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Innovation responses of Japanese firms to Chinese import competition*

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Abstract

This paper examines innovation response of a panel of Japanese firms to the intensified import competition from China for the period 1995-2010. We build a comprehensive firm-level dataset linking innovation activities including patenting and research and development (R&D) merged to cross-industry measures of Chinese import competition. Carefully accounting for a simultaneity bias between innovation and importing and the possible heterogeneous effects across firms, it is found that firms filed for more patens in response to increased import competition from China. However, this effect is only evident for a group of globally engaged firms. At the same time, Chinese import competition has adversely affected the quality of innovation as measured by citations. Overall, firms with a more domestic market focus are the ones who have felt most of the Chinese import competition, which is also reflected in the ir declined R&D efforts.

Keywords: Innovation, Patents, R&D, Import competition, Japan, China
JEL classification: F14, O31, O32

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1. Introduction

In 2010 China overtook Germany to become the world's largest manufacturing exporter, having increased its share in world exports to almost 10% up from around 3% in 1999 – one of the most monumental events in our time, exerting the tremendous competitive pressures on the world economy. Substantial evidence now suggests that an exposure to Chinese import competition has the adverse effects on the wider dimensions of manufacturing activities in developed countries including the survival rate of manufacturing plants (Bernard et al. 2006), large contraction in manufacturing employment (Pierce and Schott 2015), depressing wages and the employment prospects for occupations and skills which can be easily substituted from Chinese goods (Autor et al. 2013, Autor et al. 2015, Ebensteinet et al. 2014, 2016, Hummels et al. 2013). However, the impact of import competition from China on innovation has so far comparably received sparse attentions. This is rather surprising because the above studies also suggest that import competition from China can foster skill-biased technological change (Ultar and Torres Ruiz 2013) and the corresponding productivity growth in firms and industries which are more exposed to Chinese import competition (Mion and Zhu 2013).

Against this backdrop this paper examines innovation response of Japanese firms to the increased Chinese import competition in the period 1995-2010.[2] [3] We build a comprehensive, firm-level dataset merging firm-level accounting information with patent statistics drawn from the Institute of Intellectual Property (IIP) Patent Database (Goto and Motohashi 2007).[4] The data are complemented by an index measuring firms' exposure to the intensity of cross-industry Chinese import competition.

The exploration in the present study is motivated by the inconclusive findings of existing studies. Studies examining which are available to us offer mixed evidence on the effects of Chinese import competition on innovation (Bloom et al. 2005; Arora et al. 2015; Autor et al. 2016). Collecting data for a large sample of European firms, Bloom et al. (2015) find that innovating firms have proactively responded to the intensified Chinese import competition by increasing a wider range of innovative activities including patenting, research and development expenditures, computer usage, and TFP growth.[5] The contradictory evidence is found in Autor et al. (2016) that Chinese import competition does actually lead to not only a decline in patenting by U.S. firms but also the profitability and R&D investment in the affected industries.

[2] We focus on 'domestic innovation' because our measure of innovation covers patents that are applied by the residents (i.e. firms) in the Japan Patent Office (JPO).
[3] The end year 2010 is set due to the data constraints of patent statistics (to be discussed in section 4).
[4] The data matching procedure undertook between firm accounting data and the patent statistics is similar to the NBER project (matching Compustats and U.S. patent data). Our work is the first attempt to create the matched firm-patent dataset for Japanese firms. We describe the name matching procedure in section 4. Compared to the Compustats in the U.S. studies, our dataset covers both unlisted and listed companies, while the Compustats based on the NBER project only cover listed companies.
[5] It should be noted that Wood (1994) raises a similar question much earlier but his focus is on import competition from low-wage countries more broadly, not just China.

In light of the divergent empirical findings, a key concern is that innovation and importing from China are the endogenous decisions of firms. For example, it is possible that firms in industrial economies opt out to import the labour-intensive segment of production and intermediate and raw materials from China may optimally shift the within-firm resource enhancing the innovative capacity (Grossman and Rossi-Hansberg 2008). Hence, importing from China may not be an accurate indicator of the product market competition.[6] We first tackle this identification challenge by employing more detailed dataset reporting firms importing activities. Our dataset allows us to split firms into importing and non-importing at firm-level. The latter group of firms are completely insulated from the identification concern, but they are still exposed to increased competition from China. Hence, this splitting can create exogenous import shock to this group of firms. Second, we employ the instrumental variable based on the degree of cross-industry Chinese import competition in the pre-sample period. This is an effort of isolating the influence from Japan-specific demand factors.

We find evidence that Japanese firms respond positively by patenting more when exposed to greater Chinese import competition. But, an in-depth analysis presents more nuanced interpretations: Global firms, defined as firms engaging both exporting and importing, have responded positively by patenting more as compared to the group of firms with the domestic focus. However, increased patenting is mostly driven by incremental innovation (measured by patents attached zero citation). We do not find that innovation efforts (measured by R&D expenditures) increase in tandem with patenting. Instead, it is found that the group of firms with a domestic market focus are the ones most impacted by increased Chinese import competition, which is reflected in the cutting back in their R&D expenditures.

Overall, as China's export bundles have sharply moved up from more labour-intensive to more capital-intensive industries, this does not result in stimulating innovation in Japan. Rather, our evidence points to the possibility that firms, especially those that focus more on external markets, strategically increase patenting as the defensive means in response to Chinese import competition without exerting more research effort. On the other hand, firms focusing on the domestic market are the ones that have been squeezed more by import competition from China and their innovation efforts have decreased.

The organization of this paper is as follows. The next section presents an overview of Chinese performance in order to capture the evolution of the Chinese import competition felt across manufacturing industries in Japan. Section 3 presents the empirical methodology, followed by a discussion on data and the variable construction in Section 4. Section 5 summarised the main findings before concluding the paper in Section 6.

[6] The process of production networks between Japan and China is much more prevalent as compared to the U.S. and Europe because of the active operations of Japanese multinational firms (Yamashita, 2010).

