RIETI Discussion Paper Series 19-E-068

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The Research Institute of Economy, Trade and Industry
https://www.rieti.go.jp/en/

RIETI Discussion Paper Series 19-E-068

September 2019

Effects of Offshore Production and R&D on Domestic Innovation Activities*

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Abstract

There has been a global shift in the distribution of manufacturing jobs and activities away from high-wage countries to low-wage countries for the past few decades. This paper examines a largely unexplored channel of the effects of offshore production on onshore (domestic) innovation performance. Controlling for the endogeneity, we find that increased offshore employment and R&D do not have positive impact on the domestic innovation measured by the number of patent applications and the number of forward citations on average. However, offshore R&D increases the quality of domestic innovation when the firms expand R&D function to the developed countries while it has a negative effect in the developing countries. We also find a synergistic effect between production and R&D activities. Therefore, separating the two activities can decrease the efficiency of resource allocation on the domestic innovation.

Keywords: Innovation, Offshoring, International knowledge sourcing, Multinational firms

JEL classification: F14, O31, O32

*This study is conducted as a part of the project "Frontiers of Innovation Policy: Evidence from micro data" undertaken at the Research Institute of Economy, Trade and Industry (RIETI). This study utilizes the micro data of the questionnaire information based on the "Basic Survey of Japanese Business Structure and Activities" and the "Basic Survey on Overseas Business Activities" which are conducted by the Ministry of Economy, Trade and Industry (METI), and the Kikatsu Oyako converter which is provided by RIETI. For the useful comments, we would like to thank Yasuyuki Todo, Russell Thomson, Chandra Athukorala, Willem Thorbecke, Shujiro Urata and seminar participants at the Economic Research Institute for ASEAN and East Asia (ERIA), the second annual conference of the Japan Economy Network, ANU, Keio, Swinburne and RMIT University. We are also grateful to Matt Crichton for a careful editing work and Trong Anh Trinh for the excellent research assistance. This work was supported by JSPS KAKENHI 17K03721 and 16K03882.

1. Introduction

There has been a global shift in the distribution of manufacturing jobs and activities away from high-wage countries to low-wage countries in the past few decades. For instance, in the US, the share of value-added in the GDP went down from 15 per cent in 2000 to 11.6 per cent in 2016. For the same measure, China recorded 30 per cent in 2016.[2] One of the driving forces for this shift has been attributed to the rapid expansion of offshore production – the cross-border splitting of the production process within vertically integrated manufacturing by multinational enterprises (MNEs). This generally involves unbundling and relocating labour-intensive production from the home operations of MNEs to offshore locations where labour costs are relatively cheap, while retaining the activities that require specialized skills and technologies, such as R&D activities in home operations (Athukorala and Yamashita, 2006; Baldwin, 2016).

While there has been a substantial amount of studies on the effects of offshore production in several aspects of the offshoring economy (Feenstra and Hansen, 1999; Bernard et al., 2006; Harrison and McMillan, 2011), the literature has devoted scant attention to the causal effects of offshore production and R&D on innovation performance at home.[3] Some theoretical studies suggest that this increased offshore production can foster internal resource allocation of MNEs, shifting resources toward innovation activities at home and achieving an overall cost efficiency. For instance, Grossman and Rossi-Hansberg (2008) support this view by showing the gains in productivity of home operations induced by offshore production. Moreover, international knowledge sourcing through the offshore R&D can improve the domestic innovation performance (Almeida and Kogut, 2004). On the other hand, some studies from a management and strategy perspective present the case that separating manufacturing into offshore production and R&D functions may undermine the potential for greater innovation (Fuches and Kirchain, 2016). The key account in this prediction is that offshore production may weaken the transfer of knowledge and feedback between R&D and production (Fuchs and Kirchain, 2010; Rodrigues-Clare, 2010; Branstetter et al., 2017). Despite the theoretical interest and the policy importance of the effects of offshoring, few studies have focused on the issue empirically. Most empirical studies have focused only on the productivity outcome induced by offshore production (Hijzen et al., 2010; Castellania and Pieri, 2013; Ito et al., 2013)[4] and this leaves a significant gap that our study begins to fill.

We contribute to this literature by estimating the contribution of offshore production (measured by the

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[2] Over the same time period, the share of manufacturing employment was 23 per cent in the US in 1995 and it declined to 19 per cent by 2016. The same in China in 1995 was 28 per cent and it had slightly declined to 27 per cent by 2016 (World Bank): http://databank.worldbank.org/data/source/world-development-indicators.

[3] Our study takes a different angle by focusing on offshore production compared to studies examining the effects of international knowledge sourcing in the form of overseas R&D on innovation performance of home operations (Almeida and Kogut, 2004; Todo and Shimizutani, 2008; Picci, 2010; Castellania and Pieriea, 2013).

[4] Of course, one can argue that productivity (TFP) is a measure of innovation, capturing the tacit knowledge and unobserved gains in efficiency. However, market power and profitability tend to blur the estimates of TFP measures. The patents we use are more closely related to inventive activities. If offshore production can effectively increase home productivity, as is found in several studies, it should also have the potential to contribute to innovation outcomes (Branstetter, 2006).

number of employees of MNE foreign affiliates in host countries) and offshore R&D to the onshore (domestic) innovation performance of Japanese MNEs for the period 1997–2011. We develop a novel dataset linking the global operations of Japanese MNEs to patent data as a key indicator of innovation performance.[5] Based on this comprehensive dataset, we estimate a variant of the knowledge production function, assigning the number of patents in the dependent variable and the measure of offshore activities in a key explanatory variable.

