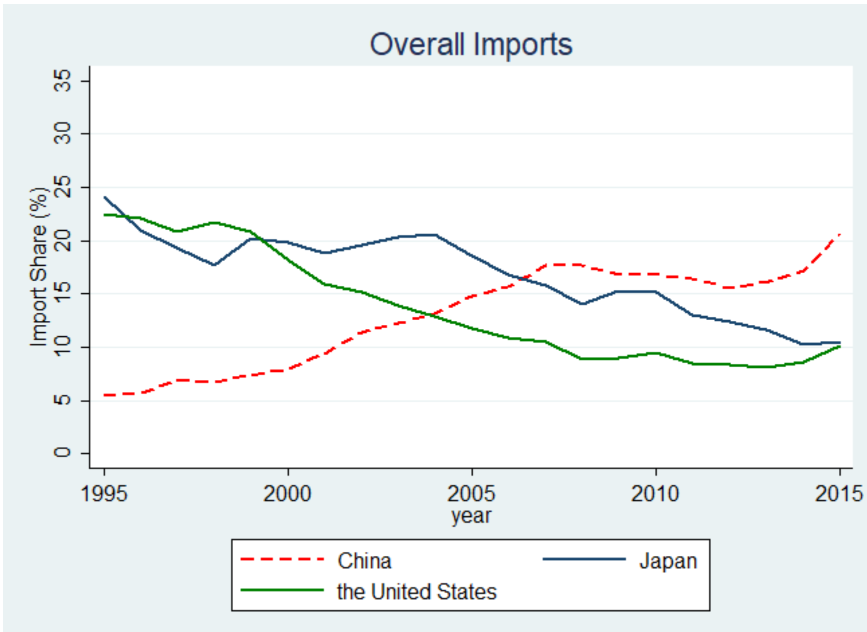
Figure 1: Export of China to the Worlds, 1995-2015



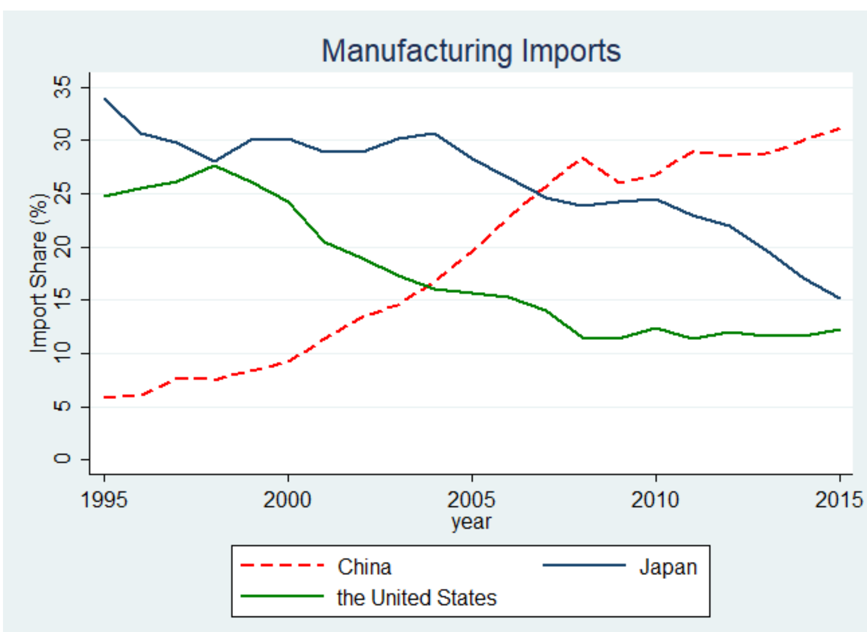
Source: Authors' calculation, World Integrated Trade Solution(WITS)

Figure 2: Three Major Import Partners of Korea, 1995-2015:
(a) Overall Sectors, (b) Manufacturing Sectors

(a)



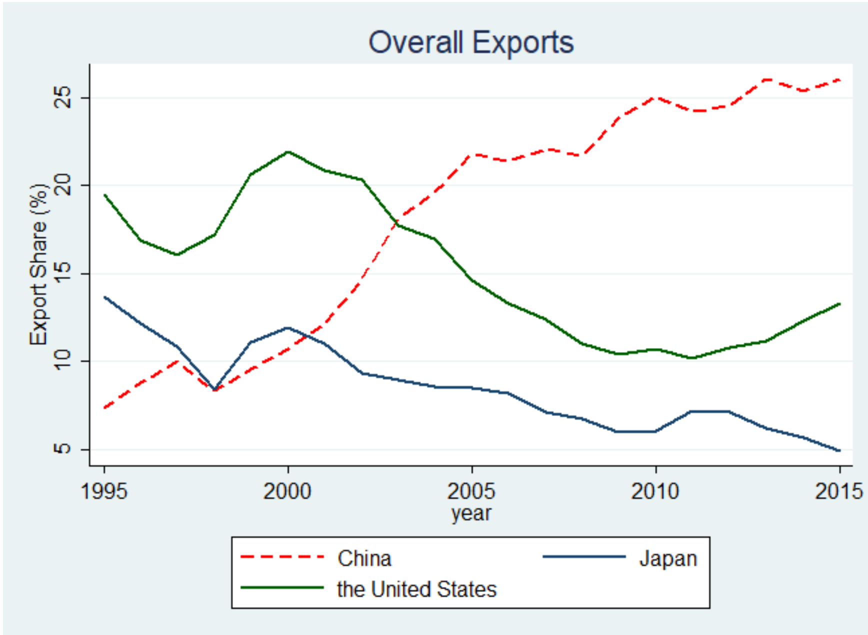
(b)



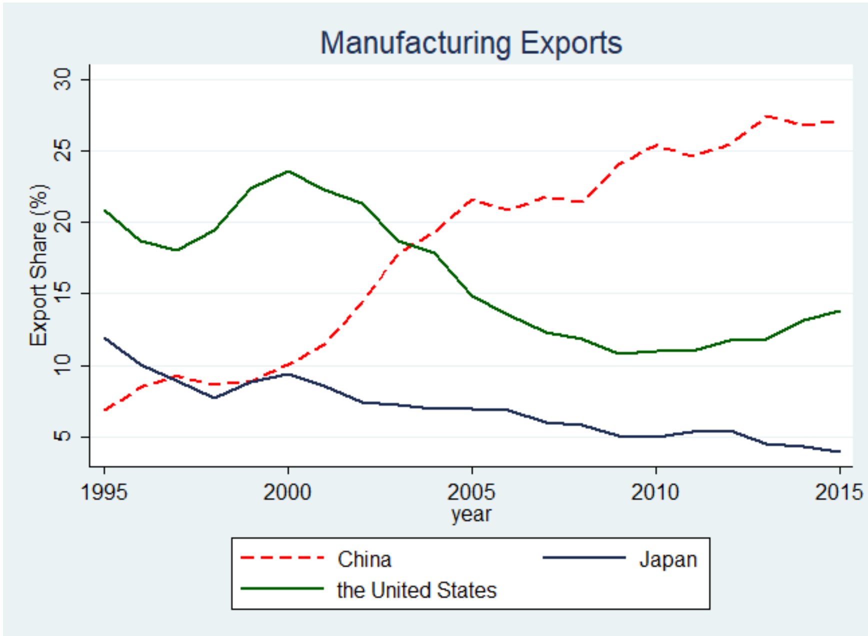
Source: Authors' calculation, World Integrated Trade Solution(WITS)