2. The Rise of China in World Trade

Figure 1 depicts the rise of China in world exports for the period 1990-2011. In 1990 China's exports accounted for the small share (around 3%) in world exports. Since then, China's share has gradually increased. In particular, China's export growth took off since around the early 2000s around time of China's admission to the WTO. In the second half of 2000s, China has achieved a formidable export expansion by overtaking Germany for the position of the world's largest exporter, accounting for above 10% of world exports. China's export share has been growing without any disruptions, while the world shares of Japan, the USA and Germany have not grown during the same period.

With the rise of China in world trade, its specialisation has dramatically changed as well. Figure 2 depicts the share of relatively more capital and technology-intensive products of electrical machinery and household electric appliances as compared to more labour-intensive products of textiles and toys. There has been a notable shift of comparative advantages from more labour-intensive products towards more capital and technology-intensive products. In 1992 textiles and toys account for around 45% in China's total exports. However, its share continuously declined and dropped close to 20% in 2011. On the other hand, the export share of electrical machinery and household appliances doubled the share from less than 15% in 1992 to 30% in 2011. In this product category, the export composition is highly concentrated in 'Information Communication Technology' (ICT) products. Other important product categories include office machines, and telecommunication sound equipment (including smart phones).

Some commentators (eg, Rodrik 2006) argue that there has been a sign that technological capability of China has already taken off and has been rapidly converging to one of advanced OECD countries technology standard ladder based on a measure of GDP per capita weighted export bundle of Chinese goods. However, this should be interpreted cautiously. Once allowing for international fragmentation of production and global production networks, China's export specialisation still largely rests on the labour-intensive assembly stage rather than specialisation in technological content in the high-tech industries such as consumer electronics (Athukorala 2009). This explains why Schott (2008) observes that the unit price of Chinese export bundles hover around the lower rung of the unit-price range, as compared to those of OECD countries despite a widespread overlap (see also Kiyota 2014). In sum, the bulk of Chinese exports are the mass-market commodities assembled with relatively low unit costs and imported high-tech parts and components from other industrial economies.

From the theoretical points of views, it is also interesting how the increased import competition from a low-wage country (China) shapes the innovation activities of the firms in a developed country (Japan). In general, theoretical predictions of competition on innovation of incumbent firms remains ambiguous: Aghion et al. (2005) and subsequent studies have theoretically and empirically verified that innovation efforts are the greatest when firms are exposed to the intermediate level of competition because of a possibility of the post-innovation rents exceeding the pre-innovation rents.[7] However, this pro-competitive motive does not sit well with an explanation of the innovation consequence of low-cost import competition because of the possibility of non-overlapping in the product market competition. In a different modelling framework, Thoenig and Verdier (2003) postulates that firms in developed countries innovate more by upgrading their technologies when they are more exposed to low-cost import competitions. Bloom et al. (2012, 2013) introduce the 'trapped' factors of production (eg, firm-specific skilled workers) to model innovation response of import competition from China. In this model, firms which are exposed to low-technology intensive import competition deploy the trapped factors by making the product lines with more updated technologies, resulting in more innovation. All in all, without a clear theoretical guidance, the effects of Chinese import competition is an intrinsically empirical question.

3. Innovation and Import Competition

Our estimation strategy follows estimating the knowledge production approach capturing patent outputs as the dependent variable and research inputs in the explanatory variables (Parkes and Griliches, 1980, Dang and Motohashi 2015). We consider the log-linear specification, allowing for a set of firm and year fixed effects. It takes the following form,

(1) $$\ln(PAT)_{it} = \alpha_i + \alpha_t + \beta_1 \ln(IM^{China})_{jt-1} + \varphi' X_{it-1} + \varepsilon_{it}$$

where *PAT* represents the number of patents applied by firm *i* in year *t*. Firm fixed effects (α_i) purges any time invariant shocks common such as the unobserved managerial techniques within firms and industry specific propensity to patent which are time invariant characteristics. Firm-fixed effects also subsume industry fixed effects in which firms are affiliated with. It is well known that some industries have higher propensity to patent than other industries (eg, pharmaceutical). Year fixed effects (α_t) control for unobservable variations in patenting over time which is common across firms and industries (such as the business cycle) and any major change in the patent policy affecting all patentees.

The explanatory variable of our interest, IM^{China} captures the effects of industry-level (*j*) import penetration from China on patenting for firm *i*, lagged for one year to reduce the simultaneity concern. The exposure to Chinese import competition is thus defined at follow.

(2) $$IM^{China}{}_{it-1} = \frac{M^{\text{China}}_{j,t-1}}{(Q_{j,t-1} + M^{Total}{}_{j,t-1}) - X_{j,t-1}}$$

IM^{China} denotes the value of imports originating from China as the share of domestic absorption (defined as domestic absorption = (value added + imports) – exports) for industry *j* at year *t*.[8] [9] If β_1 turns out to be positive and supported by the statistical significance, it indicates the pro-competitive effects of Chinese import competition stimulating firms to innovate.

The vector of firm-level controls (***X***) includes other firm-level factors influencing innovation performance.[10] It controls several innovation inputs proxied by the intensity of R&D, and dummies for zero R&D expenses per firm-year cells. The number of total employment is also included to capture the size of firms and possible economies of scale in patent production. These firm-level factors are also lagged one year to reduce the simultaneity concern. The standard errors are clustered at the level of firm.

Because of the inclusion of the large number of fixed effects in the above specification, we opted out to estimate the nonlinear count-data model which is known for the serious bias created due to the incidental parameter problem (Eberhardt et al. 2016). We also prefer the linear estimator because it is easier to implement the instrumental variable with a large number of fixed effects (Angrist and Pischke, 2009).

To further complement the patent analysis, we also perform a regression analysis by placing R&D expenditure in the dependent variable in equation (1). In contrast to patent counts, R&D is treated as innovation inputs. Hence, two indicators being put together offer a more comprehensive picture of Japanese firms' innovative response to Chinese import competition.

