Industrial Agglomeration, Business Globalization and Productivity: An Empirical Study on Taiwanese Firms

Yih-Luan Chyi, Yi Lee, Eric S. Lin, Shih-Ying Wu

Department of Economics
National Tsing Hua University

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Abstract

This paper examines impacts of industrial agglomeration and foreign direct investment (FDI) on total factor productivity of Taiwanese firms. Our model of FDI decisions of heterogeneous firms with agglomeration economies suggests that given firms located in more concentrated industrial agglomerations become more productive, undertaking FDI have either positive or negative influence on firm productivity. Using plant-level data, this paper constructs an indicator of industrial agglomeration to appraise agglomeration economies on firm productivity. Based on the data of 601 manufacturing firms and the agglomeration indicator, this paper estimates a cross-sectional econometric model to empirically assess the impacts of industrial agglomeration and FDI on firms’ performances. The empirical results show that both local industrial agglomerations and FDI in China provide positive contribution to firm productivity after firms’ attributes are controlled.

JEL Classification: L25, R30

Keywords: industrial agglomeration, knowledge spillovers, total factor productivity
1 Introduction

Since Taiwan outward FDI to China has been permitted officially in 1990, local firms have totally invested $34.3 billion in China from 1991 to 2003\(^1\). The ongoing massive FDI outflows provoke a heated debate on the possibility of Taiwanese manufacturing industry being jeopardized and hollow up. However, domestic industry and regional economy may still be prosperous when firm productivities remain strong even after their participation in FDI. Figure 1 depicts the FDI outflows approved by the MOEA between 1990 and 2006. FDI into China grew sharply starting from 1991 and these figures are over the total FDI flows into all other countries after 2001. The period of FDI outflows to China outpacing those to other destinations coincided with a rightward shift of the entire productivity distribution of Taiwanese firms in Figure 2. While there are many explanations for this shift, this study emphasizes influences of industrial agglomeration and FDI on firm productivity in Taiwan.

Marshallian externalities can arise through localized industry-level knowledge spillovers, input-output linkages together with transportation costs to ensure that externalities remain local, and labor pooling (Harrison and Rodriguez-Clare 2007). Mounting empirical findings of linkages between agglomerations and productivity suggest that firms being driven by agglomeration economies are likely to geographically cluster and thus improve their performances (Ciccone and Hall 1996, Braunerhjelm and Borgman 2004, Rice et al. 2006, Brühlhart and Mathys 2008). Phenomenon industrial agglomerations have been experienced in Hsinchu City and County since early 1980s, and just recently expanded to other regions in Taiwan. The number of employees in Hsinchu Science Park (HSP) had increased more than ten times during 1986 to 2004\(^2\). Studies of Taiwanese high-tech clusters have identified strong knowledge

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\(^1\)The FDI statistics are from the Industrial Development and Investment Center, Taiwan Ministry of Economic Affairs (MOEA). (http://www.idic.gov.tw/html/c3409.htm)

\(^2\)The government has invested over 1.5 billion US dollars in the HSP since its founding in 1980 till the end of 2004. The number of employees in HSP rose from 8,275 in 1986 to 113,000 in 2004. All the statistics quoted here are from the HSIP website: http://service.sipa.gov.tw/WEB/Jsp/Page/index.jsp?thisRootID=115.
spillovers for firms locating in close geographical and technological proximity (Tsai, 2005, Chyi and Lai, 2008). Besides, firms tend to perform FDI for the benefit of cross-country knowledge spillovers (Branstetter, 2006; Neven and Siotis, 1995; Pottelsberghe de la Potterie and Lichtenberg, 2001). According to recent research findings, we gauge that by aggressively forming industrial agglomerations and heavily engaging in FDI, Taiwanese firms can improve productivities during the 1990s. We aim at revealing industrial agglomeration effect on productivity and overall productivity gain from FDI decisions at firm level, so that FDI effects can be examined by controlling agglomeration effects.

This paper contributes to the related literature in two aspects. First, based on Holmes (1999), this paper constructs an indicator of industrial agglomeration to appraise agglomeration externalities on firm productivity. Second, a theoretical model of FDI decisions is provided in order to identify underlying causal links between agglomeration externalities, global knowledge sourcing and total factor productivity. Our model predicts that given firms located in more concentrated industrial agglomerations are more productive, there are international knowledge spillover effects and technology transferring costs from FDI, so that firms became more or less productive by taking on FDI when considering local agglomeration economies.

Comprehensive plant-level data from the Taiwanese Survey and Census of Manufacturing Operation (TSCMO) are used to measure the industrial agglomeration indicators across different villages and 4-digit Standard Industrial Classification (SIC) industries. The Taiwan Economic Journal (TEJ) reports annual FDI amounts, sales, ages, employees, R&D expenditures, and other firm characteristics of companies listed on Taiwan Stock Exchange and Gre-Tai Securities Market. We estimate a cross-sectional econometric model of productivity evolution using the TEJ data of 601 manufacturing firms and the agglomeration indicator. We found that after firms’ attributes are controlled, firm productivities are positively affected by local industrial agglomerations and FDI in China by Taiwanese firms. Moreover, more productive
firms benefit more from local agglomeration economies relative to FDI.

Second 2 is the literature review. We show the theoretical model of FDI decisions in Second 3. The data sources and “Holmes” indicator of industrial agglomeration are presented in Section 4. Section 5 illustrates the econometric models and empirical results. Finally, Section 6 is the conclusion.

2 Literature Review

In this study, we construct a simple theoretical model to investigate the underlying relations among agglomeration, firm FDI and TFP. Our preliminary attempt is to focus on mechanisms through which FDI can influence firm productivity under a simplified assumption that firms have already selected into their domestic locations before they made FDI choices. Based on literature backgrounds of agglomeration economies and FDI, the theoretical model is established in the following section.

