Revisit the Domestic Innovation Effect of Outward FDI in Taiwan: Quantity or Quality?

Chih-Hai Yang* and Kuo-An Li**

Abstract

This study investigates how outward foreign direct investment (OFDI) influence innovation activity and efficiency in Taiwan. On the basis of a firm-level panel dataset of publicly listed electronics firms for the period 2002–2018, various estimations reveal that OFDI overall has a positive influence on research and development (R&D) expenditure and patent numbers. However, this R&D effect may be adverse across destinations and time periods. Before the late 2000s, the pro-R&D effect existed for OFDI to developing countries only, particularly China, but this R&D effect became negative after the late 2000s. The patent effect of OFDI is also found, particularly the technology sourcing through OFDI to advanced countries. Regarding high-novelty patents measured by inventions, we find that the OFDI in

---

* Professor, Department of Economics, National Central University, Taiwan. Corresponding Author. Email: chyang@mgt.ncu.edu.tw. The authors acknowledge financial support by the Science & Technology Research Policy and Information Center, National Applied Research Laboratories (STPI-A-110058). Helpful comments and suggestions from referees are highly appreciated. We are responsible for all errors.

** Researcher, Science & Technology Policy Research and Information Center, National Applied Research Laboratories. Email: kali@narlabs.org.tw.

DOI: 10.53106/054696002023120114001

Reveiced March 13, 2023; Revised October 1, 2023; Accepted November 10, 2023.

both developing and developed economies indicates a positive relationship with invention grants at home. Further, OFDI also facilitates multinational enterprises' promotion of R&D productivity in patents and high-novelty inventions in particular.

Keywords: Export, FDI, R&D, Patent
JEL Classifications: F19, F21, F23, F61, O31, O32

Revisit the Domestic Innovation Effect of Outward FDI in Taiwan: Quantity or Quality?

Chih-Hai Yang and Kuo-An Li

I. Introduction

Innovation is recognized as one of the driving forces to sustain long-term growth, but the interplay between technology and various economic characteristics affect the economic growth realized (Aghion et al., 1998). With the advent of the liberalization of international investment and the development of global production fragmentation in the 1990s, there was a considerable rise in the flow of global foreign direct investment (FDI). FDI is one channel of international knowledge spillover (Keller, 2010), so it can generate significant influences on the innovative activity of the host economy. Numerous studies have previously demonstrated the pro-innovation effect brought about by FDI in both developing host countries (Cheung and Lin, 2004; Hoang et al., 2021; Vahter, 2011) and developed countries (Branstetter, 2006; García et al., 2013).[1]

However, from the perspective of investing countries, how outward FDI (OFDI) impacts innovation in the home country is complex and controversial. Through OFDI/offshoring,[2]

---

[1] Rojec and Knell (2019) provided a comprehensive survey on this line of literature.

[2] OFDI and offshoring share similar concepts, but are not the same. In this study, OFDI refers to Greenfield investments. Offshoring is a contracting-out phenomenon. It also denotes the relocation of production lines to another country, wherein this production process can be implemented either externally or internally to the firm.

firms change their operation modes substantially, inducing a corresponding adjustment of innovation activity in firms. Reallocating production processes to other countries, particularly labor-intensive and routine tasks, it may facilitate multinational enterprises (MNEs) to focus more on R&D activity, while it may also reduce feedback from plants to R&D departments. Additionally, recent theoretical works are ambiguous regarding the relationship between OFDI/offshoring and innovation in parent firms, hinging on the level of technological spillover in the host country (Chen and Hsu, 2003), relative technological opportunities and demand conditions between host and home countries (Belderbos et al., 2008), the feedback effect from plant to laboratory (Naghavi and Ottaviano, 2009), offshoring cost (Acemoglu et al., 2015), and trade cost (Saito, 2018). A growing body of literature has examined the impact of OFDI on firms' innovation activity in the home country, while extant studies yield inconsistent findings (reviewed in the next section). The R&D response to OFDI depends on heterogeneity OFDI, as argued in the above theoretical works.

The issue of the OFDI – innovation at home is particularly relevant to Taiwan whose OFDI accounted for a large share of gross domestic product and concentrated on the electronics industry toward China.[3] Along with the lifting of OFDI restrictions to China posed on electronics firms in late 2001, in combination with the development of global production chains (GPCs), export-platform FDI to China by electronics firms has mushroomed.[4] As depicted in Figure 1, the ratio of manufacturing OFDI to China to total manufacturing OFDI increased sharply since 2002 and reached the peak surrounding 90% in 2010-2011, and then declined gradually. The average ratio was 75.94% for the period 1998–2018. Crucially, the manufacturing OFDI to China is composed primarily of the electronics sector (Electronic Parts

---

[3] According to the 2009 World Investment Report of Union Nation, the average of the accumulated amount of OFDI to GDP ratio was 33.0% in developed countries in 2008, while the corresponding number of Taiwan reached 44.6%.

[4] For details about lifting restrictions on electronics firms' OFDI to China in 2001 and firm response to this deregulation, please refer to Branstetter et al. (2017) and Yang et al. (2010).

and Components Manufacturing; Computers, Electronic and Optical Products Manufacturing; Electrical Equipment Manufacturing) that accounted for 51.70%, on average. The electronics industry not only is the key industry in Taiwan's manufacturing sector in terms of exports and R&D expenditure, accounting for 45.97% and 80.75% in the manufacturing sector in 2015,[5] but also plays a crucial role in existing global electronics production chains; for semiconductor products in particular. Therefore, the issue of whether the large capital outflow to China undertaken by the electronics sector affects domestic innovations has caused public concern in Taiwan.

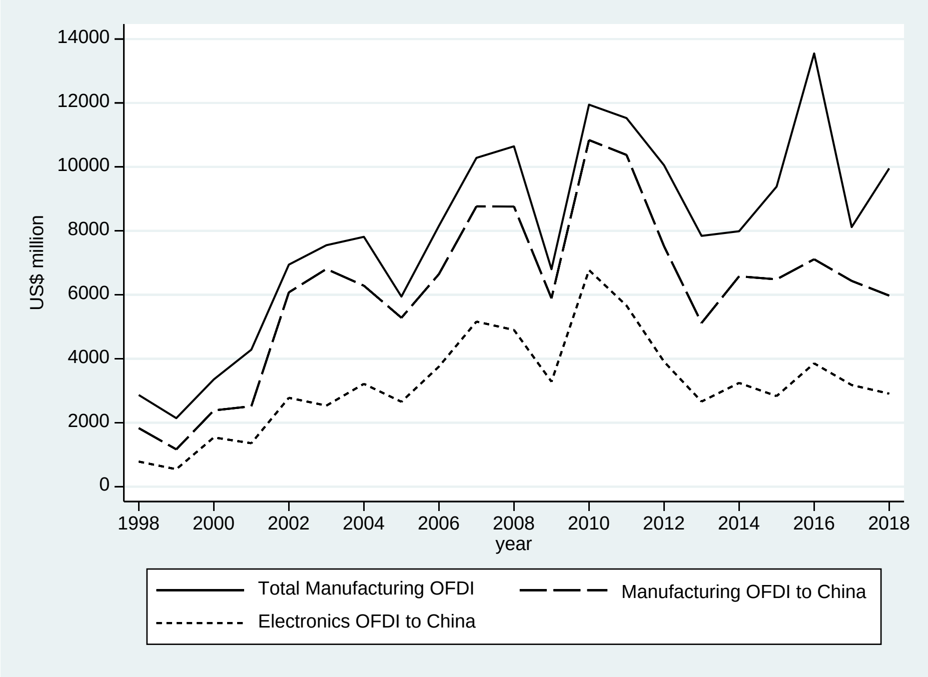


Figure 1 Manufacturing and Electronics OFDI to China, 1998–2018
Source: Investment Commission, Ministry of Economic Affairs, Taiwan.

[5] Export information is extracted from the database of Bureau of Foreign Trade, Ministry of Economic Affairs, whereas R&D information is obtained online from websites of the Ministry of Science and Technology of Taiwan.

Several studies have examined OFDI and parent firms' innovation in Taiwan (Yang et al., 2010; Lin et al., 2015; Branstetter et al., 2017), and their results are inconsistent, and some limitations remain. Focusing electronics firms' offshoring to China, Yang et al. (2010) and Branstetter et al. (2017) found that OFDI has a positive and negative impact on firms' patenting based on a sample for the 1997-2005 and 1999-2013 period, respectively. Notably, the endogeneity problem of input R&D that is affected by OFDI is not well addressed. This may lead to bias toward the patent effect of OFDI. Moreover, the OFDI measure is a binary variable or implicit rather than a stock measure (Branstetter et al., 2017; Lin et al., 2015).

This study revisits the influence of OFDI on innovation, as well as the R&D productivity in Taiwan's electronics firms for the period 2002–2018. Compared with the above studies, our analysis adds value in several ways. First, the relationship between OFDI and innovation remains an empirical question that may vary across time periods because MNEs may undergo a gradual and comprehensive change in internationalization of R&D and innovation (Papanastassiou et al., 2020). Allocating labor-intensive production lines may enable the parent firms of MNEs to focus more on innovations at home. However, China has experienced an accelerated technological catch-up in the high-tech sector since the late 2000s (Zhang and Zhou, 2016; Zhang et al., 2021). Along with the increases in market localization and localization of the R&D network in China, affiliates of Taiwanese MNEs may increase their R&D in China (Yang and Hayakawa, 2015), thereby lowering the amount of innovative activities at home. Using a similar sample of electronics firms as that in Branstetter et al. (2017) and Yang et al. (2010), our dataset covers a longer period of 2002 – 2018 that enables this study to examine whether the OFDI – innovation nexus in parent firms varies in different periods.