Identification strategy

An important identification issue in the above formulation is that the effects of Chinese import competition on innovation may be endogenous: It is well known that many Japanese firms import intermediate inputs and raw materials from China as a part of the offshoring strategies (Yamashita, 2010). As a consequence, the degree of import competition from China may not be an accurate indicator of the pro-competitive effects to innovation. It is possible that more patenting is just a reflection of importing offshored labour-intensive parts of the production from China. To some extent, it is a lesser problem in our context because Chinese import competition is constructed at industry level, while

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[8] Value-added is defined as the difference between gross output and intermediate inputs Gross output is measured as the sum of industry shipment, revenues from repairing and fixing services, and revenues from performing subcontracting works. Intermediate inputs are defined as the sum of raw materials, fuels, electricity, and subcontracting expenditure.

[9] Alternatively, we define import competition as the share of imports from China derived from total industry import at industry j. However, the results remain the same.

[10] By the focus of our analysis, the effect of exports to China on innovation is ignored. However, the preliminary analysis suggests that including export to China does not alter the main results of the analysis.

innovation activities are captured at firm-level.[11] However, a simultaneity bias might not be removed completely. To address this, we implement the following approaches.

First, we simply split the sample of firms according to their external engagement and estimate patent count regressions in the group-wise fashion. The benefit of the split sample approach is that Chinese import penetration creates exogenous variation to firms which do not engage in importing. More specifically, we define the sample of firms according to a firm-level record of importing and exporting activities. It should be noted that at firm-level we do not have information of exporting and importing by the geographical destinations (eg, importing from and exporting to China). Instead, our dataset only record firms with total value of importing and exporting. 'Pure domestic firms' are defined as the ones whose the main line of business exclusively confine to the domestic (Japanese) market, with no records of importing and exporting during the entire estimation period. This is admittedly a naïve definition. However, it is a necessary requirement so that our estimation is free from being contaminated by the reserve causality (eg, innovating firms start to import more from China leading to more import penetration). We also define the sample of firms with at least one-year importing (and exporting) firms (denoted 'globally engaged firms') during the entire estimation period. It is well established in the literature that global engaged firms have the intrinsic aptitude being innovative as compared to pure domestic firms. Hence, the innovative responses between two types of firms ought to be different.

Second, we perform an instrumental variable (IV) estimation to identify the impact of import competition on innovation. Our instrument is a natural modification of the method used by Autor et al. (2016). Our instrument takes the following form;

(3)
$$IM_{US,j,t=1991}^{China} = \frac{M_{US,j,t=1991}^{\text{China}}}{(Q_{j,t=1991} + M^{Total}{}_{j,t=1991}) - X_{j,t=1991}} \times IM_{World,t}^{China}$$

where $IM_{US,j,t=1991}^{China}$ denotes the share of China in US import in year 1991 and $IM_{World,t}^{China}$ is the share of China in world imports in year *t*. This instrument is potentially correlated with the import penetration in the corresponding industry *j* in Japan because it reflects the relative competitiveness of China in industry.

This instrument limits industry-specific U.S. imports from China in year 1991 (ie, $IM_{US,j,t=1991}^{China}$) in the pre-sample period and gives the weight to the time-variant share of China in world imports in year *t*.[12] In other words, it captures the cross-industry variation of the pre-sample conditions of Chinese

[11] This means that each individual firms are small enough to influence the degree of Chinese import penetration. Hence, industry-level import competition should be treated as the exogenous shock to firms.

[12] All results are robust to the following variations. First, instead of fixing the initial condition at year1991, we made the share of China in US imports at time variant *t*. Second, the denominator in equation (4) is replaced by total US imports for industry *j* and year *t*.

import competition in U.S. industries, weighted by the time-variant share of China in world total imports to capture an overall trend of Chinese relative competitiveness. Arguably, the pre-sample condition in U.S. industries and the time-varying share of China in world imports are exogenous to the view of Japanese firms, little driven by changes in Japan-specific demand. By not directly relating to import penetration in Japanese industries, Eq.(3) can capture the productivity component underlying the sharp rise in Chinese import penetration, not driven by the industry-specific demand factors (Ulta and Ruiz 2013, Bloom et al. 2015). The U.S. data come from David Dorn's website[13] which stores the data for U.S. imports from China at 4-digit industries of Standard Industry Classification (SIC) for the period 1991-2007.[14]

4. Data and variables

METI-IIP dataset

We combine data from two sources of microdata to create a novel firm-level dataset. We first extract the Japanese firm accounting data from *the Basic Survey of Japanese Business Structure and Activities*, conducted by the Ministry of Economy, Trade and Industry in Japan.[15] The original survey sample is restricted to any firms that have both more than 50 employees and capital of more than 30 million yen (≈US$300,000). The survey collects firms' accounting information (sales, the number of employment, R&D spending, values of exports, and imports). The industry classification is available at 3-digit level. Because of the interest in this study, the data has been restricted to cover only manufacturing firms. All individual firms are assigned the unique identifier, making it possible to track the same firms over time.

We piece together the dataset linking patent statistics to firm-accounting information. The Institute of Intellectual Property (IIP) Patent File provides a rich set of information including patent application (traceable by the unique application number), patent assignee names, the number of citation received (also, citing patents) by each patent, etc. (Motohashi and Goto 2007). Matching between patent applications and firm-level accounting data is complicated by inconsistencies in how firm names are listed in the patent records in IIP files due to spelling (Japanese, Chinese and Roman characters) and typographical variations. With an absent of consistent firm ID between METI and IIP database, string (name) matching was mediated by the company directory prepared by the NISTEP.[16] This directory contains the 'consistent' name of firms listed in the IIP database. After assigning the consistent name

[13] http://www.ddorn.net
[14] Alternatively, we also experimented the share of imports from China in other advanced countries other than Japan and the U.S. but the results are quantitively the same.
[15] This firm-level survey is governed by the statistical law in Japan, hence failing to reply results in the fine. Hence, the survey is thought to provide the reliable data.
[16] http://www.nistep.go.jp/en/?page_id=48

of firms, matching between METI firm data and the IIP Patent Database by firm names was conducted. We call the resultant dataset as METI-IIP. [17]

Industry level data are sourced from the Japan Industrial Productivity (JIP 2013) stored at the online database in the Research Institute of Economy, Trade and Industry (RIETI) in Japan.[18] Industry-level imports from China, exports and value-added are collected from the JIP database.