Industrial agglomerations are formed by firms operating in a geographically concentrated area in the same industry or in vertically linked industries. Alfred Marshall (1890) pioneers in introducing three motives of agglomeration: specialized inputs sharing, labor market pooling, and knowledge spillovers. Studies surveyed by Duranton and Puga (2004) suggest that agglomeration economies may stem from different mechanisms such that similar firms have better chances of sharing suppliers, thick labor markets contribute to easing firm-level shocks or matching jobs, and localized firms are more likely to benefit from technologies and innovations of others. Subsequently, these mechanisms lead to a shared prediction: “the concentration of firms and workers in space makes them more productive.” (Duranton, Gobillon, Puga, and Roux, 2009, p. 3)

\(^3\)Comprehensive literature reviews on agglomeration and its micro-foundations are provided recently by Duranton and Puga (2004) and Ottaviano and Thisse (2004).
Two strands of literature built up lately provide supportive empirical evidences for positive association between agglomeration and firm performance. On the one hand, recent empirical studies (Henderson, 2003; Combes, Duranton, and Gobillon, 2008) confirm that firms and workers in larger cities generally are more productive. In Rosenthal and Strange (2004) and Combes, Duranton, Gobillon, and Roux (2007), it is indicated that doubling city size can raise productivity by a range of 2 to 8 percent depending on which sector is studied and what estimation method is implemented. Another newly developed body of literature aims at identifying empirically the “district effect” using different econometric specifications and data sets. Studies such as Bagella and Becchetti (2000) and Fabiani et al. (1999) have shown that firms located in an industrial district can benefit from agglomerative advantages, which is a “district effect”. Further empirical results of Cainelli (2008) imply that productivity growth of firm is mainly attributed to its memberships of an industrial district and product innovations. Even though various econometric specifications and data sets are used in different studies, “K results on the positive effects of agglomeration on firm performance were unanimous.” (Cainelli, p. 417)

The most fundamental questions about FDI are why a firm chooses to serve a foreign market through subsidiary production rather than through other options, such as exporting or licensing, and how FDI affects Home economic activities. The FDI determinants not only affect a firm’s production location choices but also have influence on a firm’s performance. The proximity-concentration hypothesis indicates that firms should engage in horizontal FDI whenever the advantages associated with access to the destination market outweigh the advantage from production scale economies.

Brainard (1997) provides a mixed equilibrium where some firms undertake FDI and other firms export. By choosing FDI instead of exporting, a firm gives up the scale economies in production but saves on trading costs (variable costs). Brainard proposes an econometric model
in which the share of firms doing export and FDI depends on firm-specific and plant-specific economies of scale, industry-and country-specific trade costs, and a set of control variables related to the host country characteristics. While the results support the proximity-concentration hypothesis, the model ignores the role of firm heterogeneity.

Helpman et al. (2004) add a role for productivity differences into this proximity-concentration trade-off model to explain the choices across firms within the same industry. Their model focuses on a firm’s choice between exports and horizontal FDI. A new entrant draws its productivity level from a distribution after paying an entry cost. A firm may decide to exit or continue production after observing its productivity level. If it chooses to produce, it bears a fixed production cost. Any firm which remains in the industry always serves its domestic market and can decide to serve foreign markets through exporting or FDI. If the firm chooses to export, it bears additional fixed cost $f_X$ and an iceberg transportation cost. On the other hand, if this firm serves the foreign market through FDI, then it bears the fixed cost $f_I$. A firm’s decision between exports and FDI is driven by the proximity-concentration trade-off whereby FDI saves on transportation costs but incurs higher fixed costs relative to export. Given the assumption on the relationship between fixed costs, relative production costs between domestic and foreign countries and transportation costs, the most productive firms will prefer FDI over exporting.

Helpman et al.’s (2004) empirical tests focus on the effect of some measures of the dispersion of productivity, fixed costs and trading costs on the cross-country and sector variation of the volume of exports relative to FDI. They find that the ratio of industry exports to FDI sales is positive correlated to plant scale economies, but negative correlated to trading costs and the dispersion of productivity.

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[^4]: In their model, the operating profits for domestic firms, $\pi_D$, exporting firms, $\pi_X$ and FDI firms, $\pi_I$, can be expressed as: $\pi_D = (w_i a_i)^{1-\sigma} B_i - f_D$, $\pi_X = (w_i t a_i)^{1-\sigma} B_j - f_X$ and $\pi_I = (w_j a_j)^{1-\sigma} B_j - f_I$, where $i$ presents domestic market, $j$ presents the foreign market, and $B$ and $a$ presents market size and firms’ efficiency levels, respectively. If the condition $w_i^{\sigma-1} f_I > (w_i t)^{\sigma-1} f_X > f_D$ is satisfied, then the most productive firms will choose FDI, firms with productivity levels fall into the middle range become exporters and the least productive firms only serve the domestic market.
While most of horizontal FDI literature focusing on the proximity-concentration tradeoff, researchers have worked on whether firms undertaking FDI in order to acquire foreign technology. Fosfuri and Motta (1999) demonstrate that spillovers may induce a technologically less advanced firm to undertake technology sourcing FDI. Firms decide to serve foreign market through exporting or FDI by comparing transportation costs with FDI investment costs. In addition to the traditional components (proximity-concentration tradeoff), they allow the laggard firm to acquire technology from its more efficient competitor with some probability if both firms located within the same country. The technology acquisition effect encourages the technological followers to invest abroad not only to save transportation costs, but also to acquire location-specific knowledge. Even in the case of zero transportation costs, foreign direct investment might be the optimal choice rather than export for the technological followers. Recent empirical evidence has supported this technology spillovers effect from outward FDI. Pottelsberghe de la Potterie and Lichtenberg (2001) use data from 13 OECD countries and find that investing in R&D intensive countries improves a country’s productivity. Branstetter (2006) uses patent citations as the measure of technology transferring and examines if FDI is a channel of knowledge spillovers for Japanese multinationals undertaking direct investments in the United States. He finds the positive relationship between the number of Japanese subsidiaries in the U.S. and the extent of U.S. patent citations. Griffith et al. (2006) provide evidence that the U.S. R&D stock had a strong impact on the total factor productivity (TFP) of U.K. firms with lead inventor in the U.S. Yeaple and Chung (2008) find country-industries with similar technical profiles are more attractive to U.S. outward FDI.