Second, although OFDI can trigger either positive or negative change in innovations measured by patents, offshoring production may impact onshore patent quality (Yamashita and Yamauchi, 2019). Using invention patents as the measure of quality, this study also assesses the influence of OFDI on high-novelty inventions. Furthermore, if OFDI trigger firms' R&D adjustment, one further and more important issue is that whether firms undertake R&D in a more productive way in terms of patent grants? This study examines the trajectory of the innovation efficiency (R&D productivity with respect to patents) of electronics MNEs in Taiwan.

Third, inconsistent findings regarding the OFDI–innovation nexus is relevant to the measurement of OFDI and OFDI contents. Besides adopting the OFDI dummy that is used in prior studies, such as those of Junge and Sørensen (2018) and Lin et al. (2015), we construct several OFDI variables based on subsidiary numbers and their country distribution in different economic development degrees. In particular, the number of subsidiaries in China is separated and examined, because China is the main OFDI destination of Taiwanese electronics MNEs. Various and robust estimations provide better understanding regarding the innovation effect generated by undertaking OFDI and delineations of OFDI in developing or developed countries.

The remainder of this paper is organized into five sections. Section 2 reviews the related literature; Section 3 presents the data and estimation strategy; Section 4 reports and discusses the main results regarding the influences of export and OFDI on R&D; Section 5 examines the globalization–innovation nexus and conducts further investigation of innovation efficiency in terms of R&D productivity in producing patents. Section 6 concludes.

II. OFDI and Innovations at the Parent Firms

Conceptually, firms' motivations of OFDI direct their resource management within firms. Technology sourcing is one of OFDI incentives (e.g., Kogut and Chang, 1991; Neven and Siotis, 1996), particularly for OFDI toward advanced countries. Through technological acquisitions and spillovers, investing firms can promote productivity and technological capability, thereby facilitating more innovations. In view of the development of GPCs, a stream of theoretical literature using a North-South framework mostly claim a positive association, asserting that reallocating production lines to developing countries helps resource reallocation and generates efficiency gains and facilitates innovations (Petit and Sanna-Randaccio, 2000; Glass and Saggi, 2001; Rodriguez-Clare, 2010). However, separating the manufacturing and R&D functions of a firm may hamper parent firms from engaging in R&D due to various extenuating factors, as discussed in Acemoglu et al. (2015), Belderbos et al. (2008), Chen and Hsu (2003), Naghavi and Ottaviano (2009), and Saito (2018). Therefore, the OFDI/offshoring–innovation relation remains uncertain.

The research question of how OFDI affects domestic firms' innovation has attracted numerous studies in the past two decades, while the findings obtained in numerous studies are controversial. One line of empirical studies examines the influence of offshoring on innovation, adopting the ratio of imported intermediates to sales to represent the degree of offshoring (e.g., Fritsch and Görg, 2015; Karpaty and Tingvall, 2015; Baum et al., 2022) rather than considers the amount and destination of OFDI directly. Using firm-level data for over 20 emerging economies, Fritsch and Görg (2015) find that outsourcing increases the propensity of R&D, introducing new products and upgrading existing products. A weakly positive effect in Swedish manufacturing firms is also found in Baum et al. (2022), which use patents as a measure of innovation. In contrast, Karpaty and Tingvall (2015) determine a negative net effect of offshoring on R&D in Swedish firms. This negative effect stems from offshoring by small firms from other high-income countries, whereas offshoring increases home country R&D among large firms. Junge and Sørensen (2018) also examine whether offshoring lowers R&D intensity in firms with preexisting R&D spending. Evidence from Danish firms indicates that offshoring does not lead to lower R&D intensity, and their measure of offshoring is represented as binary variables.

Literature explicitly investigating the impact of OFDI on parent firm innovation is rare, but growing. For the perspective of advanced countries' MNEs, Yamashita and Yamauchi (2019) find that offshore production (measured by the number of employees in foreign affiliates) has no significant effect on parent firms' patent grants in Japan. Driffield and Love (2003) test the 'reverse spillover' effect of OFDI for UK manufacturing industries and find that this effect exists in sectors that technology sourcing is not a motivating influence. Alternatively, this effect hinges on the domestic-to-foreign technological externalities within the host country.

A country-level analysis conducted by Filippetti et al. (2017) reports a positive association between OFDI and patenting; the strength of this innovation effect hinges on the absorptive capacity of investing countries. Crucially, the innovation effect of OFDI exhibits large differences between technological leading countries and technological followers (AlAzzawi, 2012). Technological followers gain more from FDI-induced R&D spillovers, although OFDI is also conducive to increased domestic innovation in technological leaders. It is because technology sourcing is one of important motives driving MNEs' OFDI from developing countries, but this factor is less relevant to technological leaders' outward FDI.

Along with the emerging of FDI from developing countries, recent studies examining this issue focus on emerging economies. MNEs from emerging economies tend to use OFDI in developed market to acquire new knowledge and capture the knowledge-spillover effect, which contributes to the technological catch-up of their home countries (Amighini and Rabellotti, 2010; Chen et al., 2012) Thus, a positive relationship between OFDI and parent firms' innovations is found in evidence from developing countries, such as Peddy et al. (2022). As China emerged as the largest developing country which undertakes foreign acquisitions and greenfield investment globally, several studies have also verified that China's going-out strategy facilitates innovations at home and boosts its indigenous innovation capabilities (e.g., Li et al., 2016; Piperopoulos et al., 2018; Zhou et al., 2019; Howell et al., 2020; Dong et al., 2021).[6]

Several studies have also examined this issue in Taiwan which are closely related to our analysis, while they provided various results. Yang et al. (2010) examine the effect of OFDI to China on domestic innovation activity using publicly listed firms for the period 1997–2005. An overall positive relationship between OFDI to China and innovation (R&D intensity and patents) at home is demonstrated, in particular, with electronics firms. However, engaging OFDI to developed countries appears to have no significant influence on innovation. Contrasting results are reported by Branstetter et al. (2017), who study the causal relationship

[6] See Papanastassiou et al. (2020) for a comprehensive review on internationalization of R&D and innovation by MNEs.

between offshoring and patenting in listed electronics firms. The authors find that offshoring to China has a negative impact on patenting, whereas patent counts are those granted in the U.S. rather than in Taiwan, as used in Yang et al. (2010).

Chen and Yang (2013) examine the impact of OFDI to low-wage countries (mainly China) on domestic R&D activity. The analysis obtained based on a firm-level panel dataset from 1992 – 2005 reveals that OFDI is positively related to domestic R&D spending, particularly in R&D-intensive industries. Lin et al. (2015) argue that OFDI types may matter to parent firms' R&D expenditure. By dividing firms' OFDI into four types: non-FDI, defensive OFDI only, expansive OFDI, and both defensive and expansive OFDI, the authors use propensity score matching to conduct estimations based on a two-period data (2001 and 2006). Estimations demonstrate that R&D expenditure increases regardless of the type of OFDI strategy, whereas defensive OFDI has the smallest effect among the four OFDI types.

III. Data and Estimation Strategy

A. Data and Overview

The dataset used in this study is drawn from three data sources. The first is the Taiwan Economic Journal database, which contains comprehensive information on publicly listed companies,[7] including basic information, financial statements, and production information, among other characteristics. According to the registered two-digit industry code of firms, we select electronics firms (TSIC 26–28) because Taiwan's OFDI is mainly initiated by firms in the electronics industry since the early 2000s. The second data source is OFDI information

---

[7] Publicly listed companies include those listed on the Taiwan Stock Exchange or the Taipei Exchange.

collected and maintained by the Investment Commission, Ministry of Economic Affairs. We check the established years and destinations of each individual company's subsidiaries, which enables us to construct various OFDI variables. OFDI stock could be also a more adequate indicator than OFDI dummy and even more than subsidiary numbers, while acquiring this information is a challenge in Taiwan. Thus, previous firm-level studies, such as Chen and Yang (2013) and Lin et al. (2015), adopts a binary dummy variable of OFDI to examine MNEs' behaviors.[8] Our OFDI stock measure in terms of the number of foreign subsidiaries complements the insufficiency of a binary measure. We then use the company name to extract patent information from the third data source, the patent database of the Taiwan Intellectual Property Office. The aforementioned data collecting procedures yield a firm-level panel dataset of Taiwanese electronics firms between the years 2002 and 2018. As mentioned previously, the response of Taiwan's electronics firms to the 2001 de-regulation policy was rapid and substantial. Thus, the study period begins in 2002.[9]

Although publicly listed companies are generally large- and medium-sized enterprises (LMEs), the dataset constructed is suitable for examining the OFDI–innovation nexus. The reasons and limitations are as follows. (1) Small firms, mostly with a single plant, also implement OFDI, while they often shut down the domestic plant and relocate all production resources overseas. This situation suggests that such small firms have no parent firms in the home country after OFDI; they are excluded from our dataset. As the main purpose of this study is examining the innovation effect of OFDI on domestic parent firms, the exclusion of such firms is acceptable in sampling. However, certain small firms which implemented OFDI and remained the parent firms in Taiwan are also excluded. We noted this potential sample

[8] Yang et al. (2010) is the exception that examines the influence of OFDI on parent firms' innovations in Taiwan by using OFDI stock as an indicator. That study obtained the information about firms' capital outflow from the Central Bank.