Figure 3: Three Major Export Partners of Korea, 1995-2015:
(a) Overall Sectors, (b) Manufacturing Sectors

(a)



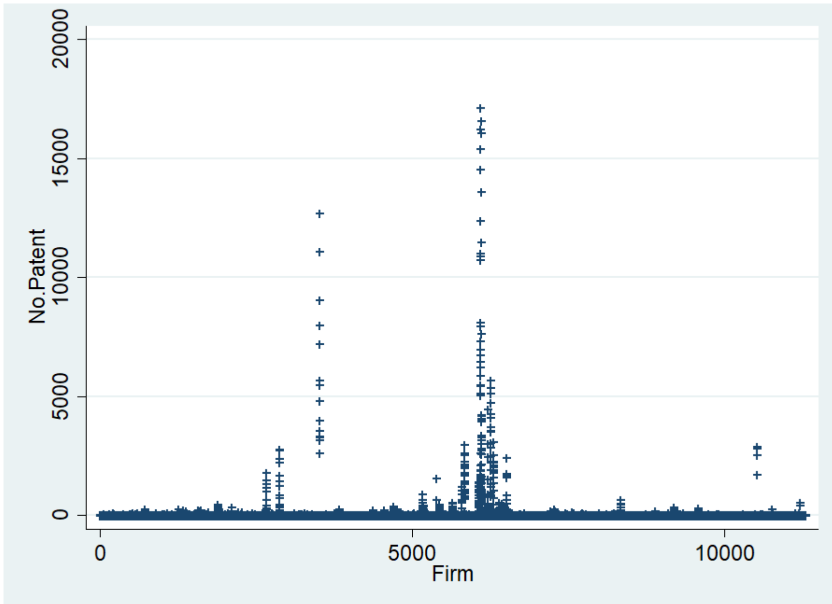
(b)



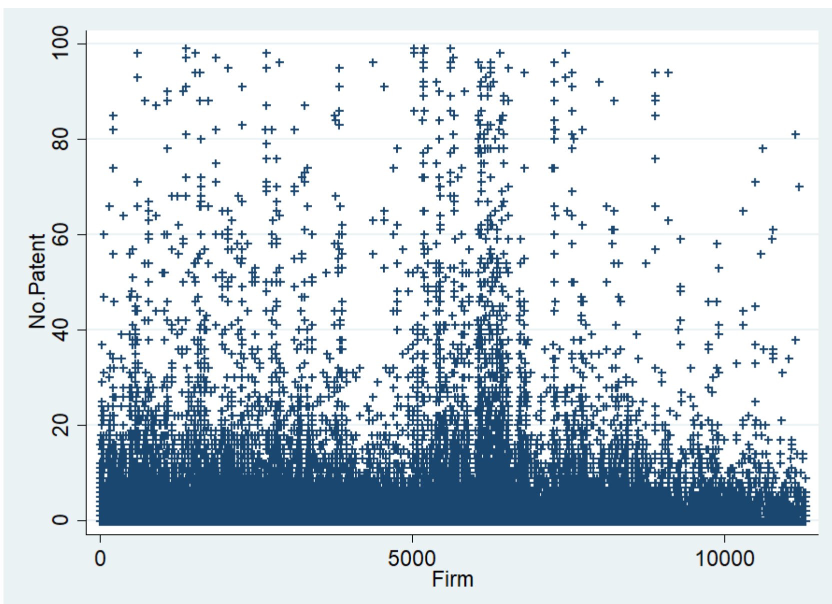
Source: Authors' calculation, World Integrated Trade Solution(WITS)

Figure 4: Scatter Plot:The number of Patent by a Firm

(a) Full Sample

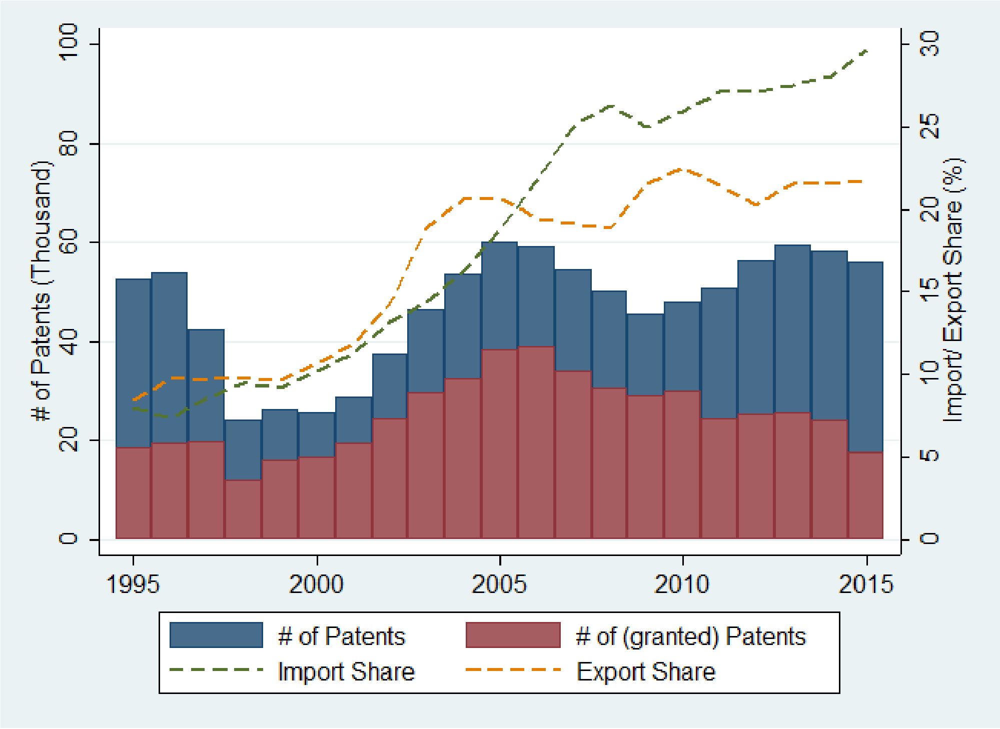


(b) Restricted Sample



Source: Authors' calculation, NICE KIS and KIPRIS

Figure 5: The number of Patent Application and Import/Export Penetration, 1995-2015



Source: Authors' calculation, NICE KIS, KIPRIS, World Integrated Trade Solution(WITS)

Table 1: Source of Data

Variable	Source	Classification
Innovation	KIPRIS	KSIC 9
Trade (Imports and Exports)	BACI CEPII	HS 1992
Firm Controls	NICE Korea Information Service, Inc (KIS-Value)	KSIC 9