The immediate challenge of establishing a causal estimation is that decisions to engage offshore production and innovation are endogenous to individual firms. It may be the case that the firms innovating more are the ones that aggressively engage in offshoring in production. Furthermore, there is substantial evidence to suggest that multinational firms are more innovative than domestic firms with no overseas affiliates (e.g., Criscuolo et al., 2010; Haneda and Ito, 2014). These issues tend to generate an upward positive bias when estimating the effects of offshore production on domestic innovation. We address this issue by employing an instrumental variable approach: we use information about the operations of the foreign affiliates of US MNEs to predict the intensity of the offshore operations of Japanese MNEs in the same host countries. The exclusion restriction states that innovation outcomes of Japanese MNEs at home are exogenous to the operations of US MNEs in host countries. The capacity of Japanese MNEs to innovate is influenced only through the channel of predicted offshore production and R&D activities. We also introduce the instruments generated only from the dataset as developed by Lewbel (2012) for the robustness and controlling for another endogeneity between offshoring and domestic R&D.

Broadly, we find that increased offshore employment and R&D do not have positive impact on the domestic innovation measured by the number of patent applications and the number of forward citations on average. However, we also find that offshore R&D increases the quality of domestic innovation when the firms establishes R&D bases in the developed countries while it has a negative effect when the firms have R&D bases in the developing countries. These results suggest that the positive effect through knowledge transfer dominates the negative effect of losing R&D base when the host country has higher technological capacity. [6] At the same time, the results show that increased offshore production decreases the positive effect of domestic R&D on the quality of domestic innovation, which indicates the synergy between production and R&D activities. This finding is consistent with the theoretical concerns expressed in discussion about the separation of production to offshore locations and the domestic innovation capacity (see Naghavi and Ottaviano, 2009; Fuchs and Kirchain, 2010; Rodrigues-Clare, 2010; Branstertter et al., 2016).

[5] This data matching is similar to the NBER project (matching the listed firm in *Compustat* and patents at the United States Trademarks and Patent Office) - https://sites.google.com/site/patentdataproject/. Our dataset covers both listed and private firms.

[6] The positive effects of offshore R&D in developed countries on the quality of innovation is partly consistent with extensive evidence in the literature (e.g., Branstetter, 2001; Iwasa and Odagiri, 2004; Rahko, 2016).The usual channel would be the physical location of the R&D centre and how this allows absorption of innovation, provides spillovers and offers a direct interaction of scientists and engineers through formal and informal meetings.

In sum, we made improvements by building on previous research. First, we simultaneously controlled for the effects of offshoring of manufacturing and R&D, and related them to home (domestic) patenting in a unified framework. The existing studies only consider offshore R&D through the channel of international knowledge sourcing. The scope of our analysis is thus more comprehensive, capturing a wider range of offshore operations. This paper sees the different effect of offshoring depending on the degree of development of the host countries. Second, we apply an instrumental variable approach to causally estimate the effects of offshore production and R&D on domestic innovation. On a similar topic, Branstter et al. (2017) also exploit the exogenous variation in the outward FDI policy on Taiwanese firms to causally estimate the effects of offshore production on domestic innovation; however, this is restricted to firms in the electronics industry.[7] In our application, an instrumental approach is implemented in a broader set of industries. Third, exploiting the Lewbel (2012) method, we identify the synergistic effect of manufacturing and R&D activities. Fourth, the outcome measure that we use is the number of patents registered in Japan's domestic patent office (JPO). Branstetter (2001) and Iwasa and Odagiri (2004) only use Japanese patents registered at the US Patent and Trademark Office (USPTO). While it is well known that Japanese firms are aggressive in patenting at the USPTO, the patents registered by Japanese firms in the U.S. tend to be a small proportion of the total patent portfolio and tend to be associated with high inventive values. In other words, the patents from the USPTO may not be an ideal metric to measure the full breadth and depth of the innovative capacity of Japanese firms. Overall, our analysis, therefore, takes one step closer to understanding how different offshoring activities of MNEs can shape onshore innovation performance.

In the remainder of the paper, section 2 develops the underlying theoretical framework and discusses the related literature, and section 3 describes the data. Section 4 presents the empirical approach and the construction of key variables. The main results are presented in section 5 and section 6 provides a conclusion to the paper.

2. Related literature and hypothesis

There has been much theoretical development about the possible domestic effects of increased offshore production in high-wage countries, particularly through the channel of labour market adjustments. Those with favorable views have highlighted the gains in productivity driven by increased offshore production (e.g., Grossman and Rossi-Hansberg, 2008), while the critics have emphasized concerns for the adverse effects of so-called 'exporting jobs' on wages for skilled and unskilled workers. The connection between offshore production and innovation has received comparatively scant attention in the literature. This section synthesizes theoretical studies to develop the hypothesis that we test and bring to the data in the ensuing analysis.

[7] In a similar vein, Fuchs and Kirchain (2010) have a narrower focus by looking at the US optoelectronics industry.

Hypothesis1: Offshore production raises innovation through more efficient resource allocation

Offshore production refers to slicing up what used to be done in domestic processing and relocating parts of production overseas (Yamashita, 2010). In theory, this implies a within-firm structural adjustment leading to rationalizing the entire production system into a new one. This naturally allows the onshore (home) manufacturing process to specialize more on high-tech and skill-intensive operations, while more routine production processes are migrated overseas to take advantage of the relatively lower labour costs. According to this view of within-firm resource allocations, MNE operations at home should focus more on generating new ideas and innovation, which then feed into the production overseas. One of the channels that Rodrigues-Clare (2010) examines in the dynamic general equilibrium Ricardian model is the possibility of reallocation within firms, leading to an enhanced technological capacity. It is, in fact, conceivable that resources released by increase production offshore would lead to an increase in innovation capacity in the long run with firms for which technology is more endogenous.