[9] As covariates enter the empirical specification in the one-year lagged form, firm information in 2001 is also collected.

selection issue, despite this issue may be not considerable.[10] (2) LMEs have a higher propensity for undertaking R&D than small firms; their R&D expenditure accounts for an overwhelming share of total R&D expenditure in the manufacturing sector. For example, in 2011, the R&D propensity of small firms and LMEs were 4.94% and 43.26%, respectively. Meanwhile, LMEs contributed 90.56% of total R&D.[11] Despite small firms also implemented OFDI, it is reasonable to expect that their levels of R&D expenditure and patent activity may remain relatively lower. (3) There are more and more listed electronic firms which made an initial public offering since the 2000s, implying that the inclusion of new firms in the dataset may impact the sample. Compared with the number of incumbent and rarely existing firms, new listed firm-observations are the minority. Thus, including or excluding the entry of new firms are less relevant to estimation results.[12]

Table 1 presents an overview of OFDI and innovation in the sample. We categorize electronics firms into OFDI firms and non-OFDI firms. OFDI is a prevailing phenomenon in the electronics sector: the upper row shows that the number of firms with OFDI (7,314) is larger than non-OFDI (4,841), accounting for 60.173% of firm observations in the whole period (2002-2018). Columns 2 and 3 demonstrate the means of R&D expenditure and patent grants of two groups of firm-year observations. Notably, OFDI firms have a larger R&D expenditure and more patent grants which are more than two times compared with their

---

[10] Among the 240 OFDI cases registered to the Department of Investment Review, Ministry of Economic Affairs in 2007, 162 OFDI cases were undertaken by firms in our sample, accounting for 67.91%. This implies that this sample selection bias appears to only a relatively small extent because the expenditure of each OFDI case undertaken by these large listed firms is much larger compared with that of small firms.

[11] These numbers are calculated by the authors based on the 2011 Census data.

[12] Firm-observations appearing every year account for more than 90% of total firm-observations; thus, estimates obtained by using the balanced panel dataset are similar. Results are available upon request from the corresponding author.

Table 1 Summary Statistics by Firm Type

Export types	(1) Number of observations	(2) R&D expenditure (NT$ million)	(3) Patents	(4) Number of foreign subsidiaries
OFDI status (2001-2018)				
OFDI firms	7,356	447.306	27.670	2.816
Non-OFDI firms	4,662	205.295	9.989	
Observations	12,018			
OFDI status (2001-2010)				
OFDI firms	3,609	315.932	23.664	2.386
Non-OFDI firms	2,605	171.185	8.366	
Observations	6,214			
OFDI status (2011-2018)				
OFDI firms	3,747	573.841	31.586	3.229
Non-OFDI firms	2,057	248.492	12.046	
Observations	5,804			

Note: The numbers displayed are firm-observations with R&D information. As covariates enter the empirical specification in the one-year lagged form, firm information in 2001 is also collected. The observation numbers may decrease in empirical estimations because information on other firm characteristics is missing in some firm observations.

non-OFDI counterparts, on average. Without controlling other firm characteristics, it seems to show a positive association between OFDI and innovation activities.

Although Yang et al. (2010) found that OFDI has a positive impact on electronics firms' patenting in 1997-2005, Yang and Hayakawa (2015) argued that, along with the increase in experience and degree of localization of subsidiaries in China, Taiwanese MNEs allocate more innovation resources in their Chinese subsidiaries. Liu and Chen (2012) also indicated a growing number of Taiwan-based firms establishing R&D units in China. Utilizing China's abundant and low-cost labor to undertake processing export is one of primary motivations for

Taiwanese electronics firms to invest in China in the early 2000s. However, this low-cost advantage was eroded since 2010 when China enforced the Labor Contract Law in 2010 (Yang, 2023). Thus, the OFDI – innovation could vary in periods of pre- and post-2010. The middle and lower rows present summary statistics in 2002 – 2010 and 2011 – 2018, respectively.

The middle and low rows show that both OFDI and Non-OFDI groups exhibited an increase in R&D expenditure and patent grants. Non-OFDI firms demonstrated a similar R&D-to-patent ratio in both periods, whereas OFDI firms experienced a sharply increase in the R&D-to-patent ratio in the 2011-2018 relative to that in 2002-2010, implying that OFDI firms produced less patents given the same input of R&D expenditure. Column 4 shows that the number of foreign subsidiaries of OFDI firms increased from 2.386 in 2001 – 2010 to 3.229 in 2011 – 2018, on average, reaching a growth rate of 35.33%. This number is lower and higher than the corresponding growth rates of R&D expenditure and patents in OFDI firms, respectively. However, we cannot infer a change in the OFDI-innovation nexus because controlling firm characteristics and adopting an adequate OFDI measure are required.

B. Estimation Strategy

To assess the impact of OFDI on domestic innovation activity, it is imperative to adopt adequate innovation measures. Patents, new product/process innovation, and R&D are widely adopted in existing studies, and R&D expenditure is the mostly used measure. Product and process innovation reported by firms is a subjective measure. Patents could be a good indicator of R&D output, but this indicator also exists minor drawbacks: some firms may not apply for patents for R&D output; R&D expenditure may generate non-technological and non-patentable innovations. Hence, we first adopt R&D expenditure as an indicator of innovation and specify the empirical model as follows:

$$\begin{aligned}\ln RD_{it} &= \beta_0 + \beta_1 OFDI_{i,t-1} + \beta_2 \ln Export_{i,t-1} + \beta_3 \ln SIZE_{i,t-1} \\ &\quad + \beta_4 \ln KL_{i,t-1} + \beta_5 Finance_{i,t-1} + u_t + v_i + \varepsilon_{it} \qquad (1)\end{aligned}$$

where *RD* is the R&D spending by firm *i* in year *t*.

All covariates enter the equation in a 1-year lagged form to mitigate simultaneity problems. *OFDI* is the key covariate of concern, denoting the behavior of outward FDI. Here we use several sets of OFDI measures. The first one is an OFDI dummy variable (*OFDI_dum*), equaling 1 if a firm has engaged in OFDI. As OFDI is essentially a stock concept, we further adopt the number of foreign subsidiaries (*OFDI_num*) and the number of foreign subsidiaries in developing countries (*OFDI_num_dev*) and in advanced economies (*OFDI_num_adv*).[13]

Regarding other covariates, ln*Export* is the logarithm of export value.[14] The pro-innovation mechanisms for exporters are multi-dimensional, mainly the competition effect (Clerides et al., 1998), demand-driven forces (Yang, 2018), the learning effect (Clerides et al., 1998; Keller, 2010), and market size effect (Aghion et al., 2018). Thus, a positive association between exports and innovation is expected. Other controlled firm characteristics include firm size (the logarithm of number of employees), capital intensity (the logarithm of fixed capital per employee), and internal finance (return to assets, ROA). Larger and more capital-intensive firms are expected to devote more R&D expenditure. As firms prefer internal funds for financing R&D investments (Hall, 2002), internal finance should be positively related to R&D. The term *u* is the year fixed effect, capturing macroeconomic shocks affecting firms' R&D expenditure. Finally, *v* and *ε* denote the unobserved firm heterogeneity and the error terms, respectively. Table 2 summarizes definitions and basic statistics of variables.

---

[13] As Table 2 shows below, the mean of *OFDI_num* might be relatively low, standing at 1.692. If we only use OFDI firms to calculate the mean of the number of foreign subsidiaries, the corresponding number is 2.816 with a range between 1 and 194, suggesting a considerable difference in *OFDI_num* across firms.

[14] If a zero export value is reported by firms, it is replace by one, resulting in the lnExport to be zero. If our sample, more than 99% of firm observations report a positive export value because Taiwan's electronics firms are highly export-oriented.

Table 2 Variable Definitions and Basic Statistics

Variable	Definition	Mean (S.D.)	Obs.
R&D expenditure	R&D expenditure (NT$ million)	361.872 (2,105.73)	11,486
Patent	Number of patents granted	20.674 (134.689)	12,155
Invention	Number of granted invention patents granted	16.697 (118.157)	12,155
Export	Exports (NT$ billion)	13.812 (108.187)	11,351
Expint	Export intensity: The export-to-sale ratio (%)	71.938 (27.396)	11,347
OFDI_dum	OFDI dummy: 1 = OFDO; 0 = without OFDI	0.602 (0.690)	12,155
OFDI_num	Number of foreign affiliates	1.692 (4.693)	12,155
OFDI_num_dev	Number of foreign subsidiaries in developing countries	1.406 (3.800)	12,155
OFDI_num_adv	Number of foreign subsidiaries in advanced economies	0.286 (1.218)	12,155
OFDI_num_cn	Number of foreign subsidiaries in China	1.406 (3.800)	12,155
OFDI_num_othdev	Number of foreign subsidiaries in developing countries other than China	0.139 (0.498)	12,155
Size	Firm size: the number of employees	691.793 (1,952.7)	11,602
TFP	Total factor productivity: calculated using the method of Levinsohn and Petrin (2003)	11.382 (1.380)	11,143
KL	Capital intensity: fixed per employee (NT$ million)	1.983 (2.965)	11,602
Finance	Internal finance: quick ratio (%)	226.341 (1,355.22)	11,640

Note: The basic statistics of firm characteristics are calculated using data for 2002–2018.

IV. Results and Discussion

First, we illustrate the estimation results in Table 3 using R&D expenditure as the indicator of innovation.[15] Estimates are obtained based on the fixed effect (FE) of panel data model accompanied with Hausman test statistics. As the values of Hausman tests are statistically significant, this suggests that FE model is more adequate than the random effect model. That is, unobserved firm heterogeneity is correlated with regressors, suggesting that controlling the firm fixed effect is required.