Variable construction

To gauge firms' innovativeness, we prepare the following metrics. First, we simply use the number of patent applications in each firm-year observations. This forms the dependent variable in patent estimation. Our patent data cover the application basis patents. Patent counts also preserve zeros in some firm-year cells. Following the standard procedure in the literature, we add one to the actual values before the natural logarithmic transformation.

Second, we control for the quality of patents by computing the number of forward citations per patent (ie, citations/patents) in firm-year cells. Given firms size and innovation inputs, the average number of citations captures the significance and quality of innovation outputs (Trajtenberg 1990, Hall et al. 2005). Additionally, citation information stored in IIP database offers a cleaner metric of the value of inventions since citations are provided by the examiners (Yamauchi and Nagaoka 2015). This limits the possibility of diluting citations made by the applicants' strategic motives (Lampe 2012).[19] Because forward citations suffer from the truncation problems,[20] we limit the number of citations received in a 5-year window.[21] Together with the inclusion of year-fixed effects, the truncation problem should be kept minimum.

Third, we collect patent counts which attracted zero forward citation. If more citations reflect the economic importance of patents, by the same reason patents with zero citations should indicate the lower quality (Amore et al. 2013). There are several reasons for why we may observe lower quality patents. Perhaps, the most common in the complex and cumulative technology industry such as Information and Communication Technology (ICT) is that firms take out patents in order to increase the transaction costs for new entrance ('patent thickets'). This nature of patents might not have the high inventive valuation but being highly effective blocking other patenting (Hall et al., 2014).[22]

[17] The METI-IIP database is similar to the NBER patent linking project led by Professor Hall in the USPTO. Ours would be the first project linking firm-level accounting information to patents in the Japan Patent Office (JPO).
[18] http://www.rieti.go.jp/en/database/JIP2013/
[19] The downside of the examiners' citations is that the use of citations become less informative about knowledge diffusions and technology transfers (Branstetter 2006).
[20] That is, newer patents receive relatively fewer citations, while the old ones are cited much more for the same technological importance between newer and older patents.
[21] We have also experimented it with a three-year window and all the cumulative citations until year 2014, but all the results are virtually unchanged.
[22] In contrast, a room for the strategic patenting is limited in the pharmaceutical, chemical and medical equipment industries because of the more discrete nature of technology. The stand-alone patents typically secure intellectual

Forth, we use counts of patents which are applied under the Patent Cooperation Treaty (PCT).[23] While the citation weighted patents can be informative about the underlying quality of innovation, they are by construction *ex post* - the valuation of technology by others arrives with significant time lags. Alternatively, PCT patents provide *ex anti* valuation of substantial innovation by patentees since the cost and standard of PCT patent filling are relatively higher than domestic patent filing. It hence serves a natural selection of only important innovations.

Descriptive statistics

Table 1 displays annual mean of selected variables used in a regression analysis below. Overall, annual average patent applications have been quite stable for the estimation period, hovering around 30 patent applications per firm. There was a sudden dip in the average number of patents in 2010 because of the global financial crisis in that year. The similar observations can be made for trends in R&D expenses.

There has been a surge in Chinese import penetration, up from less than 1 percent in 1995 closer to 6 percent in 2010. This is a contrast to the high income import penetration in which accounted for 3.5 percent at the beginning of the period in 1995 but has barely grown in the whole period. Hence, the rise of China has not only exerted the pro-competitive pressures to Japanese firms but also it has grown at the expenses of other high income exporters to Japan.

Table 2 presents the 2-digit industry distribution of patenting in total manufacturing and Chinese import penetration at industry average in year 1995, 2001 and 2010. Patenting is concentrated in three industries (electronic, transport equipment and instruments), making up 48 percent of patenting in total manufacturing. Traditionally, electronics related industries have comparatively the higher propensity to patent because some firms actively sell patents in return of the loyalty fees. Patenting in electronic and equipment has been the largest (around 20 percent in total) since 1995. This is the same industry who has experienced a sharp increase in Chinese import penetration (ie, up from 0.6 percent in 1995 to 11.2 percent in 2010). In textile industry where Chinese firms are considered to have comparative advantages over the Japanese counterparts, the degree of import competition was already felt strong in 1995 – 8 percent of Chinese import penetration accounting for the largest in 1995. It has continued to increase by reaching 40 percent in 2010. It is also notable that the Japanese textile industry has one of the lowest patenting activities in the whole industries.

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property of the whole invention in these industries. However, it should be noted that even in these industries we may also observe zero-cited patents because firms tend to apply patents at the infancy stage of R&D process. Because it usually takes 10-15 years for new drugs to be introduced to be commercialised, the substantial number of patents are not eventually commercialised. In this case, any inferences on zero-cited patents are more nuanced.

[23] PCT patents provide the intellectual protection up to 147 countries in a unified procedure.

5. Results

We report our empirical analyses and results first by presenting the patent equation both by OLS and instrumental variable regressions. We then proceed to report R&D equation. The results for the split sample are also presented in each table.

The benchmark results are shown in Table 3. We report from column (1) which includes all firms in the METI-IIP dataset. From column (2) onward, the sample of firms is split according to firm-level information of importing and exporting: column (2) only firms with zero records for both imports and exports (denoted as 'Pure domestic firms'), column (3) firms with positive imports and exports, denoted as 'Global firms'. Column (4) includes firms with positive records of exports and no import records. In column (5), firms are with positive records of imports but not engaged in exports.