A more practical example is presented by Brown and Linden (2005), where they describe the three-step semiconductor manufacturing processes: design, wafer fabrications, and test and assembly. Design requires more highly skilled workers and sophisticated technology. Wafer fabrication requires workers with fewer skills, and testing and assembling requires the least average skills of workers. Thus, the required skills of the workers decrease along the value chain from design to testing and assembling. In the 1980s, the US computer chips industry began to move assembly activity to lower-cost countries in Asia, while home production focused more on design, fabrication, and managerial functions. Chips were fabricated in the US, flown to Asia for assembly, and then returned to the US for final testing and packing. This had a direct favorable effect on the rate of innovation and competitiveness in the US semiconductor industry.

Hypothesis 2: Offshore R&D promotes innovation through knowledge sourcing

Since information is sticky (von Hippel, 1994), the firms can acquire local technological knowledge and idea that is new to firm. Such international knowledge sourcing through the offshore R&D can improve the domestic innovation performance (Almeida and Kogut, 2004). Almeida (1996) finds that MNEs exploit local knowledge significantly more than domestic firms.

Hypothesis 3: Offshore production stifles innovation through the decrease in the synergistic effect of production and R&D

The process of generating new inventions has long been understood as a system of feedback loops connecting a set of interrelated factors for promoting the capacity for innovation (Furman et al., 2002). Because of this feedback system, there are concerns that a physical separation of manufacturing away from the core R&D department can slow down the rate of discovery and the transfer of knowledge, leading to reduced innovation (see Fuchs and Kirchain, 2010 for a case study from the optoelectronics industry; Pisano and Shil, 2009, 2012 for a general discussion). The basic premise in these management studies is that knowledge transfers and the creation of new ideas does not happen automatically. Rather, the process requires the continuous feedback and technological learning between manufacturing and R&D. The often-cited success of the Japanese industrial export sectors in the 1980s was partly due to the practice of rotating R&D personnel through manufacturing operations to foster the effects of feedback and knowledge transfers between the two segments (Branstetter et al., 2017).

In sum, the literature survey indicates some points of reference to guide our empirical analysis. The first is that the offshoring of production and R&D can have positive effects on domestic innovation through more efficient resource allocation and knowledge sourcing. However, it can also have negative effect on domestic innovation by switching the resources to overseas market-oriented activities. Moreover, offshoring can slow the rate of innovation by limiting the possibility of knowledge creation and transfers between R&D operations and manufacturing. While several case studies exist, a systematic empirical analysis for the latter point is lacking. In particular, there has been a lack of studies in terms of the synergetic effects of manufacturing and R&D focusing on the offshoring on domestic innovation. The important exception is Branstetter et al. (2017) who took a quasi-experimental approach by looking at the policy change for Taiwanese electronics firms offshoring to China. By considering a fall in the offshoring costs of Taiwanese firms as a result of the exogenous policy changes, Branstetter et al. (2017) showed that the greater offshoring of production to China lead to a reduction in propensity of innovation.

3. Identification strategy

The empirical analysis follows the strategy of estimating the knowledge (patent) production function, commonly used in the literature of innovation economics (Griliches, 1986). The basic idea follows from the production function wherein innovation outputs (patents) relate to innovation inputs (such as R&D expenses). In our application to the MNE data, we extend the basic knowledge input factors to include the extent of offshore production, measured by the number of employees in foreign affiliates in host countries as well as the overseas R&D expenditure. Thus, we consider the following log-linear equation:

$$(1)\quad \log(Pat_{it}^{H}) = \beta_0 + \beta_1 \log(L_{it}^{O}) + \beta_2 \log(RD_{it}^{O}) + \beta_3\, log(\, L_{it}^{O}) * log(\, RD_{it}^{H}) + X_{it-1t}^{H}\gamma + \theta_i + \theta_t + \varepsilon_{it},$$

where the superscript H represents the home country (i.e., Japan) and O stands for offshore operations. Pat^{Home} represents the number of new patents created by the parent firm (MNE) i in year t recorded in the Japan Patent Office. Offshore production is expressed by L^{O} and the amount of offshore R&D expenditure is expressed by RD^{O}. Similarly, RD^{H} represents the onshore R&D.

The interested coefficient of L^{O} captures the contributions of offshore production to onshore innovation performance. As developed in section 2, theoretical predictions on the causal effects of increased offshore production on innovation are positive if the impact of resource allocation is significant. As for the coefficient β_2, there is substantial evidence to confirm that overseas R&D operations are an effective way of transferring otherwise unavailable knowledge to home operations (Almeida and Kogut, 2004; Iwasa and Odagiri, 2004; Todo and Shimizutani, 2008).[8] To identify the effect of knowledge sourcing more clearly, we divide the sample in terms of development of the host countries. Moreover, limiting the sample to the MNEs that extends only manufacturing function to the abroad, we see the synergistic effect of manufacturing and R&D by the coefficient β_3.

As informed by the literature, a vector of X^H includes a set of knowledge inputs including onshore (domestic) R&D (RD^H),[1] the size, capital-labour ratio and the age of firms (Aghion et al. 2009). Firm-fixed effects are θ_i, and the year dummies (θ_t) controls any time variant shocks that affect all firms[9]. Noting that competitive pressure is found to be relevant in stimulating corporate innovation (Aghion et al., 2005), we also include a variable measuring the level of market competition (the variable construction is detailed in the following section).

Instrument variables

An important identification challenge in the above equation (1) is to develop the causal estimate of β because innovation and offshore production are endogenous decisions to firms. It is possible that more patenting is just a reflection of a superior aptitude for innovation in offshoring firms. We address this simultaneity bias by implementing instrument strategies. Using the Lewbel (2012) method, we generate instruments from the variables in the data set, in addition to use the activities of US MNEs as an exogenous instrumental variable. In the Lewbel method, exploiting the scale heteroskedasticity, instruments can be generated from the product of the residuals of the first stage equation and the mean centered exogeneous variables[10]. The Lewbel method can deal with measurement error or omitted variables when appropriate instruments are not/less available.