Table 2: Summary of Data

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Year	120,402	2,007	5	1,996	2,015
Age	120,402	17	12	2	119
Asset	120,402	108,000,000	1,357,000,000	-256,775	155,800,000,000
Debt	120,402	52,670,000	470,800,000	-325,320	29,810,000,000
Capital	120,402	55,290,000	971,000,000	-3,335,000,000	126,000,000,000
Sales	120,402	107,700,000	1,312,000,000	695	144,700,000,000
R&D	50,137	1,559,000	26,590,000	115	2,962,000,000
Patent	120,402	7	178	0	17,122
(Granted) Patent	120,402	4	90	0	8,881
Imports_CHN	120,402	20	19	0	87
Exports_CHN	120,402	18	12	0	82

Table 3: Baseline OLS Results

	Patent			(Granted) Patent		
	(1)	(2)	(3)	(4)	(5)	(6)
IMP_CHN	0.007		0.008	0.006		0.006
	(0.007)		(0.007)	(0.007)		(0.007)
EXP_CHN		0.022***	0.022***		0.017***	0.017***
		(0.006)	(0.006)		(0.005)	(0.005)
Observations	91587	91587	91587	91587	91587	91587
R^2	0.521	0.521	0.521	0.493	0.493	0.493

* The dependent variables in the regression are the number of the patent application, granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Baseline IV Results

	First Stage		Patent			(Granted) Patent		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SUP_CHN	0.330***							
	(0.013)							
DEM_CHN		0.436***						
		(0.017)						
IMP_CHN			0.101***		0.158***	0.114***		0.176***
			(0.038)		(0.053)	(0.036)		(0.050)
EXP_CHN				0.064**	0.117***		0.070***	0.129***
				(0.027)	(0.040)		(0.025)	(0.037)
Observations	91587	91587	91587	91587	91587	91587	91587	91587
F	685.27	669.28						

* The dependent variables in the regression are (first stage) the share of import from China (Column1), and the share of export to China(Column 2), (second stage) the number of the patent application and granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Baseline OLS Results: Firm Characteristics

	Patent				(Granted) Patent			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IMP_CHN	-0.012	-0.005	0.007	0.005	-0.010	-0.003	0.006	0.003
	(0.008)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)	(0.008)
EXP_CHN	0.017***	0.007	0.024***	0.021***	0.015***	0.005	0.018***	0.017**
	(0.006)	(0.006)	(0.006)	(0.008)	(0.005)	(0.005)	(0.005)	(0.007)
IMP_CHN*Listed	0.101***				0.085***			
	(0.013)				(0.012)			
EXP_CHN*Listed	0.022				0.012			
	(0.015)				(0.014)			
IMP_CHN*Size		0.034***				0.025***		
		(0.007)				(0.006)		
EXP_CHN*Size		0.041***				0.034***		
		(0.008)				(0.007)		
IMP_CHN*Age			0.005				0.004	
			(0.006)				(0.006)	
EXP_CHN*Age			-0.012				-0.008	
			(0.007)				(0.007)	
IMP_CHN*Domestic				0.006				0.006
				(0.009)				(0.008)
EXP_CHN*Domestic				0.001				-0.000
				(0.010)				(0.009)
Observations	91587	91587	91587	91587	91587	91587	91587	91587

[*] The dependent variable in the regression is the number of the patent application and granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Baseline IV Results: Firm Characteristics

	Patent				(Granted) Patent			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IMP_CHN	0.110**	0.126**	0.158***	0.162***	0.140***	0.151***	0.177***	0.176***
	(0.052)	(0.053)	(0.053)	(0.053)	(0.050)	(0.050)	(0.050)	(0.050)
EXP_CHN	0.079*	0.068*	0.120***	0.101**	0.108***	0.087**	0.133***	0.121***
	(0.041)	(0.041)	(0.040)	(0.042)	(0.039)	(0.038)	(0.038)	(0.039)
IMP_CHN*Listed	0.115***				0.100***			
	(0.020)				(0.018)			
EXP_CHN*Listed	0.068*				0.025			
	(0.035)				(0.031)			
IMP_CHN*Size		0.047***				0.033***		
		(0.010)				(0.008)		
EXP_CHN*Size		0.106***				0.091***		
		(0.017)				(0.015)		
IMP_CHN*Age			0.001				0.002	
			(0.009)				(0.008)	
EXP_CHN*Age			-0.012				-0.014	
			(0.019)				(0.017)	
IMP_CHN*Domestic				-0.003				0.005
				(0.013)				(0.012)
EXP_CHN*Domestic				0.036				0.020
				(0.025)				(0.022)
Observations	91587	91587	91587	91587	91587	91587	91587	91587

[*] The dependent variable in the regression is the number of the patent application and granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Baseline IV Results: Quality, Export Unit Price

	Higher Quality Sector		Other Sector	
	(1) Patent	(2) (Granted)Patent	(3) Patent	(4) (Granted)Patent
IMP_CHN	0.481***	0.452***	-0.651	-0.036
	(0.153)	(0.146)	(1.394)	(0.595)
EXP_CHN	0.236***	0.224***	-1.037	-0.126
	(0.067)	(0.063)	(2.133)	(0.899)
Observations	62981	62981	28606	28606

* The dependent variable in the regression is the number of the patent application and granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: Baseline IV Results: Quality, Khandeiwai et al. (2013)

	Higher Quality Sector		Other Sector	
	(1) Patent	(2) (Granted)Patent	(3) Patent	(4) (Granted)Patent
IMP_CHN	0.824***	0.841***	0.085	0.119
	(0.298)	(0.293)	(0.082)	(0.080)
EXP_CHN	0.313**	0.335***	0.182	0.208*
	(0.123)	(0.119)	(0.125)	(0.122)
Observations	54530	54530	37057	37057

* The dependent variable in the regression is the number of the patent application and granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: Baseline IV Results: Quality by Technology

	High-Tech		Low-Tech	
	(1) Patent	(2) (Granted)Patent	(3) Patent	(4) (Granted)Patent
IMP_CHN	0.154***	0.153***	-0.035	0.060
	(0.055)	(0.052)	(0.183)	(0.172)
EXP_CHN	0.128***	0.120***	-0.179	-0.103
	(0.038)	(0.035)	(0.170)	(0.156)
Observations	74153	74153	17434	17434

* The dependent variables in the regression are the number of the patent application, granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 10: Baseline IV Results: Quality, Patent, Export Unit Price