The estimates of OFDI demonstrate various results, hinging on OFDI measures. Using a binary variable, OFDI_dum is associated with an insignificant coefficient in column 1, implying that OFDI is less relevant to parent firms' R&D. However, we have to note that a binary measure of OFDI is probably inadequate. Once a firm began to establish the first foreign subsidiary, the OFDI_dum was equal to unity since then, preventing it from considering the situation that MNEs set up more foreign subsidiaries in subsequent years. Alternatively, the number of foreign subsidiaries can take account of MNEs' decisions on establishing new foreign subsidiaries.

In column 2, we adopt a stock measure of subsidiary numbers (*OFDI_num*), finding a significant R&D enhancing effect brought about by OFDI, echoing the findings for Taiwan in Yang et al. (2010). The economic magnitude of the estimated coefficient suggests that firms with one more foreign subsidiary are associated with 0.0465% increase in R&D expenditure. This result is also consistent with findings in offshoring literature (e.g., Fritsch and Görg, 2015; Karpaty and Tingvall, 2015; Baum et al., 2022). To integrate into the GPCs through

---

[15] As the covariates enter the equation in 1-year lagged form, estimations for the R&D equation use data covering the period between 2001 and 2018. Moreover, replacing R&D expenditure with R&D intensity, estimation results are similar.

OFDI, Taiwanese MNEs seek to exploit the relative advantages of various host countries by undertaking export-platform FDI and/or technology-motivating FDI. Therefore, parent firms focus more on R&D activity to develop high value-added products or improve production processes. In column 3, the OFDI measure enters the equation in the natural logarithm form (lnFDI_num), the estimate is also significantly positive with an elasticity of 0.1173, consolidating our finding of a positive OFDI – R&D expenditure nexus.

The innovation effect of OFDI is relevant to the characteristics of host countries, as claimed in Glass and Saggi (2001), Petit and Sanna-Randaccio (2000), and Rodriguez-Clare (2010). We separate OFDI into those in developing and advanced countries to examine the potential difference in the R&D effect. Notable findings emerge, as illustrated in column 4. Significant R&D facilitating effects are shown only for OFDI to advanced economies that echoes the technology-sourcing arguments (Neven and Siotis, 1996), but not for OFDI to developing countries. MNEs mostly allocate production lines to developing countries, particularly China, to exploit the low-cost labor advantage. Because of lowered offshoring and trading costs of the OFDI policy change in 2001, China is the primary developing country of Taiwan’s OFDI. Although the degree of technological spillover is high in China, its huge market size also offers many technological opportunities. This tradeoff between locating R&D in foreign affiliates and domestic firms results in an insignificant effect of OFDI in developing countries on R&D at home. OFDI in advanced countries is often in the form of establishing subsidiary company distribution for sales and post-sale service or establishing plants/labs for technology-sourcing motivation, thereby executing a positive R&D enhancement effect.

The innovation effect of OFDI is relevant to the characteristics of host countries, as claimed in Glass and Saggi (2001), Petit and Sanna-Randaccio (2000), and Rodriguez-Clare (2010). We separate OFDI into those in developing and advanced countries to examine the potential difference in the R&D effect. Notable findings emerge, as illustrated in column 4. Significant R&D facilitating effects are shown only for OFDI to advanced economies that echoes the technology-sourcing arguments (Neven and Siotis, 1996), but not for OFDI to developing countries. MNEs mostly allocate production lines to developing countries,

Table 3 OFDI and R&D Expenditure

	(1) FE	(2) FE	(3) FE	(4) FE	(5) FE
OFDI_dum	0.1355				
	(0.0947)				
OFDI_num		0.0465^{***}			
		(0.0166)			
lnOFDI_num			0.1173^{*}		
			(0.0657)		
OFDI_num_dev				0.0002	
				(0.0070)	
OFDI_num_adv				0.0927^{***}	0.0874^{***}
				(0.0346)	(0.0356)
OFDI_num_cn					−0.0006
					(0.0071)
OFDI_num_othdev					0.0353
					(0.0533)
lnExport	0.0499^{***}	0.0508^{***}	0.0502^{***}	0.0507^{***}	0.0506^{***}
	(0.0114)	(0.0114)	(0.0114)	(0.0114)	(0.0114)
lnSIZE	1.4126^{***}	1.4108^{***}	1.4114^{***}	1.4108^{***}	1.4113^{***}
	(0.0275)	(0.0274)	(0.0275)	(0.0274)	(0.0275)
lnKL	0.0609^{***}	0.0635^{***}	0.0615^{***}	0.0635^{***}	0.0633^{***}
	(0.0236)	(0.0236)	(0.0236)	(0.0237)	(0.0237)
Finance	0.0030^{**}	0.0031^{**}	0.0030^{**}	0.0031^{**}	0.0031^{**}
	(0.0014)	(0.0014)	(0.0014)	(0.0014)	(0.0014)
Constant	1.4933^{***}	1.4693^{***}	1.4878^{***}	1.4692^{***}	1.4703^{***}
	(0.2465)	(0.2465)	(0.2465)	(0.2467)	(0.2466)
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
R-squared	0.261	0.261	0.261	0.261	0.261
Hausman test	256.6^{***}	263.2^{***}	265.2^{***}	278.9^{***}	278.2^{***}
Observations	10,963	10,963	10,963	10,963	10,963

Note: Covariates are measured in the one-year lagged form. Figures in parentheses are standard errors. $^{***}p < 0.01$, $^{**}p < 0.05$.

particularly China, to exploit the low-cost labor advantage. Because of lowered offshoring and trading costs of the OFDI policy change in 2001, China is the primary developing country of Taiwan's OFDI. Although the degree of technological spillover is high in China, its huge market size also offers many technological opportunities. This tradeoff between locating R&D in foreign affiliates and domestic firms results in an insignificant effect of OFDI in developing countries on R&D at home. OFDI in advanced countries is often in the form of establishing subsidiary company distribution for sales and post-sale service or establishing plants/labs for technology-sourcing motivation, thereby executing a positive R&D enhancement effect.

Since Taiwan's OFDI toward developing countries is concentrated in China, this casts a doubt regarding whether this high concentration would generate a different R&D effect relative to OFDI in other developing countries. Column 5 shows that both variables of OFDI in China (*FDI_num_cn*) and OFDI in other developing countries (*OFDI_num_othdev*) have no significant relationships with R&D. Most of Taiwan's OFDI to developing countries is export oriented and has a complementary effect on the home country's export, particularly the China-bound investment platform (Chow, 2012).

The other behavior of globalization, export, has a significantly positive influence on firms' R&D expenditure in all specifications which is consistent with findings in recent studies (e.g., Yang, 2018; De Fuentes et al., 2021). The estimated magnitude of ln*Export* in column 5 suggests that a 10% increase in exports is associated with an approximately 0.5% increase in R&D. Finally, other firm characteristics are significant with an expected sign; larger, more capital-intensive, and more profitable firms spend more on R&D investment. These results are consistent with findings in previous R&D studies (e.g., Hall, 2002; Shefer and Frenkel, 2005).

The aforementioned results regarding the R&D effects of OFDI to China and to advanced economies contradict the findings in Yang et al. (2010), who examine the same issue for listed companies for the period 1997–2005 and find that OFDI to China has a positive impact on R&D at home, whereas the corresponding R&D effect of OFDI to advanced countries is insignificant. Why did these two studies reach contradicting conclusions? As mentioned previously, the level of technological spillover R&D and demand condition in the host country may alter the allocation of R&D resources of MNEs (Chen and Hsu, 2003; Belderbos et al., 2008). Along with China's rapid economic growth to raise its national income, serving China's large domestic market has also become a primary motivation of FDI, suggesting that foreign subsidiaries have to undertake adaptive R&D. Specifically, China's growing technological capability, in combination with abundant and low-cost R&D personnel, have enabled it to become a hot spot of R&D internationalization (Holmes et al., 2016). Therefore, the R&D effect brought by OFDI may vary in different periods.

To test this conjecture, we separate the whole sample into two sub-periods: 2002-2008 and 2009-2018. Two reasons of this separation are: first, as Figure 1 depicted, the amount of OFDI to China undertaken by Taiwanese electronics firms reached the peak in 2010 and then declined gradually. Second, China implemented the Labor Contract Law (LCL) in 2008 and then this law was strictly enforced in the late 2010. This law required firms to provide sufficient employer insurance provisions, thereby raising labor cost by about 30% – 35% (Giles et al., 2013). In combination with the soaring wage in the 2000s, it announces the end of Chinese cheap labor (Li et al. 2012). For robustness checks, we also separate the sample period into 2002-2008 and 2009-2018 because both events of the global financial crisis and LCL implementation happened in 2008. The sampling period 2002-2008 is also more similar to that used in Yang et al. (2010). Table 4 report various estimation results.

Estimates of OFDI variables demonstrate considerable differences in different subsampling periods, as well as compared with those in Table 3. In columns 1-2 and 5-6, we find that that MNEs with OFDI to advanced countries have no significant influence on parent firms' R&D, whereas those with OFDI to developing countries curtail R&D expenditure at home, especially OFDI to China. This result of a positive "China Effect" is consistent with findings in Yang et al. (2010). An overwhelming fraction of Taiwanese electronics firms shifted production lines to China from 2002 onward. In the early post-deregulation period, exploiting cheap labor to undertake export-platform FDI is indeed one of the main purposes of investing in China. The reallocation of labor-intensive production to China facilitates parent firms' increased focus on R&D activity. This argument is also supported in Chen and Yang (2013) which adopted a panel dataset of Taiwanese manufacturing firms from 1992–2005.