In addition to the gains from knowledge spillovers offer another incentive for firms to undertake FDI, multinationals may also face some disadvantages such as risk of knowledge diffusion and costs on transferring technology to foreign affiliates. Keller and Yeaple (2009) construct a

\footnote{Keller (2009) provides an excellent survey.}
theoretical model which focuses on the role of technology transferring costs on firms’ foreign operation. A firm produces a final good by assembling a range of intermediate inputs. Multinational firms can choose to export the intermediates to their foreign affiliates or producing them in their foreign subsidiaries. Production abroad incurs some technology transferring costs, such as communication costs, which increase with the technological complexity of inputs. Multinational firms face a trade-off between the transportation costs of intermediates and technology transfer costs. The more technological complex the intermediates are, the more gains from saving on transportation costs. It turns out that industries entailed with higher technological complexity are less likely to produce abroad. Chang and Lu (2009) study how the risk of FDI failure affects the dynamics of FDI entry for Taiwanese firms. They assume that the success probability of FDI as a non-monotonic function of firm productivity where more productive firms face higher risk of investment failure and loss more if failure. By allowing the non-linearity relationship between firm productivity and firm FDI profit, the negative effect of investment failure will dominate the positive effect of a larger market share on variable profits for the most productive firms. Their model predicts that the least productive as well as the most productive firms will not choose FDI, and FDI firms are falling in the productivity level range in between. The risk of FDI failure decreases with the number of FDI firms, and therefore the productivity range for FDI firms increases over time.

This paper constructs a horizontal FDI model and allows both positive externalities and negative technology transfer costs or risk of knowledge diffusion to be FDI determinants. More specifically, by modifying Chang and Lu’s (2009) non-linearity model, a firm’s FDI decision will depend on the magnitude of these two impacts. This paper provides a more complete insight to analyze the determinants of FDI and the impacts of outward FDI on a firm.
3 The Model

Since firm heterogeneity play an important role on their location choices and trade behaviors, ignoring the selection effect may cause endogeneity problem in estimation and overstate the agglomeration effect (Baldwin and Okubo 2006). This model shows how the existence of positive externalities affects FDI decision across heterogeneous firms. More productive firms would benefit more from foreign knowledge spillovers. However, firms may face efficiency losses or risk of technology diffusion to their competitors when transferring their knowledge abroad and these may hurt superior technology firms more. Therefore, a firm’s incentive to undertake FDI will depend on the magnitude of these two effects; if the technology loss is larger than the externalities gain, the most productive firms will choose not to undertake FDI.

Firms in the Home country decide the production locations in order to sell their products globally. Firms serve foreign markets by either producing in their foreign subsidiary or exporting from home country. Engaging in production activities abroad incurs a fixed investment cost for building a plant outside the home country. If a firm chooses to export, there is an iceberg transportation cost. Besides the variable costs saving, firms may obtain location-specific superior knowledge through foreign investments because of spatially bounded technology spillovers. The technology sourcing strategy offers another incentive for firms to undertake foreign investment. However, foreign investment firms incur costs of transferring their technology and/or face some risks of knowledge diffusion which impedes production abroad. Firms make their production location decisions by comparing their savings on variable costs and knowledge gains from international access to new technology with costs of efficiency loss and fixed investment costs.

Each firm in the Home country \( (H) \) produces a single differentiated product and is willing to offer products to the foreign country \( (F) \). Consumers in both countries have the same CES
utility function in the consumption of product \(i\), \(q_i\), such that:

\[
U = \left( \sum_{i=1}^{n} q_i^\alpha \right)^{\frac{1}{\alpha}}, \quad 0 < \alpha < 1
\]  

(1)

The CES utility implies the inverse demand function of product \(i\) for consumers in country \(l\) as:

\[
q_{il} = Y_l \tilde{p}_{il}^{-\sigma} \quad \text{where} \quad \sigma = \frac{1}{1-\alpha} > 1, \quad Y_l = \frac{E_l}{\tilde{P}_l}, \quad \tilde{P}_l = \left( \sum_{i=1}^{n_l} P_{il}^{1-\sigma} \right)
\]  

(2)

where \(l = H, F\) indicates Home and Foreign countries, \(\sigma > 1\) is the elasticity of substitution between any pair of goods, \(p_{il}\) is the price of product \(i\) in country \(l\), \(E_l\) is the total expenditure in country \(l\) and \(\tilde{P}_l\) is the price index for all products in country \(l\).

Firms are heterogeneous in their productivity level, \(\rho\). Firms can acquire external knowledge (\(\Phi_g\)) through some channels of agglomeration externalities such as informal meetings of engineers and researchers across firms, hiring experts from competitors, and sharing common buyers and suppliers in the local area, \(g\), in the Home country. This agglomeration economies raise firm’s productivity and thus firms entailed with the same \(\rho\) may have different productivity level such that firms located in city \(g\) are entailed productivity level, \(\theta = \rho \times \Phi_g\). In addition to the domestic agglomeration, multinational firms face other foreign external impacts on their productivity. On the one hand, firms can obtain access to externally generated knowledge from foreign superior technology through establishing a foreign affiliate. On the other hand, the headquarters may have some difficulties in communication with their subsidiaries and therefore cause some efficiency loss\(^6\).

We assume that foreign investment firms can improve their productivity level by \(\theta^\gamma\), where \(\gamma \in [0, 1]\) is the elasticity of knowledge spillovers to productivity. Findlay (1978) provided a

\(^6\)The efficiency losses also can be treated as the results from technology diffusions and firm relative productivity decreases.
theoretical model that the magnitude of potential gains from spillovers may depend on the technology gap between Home and Foreign country. The greater the technological distance between the host and home country, the greater the opportunities to exploit and the higher rate the new technology is adopted. \( \gamma \) measures the relative position in knowledge stocks across countries and industries, such as accumulated innovations, human capital and technology similarity. Countries entailed with higher \( \gamma \) offer higher potential spillovers benefits for FDI firms. Glass and Saggi (2002) emphasized the role of a firm’s ability to absorb and adopt the external knowledge. Firms with higher absorptive capacity are more likely to employ additional new technology. Our model combines these two concepts. Under our specification, more productive firms have higher absorptive capacity to acquire foreign superior and new technologies conditional on the technological gap, \( \gamma \), between host and home country. This makes more productive firms face higher marginal gains from knowledge spillovers. In addition, larger relative knowledge position (\( \gamma \)) between the home and host country offers more opportunities in technology spillovers for firms.