Column (1) indicates that Chinese import competition (IM^{China}) has the positive effects on patent outputs.[24] The estimated coefficient suggests that a 10 percentage point increase in Chinese import penetration would lead to about 0.07 % increase in patenting, which is practically small. Once we move the split sample, the results vary. Global firms have proactively responded patenting (column 3),[25] while those with more focused on the domestic market (columns 2) have the muted response to the China shock. We also note that they are some variations of the innovation responses according to the different types of firms' engagement.

The model overall performs well and other firm-level controls show all the expected signs. The size of firm (measured by the number of employment) shows the expected positive effect indicating that economies of scale in patenting. Perhaps this also reflects the fact that larger firms are better financially positioned to engage in innovative activity (Nagaoka et al., 2010). In fact, among all the explanatory variables a variable EMP_{t-1}. has the largest estimated coefficient in patenting (ie, the magnitude of the estimate coefficient is 0.469 indicating that a 10% increase in the size would lead about 4.7% increase in patenting). As expected, the level of R&D expenses – an indicator of research inputs - shows a

[24] While not reported in Table 3, it is also robust to adding the following additional import competition from other country groups: from High income countries, Asian NIEs, and Developing Asia - High income is a group of countries in the following countries (U.S., Canada, Australia, Denmark, Finland, Germany, France, Spain, Italy, and Switzerland). Asian NIEs is made up from South Korea, Taiwan, and Singapore. Indonesia, Malaysia, Thailand, and the Philippines make up Developing Asia. These additional import competition measures are not statistically significant. Adding those explanatory variables hardly alter the estimated coefficient on Chinese import penetration. This documents that Chinese import competition stands out influencing innovation performance of Japanese firms.

[25] We note that 47% of total firms in this dataset are classified as 'global firms' (column 3). This indicates that about a half in our sample is firms which are both active in external engagement and patenting. This is consistent with studies demonstrating the high correlation between innovation and the external engagement (Bernard and Jensen, 2004). Put simply, more capable firms have more resources allocated to be innovative and can penetrate into other foreign countries. Hence, the threat of identification is more pronounced to global firms, in which we deal with the instrumental variable regression below.

positive sign with a statistical significance. In contrast, dummies for zero R&D expenses shows the depressed effects on patent counts.

The preceding observation is not strictly speaking of a causal relationship between import competition from China and innovation. We proceed to present instrumental variable (IV) estimation in Table 4.[26] We first note that the IV estimated coefficient on import competition from China is about an order of magnitude than the one obtained from using OLS method. The corresponding magnitude indicates that a 10 percentage point increase in import competition from China would increase the number of patent by 0.07% (OLS estimate) against 0.13% (IV estimate in column 1 in Table 4). This difference in magnitude implies that endogeneity was lending a problem with the downward biased estimate in Table 3.

Overall, IV estimates reinforce the view that Chinese import competition has induced firms to expand the innovation activities. However, we also detect the heterogeneous effects on innovation in the split sample. Pure domestic firms (column 2) have the muted response to Chinese import competition, while the positive effects are evident if firms engage to the external markets (column 3-5).

Table 5 presents IV estimation results after controlling for the quality of innovation by citations. To conserve the space, the estimation only presents the estimated coefficient instrumented IM^{China} in each row (from panel A to C), not displaying all other controls included in regressions. The dependent variable is the citation-weighted patent counts in panel (A), the number of PCT patents in panel (B), and the number of zero-cited patents in panel (C).

In panel (A), the results suggest that Chinese import competition impedes quality-adjusted innovation. Column (1) indicates that a 10 percentage increase in IM^{China} would lead to about 0.04% decline in citation-weighted patents after controlling for the size of firm and innovation inputs. The estimated magnitude is small but it does suggest that quality of patents has not improved in response to Chinese import competition. It also suggests that decline in the patent quality is more pronounced for firms engaged with global market (column 5).

In panel (B), the results indicate that firms are not necessarily patent for international markets in the response to the China shock. Panel (C), on the other hand, supports the view that enhanced patenting observed in Table 4 is largely driven by more incremental innovation (captured by counts of zero-cited patents). In column (1) it is found that a 10 percentage point increase in Chinese import competition would lead to about 0.09% increase in zero-cited patents. The same positive and statistically significance are retained only for global firms in column 3.

[26] The validity of our instruments is checked against the criteria presented in Angrist and Pischke (2009, Chapter 4). We note that the first stage F-statistics indicates that the instrument is sufficiently correlated with the endogenous variable. The significance of the chosen instruments is also confirmed with the reduced form by regressing instruments on the patent counts. These results lead us to be more confidences about the use of the instrument.

As discussed in section 4, there are several reasons for why firms patent incremental innovation which do not have the high market values. One of the reasons is that firms are patenting as a means of the defensive reaction to the widespread import competition from China. This *defensive* patenting is usually observed in ICT industry where the substantial exposer of Chinese competition occurred in the last two decades (as observed in Table 2). Taken together, our evidence provide more nuanced interpretation of the pro-competitive effects of Chinese import competition. The China shock has created the environment whereby firms are provoked to react more on the counter-productive defensive patenting rather than being stimulated to pursue the ground-breaking patenting. This interpretation is reinforced in the following R&D equations.

Results for R&D equation are presented in Table 6 (OLS estimates) and Table 7 (IV estimates).[27] Both estimates provide the similar results, so we focus on IV estimates. In contrast to the patent count analysis, the estimated R&D equation shows the *negative* effects of Chinese import competition on domestic innovation. The split sample analysis also suggests that this is mostly driven by firms without engagement to trade (column 2). Pure domestic firms have cut back about 0.1% of R&D expenditures in response to a 10 percentage point increase in Chinese import competition. The depressing effect of the China shock is absent in global firms (column 3) – it shows a negative sign but not statistically significant. Our evidence in R&D equation suggest that domestic firms are the ones which felt much of intensified competition from Chinese imports. This group of firms has been squeezed out and forced to cut back on R&D efforts in response to Chinese import competition.