Table 4 OFDI and R&D Expenditure in Different Periods

	(1) 2002-2010	(2) 2002-2010	(3) 2011-2018	(4) 2011-2018	(5) 2002-2008	(6) 2002-2008	(7) 2009-2018	(8) 2009-2018
OFDI_num_dev	0.0465***		−0.0245*		0.0493**		−0.0280***	
	(0.0173)		(0.0127)		(0.0227)		(0.0102)	
OFDI_num_adv	0.0224	0.0008	0.2109***	0.2180***	0.0084	−0.0148	0.2421***	0.2431***
	(0.0528)	(0.0557)	(0.0748)	(0.0755)	(0.0640)	(0.0678)	(0.0592)	(0.0596)
OFDI_num_cn		0.0426**		−0.0129*		0.0452**		−0.0277***
		(0.0176)		(0.0104)		(0.0230)		(0.0104)
OFDI_num_othdev		0.1635*		−0.0828		0.1774		−0.0386
		(0.0986)		(0.0828)		(0.1249)		(0.0730)
lnExport	0.1368***	0.1370***	0.1085***	0.1089***	0.1170***	0.1174***	0.0963***	0.0963***
	(0.0160)	(0.0160)	(0.0174)	(0.0174)	(0.0195)	(0.0195)	(0.0149)	(0.0149)
lnSIZE	0.9188***	0.9208***	1.3362***	1.3365***	0.8712***	0.8724***	1.4051***	1.4051***
	(0.0433)	(0.0433)	(0.0499)	(0.0499)	(0.0566)	(0.0566)	(0.0409)	(0.0410)
lnKL	0.0365	0.0375	0.1380***	0.1376***	0.0298	0.0314	0.1579***	0.1579***
	(0.0403)	(0.0403)	(0.0304)	(0.0304)	(0.0533)	(0.0533)	(0.0271)	(0.0271)
Finance	−0.0008	−0.0008	0.0033	0.0033	−0.0008	−0.0007	0.0036**	0.0036**
	(0.0018)	(0.0018)	(0.0021)	(0.0021)	(0.0022)	(0.0021)	(0.0018)	(0.0018)
Constant	3.1750***	3.1540***	1.0006***	−0.1319	3.7131***	3.6892***	−0.1318	−0.1319
	(0.4101)	(0.4105)	(0.3697)	(0.3486)	(0.5359)	(0.5364)	(0.3485)	(0.3486)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.185	0.185	0.163	0.163	0.157	0.157	0.204	0.204
Hausman test	49.98***	50.97***	71.83***	71.89***	36.39***	37.16***	111.9***	112.2***
Observations	5,275	5,275	5,688	5,688	3,945	3,945	7,018	7,018

Note: The fixed effect of panel data model is adopted for estimations. Covariates are measured in the one-year lagged form.
Figures in parentheses are standard errors. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Crucially, after the end of low-wage era in China since the late 2000s, the OFDI – R&D nexus became adverse. The association between OFDI to developing countries and R&D becomes significantly negative, as displayed on columns 5 and 7. This negative R&D effect of OFDI apples only to establishing subsidiaries in China (columns 4 and 8). In contrast, OFDI to advanced countries generates a positive effect on R&D at home, supporting the technology-sourcing hypothesis.

Along with China's rapid economic growth to raise its national income, serving China's large domestic market has also become a primary motivation of FDI, suggesting that foreign subsidiaries have to undertake adaptive R&D. China's growing technological capability, in combination with abundant and low-cost R&D personnel, have also enabled it to become a hot spot of R&D internationalization (Holmes et al., 2016). A growing number of Taiwan-based electronics firms have indeed set up R&D units in China to connect with the global innovation network (Chen, 2004) and shorten the distance from plants to labs (Liu and Chen, 2012). Specifically, along with the increase in operation experience of Taiwanese subsidiaries in China, the similar culture and business environment induce them to increase the degree of localization in R&D (Yang and Hayakawa, 2015). Therefore, Taiwanese MNEs allocate more and more R&D resources to their subsidiaries in China. The above discussions provide interpretations of a negative R&D effect is brought about by OFDI to China. Consequently, R&D at home may focus on high-end products and key components. Using a similar firm-level dataset as ours, Branstetter et al. (2017) also found a negative association between OFDI to China and parent firms' patenting in U.S.

In sum, evidence from Taiwan finds a positive relationship between OFDI to China and parent firms' R&D using data before the late-2000s, whereas a negative association is found if the used dataset covers period after the late-2000s. Our analysis highlights that the emerging China shock exists not only in trade (Autor et al., 2016), but also in innovation through attracting FDI.

V. Globalization, Patenting, and Innovation Efficiency

A. The Influences of Export and OFDI on Patents

OFDI may trigger firms to reorganize R&D investments and alter their R&D productivity rather than R&D level. We then use patents as the measure of innovation to estimate the knowledge (patent) production function proposed by Pakes and Griliches (1980). The estimation strategy is as follows:

$$\begin{aligned} Patent_{it} &= \alpha_0 + \alpha_1 \ln RD_{i,t-1} + \beta_1 OFDI_{it} + \beta_2 \ln Export_{it} + \beta_3 \ln SIZE_{it} \\ &\quad + \beta_4 TFP_{it} + \beta_5 \ln KL_{it} + \beta_6 Finance_{it} + u_t + v_i + \varepsilon_{it} \end{aligned} \tag{2}$$

where *Patent* is the number of granted patents of firm *i* in year *t*. The explanatory variables are as those in Equation (1). The incremental variable *TFP* is total factor productivity which is measured using the semi-parametric estimators developed by Levinsohn and Petrin (2003). The patent review process in Taiwan takes approximately 12–15 months; therefore, R&D expenditure variable enters the equation in 1-year lagged form.

Table 5 shows the baseline results without separating OFDI destinations. Results obtained using the fixed effect of the negative binomial (NB) model are displayed in columns 1–4. As certain covariates may exhibit the endogeneity problem, we also adopt the generalized method of moments (GMM) to conduct robustness checks. Moreover, the GMM is estimated using a linear log–log specification, following Yamashita and Yamauchi (2019) which examine the same issue. Estimation results are shown in columns 5 and 6.[16]

[16] In our dataset, among 4,633 firm observations, the patent numbers range between 0 and 5,494. This log–log specification also makes the estimation less sensitive to outliers.

Table 5　OFDI and Patents

Dep. var	(1) NB Patent	(2) NB Patent	(3) NB Patent	(4) NB Patent	(5) GMM ln(patent+1)	(6) GMM ln(patent+1)
lnRD_1			0.2323***	0.2324***	0.0407***	0.0429***
			(0.0137)	(0.0138)	(0.0076)	(0.0076)
OFDI_dum	0.1826***		0.1157**		0.5883***	
	(0.0478)		(0.0477)		(0.1555)	
OFDI_num		0.0200***		0.0105**		0.0451***
		(0.0054)		(0.0054)		(0.0165)
lnExport	0.0916***	0.0903***	0.0339***	0.0337***	−0.0048	−0.0111
	(0.0130)	(0.0130)	(0.0124)	(0.0124)	(0.0122)	(0.0122)
lnSIZE	0.2230***	0.2174***	0.0483**	0.0519**	0.4009***	0.4156***
	(0.0184)	(0.0183)	(0.0207)	(0.0206)	(0.0315)	(0.0316)
TFP	−0.0099	−0.0102	−0.0019	−0.0023	0.0399***	0.0441***
	(0.0129)	(0.0128)	(0.0125)	(0.0125)	(0.0154)	(0.0154)
lnKL	−0.0472***	−0.0413**	−0.0391**	−0.0354**	0.2474***	0.2751***
	(0.0168)	(0.0167)	(0.0171)	(0.0170)	(0.0232)	(0.0321)
Finance	−0.0051***	−0.0052***	−0.0028**	−0.0029**	−0.0092***	−0.0084***
	(0.0012)	(0.0012)	(0.0011)	(0.0011)	(0.0010)	(0.0010)
Constant	−2.6443***	−2.6778***	−3.5143***	−3.5474***	−4.0451***	−4.2850***
	(0.1829)	(0.1818)	(0.1926)	(0.1915)	(0.2658)	(0.2670)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Log-likelihood	−22,297	−22,297	−21,884	−21,885		
Hausman test	298.92***	296.46***	184.29***	188.34***		
Sargan test					722.48	722.50
Observations	9,844	9,844	9,696	9,695	10,425	10,425

Note: Figures in parentheses are standard errors. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. In columns 5 and 6, we use Stata module *xtdpdgmm* to implement estimation. The instrumental variables include firm age and covariates used in columns 1 or 2 of this table.

The estimates obtained from the fixed effects of NB models without (columns 1 and 2) and with (columns 3 and 4) R&D expenditures are quite similar. We find an elasticity of R&D with respect to patents of hovering 0.23, Crucially, both *OFDI_dum* and *OFDI_num* have a significantly positive influence on patenting, although their economic magnitudes are lower when R&D expenditure is included. In column 4, the estimated coefficient on FDI_num denotes that firms with one more foreign subsidiary are associated with 0.0088% increase in patent grants, ceteris paribus.[17]

Considering the endogeneity problem of covariates, the GMM results in columns 5 and 6 also yield similar results on estimates of OFDI variables.[18] The statistics of Sargan tests do not reject the null hypothesis, suggesting that the over-identification tests do not suffer from the weak instruments problem. These analyses confirm a pro-innovation effect resulting from globalization. OFDI not only facilitate firms' increase in R&D expenditure (Table 3) but also subsequently induce them to produce more patented innovations. However, considering the endogeneity issue, two points regarding estimates of covariates are worth noting as shown in Columns 5 – 6. First, exports become to have no significant association with patent grants. Second, TFP and capital intensity (lnKL) turn to have a significantly positive influence on patents which are consistent with findings in most extant studies.