Multinational firms may face some costs to transfer technology and knowledge to their foreign facilities and difficulties to communicate with their subsidiaries. The technology transferring and communication costs are increasing in technological complexity. Given the fact that more productive firms adopt technically complex production technologies, more efficient firms suffer higher transferring and communication costs. These costs can be treated as an efficiency losses which are defined as \( \theta^{-\beta} \). \( \beta \in [0, 1] \) may be geographic and industrial specific which determines the communication and technology transferring costs such as infrastructure, intellectual property and human capital within a geographical area. Yeaple and Keller (2008) recently developed a model accounting for costly technology transfer within multinational firms where the costs of transferring technology to relative poor countries are higher than to richer countries. They also provide the evidence that technological complexity will deter the open-
ing of a subsidiary for the U.S. multinational firms. Our model also captures the relationship between firm productivity (technology complexity) and the potential for efficiency losses.

In addition to the external sources for improvement in firm productivity through domestic agglomeration and foreign investments, we also allow firms to raise their productivity by investing in research and development (R&D). A firm’s investments in R&D improve a firm’s ability to develop new technologies of its own as well as to absorb and adapt new technologies from external sources\(^7\). We assume that the productivity improvement is increasing in the R&D spending levels \((rd)\) with an elasticity \(\delta\), and there exists an additional R&D investment cost, \(C(rd)\). According to these settings, exporting and FDI firms’ productivity levels can be represented as \(\theta_x \equiv \theta \times rd^\delta\) and \(\theta_f \equiv \theta^{[1+(\gamma-\beta)]} \times rd^\delta\), respectively.

The timing of a firm’s decision is as following: firms first decide to undertake FDI or export in order to serve foreign markets. Firms next decide the R&D investment level and finally choose the optimal production level based on \(\theta_x\) and \(\theta_f\). Backward induction is used and we will discuss firms’ decisions in the following subsections.

### 3.1 Production output level

Assume that production only requires labor input in the production function, \(q_i = \theta_i L_i\). This production technology incurs a constant marginal production cost of product \(i\), \(MC_{il} = \frac{w_l}{\theta_i}\), produced by a facility in country \(l\) with productivity level, \(\theta_i\) and wage level, \(w_l\). If firms produce in the Home country and export to country \(l\), the marginal cost of producing and delivering goods to the consuming markets is \(\frac{w_H \tau}{\theta_i}\), where \(\tau\) is the transportation costs. The

\(^7\)Multinational firms can become more effective in assimilating the new foreign technology through R&D investments.
optimal pricing rule for a CES-induced demand function is \( p_{il} = \frac{MC_{il}}{\alpha} \), where

\[
MC_{il} = \begin{cases} 
\frac{w_l}{\theta_i}, & \text{if production and consumption in the same country} \\
\frac{w_H \tau}{\theta_i}, & \text{if exporting}
\end{cases}
\]

The constant marginal costs and independent demands across domestic and foreign markets imply that firms choose their optimal production levels separately for domestic and foreign markets. Solving the production profit, \( \pi_{il} \), for firm \( i \) serving country \( l \), we obtain

\[
\pi_{il} = p_{il}q_{il} - MC_{il}q_{il} = Y_l(\alpha - 1)\alpha^{\sigma-1}MC_{il}^{1-\sigma} = B_lMC_{il}^{1-\sigma},
\]

where \( Y_l = \frac{E_l}{P_l^{1-\sigma}} \) and \( B_l = Y_l(\alpha - 1)\alpha^{\sigma-1} \). Since each firm produces a single variety and firms differ only in productivity, we can use \( \theta \) to represent each variety in the product market and drop the subscript \( i \) in the following discussions without loss of generality. The profits for exporting firms (\( \pi_x \)) and FDI firms (\( \pi_f \)) can be shown

\[
\pi_x = B_H w_H^{1-\sigma} \theta_x^{\sigma-1} + B_F (w_H \tau)^{1-\sigma} \theta_x^{\sigma-1} \equiv \psi_x \theta_x^{\sigma-1} \\
\pi_f = B_H w_H^{1-\sigma} \theta_f^{\sigma-1} + B_F w_F^{1-\sigma} \theta_f^{\sigma-1} \equiv \psi_f \theta_f^{\sigma-1}
\]

where \( \psi_x = B_H w_H^{1-\sigma} + B_F (w_H \tau)^{1-\sigma} \) and \( \psi_f = B_H w_H^{1-\sigma} + B_F w_F^{1-\sigma} \) are the combination of market size (\( B_l \)) and variable unit costs (\( w_l, \tau \)) which increases in market size and decreases in variable unit costs.

### 3.2 Optimal R&D level

After solving firm optimal choices of output level conditional on firm productivity (\( \theta_x \) and \( \theta_f \)), we next find out the optimal R&D investment level. Assume the cost of R&D (\( C(rd) \)) is \( rd^aC_l \)
where \( \eta \) denotes the elasticity of costs on R&D investments, and \( C_l \) represents geographic and industrial specific costs on R&D which may differ for exporting and multinational firms. \( C_x \) and \( C_f \) represent the geographic and industrial specific R&D costs for exporting and FDI firms, respectively. Given this setup, the profit functions for exporting and FDI firms under R&D investments are

\[
\Pi_x = \psi_x (\theta x \times \delta_x)^{\sigma - 1} - \theta^{\sigma} C_x
\]

\[
\Pi_f = \psi_f (\theta^{1+\gamma-\beta} \times \delta_f)^{\sigma - 1} - \theta^{\sigma} C_f
\]

Firms maximize equation (4) and choose the optimal R&D level, \( rd^* \), such that

\[
r_d^* = \left( \frac{\psi_x \delta (\sigma - 1)}{C_x \eta} \right)^{\frac{1}{\eta - \delta (\sigma - 1)}} \theta^{\sigma - 1}\left(\frac{1}{\eta - \delta (\sigma - 1)}\right)
\]

\[
r_d^* = \left( \frac{\psi_f \delta (\sigma - 1)}{C_f \eta} \right)^{\frac{1}{\eta - \delta (\sigma - 1)}} \theta^{\sigma - 1}\left(\frac{1}{\eta - \delta (\sigma - 1)}\right)[1 + (\gamma - \beta)]
\]

Assumption 1. \( \eta - \delta (\sigma - 1) > 0 \)