As for the exogenous instrument we rely on the evidence that MNEs have a tendency to form clusters around similar activities in the same host countries (Head et al., 1995; Alfaro and Chen, 2014). The prime example is that MNEs from various countries form the industrial cluster in Silicon Valley in California in the US. It is commonly found that locations with the presence of many MNE plants from the same or vertically-related industries are more likely to attract more MNE plants of the same national origin (Smith and Florida, 1994;

[8] International knowledge spillovers and sourcing would allow firms to access newer knowledge, ideas, and technical skills which might lead to innovative products, management and commercialisation. Firms are thus incentivised to tap into the latest technology networks by setting up an R&D centre overseas to benefit from the informal interactions of scientists and engineers and from directly hiring competitors' employees.

[9] Since some firms change the industry they belong to during the sample period, we also include the industry dummies. In the Appendix, we also show the results when we include the cross terms of year and industry dummies for the main estimation.

[10] The residuals of the first stage estimation have zero covariance with each of the regressors, which implies that the means of the generated instruments are zero. However, the products with the centered regressors cannot be zero. The generated instruments have larger correlation with the endogenous variables as the heteroskedasticity becomes greater.

Head et al., 1995; Belderbos and Carree, 2002; Chang et al., 2013). This reflects the fact that the presence of MNE affiliates raises the probability of subsequent investment at the same location.

Observing this tendency of MNEs to cluster, we argue that the operations of foreign affiliates of US MNEs are highly correlated with those of Japanese MNEs in the same host countries (we present a check of the relevancy test with the first stage regression in the next section). Hence, we use employment and R&D activities of US MNEs to predict the intensity of the same activities for Japanese MNEs in the same host countries. The exclusion restriction follows that changes in the innovation capacity of Japanese MNEs at home is not correlated with changes in the operations of US MNEs in host countries. They are only influenced by the predicted change in offshore production. More specifically, the instrument for offshore employment (denoted as *IV1*) can be written as follows:

$$IV1_{it} = \sum_{c} \omega_{act-1} \times US_{ct}^{Emp} \tag{2}$$

US_{ct}^{Emp} purports to capture the size of the employment of foreign affiliates of US MNEs in a host country, *c*, in the previous time period, t. It is weighted by the proportion of employment for an MNE, *i*, in a host country, *c*, of the total worldwide employment of the MNE, *i*, in time *t-1*. In a similar fashion, the weighted R&D expenditures of US MNEs (denoted as *IV2*) is also computed for MNE *i* for year *t.* It is expressed as:

$$IV2 = \sum_{c} \omega_{act-1} \times US_{ct}^{R\&D}. \tag{3}$$

4. Data and variable construction

This study combines two micro-data sources: (i) data on onshore and offshore operations of MNEs, and (ii) information on patents and citations from the Japan Patent Office (JPO) from the Institute of Intellectual Property (IIP) Patent database.[11]

First, we constructed a dataset of parent-affiliates matched with firm-level panels, covering the global operations of Japanese multinationals over the period 1996–2011. The data was drawn from two annual surveys of Japanese firms collected and maintained by Japan Ministry of the Economy, Trade and Industry (METI): *Basic Survey of Japanese Business Structure and Activities*[12] for Japanese parent firms, and the *Basic Survey on Overseas Business Activities* for their foreign affiliates. We also use Kikatsu Oyako converter which is provided by RIETI. Initially, we extracted the accounting data of the parent firms from the former survey. It collects sufficient information to quantify the domestic operations of Japanese firms,

[11] https://www.iip.or.jp/e/e_patentdb/

[12] This survey is legally mandatory, and generally receives a high response rate of about 90 per cent. The survey sample is restricted to firms that have more than 50 employees and capital of more than 30 million yen.

including employment and R&D spending. The survey covers both manufacturing and non-manufacturing industries, but this study limits the analysis to the manufacturing industry because of our focus on offshoring in production.[13] All individual firms were assigned unique identifiers, making it possible to track their operations over time. For offshoring activities, we collected data from the second survey. It includes information about overseas employment and R&D activities in the host countries for the time period of the study. We discuss the variable construction in the next section.

Second, we created a firm-level measure of innovation by matching all awarded patent applications from the Japan Patent Office (JPO) to firms in the aforementioned METI database. The Institute of Intellectual Property (IIP) Patent File[14] provides a rich set of information for both applied and granted patents together with citation information attached (Goto and Motohashi, 2007).[15] We matched the names of the patent applicants listed on the patent document to the names of firms listed in the METI database. Matching the names of patent applications and firms was complicated by inconsistencies in the spelling of names in the original patent document (uses of Japanese, Chinese and English lettering) and typographical variations. In the absence of consistent firm IDs, string (name) matching was mediated by the directory of Japanese company names prepared by the National Institute of Science and Technology Policy (NISTEP).[16] Other information such as the companies' addresses was also used to enhance the accuracy of the matching.

The name-matching procedure initially created 55,122 records of firms matched for the time period 1996–2011. Subsequently, we dropped firms that did not have offshore affiliates (thus, were not MNEs) and only retained firms with at least one patent application in the estimation period. We arrived at a total of 5,406 firms and 32,743 firm-year observations. This meant that we only retained about 10 per cent of the total number of firms in the original matching; however, this small fraction of firms accounted for over 80 per cent of the total patent applications in the time period.