Table 6 demonstrates estimation results for the potential difference in the innovation effect of OFDI in various destinations. Results obtained by using the GMM approach present that OFDI to advanced economies generates a pro-innovation effect because operating business or labs in advanced economies can benefit from international knowledge spillover, which improves R&D productivity in developing new products and processes. In column 1, the

[17] Based on the specification in column (4), we have also implemented estimation by using ln*FDI_num* instead of *FDI_num*. The estimate of ln*FDI_num* is significantly positive with an elasticity of 0.0946.

[18] We cannot directly compare the estimated coefficients with those in Columns 1–4 of Table 5, because the identification strategies are not the same.

estimate on *OFDI_num_dev* is insignificant. This insignificant association between of OFDI to developing countries and patents exhibits in China (*OFDI_num_cn*) particularly, as shown in column (2). By contrast, column 3 displays an innovation-enhancement effect brought by investing in developing countries (*OFDI_num_otherdev*). Branstetter et al. (2017) find a negative association between OFDI to China and parent firms' patenting, but it is inadequate to compare our results with that study because their innovation measure is US patents rather than Taiwan patents. Our results imply that OFDI to China is overall irrelevant (reduce) firms' R&D investment, it has no significant influence on producing patents. The possible interpretation is that foreign subsidiaries may increase patent applications for adaptation innovations in the host countries. Investing in other developing countries is probably driven by various motivations and incentives, but it overall induces MNEs to perform better in patenting.

Todo and Shimizutani (2008) indicate that OFDI encourages parent firms to focus more on innovative R&D as opposed to adaptive R&D; export may also have this R&D reorganizing effect. We thus replace the dependent variable (*Patents*) with high-novelty invention patents (*Invention*), to conduct further analysis. Table 7 presents the estimation results obtained using the technique of GMM.

Notably, we find that OFDI-related variables are significantly positive in all specifications. MNEs with OFDI or more foreign subsidiaries produce more inventions. OFDI to either advanced economies or developing countries (China or other developing countries) enables parent firms to perform better in successfully applying for more invention patents. Production offshoring could induce MNEs to concentrate R&D resources on innovative R&D, as claimed in Todo and Shimizutani (2008); the target then becomes producing high-novelty innovations. However, our findings contradict the evidence from Japan (Yamashita and Yamauchi, 2019), which is one of the global technology frontier countries.

Table 6 OFDI Destinations and Patents

	(1)	(2)	(3)
Dep. var. = ln(patent+1)	GMM	GMM	GMM
lnRD_1	0.0535^{***}	0.0531^{***}	0.0386^{***}
	(0.0073)	(0.0073)	(0.0075)
OFDI_num_dev	0.0048		
	(0.0040)		
OFDI_num_adv	0.0767^{**}	0.0679^{*}	0.0690^{**}
	(0.0318)	(0.0372)	(0.0344)
OFDI_num_cn		0.0032	
		(0.0039)	
OFDI_num_othdev			0.1667^{***}
			(0.0552)
lnExport	0.0052	0.0026	−0.0041
	(0.0119)	(0.0119)	(0.0121)
lnSIZE	0.3666^{***}	0.3687^{***}	0.4105^{***}
	(0.0303)	(0.0304)	(0.0310)
TFP	0.0340^{**}	0.0331^{**}	0.0520^{***}
	(0.0148)	(0.0148)	(0.0150)
lnKL	0.2373^{***}	0.2376^{***}	0.2736^{***}
	(0.0222)	(0.0223)	(0.0224)
Finance	-0.0090^{***}	-0.0091^{***}	-0.0090^{***}
	(0.0010)	(0.0010)	(0.0010)
Constant	-3.9306^{***}	-3.8931^{***}	-4.3790^{***}
	(0.2567)	(0.2570)	(0.2618)
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Sargan test	722.42	722.43	722.58
Observations	10,425	10,425	10,425

Note: Figures in parentheses are robust standard errors. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. We use Stata module *xtdpdgmm* to implement estimation. The instrumental variables include firm age and covariates used in same column of this table.

Table 7　OFDI and Invention Patents

Dep. var. = ln(invention+1)	(1) GMM	(2) GMM	(3) GMM	(4) GMM
lnRD_1	0.0160**	0.0155**	0.0286***	0.0249***
	(0.0072)	(0.0072)	(0.0070)	(0.0069)
OFDI_dum	0.5312***			
	(0.1476)			
OFDI_num		0.1231***		
		(0.0157)		
OFDI_num_dev			0.0185***	
			(0.0038)	
OFDI_num_adv			0.1419***	0.0738**
			(0.0359)	(0.0351)
OFDI_num_cn				0.0170***
				(0.0036)
OFDI_num_othdev				0.2394***
				(0.0482)
lnExport	−0.0280**	−0.0295**	−0.0102	−0.0096
	(0.0116)	(0.0116)	(0.0112)	(0.0112)
lnSIZE	0.3320***	0.3495***	0.2955***	0.3007***
	(0.0299)	(0.0301)	(0.0288)	(0.0283)
TFP	0.0494***	0.0520***	0.0528***	0.0561***
	(0.0146)	(0.0146)	(0.0141)	(0.0138)
lnKL	0.2776***	0.3063***	0.2565***	0.2620***
	(0.0221)	(0.0219)	(0.0211)	(0.0206)
Finance	−0.0095***	−0.0085***	−0.0091***	−0.0096***
	(0.0010)	(0.0010)	(0.0010)	(0.0010)
Constant	−3.8479***	−4.1721***	−3.8716***	−3.9397***
	(0.2523)	(0.2539)	(0.2435)	(0.2401)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Sargan test	722.05	721.73	721.81	722.06
Observations	10,425	10,425	10,425	10,425

Note: Figures in parentheses are robust standard errors. ***$p < 0.01$, **$p < 0.05$. We use Stata module *xtdpdgmm* to implement estimation. The instrumental variables include firm age and covariates used in same column of this table.

B. Innovation Efficiency

The aforementioned analyses find that OFDI and facilitate or reduce R&D at home, hinging on destinations and time period. One further important issue emerges: can firms efficiently adjust R&D resources to achieve better innovation efficiency measured by R&D productivity in producing patents? We consider the knowledge production function with the key input R&D and other covariates as follows:

$$Patent_{it} = \alpha_0 + \alpha_1 \ln RD_{i,t-1} + \beta X_{it} + \sum \gamma (\ln RD \times Year)_{it} + v_i + \varepsilon_{it} \qquad (3)$$

This specification is similar to the above Equation (2) with a difference that year dummies are replaced by a series of interaction terms between R&D expenditure and year. The estimated coefficients of these interaction terms, γ, capture firms' R&D productivity with respect to patent grants. In addition to patent number, this study also adopts invention number (*Invention*) to examine the R&D productivity of high-quality innovations. Using the fixed effect of negative binomial model to implement estimations, the estimates of R&D productivity with respect to patents (inventions) can be compared with finding in previous studies which also adopted this specification.[19]

Notably, all estimated coefficients of the interaction terms are significantly positive, indicating an increase in innovation efficiency compared with that of the base year 2002. Figure 2 depicts trajectories of the estimates for these interaction terms: the solid line denotes the R&D productivity of patents; the long-dash line represents the R&D productivity of inventions. The R&D productivity in producing patents increased sharply during the

---

[19] Corresponding to column 6 of Table 5 and column 3 of Table 6, this study also implements estimations for patent (ln(patent+1)) equation and invention (ln(invention+1)) equation respectively by employing the GMM approach. The trajectory of the estimates for these interaction terms is depicted in Appendix Figure 1 and displays a similar pattern.

2002–2005 period, exhibiting a plateau between 2006 and 2013 that experienced higher innovation efficiency, hovering around 6.87%. This innovation efficiency then re-ascended to a peak of 8.15% in 2014 and then gradually declined.

Regarding the R&D productivity of inventions (long-dash line), it demonstrates a similar trend, but exhibits distinct features. The increase in productivity number of inventions was lower than that of patents in 2003 and then experienced a larger increase in the innovation efficiency of producing inventions, reaching a peak of 11.87% in 2014. The innovation efficiency of invention patents also declined gradually during the 2014–2018 period. Notably, the degree of decrease in R&D productivity of inventions is smaller than that of patents. As discussed previously, parent firms adjust R&D composition toward more innovative R&D after undertaking OFDI, thereby leading to higher innovation efficiency in producing high-novelty inventions.