By making Assumption 1, the elasticity of costs on R&D investments (\( \eta \)) are higher than the elasticity of benefits on R&D investments (\( \delta (\sigma - 1) \)). This guarantees the bounded solution of R&D investment to exist. Under this assumption and from equation (5), we know that optimal R&D investment is increasing in market size, \( B \), as well as firm productivity, \( \theta \), and is decreasing in cost parameters \( \eta \), \( w_l \), and \( C_l \). Equation (5) also implies multinational firms may invest more in R&D relative to exporting firms since R&D is complementary to the foreign technology sourcing strategy. Substituting the optimal R&D level, \( rd^* \), into equation (4), we
have

\[
\Pi_x = \psi_{\frac{n}{\eta-\delta(\sigma-1)}} \theta^{(\sigma-1)} X^{-\frac{\delta(\sigma-1)}{\eta-\delta(\sigma-1)}} \left[ \left( \frac{\delta(\sigma-1)}{\eta} \right)^{\frac{n}{\eta-\delta(\sigma-1)}} - \left( \frac{\delta(\sigma-1)}{\eta} \right)^{\frac{n}{\eta-\delta(\sigma-1)}} \right]
\]

\[
\Pi_f = \psi_{\frac{n}{\eta-\delta(\sigma-1)}} \theta^{(\sigma-1)} \left[ \left( \frac{\delta(\sigma-1)}{\eta} \right)^{\frac{n}{\eta-\delta(\sigma-1)}} - \left( \frac{\delta(\sigma-1)}{\eta} \right)^{\frac{n}{\eta-\delta(\sigma-1)}} \right]
\]

(6)

It is apparent that \( \Pi > 0 \) if \( \eta - \delta(\sigma - 1) > 0 \). Equation (6) implies that \( \Pi(B_l, C_l, w_l, \tau, \theta) \) increases in market size \( B_l \) and productivity \( \theta \), and decreases in production and R&D costs \( C_l \), \( w_l \) and \( \tau \).

### 3.3 FDI or Export?

Finally, we consider firms' production location choices. Denote \( \theta^{(\sigma-1)} \frac{1}{\eta-\delta(\sigma-1)} \) to be \( \tilde{\theta} \) and \( A = \left[ \left( \frac{\delta(\sigma-1)}{\eta} \right) - \left( \frac{\delta(\sigma-1)}{\eta} \right) \right] \), we can rewrite the profit function as following:

\[
\Pi_{NonFDI} = \psi_{\frac{\eta}{\eta-\delta(\sigma-1)}} \tilde{\theta} X^{-\frac{\delta(\sigma-1)}{\eta-\delta(\sigma-1)}} \left[ \left( \frac{\delta(\sigma-1)}{\eta} \right) - \left( \frac{\delta(\sigma-1)}{\eta} \right) \right] A
\]

(7)

\[
\Pi_{FDI} = \psi_{\frac{\eta}{\eta-\delta(\sigma-1)}} \tilde{\theta}^{1+\gamma-\beta} C^{-\frac{\delta(\sigma-1)}{\eta-\delta(\sigma-1)}} A - f_I
\]

(8)

where \( f_I \) is the fixed cost. Each firm chooses the production location for serving foreign market by comparing \( \Pi_{NonFDI} \) with \( \Pi_{FDI} \). We then compare the operating profits attainable for a firm with the measure of productivity, \( \tilde{\theta} \), from equations (7) and (8). Since \( \Pi_{FDI} \) is nonlinear in \( \tilde{\theta} \), we characterize the curvature of \( \Pi_{FDI} \) by differentiating equation (8) with respect to \( \tilde{\theta} \),

\[
\frac{\partial \Pi_{FDI}}{\partial \tilde{\theta}} = (1 + (\gamma - \beta)) \psi_{\frac{\eta}{\eta-\delta(\sigma-1)}} \tilde{\theta}^{-(\gamma-\beta)} C^{-\frac{\delta(\sigma-1)}{\eta-\delta(\sigma-1)}} A > 0
\]

\[
\frac{\partial^2 \Pi_{FDI}}{\partial \tilde{\theta}^2} = (1 + (\gamma - \beta))(\gamma - \beta) \psi_{\frac{\eta}{\eta-\delta(\sigma-1)}} \tilde{\theta}^{-(\gamma-\beta)-1} C^{-\frac{\delta(\sigma-1)}{\eta-\delta(\sigma-1)}} A
\]
It is obvious that the sign of \( \frac{\partial^2 \Pi_{FDI}}{\partial \tilde{\theta}^2} \) depends on the difference in magnitudes between knowledge spillovers and technology transferring costs, \((\gamma - \beta)\). We will discuss both conditions in turn. Figures 3 and 4 show the profits attainable for different levels of productivity. Figure 3 depicts the profit functions of equations (7) and (8) when the benefits of knowledge spillovers overcome the losses of technology transferring, i.e., \((\gamma - \beta) > 0\). Firms with productivity levels higher than \(\tilde{\theta}_N\) will build a facility abroad to serve the foreign market, and firms with productivity levels lower than \(\tilde{\theta}_N\) will produce domestically and then export to the foreign market. More productive firms have higher returns on saving transportation costs and have higher incentives to undertake FDI. This is consistent with Helpman et al.’s (2004) theoretical prediction. Comparing with their model, the positive externalities (higher \(\gamma\)) offer another advantage for incurring production activities abroad. Therefore, FDI is still attractive to firms even if the production costs abroad, \(w_F\), are higher than the costs of delivering products to foreign market, \(w_H\). Without the benefits of knowledge spillovers, firms have no incentive to undertake FDI in a foreign country where the production costs are higher than domestic and transportation costs. Since more productive firms have higher capability to absorb the positive externalities, only firms with higher productivity level have the incentives to undertake FDI.

Figure 4 shows the case that the efficiency loss dominates the benefits from knowledge spillovers, \((\gamma - \beta) < 0\). Under this situation, firms with productivity at the intermediate level \((\tilde{\theta}_0 < \tilde{\theta} < \tilde{\theta}_1)\) choose to undertake FDI and the most productive and the least productive firms produce in the Home country. Even if the lower production costs in the foreign market trigger firms to undertake FDI, the loss of knowledge diffusion discourages firms from production abroad. Moreover, if the costs of setting up a foreign affiliate is high enough, then all firms will keep production activities domestically.\(^9\). Even if the most productive and the least productive

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\(^8\)Fosfuri and Motta (1999) also provide a case of technological sourcing FDI without advantages that a firm invests abroad in order to obtain its rival’s technology.