The data for our instruments were compiled from the electronic data files of the Annual Survey of US Direct Investment Abroad conducted by the Bureau of Economic Analysis (BEA), the US Department of Commerce ('the BEA data' for short).[17] One unavoidable limitation is that there are no data for the US. Therefore, employment and R&D data for the US were extracted from the NBER manufacturing productivity database.[18]

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[13] It should also be pointed out that the bulk of patents come from manufacturing sectors rather than service and financial sectors (Goto and Motohashi, 2007).
[14] The IIP datafile is the 2015 version (https://www.iip.or.jp/e/e_patentdb/)
[15] This name directory checks the names of firms in the IIP Patent database and reports consistent names which can then be used to match with the external source (such as the METI data).
[16] http://www.nistep.go.jp/en/?page_id=48
[17] The electronic files are available at http://www.bea.gov/bea/ai/iidguide.htm#USDIA1. This is the most comprehensive and consistent source of data available on international production by US MNEs (Lipsey 2003). The BEA data include wage bills paid as well as valued-added produced by majority-owned foreign affiliates of US MNEs operating in various host countries. Employment includes the number of full-time and part-time workers on the payroll at the end of the fiscal year. Value-added is measured by the sum of the costs incurred for production, namely compensation of employees, net interest paid, indirect business taxes, and capital consumption allowance.
[18] http://www.nber.org/nberces/

Dependent variable

To capture the innovation performance, we prepared the following metrics: (i) the number of patents awarded at the JPO in the firm-year observations; (ii) the number of forward citations made within 5 years from the date of application.

The use of patent statistics as an indicator of innovation presents the following advantages. First, patents are the outcome-based measures of inventions, while R&D expenditure, an alternative metric for innovation, is input-based. Because of this difference, patents conceptually fit better as the outcome variable. However, the R&D measure is inheritably prone to an endogeneity bias since offshoring decisions and plans for R&D expenses are internal to firms. Second, unlike R&D expenditure, the quality of innovation can be measured using the trail of citations to patents (Hall et al., 2005). A simple count of patents does not distinguish breakthrough innovations from less significant and incremental technological discoveries. In contrast, citations capture the economic importance and the drastic nature of innovation. If firms are willing to further invest in a project that is building on a widely cited patent, the citation information is likely to be an influential indicator of an economically significant invention.[19]

We, therefore, controlled for the quality of patents by attaching forward citation information. Citations refer to the forward citations accumulated in the 5 years following the application of a given patent.[20] In IIP patent data, at the time of our access, the final data point was the year 2011; consequently, when estimating the regression with the citation-adjusted patent, the data coverage is for the period up to the year 2007 to allow for the 5-year interval (accordingly, the sample size gets smaller).

While the citation-adjusted patents can inform us about the underlying quality of innovation, they are by construction *ex post* valuations of the quality of patents – the valuation of technology arrives with significant time lags.

Explanatory variables

We measured the intensity of offshore production (L^O) by using the employment data of the overseas affiliates of Japanese MNEs, aggregated up to firm-level in the case of multiple productions across host countries. We calculated the overseas R&D variables (RD^O) in the same way.

The size of the firm is captured by its sales. In a variant of the patent production function for MNEs, we also

[19] Patents, of course, are imperfect in several other aspects. It has been known for a long time that patenting reflects much more than indication of knowledge capital output (Griliches, 1990; Nagaoka et al., 2010). In fact, well-known inventor surveys have revealed that many patents are not used to introduce new products in the market; instead, they are used as effective strategic instruments to 'block' other competitors from innovating or imitating (Boldrin & Levine, 2013). Hence, without proper care to control for quality, patent statistics might obscure the measure of innovation.

[20] This is normally done to minimise the arbitrariness caused by the time lag between the date of the patent applications and the date of the patent examinations.

included measures of the market competition, which is usually considered one of the important factors driving innovation (Aghion et al., 2005). [21] We calculated a Lerner index, measured by median gross margin of all firms in the three-digit industry. To ease the interpretations, we defined this as *1-Lerner index*, with an index of one indicating perfect competition and an index of less than one showing some market power.[22]

Table 1 shows summary statistics for the key variables to help with interpreting the estimation results in the next section.

5. Results

First, in Table 2, we checked the statistical validity of the chosen instruments by presenting the first stage regressions since we had two endogenous variables, namely offshore production and overseas R&D. In each column, we used multiple instruments to check the statistical validity of the chosen instruments. The results consistently showed that the activities US and Japanese MNEs were highly correlated. More importantly, the F-statistics of the joint significance in each column indicate that the chosen instruments were strong and relevant.

Table 3 shows the results using standard IV-2SLS with other firm-level controls. In this specification, we assume the exogeneity of domestic R&D. However, sometimes it may not the case. Therefore, we apply Lewbel (2012) in Table 4, where we augmented the instruments generated in the dataset to the two external instruments (we provide OLS estimation results in the Appendix). Comparing Table 3 with Table 4, we see that the results of the model using the number of patents as dependent variable ((1), (2) and (3)) are similar. Offshore employment and offshore R&D have less significant effect on both the number of patents and the number of forward citations. This result suggests that the effects of resource allocation are small and do not dominate the decrease in the inputs for the domestic innovation on average, which rejects the hypothesis 1.

However, once we classify the host countries to which the firms expand their function by the degree of development, we find in Table 5 that offshoring R&D to developed countries has a significant positive effect on the quality of domestic innovation measured by the number of forward citations, while establishing R&D base in developing countries has a negative effect. This result indicates that 2 holds: offshoring of R&D promote innovation in terms of the quality through the knowledge sourcing.[23]

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[21] We thank one of the referees suggesting this exercise.

[22] Similarly, we constructed the measure of the presence of foreign owned firms in Japanese domestic industries. It is possible that the concentration of foreign-based MNEs means fierce competition in the area of technology and product competition. This may impair the opportunities for creating new inventions. This was done by a simple count of the number of foreign owned firms that are defined as more than 50% in foreign ownership. However, this variable did not carry any statistical power in explaining innovation performance of Japanese firms. Hence, we decided to omit the estimation results for this variable. In fact, this is consistent with a study by Kwon and Park (2018), which found that R&D spillover from foreign-owned firms in Japanese industries is quite limited.

[23] There is also a possibility that the host country needs different technology depending on the degree of development, which may generate another endogeneity.