	Higher Quality Sector				Other Sector			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IMP_CHN	0.398***	0.409***	0.478***	0.481***	-1.209	-0.878	-0.646	-0.561
	(0.151)	(0.152)	(0.153)	(0.153)	(2.988)	(1.878)	(1.376)	(1.251)
EXP_CHN	0.179***	0.159**	0.233***	0.225***	-1.956	-1.368	-1.031	-1.003
	(0.067)	(0.067)	(0.067)	(0.069)	(4.861)	(2.962)	(2.102)	(2.026)
IMP_CHN*Listed	0.084***				0.138*			
	(0.027)				(0.081)			
EXP_CHN*Listed	0.102**				0.429			
	(0.043)				(0.942)			
IMP_CHN*Size		0.023**				0.091**		
		(0.011)				(0.044)		
EXP_CHN*Size		0.147***				0.119		
		(0.024)				(0.178)		
IMP_CHN*Age			0.006				-0.020	
			(0.009)				(0.067)	
EXP_CHN*Age			0.006				-0.029	
			(0.028)				(0.043)	
IMP_CHN*Domestic				0.002				-0.056
				(0.016)				(0.091)
EXP_CHN*Domestic				0.024				0.115
				(0.029)				(0.124)
Observations	62981	62981	62981	62981	28606	28606	28606	28606

* The dependent variable in the regression is the number of the patent application plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 11: Baseline IV Results: Quality, (Granted) Patent, Export Unit Price

	Higher Quality Sector				Other Sector			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IMP_CHN	0.387***	0.391***	0.450***	0.451***	-0.188	-0.152	-0.037	0.038
	(0.144)	(0.144)	(0.146)	(0.146)	(0.889)	(0.719)	(0.591)	(0.562)
EXP_CHN	0.180***	0.156**	0.223***	0.223***	-0.328	-0.273	-0.130	-0.057
	(0.063)	(0.063)	(0.063)	(0.065)	(1.432)	(1.122)	(0.891)	(0.898)
IMP_CHN*Listed	0.070***				0.092**			
	(0.025)				(0.037)			
EXP_CHN*Listed	0.079**				0.014			
	(0.039)				(0.283)			
IMP_CHN*Size		0.013				0.070***		
		(0.010)				(0.024)		
EXP_CHN*Size		0.129***				0.041		
		(0.022)				(0.070)		
IMP_CHN*Age			0.006				-0.017	
			(0.008)				(0.037)	
EXP_CHN*Age			0.001				-0.017	
			(0.025)				(0.022)	
IMP_CHN*Domestic				0.013				-0.008
				(0.014)				(0.047)
EXP_CHN*Domestic				0.004				0.065
				(0.026)				(0.063)
Observations	62981	62981	62981	62981	28606	28606	28606	28606

* The dependent variable in the regression is the number of the granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 12: Baseline IV Results: Quality, Patent, Khandeiwai et al. (2013)

	Higher Quality Sector				Other Sector			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IMP_CHN	0.713**	0.720**	0.820***	0.825***	0.045	0.067	0.085	0.103
	(0.288)	(0.285)	(0.299)	(0.298)	(0.082)	(0.083)	(0.084)	(0.084)
EXP_CHN	0.250**	0.228*	0.311**	0.335**	0.143	0.142	0.185	0.145
	(0.123)	(0.119)	(0.126)	(0.132)	(0.134)	(0.130)	(0.126)	(0.125)
IMP_CHN*Listed	0.116***				0.126***			
	(0.028)				(0.037)			
EXP_CHN*Listed	0.054				0.102			
	(0.042)				(0.100)			
IMP_CHN*Size		0.042***				0.035**		
		(0.014)				(0.016)		
EXP_CHN*Size		0.129***				0.089***		
		(0.027)				(0.025)		
IMP_CHN*Age			0.008				-0.008	
			(0.016)				(0.015)	
EXP_CHN*Age			0.001				-0.054**	
			(0.037)				(0.025)	
IMP_CHN*Domestic				0.033*				-0.028
				(0.019)				(0.021)
EXP_CHN*Domestic				-0.028				0.097
				(0.034)				(0.061)
Observations	54530	54530	54530	54530	37057	37057	37057	37057

[*] The dependent variable in the regression is the number of the patent application plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 13: Baseline IV Results: Quality, (Granted) Patent, Khandeiwai et al. (2013)

	Higher Quality Sector				Other Sector			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IMP_CHN	0.760***	0.753***	0.840***	0.839***	0.088	0.107	0.119	0.131
	(0.286)	(0.280)	(0.294)	(0.292)	(0.079)	(0.080)	(0.081)	(0.081)
EXP_CHN	0.291**	0.260**	0.337***	0.360***	0.212	0.175	0.210*	0.180
	(0.121)	(0.115)	(0.123)	(0.129)	(0.130)	(0.127)	(0.124)	(0.122)
IMP_CHN*Listed	0.095***				0.128***			
	(0.025)				(0.032)			
EXP_CHN*Listed	0.032				-0.020			
	(0.038)				(0.088)			
IMP_CHN*Size		0.031**				0.018		
		(0.013)				(0.014)		
EXP_CHN*Size		0.114***				0.069***		
		(0.025)				(0.023)		
IMP_CHN*Age			0.011				-0.006	
			(0.016)				(0.013)	
EXP_CHN*Age			-0.009				-0.047**	
			(0.036)				(0.023)	
IMP_CHN*Domestic				0.036**				-0.014
				(0.018)				(0.019)
EXP_CHN*Domestic				-0.037				0.079
				(0.032)				(0.052)
Observations	54530	54530	54530	54530	37057	37057	37057	37057

* The dependent variable in the regression is the number of the granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A-1: Origin and Destination of Trade in Korea: Overall, 1995 and 2015

Imports						**Exports**					
1995			2015			1995			2015		
country	*value*	*share*	*country*	*value*	*share*	*country*	*value*	*share*	*country*	*value*	*share*
Japan	32.60	24.13	**China**	90.24	20.67	United States	24.34	19.47	**China**	137.14	26.03
United States	30.42	22.51	Japan	45.85	10.5	Japan	17.05	13.63	United States	70.13	13.31
China	7.40	5.48	United States	44.21	10.13	Hong Kong, China	10.68	8.54	Hong Kong, China	30.42	5.77
Germany	6.58	4.87	Germany	20.95	4.8	**China**	9.14	7.31	Vietnam	27.77	5.27
Saudi Arabia	5.43	4.02	Saudi Arabia	19.57	4.48	Singapore	6.69	5.35	Japan	25.60	4.86
Australia	4.90	3.62	Other Asia, nes	16.65	3.81	Germany	5.97	4.77	Singapore	15.02	2.85
Indonesia	3.33	2.46	Qatar	16.48	3.77	Other Asia, nes	3.88	3.1	India	12.03	2.28
Canada	2.60	1.93	Australia	16.45	3.77	Indonesia	2.96	2.37	Other Asia, nes	12.01	2.28
Other Asia, nes	2.56	1.9	Russian Federation	11.31	2.59	Malaysia	2.95	2.36	Mexico	10.89	2.07
Malaysia	2.52	1.86	Vietnam	9.80	2.25	United Kingdom	2.87	2.3	Australia	10.84	2.06
Others	36.77	27.22	Others	145.01	33.23	Others	38.52	30.80	Others	175.05	33.22
Total	135.11	100	Total	436.54	100	Total	125.06	100	Total	526.90	100

Source: Authors' calculation, World Integrated Trade Solution(WITS)