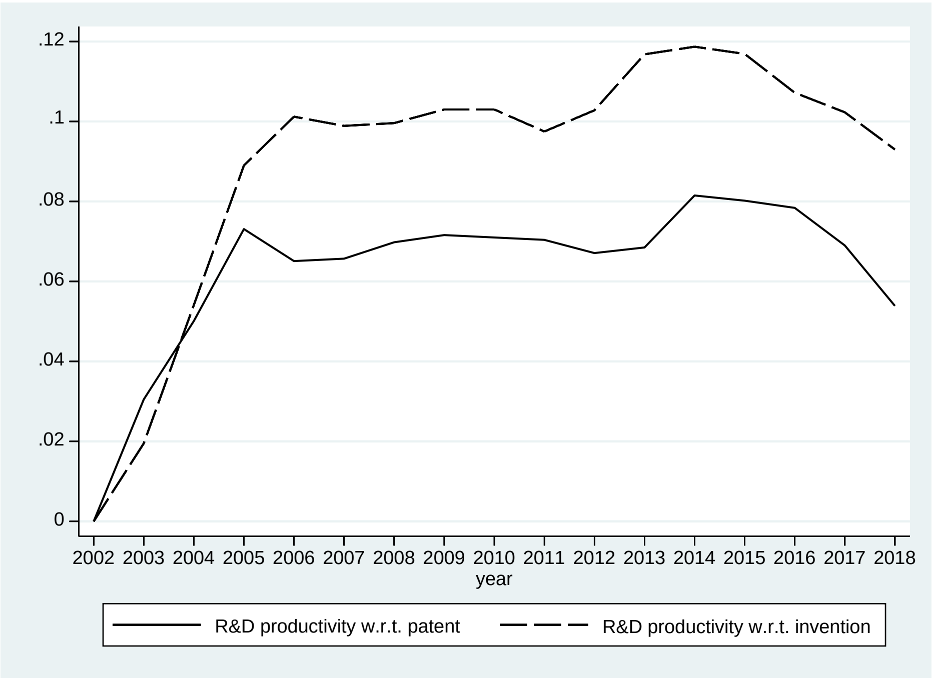


Figure 2 R&D Productivity of Patents and Inventions

Taiwan's electronics firms gradually upgraded technological capability in the 2000s. Along with arrangements for exporting and OFDI strategies, they distribute more resources on R&D; in particular for developing high-novelty innovations. Therefore, a greater improvement in R&D productivity of inventions is witnessed. This increased innovation efficiency further helps electronics firms' expansion to international markets, arrangements with and participation in international production/distribution networks, and defense against patent infringement.

VI. Conclusions

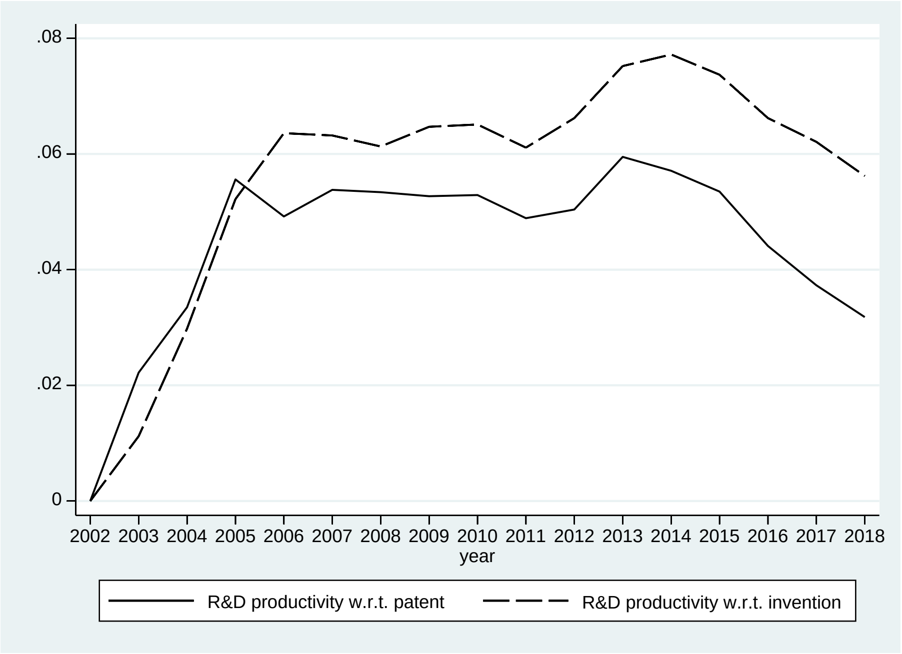
Along with Taiwan's access to the WTO in 2002, in combination with the deregulation of OFDI to China, the production structure and exports altered considerably in the electronics industry. How does the globalization strategy of OFDI influence innovation activities and efficiency at home? This research question is crucial and topical for Taiwan.

Using publicly listed electronics firms for the period 2002–2018, the empirical results are summarized into three main points. First, the R&D effect of OFDI varies across destinations and time periods. OFDI overall has a positive influence on R&D expenditure of parent firms and particularly OFDI to advanced countries. Decomposing OFDI into various time period, the pro-R&D effect was apparent brought by OFDI to developing destination, mainly China, but OFDI to advanced countries has no such a pro-R&D effect before the late 2000s. These results echo findings in Yang et al. (2010). More importantly, the OFDI – RD nexus across destinations reversed: The pro-R&D effect is witnessed for OFDI to advanced countries, whereas OFDI to developing countries, especially China, generates a negative impact on R&D at home. OFDI to China leads MNEs to adjust the reallocation of R&D resource; crucially, their R&D strategies may adjust in response to the change of technological conditions of the host country.

Second, using patents as the indicator of innovation, the impact of OFDI on patents varies, depending on investing destinations. As OFDI to advanced economies is often technology-sourcing motivated, it is associated with a positive relation. In contrast, OFDI to the developing country, China, is less relevant to patent grants at home. This is because MNEs may reallocate some adaptive R&D/innovation to host developing countries, whereas they pay more attention at innovative R&D at home. This conjecture is verified when we focus on high-novelty patents measured by inventions. OFDI in both developing and developed countries has a positive relationship with invention patents granted at home.

Third, OFDI not only alter R&D expenditure at home but also promote MNEs' R&D productivity in producing (invention) patents. Because of the adjustment of R&D composition toward more innovative R&D, the innovation efficiency of inventions raises more than that of total patents. However, after reaching a peak in innovation efficiency of invention patents (7.72% in 2014) and total patents (5.95% in 2013), it demonstrated a trajectory of gradual slight decline.

Appendix



Appendix Figure 1 R&D Productivity of Patents and Inventions – GMM Estimations

Reference

Acemoglu, D., G. Gancia, and F. Zilibotti, 2015, “Offshoring and Directed Technical Change”, *American Economic Journal: Macroeconomics*, 7: 84-122.

Aghion, P., A. Bergeaud, M. Lequien, and M. J. Melitz, 2018, “The Impact of Exports on Innovation: Theory and Evidence”, *NBER Working Paper*, No. 24600.

Aghion, P., P. Howitt, M. Brant-Collett, and C. García-Peñalosa, 1998, *Endogenous Growth Theory*, Cambridge, Massachusetts: MIT Press.

AlAzzawi, S., 2012, “Innovation, Productivity and Foreign Direct Investment-induced R&D Spillovers”, *Journal of International Trade & Economic Development*, 21: 615-653.

Amighini, A. A. and R. Rabellotti, 2010, “Outward FDI from Developing Country MNEs as a Channel for Technological Catch-up”, *Seoul Journal of Economics*, 23: 239-261.

Autor, D. H., D. Dorn, and G. H. Hanson, 2016, “The China Shock: Learning from Labor-market Adjustment to Large Changes in Trade”, *Annual Review of Economics*, 8: 205-240.

Baum, C. F., H. Lööf, A. Stephan, and I. Viklund-Ros, 2022, “The Impact of Offshoring on Technical Change: Evidence from Swedish Manufacturing Firms”, *Review of International Economics*, 20: 796-818.

Belderbos, R., E. Lykogianni, and R. Veugelers, 2008, “Strategic R&D Location by Multinational Firms: Spillovers, Technology Sourcing and Competition”, *Journal of Economics & Management Strategy*, 17: 759-779.

Branstetter, L., 2006, “Is Foreign Direct Investment a Channel of Knowledge Spillovers? Evidence from Japan’s FDI in the United States”, *Journal of International Economics*, 68: 325-344.

Branstetter, L., J. R. Chen, B. Glennon, C. H. Yang, and N. Zolas, 2017, “Does Offshoring Manufacturing Harm Innovation in the Home Country? Evidence from Taiwan and China”, in Proceedings of *NBER Summer Institute 2017 Innovation*, The National Bureau of Economic Research, Cambridge, Massachusetts, United States.

Chen, S. H., 2004, "Taiwanese IT firms' Offshore R&D in China and the Connection with the Global Innovation Network", *Research Policy*, 33: 337-349.

Chen, C. L. and F. S. Hsu, 2003, "Defensive Foreign Direct Investment and Endogenous R&D", *Academia Economic Papers*, 31: 577-603.

Chen, V. Z., J. Li, and D. M. Shapiro, 2012, "International Reverse Spillover Effects on Parent Firms: Evidences from Emerging-market MNEs in Developed Markets", *European Management Journal*, 30: 204-218.

Chen, K. M. and S. F. Yang, 2013, "Impact of Outward Foreign Direct Investment on Domestic R&D Activity: Evidence from Taiwan's Multinational Enterprises in Low-wage Countries", *Asian Economic Journal*, 27: 17-38.

Cheung, K. Y. and P. Lin, 2004, "Spillover Effects of FDI on Innovation in China: Evidence from the Provincial Data", *China Economic Review*, 15: 25-44.

Chow, P. C. Y., 2012, "The Effect of Outward Foreign Direct Investment on Home Country's Export: A Case Study on Taiwan, 1989–2006", *Journal of International Trade & Economic Development*, 21: 725-754.

Clerides, S, S. Lach, and J. Tybout, 1998, "Is Learning by Exporting Important? Micro-dynamic Evidence from Columbia, Mexico and Morocco", *Quarterly Journal of Economics*, 113: 903-948.

De Fuentes, J. Niosi, and J. A. Peerally, 2021, "Exploring Innovation and Export Interplay in Canadian Firms", *Economics of Innovation and New Technology*, 30: 786-806.

Dong, Z., Z. Maio, and Y. Zhang, 2021, "The Impact of China's Outward Foreign Direct Investment on Domestic Innovation", *Journal of Asian Economics*, 75: 101307.