\(^9\)There could be the cases that no firm chooses to FDI if the costs of producing abroad, such as fixed investment costs and production factor prices, are too large. We discuss these conditions in Appendix 1.
firms choose not to undertake FDI, the main reasons for being NonFDI are different for these two types of firms. The least productive firms cannot afford the fixed investment costs and stay domestically. The most productive firms face larger disadvantages of efficiency losses relative to less productive firms. The disadvantages overcome the gains from saving on variable costs which discourage production abroad for the most productive firms. This is consistent with Chang and Lu’s (2009) findings that the most and least productive Taiwanese firms chose not to invest in China in the early 1990s, if $\beta$ is higher at the early stage of FDI in a foreign country.

In summary, two sources of positive externalities exist in this model, domestic and foreign sources. A firm gains from agglomeration economies, $\Phi_g$, from domestic market. Multinational firms face other foreign external impacts on their productivity: knowledge spillovers and efficiency losses. Knowledge spillovers and efficiency losses disproportionately affect firm production efficiency based on their current productivity. More productive firms gain more since they have higher ability to adopt foreign new technology. On the other hand, more productive firms face higher risk to technology transferring losses. In sum, the magnitude of these two impacts will affect a firm’s FDI decision\textsuperscript{10}. If the efficiency losses ($\beta$) are larger than the gain form knowledge spillovers ($\gamma$), i.e., $(\gamma - \beta)$ is negative, then the most productive firms have no incentive to undertake FDI. The size of $\gamma$ and $\beta$ also affect firms’ performance. The larger $(\gamma - \beta)$ is, the more benefits that multinational firms can gain through undertaking FDI.

4 Data Sources and Variables

In this paper, comprehensive plant-level data from the 2000 TSCMO collected by the Ministry of Economic Affairs in Taiwan are used to compute the industrial agglomeration indicators across

\begin{footnotesize}
\textsuperscript{10}$\beta$ and $\gamma$ can be treated as geography-specific parameters for agglomeration effect which capture the technological distance between the host and home countries. Greater differentials($\gamma$) give firms more opportunities to exploit foreign technologies which is also provided by Findlay (1978), Glass and Saggi (2002), and Yeaple and Chung (2008).
\end{footnotesize}
different villages and 4-digit Standard Industrial Classification (SIC) industries. The agglomeration effect, sometimes call Marshall-Arrow-Romer (MAR) externality concerns externalities between firms in an industry, which can result from division of labor, knowledge spillovers, or technology spillovers. Various indices for industrial agglomeration have been proposed in the literature. Most of the indices are based on labor while the other are based on measures such as firm establishments, innovation, inter-industry linkage and qualitative aspect of firms. The indices based on labor emphasize that pooled labor markets promote knowledge spillovers and technological spillovers through channels including labor mobility, interaction between firms in geographic proximity, specialized intermediary firms resulting from intra-industry input-output linkages (Krugman and Venables, 1995).

This study utilizes the index proposed by Holmes (1999) to measure the agglomeration effect. In this study the agglomeration index for firm $i$ of industry $m$ in location $g$ is defined as $H_{mg} = \sum_{j \in mg} L_{jmg}$, which represents the sum of all employments of industry $m$ in location $g$. Specifically, all firms within the circle of a radius of 20 kilometers (about 13 miles) of firm $i$ are defined as located in the same cluster area as firm $i$. Therefore, whether firms are in the same area is defined in terms of distance instead of jurisdiction. We choose a radius of 20 kilometers to approximate possible agglomeration effect partly because Taiwan has 23 local jurisdiction and the area of each local jurisdiction approximately equals a circle with a radius of 20 kilometers. Because the agglomeration effect, if any, tends to decline with distance, a distance of 20 kilometers span a wide area in the case of Taiwan and therefore the estimate of agglomeration effect based on our index is likely biased toward zero.

The annual FDI amounts, sales, ages, employees, R&D expenditures, and other firm characteristics of companies listed under the Taiwan Stock Exchange and ROC Gre-Tai Securities Market (GTSM) are adapted from the Taiwan Economic Journal (TEJ) in 2001 and 2002. FDI is defined as a binary variable, i.e., it is one when there is either approved or realized invest-
ment in year 2001; it is zero otherwise. Since the FDI and R&D variables are considered to be endogenous in our theoretical argument, we calculate the dependent variable (i.e., total factor productivity) using the data in 2002 and utilize the lagged variables (i.e., measured in 2001) as covariates.\footnote{The details for computing total factor productivity are deferred to Appendix 3.} This may bypass the possible endogeneity running from the firm’s performance to other control variables. Furthermore, due to the data limitation on cluster indicators, we have only cross sectional data on hand. The unobserved firm-specific heterogeneity can not be modeled directly. There are approximately 1,532 firm collected by TEJ. Since we focus on the manufacturing firms, service firms are therefore removed from our sample. Firms with missing values are deleted from our sample. Combining TSCMO and TEJ data sets leads to 601 manufacturing firms. Summary statistics for key variables are presented in Table 1.

\section{Econometric Method and Empirical Results}

The theoretical model presented in Section 2 allows that local agglomeration economies improve firm performance. Firms undertaking FDI face other foreign external impacts on their productivity: knowledge spillovers and efficiency losses. The relative scale of these two effects determines the contribution of FDI to firm productivity. In this section, we examine the impacts of agglomeration and FDI on firm productivity. We construct a linear econometric model to empirically assess the impacts of industrial agglomeration, FDI and R&D on firms’ performances as follows:

\[
\text{TFP}_{i2002} = \beta_0 + \beta_1 \text{TFP}_{i2001} + \beta_2 \text{Cluster}_i + \beta_3 \text{FDI}_i + \beta_4 \text{R&D}_i + Z_i' \gamma + \varepsilon_i,
\]

where TFP\textsubscript{2002} and TFP\textsubscript{2001} denote respectively the total factor productivity of firm i in 2002 and 2001, Cluster\textsubscript{i} is the agglomeration index of firm i, FDI\textsubscript{i} is the dummy variable to denote
whether firm \( i \) conducts FDI in China, \( R&D_i \) is firm’s R&D expenditure, and \( Z_i \) denotes the vector of other control variables such as firm age, firm size, capital, industry dummies and possibly the interaction term between \( TFP_{i2001} \) and \( \text{Cluster}_i \). Note that the agglomeration index is measured for year 2000 while all other right-hand-side variables are measured for year 2001.