Table A-2: Origins of Trade in Korea: Manufacturing and High Technology Sector, 1995 and 2015

Manufacturing						High Technology					
1995			2015			1995			2015		
country	*value*	*share*	country	*value*	*share*	country	*value*	*share*	country	*value*	*share*
Japan	30.57	33.94	**China**	83.82	31.12	United States	10.06	36.19	**China**	33.99	36.99
United States	22.29	24.74	Japan	40.85	15.17	Japan	9.80	35.24	Other Asia, nes	12.02	13.09
Germany	6.23	6.91	United States	33.05	12.27	Singapore	1.27	4.58	United States	11.78	12.82
China	5.32	5.91	Germany	19.56	7.26	Other Asia, nes	1.00	3.58	Japan	8.73	9.5
Italy	2.37	2.63	Other Asia, nes	15.99	5.94	Germany	0.95	3.42	Singapore	3.94	4.28
Other Asia, nes	2.32	2.57	Vietnam	8.14	3.02	**China**	0.62	2.22	Germany	3.33	3.62
Singapore	1.81	2.01	Singapore	6.64	2.47	Malaysia	0.57	2.07	Vietnam	2.71	2.95
France	1.78	1.98	France	5.44	2.02	Hong Kong, China	0.49	1.75	Malaysia	2.44	2.65
United Kingdom	1.69	1.88	Italy	5.21	1.94	United Kingdom	0.44	1.59	France	1.95	2.12
Malaysia	1.16	1.29	Malaysia	4.23	1.57	France	0.40	1.46	Philippines	1.36	1.48
Others	14.55	16.14	Others	46.41	17.22	Others	2.20	7.90	Others	9.63	10.50
Total	90.07	100	Total	269.34	100	Total	27.80	100	Total	91.88	100

Source: Authors' calculation, World Integrated Trade Solution(WITS)

Table A-3: Destination of Trade in Korea: Manufacturing and High Technology Sector, 1995 and 2015

Manufacturing						High Technology					
1995			2015			1995			2015		
country	*value*	*share*	country	*value*	*share*	country	*value*	*share*	country	*value*	*share*
United States	23.89	20.87	**China**	127.70	27.11	United States	12.11	31.54	**China**	65.47	40.68
Japan	13.63	11.91	United States	65.29	13.86	Japan	4.60	11.98	Hong Kong, China	20.11	12.50
Hong Kong, China	9.14	7.99	Hong Kong, China	27.85	5.91	Singapore	3.77	9.83	United States	16.03	9.96
China	7.88	6.88	Vietnam	25.78	5.47	Germany	3.61	9.39	Vietnam	10.84	6.74
Germany	5.94	5.19	Japan	18.52	3.93	Hong Kong, China	2.38	6.21	Japan	5.15	3.20
Singapore	5.60	4.89	Mexico	10.77	2.29	Other Asia	1.58	4.13	Singapore	4.55	2.83
Other Asia	3.28	2.87	Indonesia	10.47	2.22	Malaysia	1.34	3.49	Other Asia	4.08	2.54
United Kingdom	2.85	2.49	Other Asia	9.75	2.07	Germany	0.90	2.34	Mexico	3.80	2.36
Indonesia	2.76	2.41	Singapore	9.71	2.06	**China**	0.59	1.54	Philippines	3.47	2.16
Malaysia	2.55	2.23	Saudi Arabia	8.99	1.91	Netherland	0.55	1.43	India	2.50	1.55
Others	36.92	32.27	Others	156.28	33.17	Others	6.95	18.11	Others	24.93	15.49
Total	114.44	100	Total	471.12	100	Total	38.38	100	Total	160.96	100

Source: Authors' calculation, World Integrated Trade Solution(WITS)

Table A-4: The Number of Patent and Patenting Firms,1996-2015

Year	# Patent Applications	# Granted Patents	# Patenting Firm	# Firms	Patenting Firm (%)
1996	53,489	19,295	477	4,045	11.8
1997	42,224	19,635	570	4,388	13.0
1998	23,723	11,964	681	4,797	14.2
1999	26,087	16,153	932	5,400	17.3
2000	25,314	16,615	1,302	6,072	21.4
2001	28,322	19,467	1,519	6,525	23.3
2002	37,149	24,205	1,591	6,973	22.8
2003	45,968	29,709	1,739	7,350	23.7
2004	53,103	32,260	1,954	7,742	25.2
2005	59,573	38,220	2,242	8,128	27.6
2006	58,960	38,741	2,387	8,481	28.1
2007	53,671	33,757	2,358	8,566	27.5
2008	49,367	30,519	2,452	8,847	27.7
2009	44,561	28,906	2,709	9,145	29.6
2010	47,140	29,881	2,753	9,484	29.0
2011	49,866	24,423	2,915	9,785	29.8
2012	55,490	25,360	3,044	10,093	30.2
2013	58,463	25,369	3,128	10,267	30.5
2014	57,204	24,002	3,060	10,281	29.8
2015	53,826	17,453	2,863	10,080	28.4

Source: Authors’ calculation, NICE KIS and KIPRIS

Table A-5: Average Number of Patent, Import and Export Shares
Sample of Innovative Firms,1996-2015

Sector	No.Patent Application	No. Granted Patent	Imports (%)	Exports (%)	No. Firms
Food_Beverages	0.71	0.50	20.37	9.04	9,603
Tobacco	3.16	2.57	1.28	3.61	99
Textiles	0.45	0.32	48.67	17.12	5,314
Wearing apparel	0.25	0.19	61.11	14.65	4,992
Leather	0.37	0.28	43.26	28.35	1,456
Wood	0.28	0.21	30.38	16.54	1,200
Paper	0.45	0.33	22.83	22.37	3,680
Publishing	0.36	0.27	18.85	6.35	1,483
Petroleum	0.68	0.50	13.86	20.61	938
Chemicals	3.59	2.22	10.56	19.28	17,926
Rubber_Plastics	1.63	1.18	12.81	22.54	10,437
Mineral	0.97	0.72	28.47	10.21	7,204
Metals	4.00	2.88	22.47	19.76	12,187
Fabricated metal	0.87	0.70	34.99	11.08	11,303
Machinery	2.44	1.64	8.98	21.38	27,773
Office Computing	10.89	5.35	41.00	20.56	452
Electrical machinery	1.61	1.12	38.10	25.10	4,016
Communication eq	25.93	12.48	19.68	20.82	18,707
Medical	3.55	2.49	8.49	23.45	6,449
Motor vehicles	10.07	4.79	14.45	15.28	19,105
Other transport	9.70	4.28	17.78	1.35	4,559
Furniture	1.36	1.09	43.12	15.29	2,738