Lastly, limiting the sample only to the firms without overseas R&D affiliates, we identify the pure effect of offshore manufacturing in Table 6. To see the synergistic effect of manufacturing and R&D, we introduce the cross term of the offshore employment and the domestic R&D. In this specification, we need generated instruments for the domestic R&D as we have an external instrument only for the offshore employment. The results show that the coefficient of the cross term is negative and statistically significant in model (4). This result indicates that the positive effect of offshore employment becomes smaller when the firms put larger effort on the domestic R&D. Noting that the sample for this estimation does not have a foreign affiliate for R&D activity, this result supports hypothesis 3: production and R&D have synergistic effect.

As before, we see that offshore production and R&D do not facilitate domestic innovation on average. However, we find the evidence that offshore R&D increases the quality of the domestic innovation through knowledge sourcing. These results conform to the common findings in the literatures. In some regressions, we even found that offshore production mitigates the effect of domestic R&D. This supports concerns expressed in management studies that separating production from the main R&D functions may undermine knowledge transfers and limit the knowledge spillover between the two key functions for MNEs. As a result, innovation activities at home may suffer from greater offshore production.

6. Conclusion

An extensive literature argues that innovation is one of the fundamental driving forces for modern economic growth in industrial nations. This is an especially important topic for a country like Japan which has had slower economic growth over the past three decades. At the same time, there is little consensus on the full realization of the benefits and costs of offshore production to the home economy. Since offshore production defines the main feature of the ongoing globalization process, understanding its effects on innovation would make valuable contributions to policy debates.

In this policy context, our paper examined the effects of the offshore activities of Japanese MNEs on the onshore (domestic) innovation performance using patents as an indicator of innovation. We developed an unusually rich miro-dataset from which we were able to investigate the effects of both offshore employment and R&D in the patent production framework. From the theoretical aspect, offshore production can enhance the innovation capacity of domestic operations by mobilizing within-firm resources towards more innovation activities. On the other hand, it can slow the rate of innovation by limiting the possibility of knowledge creation and transfers between R&D operations and manufacturing.

Using standard instrument variable approach and Lewbel (2012) method to assuage the endogeneity concerns arising from the relationship between offshoring and innovation, we estimated the knowledge production of Japanese MNEs, including both offshore production and overseas R&D operations. Broadly, we found that increased offshore employment and R&D do not have significant effect on the volume and the quality of domestic innovation. Moreover, offshore R&D was found to play a critical role in transmitting frontier knowledge and technology back home. This confirmed the importance of international expansion: firms acquire ideas and technology and because of this they can innovate more. We also found that the positive effect of offshore production becomes smaller for the firms with larger amount of domestic R&D investment. This empirical finding echoes the concerns raised in management studies about the effect of separating manufacturing in the form of offshore production on the level and scope of innovation. This suggests that greater offshore production can work to hinder innovation, which partly support the insist in policy discussion that mother factory should be left in Japan while promoting expansion to overseas.

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Table 1: Summary Statistics (in 1997)

Variable	Obs	Mean	Std. Dev.	Min	Max
Ln(1+Patent)	830	2.41	1.88	0.00	8.46
Ln(1+Citation_5y)	830	2.67	2.17	0.00	8.94
Ln(1+Offshore employr	830	5.75	2.01	0.00	11.12
Ln(1+Offshore R&D)	830	1.28	2.30	0.00	10.72
Ln(1+Domestic R&D)	830	6.09	2.95	0.00	12.97
Ln(sales)	830	10.68	1.53	6.80	15.87
Capital/Labor	830	3.81	0.60	2.09	6.58
Age	830	50.18	15.34	7.00	100.00
Cmpetition	830	0.82	0.07	0.59	0.94
Ln(1+IV1)	830	10.98	1.65	0.00	13.02
Ln(1+IV2)	830	9.41	1.99	0.00	12.85

Notes: The unit of observations is firm in 1997 (initial year of sample period). The data tabulations are based on the dataset constructed from the METI surveys and IIP Patent databases. International patents refer to patents applied under the international patent cooperation treaty (PCT). Competition is the Lerner index calculated at the industry-level; following Aghion et al. (2005), this is expressed as (1-Lerner Index). IV1 refers to the instrumental variable, employment of US MNEs weighted by the geographic distribution of each firm's employment share. Similarly, IV2 is R&D expenditure of US MNEs weighted by the geographic distribution of each firm's employment share.

Table 2: First stage regression

	First stage results of Standard IV			
	Offshore employment		**Offshore R&D**	
	(1)	(2)	(3)	(4)
IV1 (US offshore emp.)	0.336***	0.343***	0.031***	
	(70.504)	(84.297)	(3.704)	
IV2 (US offshore R&D)	0.010***		0.018***	0.030***
	(3.077)		(3.031)	(5.789)
Domestic R&D	0.019***	0.019***	0.005	0.005
	(4.223)	(4.227)	(0.625)	(0.628)
Ln(sales)	0.576***	0.574***	0.184***	0.187***
	(18.716)	(18.669)	(3.374)	(3.432)
Cap_Lab	0.276***	0.277***	0.132**	0.133**
	(7.559)	(7.592)	(2.050)	(2.054)
Age	0.005***	0.005***	0.002	0.002
	(4.050)	(4.073)	(1.087)	(1.108)
Cmpetition	-0.435	-0.408	0.140	0.100
	(-1.015)	(-0.952)	(0.185)	(0.132)
year	yes	yes	yes	yes
industry	yes	yes	yes	yes
fixed effect	yes	yes	yes	yes
Observations	16,627	16,627	16,627	16,627
R-squared	0.782	0.782	0.036	0.035
Number of firmid	2,337	2,337	2,337	2,337

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: The results of standard IV-2SLS (*second stage*)