Ordinary least squares with robust standard errors are employed to obtain our estimation results. Table 2 shows that firm’s current period performance (in terms of total factor productivity) is strongly and positively associated with the next period performance. This is consistent with the theoretical predictions in Hopenhayn (1992) that firm productivity evolves persistently over time and empirically supporting by Bartelsman and Dhrymes (1992) and Baily et al. (1992). Firm age has significant impact on firm’s productivity, indicating that more experienced firms would perform better than younger firms do. In addition, more experienced firms are able to adopt the modern technology which is positive correlated with firm productivity growth. This may justify why firms with higher productivity may last longer.

R&D has positive effects on firm’s performance but the effects are not significant. The effects of R&D on firm productivity may vary across industries. To measure the variations in contribution of R&D to firm efficiency, we add the interaction terms between R&D and industry dummies. R&D investments raise firm productivity in technology-intensive industries such as computer & telecommunications equipment industry, the electronic parts and component industry and the precise instruments industry. This supports the bulk of literature such as Ericson and Pakes (1995) and a series papers by Aghion et al. (2001, 2005, 2006) considering firms investing in R&D as the primary source of productivity improvement and are better to absorb foreign technologies.

The negative coefficient on capital may reflect that adjustment costs on fixed assets hamper the ability of large firms to adjust their capital stock in response to unexpected shocks in the
short run. The dot-com bubble in 2001 caused an economic downturn in Taiwan. Large firms may not divest their physical capital to the optimal level immediately due to the inflexible adjustment\textsuperscript{12} such as indivisibility. To remedy this shortcoming of using capital as a size indicator, we also include the number of employees as the measure of firm size. The number of employees is positively correlated with total factor productivities. However, the coefficients are not always statistically significant.

The local industrial agglomerations provide significantly positive contribution to firm’s productivity, which is consistent with our presumption that firms located in more concentrated industrial agglomerations become more productive. This finding is quite robust across various model specifications. The coefficient of outward FDI in China has significantly positive impacts on firm’s performance in all settings, which suggests that undertaking FDI in China provides some net gains to firm performance.

As suggested by the theoretical model, high productivity firms may gain more than low productivity firms from agglomeration and foreign knowledge spillovers. In order to verify the existence of these complementarities, we include two interaction terms (\( \text{TFP}_{i}^{2001} \times \text{Cluster}_{i} \) and \( \text{TFP}_{i}^{2001} \times \text{FDI}_{i} \)) in Models 4-6 of Table 2. The positive coefficients on these two interaction terms indicate that higher productivity firms benefit more from industrial agglomeration and undertaking FDI than lower productivity firms. However, only \( \text{TFP}_{i}^{2001} \times \text{Cluster}_{i} \) is in general statistically significant. It is noticed that the coefficient of \( \text{TFP}_{i}^{2001} \) becomes negative. This does not mean that higher \( \text{TFP}_{i}^{2001} \) is associated with less \( \text{TFP}_{i}^{2002} \). To understand the marginal effect of \( \text{TFP}_{i}^{2001} \), we have to take into account the impacts from interaction terms. It turns out that the marginal effect of \( \text{TFP}_{i}^{2001} \) reveals to be positive according to our calculation. Even though the coefficient of \( \text{TFP}_{i}^{2001} \) is negative, positive signs on two interaction terms offset the negative effect and result in positive overall effect of \( \text{TFP}_{i}^{2001} \) on total factor productivity in

\textsuperscript{12}Domms and Dunne (1998) and Cooper and Haltiwanger (2007) document plant-level physical adjustment is infrequent and lumpy.
2002. It also implies that higher $\text{TFP}_i^{2001}$ does not guarantee to have higher $\text{TFP}_i^{2002}$. Higher $\text{TFP}_i^{2001}$ accompanied with higher degree of industrial agglomeration is more likely to increase the productivity in 2002.

6 Conclusion

Over the last two decades, outward FDI from Taiwan to China has grown at a much more rapid pace than that invested into developed countries. The ongoing massive FDI outflows trigger the interests on the impact of production location choices on firm performance. In addition to the advantage of cost savings and market seeking, FDI may also offer the channel of productivity improvement through technology spillovers. Besides the foreign source of knowledge spillovers, phenomenon industrial agglomerations have been experienced in many regions in Taiwan. The number of employees in Hsinchu Science Park had increased more than ten times during the past two decades. This paper examines impacts of industrial agglomeration and foreign direct investment on the total factor productivity of Taiwanese firms.

Comparing with traditional horizontal/vertical FDI literature focusing on market-seeking and/or cost-saving incentives for producing abroad, this paper also takes into account technology-sourcing motivation. This provides the possibility of FDI in the lack of cost advantage. Besides the gain from knowledge spillovers, we also introduce the technology replicating costs and the risk of technology diffusion which may deter the most productive firms undertaking FDI and cause efficiency losses. In addition to the foreign channel of productivity gains, this paper also introduces domestic agglomeration economies which have proven an important determinant of firm productivity in Taiwan.