Source: Authors' calculation, BACI, NICE KIS and KIPRIS

Table A-6: Innovation: SMEs vs Large Firms

	Small-Medium sized Enterprises					Large Firms					
Year	(1) No. Firms	(2) No. Patenting Firm	(3)=(2)/(1) % of Parenting Firm	(4) No.Patent	(5) No.Granted Patent	Year	(6) No. Firms	(7) No. Patenting Firm	(8)=(7)/(6) % of Parenting Firm	(9) No.Patent	(10) No.Granted Patent
1996	3,138	267	8.51	1,426	896	1996	907	210	23.15	52,063	18,399
1997	3,458	339	9.80	1,685	1,092	1997	930	231	24.84	40,539	18,543
1998	3,828	424	11.08	1,664	1,194	1998	969	257	26.52	22,059	10,770
1999	4,378	635	14.50	2,323	1,921	1999	1,022	297	29.06	23,764	14,232
2000	4,990	937	18.78	3,817	3,099	2000	1,082	365	33.73	21,497	13,516
2001	5,404	1,125	20.82	4,320	3,645	2001	1,121	394	35.15	24,002	15,822
2002	5,803	1,204	20.75	4,540	3,849	2002	1,170	387	33.08	32,609	20,356
2003	6,146	1,292	21.02	4,993	4,360	2003	1,204	447	37.13	40,975	25,349
2004	6,494	1,461	22.50	5,832	5,061	2004	1,248	493	39.50	47,271	27,199
2005	6,845	1,694	24.75	6,442	5,914	2005	1,283	548	42.71	53,131	32,306
2006	7,164	1,812	25.29	7,109	6,518	2006	1,317	575	43.66	51,851	32,223
2007	7,265	1,824	25.11	7,150	5,774	2007	1,301	534	41.05	46,521	27,983
2008	7,507	1,871	24.92	7,998	6,177	2008	1,340	581	43.36	41,369	24,342
2009	7,764	2,092	26.94	8,762	6,938	2009	1,381	617	44.68	35,799	21,968
2010	8,087	2,131	26.35	8,437	6,719	2010	1,397	622	44.52	38,703	23,162
2011	8,357	2,267	27.13	9,016	7,215	2011	1,428	648	45.38	40,850	17,208
2012	8,636	2,395	27.73	10,017	8,194	2012	1,457	649	44.54	45,473	17,166
2013	8,794	2,461	27.98	10,143	8,184	2013	1,473	667	45.28	48,320	17,185
2014	8,808	2,443	27.74	10,094	7,535	2014	1,473	617	41.89	47,110	16,467
2015	8,668	2,269	26.18	9,994	6,420	2015	1,412	594	42.07	43,832	11,033

Source: Authors' calculation, KIS and KIPRIS

Table A-7: Innovation: Private vs Public Firms

	Private Firms					Public Firms					
	(1)	(2)	(3)=(2)/(1)	(4)	(5)		(6)	(7)	(8)=(7)/(6)	(9)	(10)
Year	No. Firms	No. Patenting Firm	% of Parenting Firm	No.Patent	No.Granted Patent	Year	No. Firms	No. Patenting Firm	% of Parenting Firm	No.Patent	No.Granted Patent
1996	3,346	282	8.43	1,201	818	1996	699	195	27.90	52,288	18,477
1997	3,652	349	9.56	1,579	1,146	1997	736	221	30.03	40,645	18,489
1998	4,013	439	10.94	2,168	1,437	1998	784	242	30.87	21,555	10,527
1999	4,545	622	13.69	2,668	2,056	1999	855	310	36.26	23,419	14,097
2000	5,127	903	17.61	3,806	3,182	2000	945	399	42.22	21,508	13,433
2001	5,548	1,083	19.52	4,573	3,766	2001	977	436	44.63	23,749	15,701
2002	5,956	1,148	19.27	4,845	4,018	2002	1,017	443	43.56	32,304	20,187
2003	6,308	1,241	19.67	7,072	5,507	2003	1,042	498	47.79	38,896	24,202
2004	6,661	1,415	21.24	8,791	6,359	2004	1,081	539	49.86	44,312	25,901
2005	7,026	1,646	23.43	10,088	7,847	2005	1,102	596	54.08	49,485	30,373
2006	7,357	1,760	23.92	10,908	8,651	2006	1,124	627	55.78	48,052	30,090
2007	7,455	1,754	23.53	9,906	6,945	2007	1,111	604	54.37	43,765	26,812
2008	7,714	1,834	23.77	11,235	7,617	2008	1,133	618	54.55	38,132	22,902
2009	8,010	2,068	25.82	10,828	7,884	2009	1,135	641	56.48	33,733	21,022
2010	8,316	2,088	25.11	10,704	7,828	2010	1,168	665	56.93	36,436	22,053
2011	8,619	2,215	25.70	11,241	8,003	2011	1,166	700	60.03	38,625	16,420
2012	8,911	2,351	26.38	14,246	9,256	2012	1,182	693	58.63	41,244	16,104
2013	9,073	2,414	26.61	16,034	9,442	2013	1,194	714	59.80	42,429	15,927
2014	9,098	2,365	25.99	14,858	8,262	2014	1,183	695	58.75	42,346	15,740
2015	8,953	2,194	24.51	14,940	6,794	2015	1,127	669	59.36	38,886	10,659

Source: Authors' calculation, NICE KIS and KIPRIS

Table A-8: High Quality Sector, ISIC Rev3 4-digit

High Quality Sector	
ISIC code	Description
1511	Production, processing and preserving of meat and meat products
1513	Processing and preserving of fruit and vegetables
1544	Manufacture of macaroni, noodles, couscous and similar farinaceous products
1711	Preparation and spinning of textile fibres; weaving of textiles
1721	Manufacture of made-up textile articles, except apparel
1729	Manufacture of other textiles n.e.c.
1730	Manufacture of knitted and crocheted fabrics and articles
1810	Manufacture of wearing apparel, except fur apparel
1911	Tanning and dressing of leather
1912	Manufacture of luggage, handbags and the like, saddlery and harness
1920	Manufacture of footwear
2022	Manufacture of builders' carpentry and joinery
2029	Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials
2102	Manufacture of corrugated paper and paperboard and of containers of paper and paperboard
2109	Manufacture of other articles of paper and paperboard
2211	Publishing of books, brochures, musical books and other publications
2213	Publishing of recorded media
2219	Other publishing
2222	Service activities related to printing
2330	Processing of nuclear fuel
2421	Manufacture of pesticides and other agro-chemical products
2422	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
2429	Manufacture of other chemical products n.e.c.
2511	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
2519	Manufacture of other rubber products
2610	Manufacture of glass and glass products
2691	Manufacture of non-structural non-refractory ceramic ware
2696	Cutting, shaping and finishing of stone
2699	Manufacture of other non-metallic mineral products n.e.c.
2720	Manufacture of basic precious and non-ferrous metals
2811	Manufacture of structural metal products
2812	Manufacture of tanks, reservoirs and containers of metal
2893	Manufacture of cutlery, hand tools and general hardware
2911	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
2912	Manufacture of pumps, compressors, taps and valves
2913	Manufacture of bearings, gears, gearing and driving elements
2914	Manufacture of ovens, furnaces and furnace burners
2915	Manufacture of lifting and handling equipment
2919	Manufacture of other general purpose machinery
2921	Manufacture of agricultural and forestry machinery
2922	Manufacture of machine-tools
2924	Manufacture of machinery for mining, quarrying and construction
2925	Manufacture of machinery for food, beverage and tobacco processing
2926	Manufacture of machinery for textile, apparel and leather production
2929	Manufacture of other special purpose machinery
2930	Manufacture of domestic appliances n.e.c.
3000	Manufacture of office, accounting and computing machinery
3110	Manufacture of electric motors, generators and transformers
3120	Manufacture of electricity distribution and control apparatus
3150	Manufacture of electric lamps and lighting equipment
3190	Manufacture of other electrical equipment n.e.c.
3210	Manufacture of electronic valves and tubes and other electronic components
3220	Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy
3230	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods
3311	Manufacture of medical and surgical equipment and orthopaedic appliances
3312	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
3313	Manufacture of industrial process control equipment
3320	Manufacture of optical instruments and photographic equipment
3410	Manufacture of motor vehicles
3430	Manufacture of parts and accessories for motor vehicles and their engines
3512	Building and repairing of pleasure and sporting boats
3520	Manufacture of railway and tramway locomotives and rolling stock
3530	Manufacture of aircraft and spacecraft
3591	Manufacture of motorcycles
3592	Manufacture of bicycles and invalid carriages
3599	Manufacture of other transport equipment n.e.c.
3610	Manufacture of furniture
3692	Manufacture of musical instruments
3693	Manufacture of sports goods
3694	Manufacture of games and toys
3699	Other manufacturing n.e.c.