6. Conclusion

This paper examined the innovation responses of a panel of Japanese manufacturing firms to Chinese import competition for the period 1995-2010. We have uncovered the several heterogeneous dimensions of the innovation responses by constructing the unusually detailed firm-patent dataset.

Our findings can be summarised as follows. The first cut results revealed that Japanese firms, especially those globally engaged firms, show the greater patent propensity in response to sharply increased import competition from China. This positive effect is more pronounced when we have corrected for the endogenity of import competition on innovation outcomes. In contrast, firms focusing more on the domestic market have the muted response to the increased import competition. Second, once controlling for quality of innovation, we found that while Chinese import competition has induced firms to take out more patents but they mostly were in lower quality innovation. Third, results of R&D equation suggested that firms focusing on the domestic market are the ones which have suffered most from import competition from China by cutting back on R&D expenditures.

[27] In the main regressions, we use R&D expenditures. We also experimented by specifying the R&D intensity by taking the ratio of R&D to the number of employment and sales. The results are similar.

Our evidence imply that lumping together the heterogenous innovation response between global firms and pure domestic firms leads to substantial overestimation of the impact of import competition from China, as done in Bloom et al. (2015). Our results emphasise the need for paying careful attention to the nature of innovation response by different types of firms. Our results also imply that although the composition of Chinese export bundles has moved from more labour-intensive to capital intensive goods in the last two decades, it has barely stimulated path-breaking innovation activities. Rather, firms are responding by increasing the incremental innovation. This is perhaps mirrored evidence that the widespread technological take-off of Chinese firms and products has not yet occurred (Dang and Motohashi 2015; Eberhardt et al. 2016). At the same time, patenting incremental innovation may be partly driven by the increased defensive nature of patenting in order to protect their core inventions from an influx of Chinese products in the Japanese market. We leave this channel to examine in our next research agenda.

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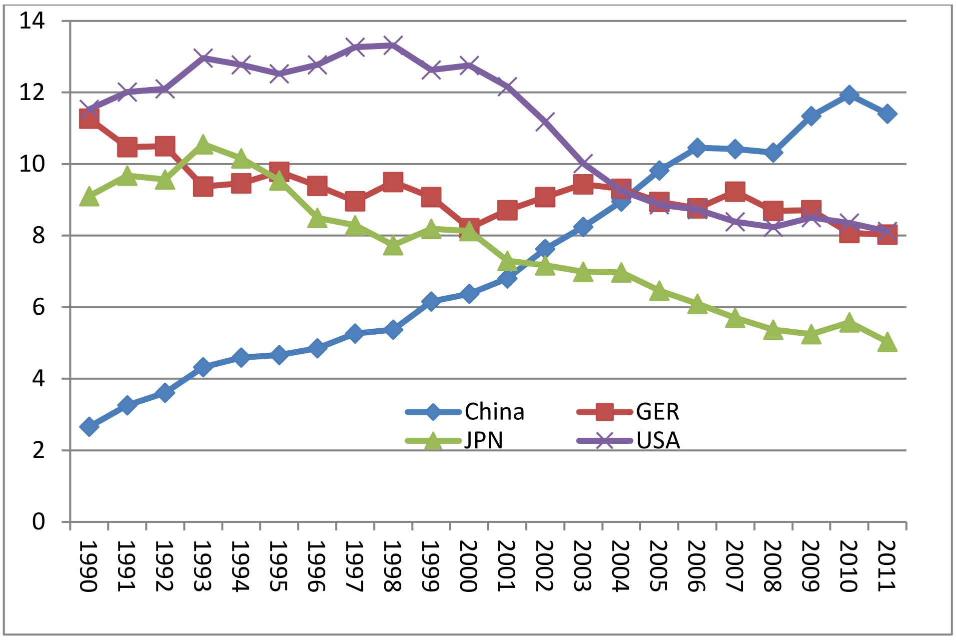
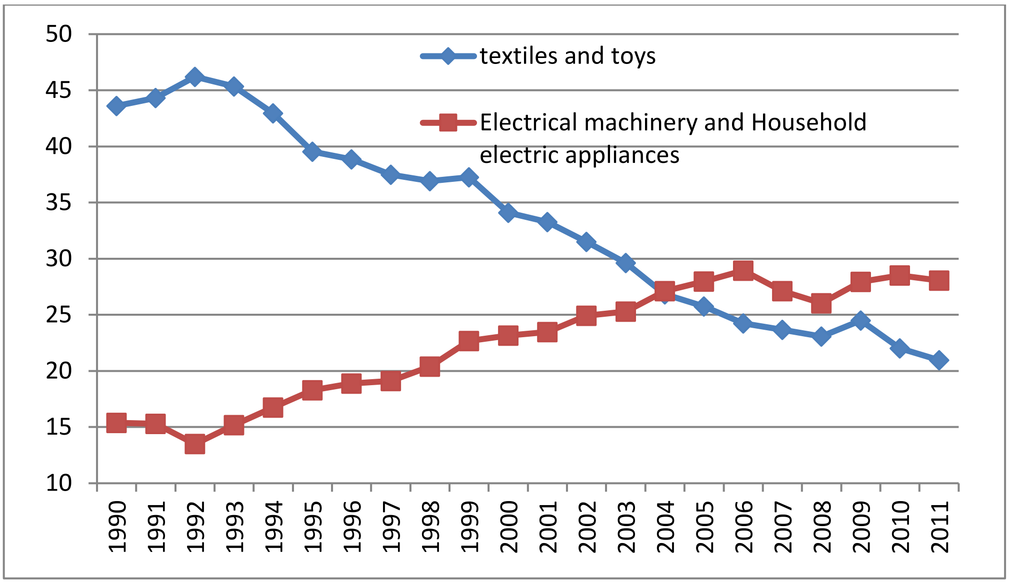
Figure1: The rise of China in world trade, 1990-2011 (%)

Export (percentage share in world exports)



Source: UN Comtrade

Figure 2: Structural Changes in China's export product compositions (% in total exports), 1990-2011



Source: UN Comtrade

Table 1: Summary statistics of key variables, 1995-2010

Year	Patent	R&D	Chinese import pen.	High income import pen.	Unique firm
	mean	mean	mean	mean	sum
	counts	million yen	%	%	counts
1995	29.2	841	0.8	3.5	7,660
2001	31.1	988	2.1	4.6	8,091
2006	30.4	1,054	4.6	4.9	7,615
2010	22.2	993	5.8	4.4	7,858

Source: Based on the constructed data from METI, IIP patents and JIP data. See section 3 for more detailed explanation. High income refers to sum of US, Canada, EU countries. plied by firms in the Basic Survey of Japanese Business Structure and Activities. This covers about 80% of all patent applied in IIP patent database.