Driffield, N. and J. H. Love, 2003, "Foreign Direct Investment, Technology Sourcing and Reverse Spillovers", *Manchester School*, 71: 659-672.

Filippetti, A., M. Frenz, and G. Ietto-Gillies, 2017, "The Impact of Internationalization on Innovation at Countries' Level: The Role of Absorptive Capacity", *Cambridge Journal of Economics*, 41: 413-439.

Fritsch, U. and H. Görg, 2015, “Outsourcing, Importing and Innovation: Evidence from Firm-level Data for Emerging Economies”, *Review of International Economics*, 23: 687-714.

García, F., B. Jin, and R. Solomon, 2013, “Does Inward Foreign Direct Investment Improve the Innovative Performance of Local Firms?”, *Research Policy*, 42: 231-244.

Giles, J., D. Wang, and A. Park, 2013, “Expanding Social Insurance Coverage in Urban China”, in Polachek, S. W. and K. Tatsiramos, eds., *Labor Market Issues in China*, 123-179, Bradford: Emerald Group Publishing Limited.

Glass, A. J. and K. Saggi, 2001, “Innovation and Wage Effects of International Outsourcing”, *European Economic Review*, 45: 67-86.

Hall, B. H., 2002, “The Financing of Research and Development”, *Oxford Review of Economic Policy*, 18: 35-51.

Hoang, D. T., A. D. Do, and M. V. Trinh, 2021, “Spillover Effects of FDI on Technology Innovation of Vietnamese Enterprise”, *Journal of Asian Finance, Economics and Business*, 8: 655-663.

Holmes, R. M., H. Li, M. A. Hitt, K. DeGhetto, and T. Sutton, 2016, “The Effects of Location and MNC Attributes on MNCs’ Establishment of Foreign R&D Centers: Evidence from China”, *Long Range Planning*, 49: 594-613.

Howell, A., J. Lin, and S. Worack, 2020, “Going Out to Innovate More at Home: Impacts of Outward Direct Investments on Chinese Firms’ Domestic Innovation Performance”, *China Economic Review*, 60: 101404.

Junge, M. and A. Sørensen, 2018, “Domestic R&D and Offshoring: Does Offshoring Reduce Knowledge Production?”, *Applied Economics Letter*, 25: 1283-1287.

Karpaty, P. and P. G. Tingvall, 2015, “Offshoring and Home Country R&D”, *The World Economy*, 38: 655-676.

Keller, W., 2010, “International Trade, Foreign Direct Investment, and Technology Spillovers”, in Hall, B. H. and N. Rosenberg, eds., *Handbook of the Economics of Innovation*, *Volume 2*, 793-829, Amsterdam: Elsevier.

Kogut, B. and S. J. Chang, 1991, “Technological Capabilities and Japanese Foreign Direct

Investment in the United States", *Review of Economics & Statistics*, 73: 401-413.

Levinsohn, J. and A. Petrin, 2003, "Estimating Production Functions Using Inputs to Control for Unobservables", *Review of Economic Studies*, 70: 317-341.

Li, H., L. Li, B. Wu, and Y. Xiong, 2012, "The End of Cheap Chinese Labor", *Journal of Economic Perspectives*, 26: 57-74.

Li, J., R. Strange, L. Ning, and D. Sutherland, 2016, "Outward Foreign Direct Investment and Domestic Innovation Performance: Evidence from China", *International Business Review*, 25: 1010-1019.

Lin, H. L., Y. C. Hsiao, and E. S. Lin, 2015, "Do Different Types of FDI Strategies Spur Productivity and Innovation Capability Growth? Evidence from Taiwanese Manufacturing Firms", *Journal of Business Economics and Management*, 16: 599-620.

Liu, M. C. and S. H. Chen, 2012, "MNCs' Offshore R&D Networks in Host Country's Regional Innovation System: The Case of Taiwan-based Firms in China", *Research Policy*, 41: 1107-1120.

Naghavi, A. and G. Ottaviano, 2009, "Offshoring and Product Innovation", *Economic Theory*, 38: 519-532.

Neven, D. and G. Siotis, 1996, "Technology Sourcing and FDI in the EC: An Empirical Evaluation", *International Journal of Industrial Organization*, 14: 543-560.

Pakes, A. and Z. Griliches, 1980, "Patents and R&D at the Firm Level: A First Report", *Economics Letters*, 5: 377-381.

Papanastassiou, M., R. Pearce, and A. Zanfei, 2020, "Changing Perspectives on the Internationalization of R&D and Innovation by Multinational Enterprises: A Review of the Literature", *Journal of International Business Studies*, 51: 623-664.

Peddy, K., S. Sasidharan, and N. Doytch, 2022, "Outward Foreign Direct Investment and Domestic Innovation Efforts: Evidence from India", *Journal of Economics and Business*, 122: 106084.

Petit, M. L. and F. Sanna-Randaccio, 2000, "Endogenous R&D and Foreign Direct Investment in International Oligopolies", *International Journal of Industrial Organization*, 18: 339-367.

Piperopoulos, P., J. Wu, and C. Wang, 2018, "Outward FDI, Location Choices and Innovation Performance of Emerging Market Enterprises", *Research Policy*, 47: 232-240.

Rodriguez-Clare, A., 2010, "Offshoring in a Ricardian World", *American Economic Journal: Macroeconomics*, 2: 227-258.

Rojec, M. and M. Knell, 2019, "Why Is There a Lack of Evidence on Knowledge Spillovers from Foreign Direct Investment?", *Journey of Economic Surveys*, 32: 579-612.

Saito, Y., 2018, "A North-South Model of Outsourcing and Growth", *Review of Development Economics*, 22: e16-e35.

Shefer, D. and A. Frenkel, 2005, "R&D, Firm Size and Innovation: An Empirical Analysis", *Technovation*, 25: 25-32.

Todo, Y. and S. Shimizutani, 2008, "Overseas R&D Activities and Home Productivity Growth: Evidence from Japanese Firm-level Data", *Journal of Industrial Economics*, 56: 752-777.

Vahter, P., 2011, "Does FDI Spur Productivity, Knowledge Sourcing and Innovation by Incumbent Firms? Evidence from Manufacturing Industry in Estonia", *The World Economy*, 34: 1308-1326.

Yamashita, N. and I. Yamauchi, 2019, "The Effects of Offshore Production on Onshore Innovation: Evidence from Japanese Multinationals", *Research Policy*, 48: 103836.

Yang, C. H., 2018, "Exports and Innovation: The Role of Heterogeneity in Exports", *Empirical Economics*, 55: 1065-1087.

Yang, C. H., 2023, "Strengthening Worker Benefits or Destroying Jobs: Effect of the 2008 Labor Contract Law in China", *International Review of Law & Economics*, 73: 106121.

Yang, C. H. and K. Hayakawa, 2015, "Localization and Overseas R&D Activity: The Case of Taiwanese Multinational Enterprises in China", *R&D Management*, 45: 181-195.

Yang, C. H., H. Lin, and I. Y. Wu, 2010, "Outward Investment to China and Domestic Innovation of Taiwanese Manufacturing Firms", *Japanese Economic Review*, 61: 538-577.

Zhang, G. and J. Zhou, 2016, "The Effects of Forward and Reverse Engineering on Firm Innovation Performance in the Stages of Technology Catch-up: An Empirical Study of China", *Technological Forecasting and Social Change*, 104: 212-222.

Zhang, H., Y. Shi, J. Liu, and X. Wu, 2021, "How Do Technology Strategies Affect the

Catch-up Progress of High-tech Latecomers? Evidence from Two Chinese Research-institute-transformed Telecommunications Firms”, *Journal of Business Research*, 122: 805-821.

Zhou, C., J. Hong, Y. Wu, and D. Marinova, 2019, “Outward Foreign Direct Investment and Domestic Innovation Performance: Evidence from China”, *Technology Analysis & Strategic Management*, 31: 81-95.

再探臺灣對外直接投資對國內創新的效果：數量或品質？

楊志海*、李國安**

摘　要

本研究探討臺灣的對外直接投資對國內創新活動與效率的影響。利用 2002-2018 年上市櫃電子業廠商的縱橫資料進行研究，不同的估計結果顯示：整體而言，對外直接投資對國內母公司的研究發展支出與專利數具有正向的影響。然而，對外直接投資的研究效果可能隨投資目的國與不同的時期而異：在 2000 年代晚期之前，對外直接投資的研發促進效果僅出現在赴開發中國家投資，特別是中國；但此研發效果在 2000 年代晚期之後變爲負向。本文亦發現對外直接投資存在促進專利申請的效果，特別是基於技術取得目的的赴先進國家投資。就高新穎性的發明專利而言，赴開發中與先進國家投資均促使國內母公司取得更多發明專利。再則，對外直接投資也促使母公司在專利的研發生產力有所提升，特別是發明專利。

---

* 國立中央大學經濟系教授，本文通訊作者，Email：chyang@mgt.ncu.edu.tw。作者感謝國家實驗研究院科技政策研究與資訊中心計畫 (STPI-A-110058) 的財務支持，兩位匿名審查人的寶貴建議也一併致謝。文中若有任何疏漏，由作者自負文責。

** 國家實驗研究院科技政策研究與資訊中心研究員，Email: kali@narlabs.org.tw。

DOI：10.53106/054696002023120114001

收件日期民國 112 年 3 月 13 日；修改日期民國 112 年 10 月 1 日；

接受日期民國 112 年 11 月 10 日。

關鍵詞：出口、對外直接投資、研究與發展、專利

JEL 分類代號：F19、F21、F23、F61、O31、O32