Source: Authors' calculation, BACI CEPII

Table A-9: Other Sector, ISIC Rev3 4-digit

Other Sectors	
ISIC code	Description
1512	Processing and preserving of fish and fish products
1514	Manufacture of vegetable and animal oils and fats
1520	Manufacture of dairy products
1531	Manufacture of grain mill products
1532	Manufacture of starches and starch products
1533	Manufacture of prepared animal feeds
1541	Manufacture of bakery products
1542	Manufacture of sugar
1543	Manufacture of cocoa, chocolate and sugar confectionery
1549	Manufacture of other food products n.e.c.
1551	Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials
1552	Manufacture of wines
1553	Manufacture of malt liquors and malt
1554	Manufacture of soft drinks; production of mineral waters
1600	Manufacture of tobacco products
1722	Manufacture of carpets and rugs
1723	Manufacture of cordage, rope, twine and netting
1820	Dressing and dyeing of fur; manufacture of articles of fur
2010	Sawmilling and planing of wood
2021	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board and other panels and boards
2023	Manufacture of wooden containers
2101	Manufacture of pulp, paper and paperboard
2212	Publishing of newspapers, journals and periodicals
2221	Printing
2310	Manufacture of coke oven products
2320	Manufacture of refined petroleum products
2411	Manufacture of basic chemicals, except fertilizers and nitrogen compounds
2412	Manufacture of fertilizers and nitrogen compounds
2413	Manufacture of plastics in primary forms and of synthetic rubber
2423	Manufacture of pharmaceuticals, medicinal chemicals and botanical products
2424	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
2430	Manufacture of man-made fibres
2520	Manufacture of plastics products
2692	Manufacture of refractory ceramic products
2693	Manufacture of structural non-refractory clay and ceramic products
2694	Manufacture of cement, lime and plaster
2695	Manufacture of articles of concrete, cement and plaster
2710	Manufacture of basic iron and steel
2813	Manufacture of steam generators, except central heating hot water boilers
2899	Manufacture of other fabricated metal products n.e.c.
2923	Manufacture of machinery for metallurgy
2927	Manufacture of weapons and ammunition
3130	Manufacture of insulated wire and cable
3140	Manufacture of accumulators, primary cells and primary batteries
3420	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
3511	Building and repairing of ships
3691	Manufacture of jewellery and related articles

Source: Authors' calculation, BACI CEPII

Table A-10: Innovation in Production Estimation

	(1)	(2)
Patent	0.012***	
	(0.004)	
(Granted)Patent		0.014***
		(0.004)
Capital	0.190***	0.193***
	(0.008)	(0.010)
Labor	0.279***	0.280***
	(0.008)	(0.011)
Input Cost	0.472***	0.470***
	(0.012)	(0.017)
Observations	40640	40640

* The dependent variable in the regression is a sales of a firm in logarithm. Control variables are the number of labor, capital, investment, raw material cost, and the number of (granted) patent plus 1 of a firm. All variables are in logarithm. Included FE are 2-digit sector FE, and year FE. Standard errors are in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix B. Explanation of Matching Strategy

We conduct the matching based on following rules. First, we match the firm to the patent data when the name of the firm is precisely matched. For instance, the number of a patent for LG Electronics is 2, and that of LG Telecom is 1 (see the table below).

Applicantname	Applicationnumber
LG electronics Inc.	1020020005278
LG electronics Incorporated.	1020020003839
LG Telecom Inc.	1020020001497

Second, the matching does not account for affiliates. For example, we count the number of patents for "CJ, Inc." and "CJ Food, Inc." differently even if they are the affiliates (see the table below).

Applicantname	Applicationnumber
CJ Inc.	1020020022748
CJ Food Inc.	1020020003280

Third, if a patent is applied by multiple applicants, we assign this patent to each of the applicants. For example, if LG Electronics, Inc. (엘지 전자 (주) in Korean) and Samsung Electronics, Inc. (삼성전자 (주) in Korean) are the applicants for a patent, we assign the patent to each firm (see the table below).

Applicantname	Applicationnumber
LG electronics Inc., Samsung electornics Incorporated.	1020030031598

After we match the patent information to the firm, we remove the duplicates of the patents based on the unique patent application number and granted patent number.

Appendix C. Alternative Measurements of Innovation: Labor Productivity and TFP

There are many ways to define innovation outcomes. Many studies in the literature on this topic have used labor productivity or TFP as proxies for the innovation levels of firms. Labor productivity is highly correlated to innovation as new technology can lower production costs, and it can increase the productivity of the labor force. Also, TFP measures the technology component of the production. For this section, we conduct a baseline IV estimation of labor productivity with TFP as a dependent variable. We define labor productivity as sales of a firm divided by the number of employees, and we follow the TFP calculation based on the method of Olley and Pekes. We control for the firm characteristics of the age and capital.

Table C-1: Baseline IV results:
Other Innovation Measurements

	Labor Productivity			TFP		
	(1)	(2)	(3)	(4)	(5)	(6)
IMP_CHN	0.076**		0.143***	0.010*		0.019**
	(0.031)		(0.044)	(0.006)		(0.009)
EXP_CHN		0.092***	0.141***		0.007	0.015**
		(0.024)	(0.035)		(0.004)	(0.007)
Observations	91587	91589	91587	59832	59834	59832

* The dependent variables in the regression is labor productivity and TFP in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The estimation using the instrumental variable shows that the labor productivity of a firm is positively associated with Chinese imports and exports in the sector (Table C-1). A 10% increase in Chinese imports boosts labor productivity by 1.43% and TFP by 0.19%. The export channel is proven to have a positive link to the alternative innovation outcomes of a firm, such that a 10% increase in exports with China may induce higher labor productivity by 1.41% and TFP by 0.15%. This result confirms our main finding of the positive trade linkage to firm-level innovation responses, and it also relates to recent empirical findings of productivity gains from trading with China by Ahn and Duval (2017).[17]

[17] Ahn, J. Bin, & Duval, R. (2017). Trading with China: Productivity gains, job losses. Economics Letters, 160, 38–42.