Table 2: Share of patenting and Chinese import penetration at 2-digit industry in 1995, 2001 and 2010

Industry	Patent (% share in total manufacturing)			Chinese import competition		
	1995	2001	2010	1995	2001	2010
	%	%	%	%	%	%
ELECTRONIC AND ELECTRIC EQUIPMENT	19.5	20.3	20.0	0.6	2.5	11.2
TRANSPORTATION EQUIPMENT	9.8	11.6	14.2	0.0	0.2	0.9
INSTRUMENTS	4.6	5.4	13.8	1.2	3.6	6.7
INDUSTRIAL MACHINERY AND EQUIPMENT	8.6	11.5	8.7	0.2	0.8	5.0
PRIMARY METAL INDUSTRIES	10.5	8.7	7.5	0.4	1.2	1.7
CHEMICALS AND ALLIED PRODUCTS	7.1	9.6	7.5	0.3	0.6	1.8
PETROLEUM AND COAL PRODUCTS	4.2	2.8	5.3	0.1	0.2	0.2
RUBBER AND PLASTICS PRODUCTS	3.3	5.2	4.9	0.8	2.0	5.3
MISCELLANEOUS	3.7	4.8	4.4	2.0	5.4	14.2
PRINTING AND PUBLISHING	2.3	4.5	3.1	0.0	0.0	0.2
FURNITURE AND FIXTURES	1.7	1.6	2.5	0.4	2.2	10.7
STONE, CLAY, AND GLASS PRODUCTS	2.0	3.6	2.3	0.5	1.4	2.5
PAPER AND ALLIED PRODUCTS	1.8	2.0	2.0	0.1	0.2	1.4
TEXTILE MILL PRODUCTS	3.8	4.4	1.3	8.1	20.5	40.1
FABRICATED METAL PRODUCTS	2.1	2.0	1.2	0.2	0.6	3.1
FOOD AND KINDRED PRODUCTS	0.8	0.8	0.8	0.8	1.4	1.6
LUMBER AND WOOD PRODUCTS	14.0	0.8	0.4	0.9	2.4	4.6
LEATHER AND LEATHER PRODUCTS	0.4	0.2	0.1	7.2	16.5	33.6
Total Manufacturing	100	100	100			

Source: Based on the constructed data from METI, IIP patents and JIP data. See section 3 for more detailed explanation. This table is sorted by the largest share of patent applications in 2007

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Table 3: Impact of Chinese import competition on domestic patent counts:

		(1)	(2)	(3)	(4)	(5)
Sample selection		**All firms**	**Pure domestic**	**Global**	**Exporters no imports**	**Importers no exports**
Imports		**-**	**No**	**Yes**	**No**	**Yes**
Exports		**-**	**No**	**Yes**	**Yes**	**No**
	IM_{t-1}^{China}	0.007***	0.002	0.008***	0.005	0.012*
		(0.002)	(0.003)	(0.003)	(0.005)	(0.007)
	$EMP._{t-1}$	0.469***	0.368***	0.518***	0.522***	0.320***
		(0.026)	(0.053)	(0.036)	(0.079)	(0.079)
	$R\&D_{t-1}$	0.048***	0.034***	0.060***	0.033***	0.046***
		(0.004)	(0.007)	(0.007)	(0.011)	(0.016)
	Zero R&D	-0.027***	-0.018	-0.033**	-0.027	-0.034
		(0.010)	(0.015)	(0.016)	(0.025)	(0.031)
	R-sq	0.056	0.036	0.068	0.058	0.049
	# of firms	9,023	2,678	4,310	1,318	717
	Obs.	68,120	16,170	37,318	9,531	5,101

Note: The Estimation period is between 1995 and 2010. 'Imports (exports)' indicates that the sample filtering of whether a firm has at least one year record of imports (or exports) in the estimation period. 'Pure domestic firms' in column (2) refers to the group of firms which have not engaged with exporting and importing activities for the entire estimation period. 'Global firms' in column (3) refers to firms with positive records of exporting and importing at least one year in the entire period. All the models are estimated by OLS with standard errors clustered by firms in parentheses. The dependent variable for patent estimation is patent counts of firm-year plus one. *EMP* refers to the number of employees and *R&D* ratio is defined as the ratio of R&D to total sales. *Zero R&D* is an indicator variable of having one if firms report positive R&D expenses for each firm-year cells, zero otherwise. *EMP* and *R&D* are taken natural logarithms. All columns include a full set of firm and time fixed effects. *** denotes 1% significance; ** denotes 5% significance; * denotes 10% significance.