	Standard IV Results					
	Ln(1+Patent)			Ln(1+Citation_5y)		
	(1)	(2)	(3)	(4)	(5)	(6)
Offshore employment	-0.039	-0.003		-0.000	0.004	
	(-1.559)	(-0.394)		(-0.004)	(0.325)	
Offshore R&D	0.274		0.098	0.028		0.028
	(1.589)		(1.395)	(0.152)		(0.308)
Domestic R&D	0.022***	0.023***	0.022***	0.025***	0.025***	0.025***
	(5.837)	(7.385)	(6.939)	(5.985)	(6.057)	(5.994)
Ln(sales)	0.286***	0.315***	0.295***	0.202***	0.205***	0.202***
	(8.796)	(14.262)	(11.441)	(5.710)	(7.011)	(6.100)
Cap_Lab	-0.045	-0.018	-0.033	0.046	0.048	0.046
	(-1.271)	(-0.709)	(-1.166)	(1.179)	(1.425)	(1.263)
Age	-0.001	-0.000	-0.000	-0.001	-0.001	-0.001
	(-0.596)	(-0.196)	(-0.488)	(-0.764)	(-0.753)	(-0.780)
Cmpetition	0.612*	0.678**	0.663**	2.047***	2.053***	2.047***
	(1.660)	(2.256)	(2.135)	(5.103)	(5.168)	(5.134)
year	yes	yes	yes	yes	yes	yes
industry	yes	yes	yes	yes	yes	yes
fixed effect	yes	yes	yes	yes	yes	yes
Observations	16,627	16,627	16,627	16,627	16,627	16,627
Number of firmid	2,337	2,337	2,337	2,337	2,337	2,337

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: The results of IV with generated instruments introduced by Lewbel (2012)

	IV with Generated Instruments and External Instruments					
	Ln(1+Patent)			Ln(1+Citation_5y)		
	(1)	(2)	(3)	(4)	(5)	(6)
Offshore employment	-0.001	-0.001		-0.008	-0.009	
	(-0.086)	(-0.172)		(-0.909)	(-1.060)	
Offshore R&D	-0.005		0.002	-0.015		-0.006
	(-0.329)		(0.135)	(-0.788)		(-0.319)
Domestic R&D	0.024***	0.023**	0.026***	0.032***	0.030**	0.033***
	(2.615)	(2.522)	(2.777)	(2.667)	(2.419)	(2.704)
Ln(sales)	0.314***	0.314***	0.311***	0.211***	0.210***	0.203***
	(13.923)	(13.964)	(13.924)	(7.067)	(7.074)	(6.881)
Cap_Lab	-0.018	-0.019	-0.019	0.055	0.053	0.051
	(-0.711)	(-0.734)	(-0.747)	(1.620)	(1.561)	(1.515)
Age	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001
	(-0.209)	(-0.214)	(-0.248)	(-0.696)	(-0.708)	(-0.768)
Cmpetition	0.681**	0.679**	0.683**	2.058***	2.052***	2.063***
	(2.271)	(2.264)	(2.276)	(5.187)	(5.169)	(5.198)
year	yes	yes	yes	yes	yes	yes
industry	yes	yes	yes	yes	yes	yes
fixed effect	yes	yes	yes	yes	yes	yes
Observations	16,627	16,627	16,627	16,627	16,627	16,627
R-squared	0.163	0.162	0.162	0.362	0.362	0.362

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Different effects of offshoring: developed countries vs. developing countries

	IV with Generated Instruments and External Instruments			
	Ln(1+Patent)		Ln(1+Citation_5y)	
	(1)	(2)	(3)	(4)
Offshore emp. (developed)	-0.025**		-0.065***	
	(-2.402)		(-4.557)	
Offshore R&D (developed)	0.014		0.096***	
	(0.711)		(3.717)	
Offshore emp. (developing)		0.000		0.001
		(0.011)		(0.057)
Offshore R&D (developing)		-0.006		-0.048**
		(-0.345)		(-2.006)
Domestic R&D	0.026***	0.027***	0.037***	0.034***
	(2.785)	(2.968)	(2.968)	(2.798)
Ln(sales)	0.314***	0.311***	0.203***	0.204***
	(14.108)	(13.924)	(6.788)	(6.888)
Cap_Lab	-0.020	-0.019	0.049	0.052
	(-0.762)	(-0.725)	(1.423)	(1.538)
Age	-0.000	-0.000	-0.001	-0.001
	(-0.160)	(-0.227)	(-0.605)	(-0.643)
Cmpetition	0.686**	0.688**	2.073***	2.084***
	(2.278)	(2.290)	(5.130)	(5.234)
year	yes	yes	yes	yes
industry	yes	yes	yes	yes
fixed effect	yes	yes	yes	yes
Observations	16,627	16,627	16,627	16,627
R-squared	0.157	0.162	0.339	0.358

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Results for the firms without overseas R&D affiliates

	IV with Generated Instruments and External Instruments			
	Ln(1+Patent)		Ln(1+Citation_5y)	
	(1)	(2)	(3)	(4)
Offshore employment	-0.000	0.014	-0.004	0.043**
	(-0.017)	(0.991)	(-0.377)	(2.497)
Offshore emp. X Domstic R&D		-0.003		-0.008***
		(-1.338)		(-3.796)
Domestic R&D	0.007	0.056***	0.026	0.115***
	(0.451)	(4.476)	(1.388)	(7.856)
Ln(sales)	0.270***	0.250***	0.137***	0.111***
	(8.782)	(8.411)	(3.822)	(3.186)
Cap_Lab	-0.021	-0.015	0.021	0.030
	(-0.610)	(-0.437)	(0.518)	(0.733)
Age	-0.002	-0.002*	-0.004**	-0.004**
	(-1.306)	(-1.674)	(-2.278)	(-2.533)
Cmpetition	1.502***	1.543***	2.219***	2.259***
	(3.400)	(3.493)	(4.319)	(4.376)
year	yes	yes	yes	yes
industry	yes	yes	yes	yes
fixed effect	yes	yes	yes	yes
Observations	12,065	12,065	12,065	12,065
r2	0.265	0.264	0.325	0.317

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Appendix

We show the results of simple OLS estimation in Table A1. We find that the results are similar with those of standard IV estimations and IV with generated instruments in Table 4 and 5. The difference is the statistical significance of offshore R&D on the quality of innovation: the coefficients of offshore R&D are negative (and statistically significant on the number of citations). We see the strong significant effect of domestic R&D and firm size measured by the sales, which imply the simultaneity with the offshoring decision.