Appendix D. Long-Run Effects

For this section, we expand the analysis with more lagged variables of trade. We examine the relationship by adding the two to four-year lagged import and export variables into the baseline (Table D-1).

Table D-1: Baseline IV Results: Long-Run Effects

	Patent				(Granted) Patent			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IMP_CHN_L1	0.158***	0.125	0.131*	1.114	0.176***	0.056	0.135*	0.792
	(0.053)	(0.159)	(0.073)	(1.688)	(0.050)	(0.153)	(0.070)	(1.245)
EXP_CHN_L1	0.117***	0.093	0.079	1.902	0.129***	-0.032	0.081	1.320
	(0.040)	(0.277)	(0.134)	(3.023)	(0.037)	(0.268)	(0.129)	(2.227)
IMP_CHN_L2		0.054	0.060	-0.979		0.154	0.122	-0.611
		(0.179)	(0.092)	(1.702)		(0.175)	(0.086)	(1.252)
EXP_CHN_L2		0.020	0.065	-1.859		0.142	0.107	-1.219
		(0.252)	(0.132)	(3.101)		(0.245)	(0.126)	(2.285)
IMP_CHN_L3			0.005	-1.327			-0.058	-0.938
			(0.085)	(2.214)			(0.083)	(1.628)
EXP_CHN_L3			-0.028	0.013			-0.065	-0.030
			(0.064)	(0.189)			(0.061)	(0.138)
IMP_CHN_L4				0.497				0.309
				(0.848)				(0.618)
EXP_CHN_L4				-0.151				-0.087
				(0.293)				(0.223)
Observations	91587	89592	87200	84574	91587	89592	87200	84574

* The dependent variables in the regression are the number of the patent application, granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The IV estimation reveals that the impacts from both import and export variables persist to be significant in 1-year lags (Column 1 and column 5). It implies that competition in imports and export channels with China boost the innovation response of a firm in a short period, and have lesser or no long-run effects over time.

Appendix E. Different Sample Period

In this section, we test the research question by decomposing the period of the sample. Trade between Korea and China substantially increased after China became the member of WTO in 2001. From the observation, we separate the analysis into two periods, which are 1996-2000 and 2001-2015.

Table E-1: Baseline IV Results: Pre & Post WTO

	1996-2000		2001-2015		1996-2015	
	(1) Patent	(2) Patent(G)	(3) Patent	(4) Patent(G)	(5) Patent	(6) Patent(G)
IMP_CHN	-0.250	-0.240	0.175*	0.214**	0.158***	0.176***
	(0.221)	(0.203)	(0.097)	(0.093)	(0.053)	(0.050)
EXP_CHN	0.445	0.386	0.144**	0.172***	0.117***	0.129***
	(0.350)	(0.320)	(0.058)	(0.055)	(0.040)	(0.037)
Observations	12697	12697	78432	78432	91587	91587

* The dependent variables in the regression are the number of the patent application, granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales, and capital of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table E-1 shows that import and export from China do not have a significant impact on innovation outcome of Korean Manufacturing firm during China's pre-WTO periods (Column 1 and Column 2). On the other hand, trade with China is positively correlated to the innovation of Korean manufacturing firm after China joined the WTO. The result implies that the positive association between trade with China and innovation is robust when the trade is sufficiently grown.

Appendix F. Alternative Measurements of China Trade Shock

Our main identification strategy for the China trade shocks is the import and export shares, which are scaled by total imports and exports. To check the robustness of our main finding, we measure China shocks scaled by total production(Y_{jt}) as follow.

$$IMP_{jt-1}^{CHN} = 100 * (\frac{M_{jt-1}^{CHN}}{Y_{jt-1}}) \tag{6}$$

$$EXP_{jt-1}^{CHN} = 100 * (\frac{X_{jt-1}^{CHN}}{Y_{jt-1}}) \tag{7}$$

To build the variables, we retrieve production data for each industry from ISTANS (Industrial Statistics Analysis System), provided by KIET (Korea Institute for Industrial Economics and Trade). ISTANS data is composed of 40 manufacturing industries. Since ISTANS industry classification does not follow the international industry classification, we manually assign the 40 industries into ISIC Rev3 (2-digit) classification[18].

Table F-1: Baseline IV Results: Scale by Production

	Restricted Sample		Full Sample	
	(1) Patent	(2) (Granted)Patent	(3) Patent	(4) (Granted)Patent
IMP_CHN_P	0.041*	0.039*	0.051***	0.055***
	(0.024)	(0.022)	(0.018)	(0.017)
EXP_CHN_P	0.047*	0.067***	0.077***	0.115***
	(0.028)	(0.026)	(0.024)	(0.022)
Observations	93810	93810	128059	128059

* The dependent variables in the regression are the number of the patent application, granted patent plus 1 in logarithm. Firm control variables are the age, number of employees, sales of a firm. Firm FE Year FE and sector trends are included. All variables are in logarithm. Standard errors are clustered on firms. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The results of both restricted and full sample deliver concrete evidence that trade with China is positively associated with innovation outcome of the Korean manufacturing firm. Significances and size of the impacts are smaller than the baseline estimates. However, the direction of the result still holds as the baseline result.

[18] Detailed matching table refers to Table F-2.

Table F-2: Corresponding Table: ISTANS to ISIC Rev.3 (2-digit)

ISIC Rev.3	ISTANS
15	(1401) Food products and beverages
16	(1402) Tobacco products
17	(1403) Textiles
18	(1404) Wearing apparel
19	(1405) Leather, Footwear
20	(1406) Wood
21	(1407) Paper
22	(1408) Printing
23	(1301) Refined petroleum
24	(1201) Petroleum Chemicals (1202) Chemicals
25	(1302) Rubber (1303) Plastics
26	(1304) Glass (1305) Ceramic (1306) Cement (1307) Non-metallic mineral products n.e.c
27	(1308) Iron and steel (1309) Non-ferrous metals
28	(1310) Casting of metals (1311) Fabricated metal products
29	(1106) Domestic appliances (1205) General purpose machinery (1206) Special purpose machinery
30	(1104) Computing machinery
31	(1103) Display (1107) Precision instrument (1108) Accumulators (1203) Other electrical equipment n.e.c. (1204) Electrical machinery
32	(1102) Semi-conductor (1105) Communication equipment
33	(1101) Medical
34	(1207) Motor vehicles
35	(1109) Aircraft (1208) Railway (1209) Transport equipment n.e.c (1312) Ships
36	(1409) Furniture