Table 4: Impact of Chinese import competition on domestic patent counts (instrumental variable)

		(1)	(2)	(3)	(4)	(5)
Sample selection		**All firms**	**Pure domestic**	**Global**	**Exporters no imports**	**Importers no exports**
Imports		**-**	**No**	**Yes**	**No**	**Yes**
Exports		**-**	**No**	**Yes**	**Yes**	**No**
	IM_{t-1}^{China}	0.013***	0.005	0.014***	0.024**	0.014**
		(0.002)	(0.004)	(0.004)	(0.009)	(0.006)
	EMP_{t-1}	0.474***	0.371***	0.522***	0.327***	0.527***
		(0.027)	(0.053)	(0.036)	(0.080)	(0.079)
	$R\&D_{t-1}$	0.048***	0.034***	0.060***	0.046***	0.033***
		(0.004)	(0.007)	(0.007)	(0.016)	(0.011)
	zero R&D	-0.027***	-0.018	-0.034**	-0.033	-0.027
		(0.010)	(0.015)	(0.016)	(0.030)	(0.025)
	F	66.5	11.4	44.8	5.0	10.9
	# of firms	7,995	2,207	4,009	629	1,150
	Obs.	67,092	15,699	37,017	5,013	9,363

Note: The Estimation period is between 1995 and 2010. ‘Imports (exports)’ indicates that the sample filtering of whether a firm has at least one year record of imports (or exports) in the estimation period. ‘Pure domestic firms’ in column (2) refers to the group of firms which have not engaged with exporting and importing activities for the entire estimation period. ‘Global firms’ in column (3) refers to firms with positive records of exporting and importing at least one year in the entire period. The dependent variable for patent estimation is patent counts of firm-year plus one. *EMP* refers to the number of employees and *R&D* ratio is defined as the ratio of R&D to total sales. *Zero R&D* is an indicator variable of having one if firms report positive R&D expenses for each firm-year cells, zero otherwise. *EMP* and *R&D* are taken natural logarithms. All columns include a full set of firm and time fixed effects. *** denotes 1% significance; ** denotes 5% significance; * denotes 10% significance.

Table 5: Impact of Chinese import competition on quality-adjusted patents

	(1)	(2)	(3)	(4)	(5)
Sample selection	**All firms**	**Pure domestic**	**Global**	**Exporters no imports**	**Importers no exports**
Imports	**-**	**No**	**Yes**	**No**	**Yes**
Exports	**-**	**No**	**Yes**	**Yes**	**No**
IM^{China}	-0.004**	-0.005	-0.001	-0.009	-0.016***
	(0.002)	(0.003)	(0.002)	(0.006)	(0.006)
IM^{China}	0.001	0.001	0.003	0.004	-0.002
	(0.002)	(0.002)	(0.003)	(0.004)	(0.008)
IM^{China}	0.009***	0.006	0.011**	0.006	0.006
	(0.003)	(0.005)	(0.005)	(0.009)	(0.009)
# of firms	6,140	1,325	3,490	453	872
Obs.	43,574	6,736	28,293	2,723	5,822

Note: The Estimation period is between 1995 and 2010. 'Imports (exports)' indicates that the sample filtering of whether a firm has at least one year record of imports (or exports) in the estimation period. 'Pure domestic firms' in column (2) refers to the group of firms which have not engaged with exporting and importing activities for the entire estimation period. 'Global firms' in column (3) refers to firms with positive records of exporting and importing at least one year in the entire period. The dependent variable for patent estimation is patent counts of firm-year plus one. *EMP* refers to the number of employees and *R&D* ratio is defined as the ratio of R&D to total sales. *Zero R&D* is an indicator variable of having one if firms report positive R&D expenses for each firm-year cells, zero otherwise. *EMP* and *R&D* are taken natural logarithms. All columns include a full set of firm and time fixed effects. *** denotes 1% significance; ** denotes 5% significance; * denotes 10% significance.

Table 6: Impact of Chinese import competition on R&D expenditures

		(1)	(2)	(3)	(4)	(5)
Sample selection		**All firms**	**Pure domestic**	**Global**	**Exporters no imports**	**Importers no exports**
Imports		**-**	**No**	**Yes**	**No**	**Yes**
Exports		**-**	**No**	**Yes**	**Yes**	**No**
	IM_{t-1}^{China}	-0.007**	-0.013**	-0.003	-0.008	-0.013
		(0.003)	(0.006)	(0.004)	(0.008)	(0.008)
	$EMP_{\cdot t-1}$	0.777***	0.786***	0.772***	0.840***	0.721***
		(0.033)	(0.080)	(0.042)	(0.094)	(0.113)
	R-sq	0.038	0.036	0.042	0.039	0.043
	# of firms	8,946	2,629	4,305	1,298	714
	Obs.	67,829	16,012	37,253	9,487	5,077

Note: 'Pure domestic firms' refers to the group of firms which have no engaged with exporting and importing for the entire period 1995-2010. 'Global firms' refer to firms with positive records of exporting and importing for the period 1995-2010. All the models are estimated by OLS with standard errors clustered by firms in parentheses. The dependent variable for patent estimation is patent counts of firm-year. All columns include a full set of sector-year dummies. *** denotes 1% significance; ** denotes 5% significance; * denotes 10% significance.

Table 7: Impact of Chinese import competition on R&D expenditures (instrumental variable)

		(1)	(2)	(3)	(4)	(5)
Sample selection		**All firms**	**Pure domestic**	**Global**	**Exporters no imports**	**Importers no exports**
Imports		**-**	**No**	**Yes**	**No**	**Yes**
Exports		**-**	**No**	**Yes**	**Yes**	**No**
	IM_{t-1}^{China}	-0.010***	-0.012*	-0.006	-0.002	-0.019
		(0.003)	(0.007)	(0.004)	(0.009)	(0.013)
	$Emp._{t-1}$	0.775***	0.787***	0.770***	0.724***	0.834***
		(0.033)	(0.080)	(0.042)	(0.113)	(0.094)
	F	43.9	9.3	28.1	4.7	7.7
	# of firms	7,971	2,191	3,993	633	1,154
	Obs.	66,854	15,574	36,941	4,996	9,343

Note: 'Pure domestic firms' refers to the group of firms which have no engaged with exporting and importing for the entire period 1995-2010. 'Global firms' refer to firms with positive records of exporting and importing for the period 1995-2010. The dependent variable for patent estimation is patent counts of firm-year. All columns include a full set of sector-year dummies. *** denotes 1% significance; ** denotes 5% significance; * denotes 10% significance.