Moreover, we include year by industry dummies instead of using year dummies and industry dummies separately since the clustering behaviors can be changed thorough time and can vary depending on the industry. The results corresponding to Table 4 and 5 are shown in Table A2 and A3. Again, we see the similar results, though the significance of the negative coefficients is stronger.

Table A1. OLS estimation results

	OLS					
	Ln(1+Patent)			**Ln(1+Citation_5y)**		
	(1)	(2)	(3)	(4)	(5)	(6)
Offshore employment	0.003	0.002		-0.010	-0.012*	
	(0.685)	(0.498)		(-1.500)	(-1.919)	
Offshore R&D	-0.005		-0.004	-0.013***		-0.014***
	(-1.432)		(-1.353)	(-3.021)		(-3.250)
Domestic R&D	0.023***	0.023***	0.023***	0.025***	0.025***	0.025***
	(7.359)	(7.357)	(7.383)	(6.145)	(6.139)	(6.103)
Ln(sales)	0.312***	0.312***	0.314***	0.215***	0.215***	0.210***
	(14.369)	(14.355)	(14.582)	(7.497)	(7.463)	(7.364)
Cap_Lab	-0.020	-0.020	-0.019	0.054	0.053	0.051
	(-0.764)	(-0.779)	(-0.727)	(1.603)	(1.572)	(1.523)
Age	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001
	(-0.229)	(-0.237)	(-0.206)	(-0.652)	(-0.668)	(-0.703)
Cmpetition	0.682**	0.681**	0.680**	2.048***	2.045***	2.054***
	(2.272)	(2.267)	(2.265)	(5.158)	(5.147)	(5.172)
year	yes	yes	yes	yes	yes	yes
industry	yes	yes	yes	yes	yes	yes
fixed effect	yes	yes	yes	yes	yes	yes
Observations	16,627	16,627	16,627	16,627	16,627	16,627
R-squared	0.163	0.162	0.163	0.362	0.362	0.362
Number of firmid	2,337	2,337	2,337	2,337	2,337	2,337

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A2. Standard IV results with year by industry dummies

	Standard IV Results					
	Ln(1+Patent)			Ln(1+Citation_5y)		
	(1)	(2)	(3)	(4)	(5)	(6)
Offshore employment	-0.043	-0.005		-0.004	0.005	
	(-1.441)	(-0.592)		(-0.118)	(0.486)	
Offshore R&D	0.287		0.083	0.069		0.051
	(1.382)		(1.118)	(0.310)		(0.534)
Domestic R&D	0.020***	0.022***	0.021***	0.022***	0.023***	0.022***
	(4.870)	(6.876)	(6.334)	(5.122)	(5.532)	(5.313)
Ln(sales)	0.327***	0.355***	0.338***	0.222***	0.229***	0.223***
	(9.368)	(15.215)	(12.659)	(5.918)	(7.448)	(6.460)
Cap_Lab	-0.063	-0.029	-0.043	0.013	0.021	0.015
	(-1.561)	(-1.120)	(-1.499)	(0.297)	(0.621)	(0.393)
Age	-0.001	0.000	-0.000	-0.002	-0.001	-0.002
	(-0.493)	(0.067)	(-0.255)	(-1.300)	(-1.295)	(-1.350)
Cmpetition	1.048**	1.058***	1.055***	2.133***	2.136***	2.134***
	(2.355)	(2.950)	(2.872)	(4.455)	(4.515)	(4.478)
year*industry	yes	yes	yes	yes	yes	yes
fixed effect	yes	yes	yes	yes	yes	yes
Observations	16,627	16,627	16,627	16,627	16,627	16,627
Number of firmid	2,337	2,337	2,337	2,337	2,337	2,337

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A3. IV using generated instruments and external instruments with year by industry dummies

	IV with Generated Instruments and External Instruments					
	Ln(1+Patent)			Ln(1+Citation_5y)		
	(1)	(2)	(3)	(4)	(5)	(6)
Offshore employment	-0.002	-0.005		-0.003	-0.009	
	(-0.348)	(-0.729)		(-0.375)	(-1.083)	
Offshore R&D	-0.020**		-0.024**	-0.046***		-0.048***
	(-2.185)		(-2.470)	(-3.890)		(-3.788)
Domestic R&D	0.019***	0.016**	0.020***	0.028***	0.023***	0.030***
	(3.066)	(2.453)	(3.024)	(3.302)	(2.659)	(3.423)
Ln(sales)	0.358***	0.358***	0.357***	0.239***	0.238***	0.236***
	(15.482)	(15.477)	(15.580)	(7.841)	(7.790)	(7.812)
Cap_Lab	-0.027	-0.030	-0.027	0.031	0.025	0.031
	(-1.051)	(-1.158)	(-1.050)	(0.923)	(0.748)	(0.912)
Age	0.000	0.000	0.000	-0.001	-0.001	-0.001
	(0.135)	(0.107)	(0.127)	(-1.154)	(-1.223)	(-1.183)
Cmpetition	1.058***	1.057***	1.058***	2.139***	2.136***	2.139***
	(2.986)	(2.983)	(2.986)	(4.571)	(4.573)	(4.571)
year*industry	yes	yes	yes	yes	yes	yes
fixed effect	yes	yes	yes	yes	yes	yes
Observations	16,627	16,627	16,627	16,627	16,627	16,627
R-squared	0.189	0.190	0.189	0.385	0.387	0.384

z-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1