In our theoretical model, domestic agglomeration economies improve firm performance. Multinational firms face other foreign external impacts on their productivity: knowledge spillovers
and efficiency losses. Knowledge spillovers and efficiency losses disproportionately affect firm production efficiency based on their current productivity. More productive firms gain more since they are more capable in adopting foreign new technology. On the other hand, more productive firms face higher risk of technology transferring losses. In sum, the magnitude of these two impacts will affect a firm’s FDI decision and its future productivity. Given this framework, our model predicts that firms located in more concentrated industrial agglomerations become more productive, and undertaking FDI may have positive or negative influence on firm productivity which depends on the magnitude of these two canceling foreign external effects. By using TEJ data of 601 manufacturing firms in 2001 and the Holmes agglomeration indicator, this paper examines impacts of industrial agglomeration and FDI on productivity of Taiwanese firms. In particular, this paper tries to distinguish influences from these domestic and foreign sources. The estimation results suggests that both local industrial agglomerations and FDI provide positive contribution to firm productivity after firms’ attributes are controlled. Even if firms can gain from externalities from both domestic and foreign sources, more productive firms can gain more through local agglomeration economies relative to FDI. Our results highlight the importance of industrial clusters in raising productivity for Taiwanese firms relative to FDI.
Appendix 1

Let $\tilde{\theta}^+$ be the $\tilde{\theta}$ level such that \[ \frac{\partial \Pi_{\text{NonFDI}}}{\partial \tilde{\theta}} = \frac{\partial \Pi_{\text{FDI}}}{\partial \tilde{\theta}} \], and

\[ \frac{\partial \Pi_{\text{NonFDI}}}{\partial \tilde{\theta}} = \psi_x \eta^{\sigma(\sigma - 1)} C_x^{-\delta(\sigma - 1)} A > 0 \]

\[ \frac{\partial \Pi_{\text{FDI}}}{\partial \tilde{\theta}} = \psi_f \eta^{\sigma(\sigma - 1)} C_f^{-\delta(\sigma - 1)} A[1 + (\gamma - \beta)] \tilde{\theta}^{(\gamma - \beta)} \]

Solving for $\tilde{\theta}^+$, we have

\[ \tilde{\theta}^+ = \left[ \left( \frac{\psi_x}{\psi_f} \right)^{\frac{\eta}{\eta - \sigma(\sigma - 1)}} \left( \frac{C_x}{C_f} \right)^{\frac{-\delta(\sigma - 1)}{\eta - \sigma(\sigma - 1)}} \frac{1}{1 + (\gamma - \beta)} \right]^{\frac{1}{(\gamma - \beta)}} \]

We then calculate the difference between $\Pi_{\text{NonFDI}}$ and $\Pi_{\text{FDI}}$ at $\tilde{\theta}^+$ (i.e., $\Pi_{\text{FDI}}(\tilde{\theta}^+) - \Pi_{\text{NonFDI}}(\tilde{\theta}^+)$) such that

\[ \Delta \Pi(\tilde{\theta}^+) \]

\[ = \Pi_{\text{FDI}}(\tilde{\theta}^+) - \Pi_{\text{NonFDI}}(\tilde{\theta}^+) \]

\[ = \psi_f \eta^{\sigma(\sigma - 1)} \tilde{\theta}^+ \left[ 1 + (\gamma - \beta) \right] C_f^{-\delta(\sigma - 1)} A - f_l - \psi_x \eta^{\sigma(\sigma - 1)} \tilde{\theta}^+ C_x^{-\delta(\sigma - 1)} A \]

\[ = \psi_x \eta^{\sigma(\sigma - 1)} C_x^{-\delta(\sigma - 1)} \tilde{\theta}^+ \left[ \frac{1}{1 + (\gamma - \beta)} \right] - f_l - \psi_x \eta^{\sigma(\sigma - 1)} C_x^{-\delta(\sigma - 1)} A \tilde{\theta}^+ \]

\[ = \psi_x \eta^{\sigma(\sigma - 1)} C_x^{-\delta(\sigma - 1)} A \tilde{\theta}^+ \left[ \frac{-\gamma - \beta}{1 + (\gamma - \beta)} \right] - f_l \]

The sign of $\Delta \Pi(\tilde{\theta}^+)$ is related to the sign of $(\gamma - \beta)$, so we will discuss these two cases as following:

1. If $(\gamma - \beta) > 0$, then $\Pi_{\text{FDI}}(\tilde{\theta}^+) - \Pi_{\text{NonFDI}}(\tilde{\theta}^+) < 0$.

   Under this case, $\Pi_{\text{FDI}}$ and $\Pi_{\text{NonFDI}}$ are always intersect at some point (Figure 5).
2. If \((\gamma - \beta) < 0\), then the sign of \(\Pi_{FDI}(\tilde{\theta}^+) - \Pi_{NonFDI}(\tilde{\theta}^+)\) is undetermined.

\[
\Delta \Pi(\tilde{\theta}^+) = \Pi_{FDI}(\tilde{\theta}^+) - \Pi_{NonFDI}(\tilde{\theta}^+)
\]

\[
= -(\gamma - \beta)\psi_x \left[ \frac{1 + (\gamma - \beta)}{(\gamma - \beta)} \right] - \frac{\chi}{(1 + (\gamma - \beta))} A \left[ \frac{1}{1 + (\gamma - \beta)} \right] - f_l
\]

where \(\chi = \frac{\eta}{\eta - \delta(\sigma - 1)} > 1\), \(1 - \chi < 0\), \(\psi_x = B_H w_H^{1-\sigma} + B_F(w_H \tau)^{1-\sigma}\) and \(\psi_f = B_H w_H^{1-\sigma} + B_F w_F^{1-\sigma}\).

Figure 6 shows that firms have incentives to undertake FDI only if \(\Delta \Pi(\tilde{\theta}^+) > 0\). We can see that the higher fixed investment costs, \(f_l\), the lower possibility that a firm chooses to build a foreign plant. When the saving on variable production and delivering costs is higher (i.e., higher \(w_H \tau\) and lower \(w_F\)), firms are more likely to undertake FDI.

\[
\frac{\partial \Delta \Pi}{\partial \psi_x} = \frac{[1 + (\gamma - \beta)]\chi \Delta \Pi}{(\gamma - \beta) \psi_x} < 0
\]

\[
\frac{\partial \Delta \Pi}{\partial \psi_f} = \frac{-\chi \Delta \Pi}{(\gamma - \beta) \psi_f} > 0
\]

\[
\frac{\partial \Delta \Pi}{\partial w_H \tau} = (1 - \sigma) \frac{\psi_x}{w_H \tau} \frac{\partial \Delta \Pi}{\partial \psi_x} > 0
\]

\[
\frac{\partial \Delta \Pi}{\partial w_F} = (1 - \sigma) \frac{\psi_f}{w_F} \frac{\partial \Delta \Pi}{\partial \psi_f} < 0
\]
Appendix 2: Impacts of $\gamma$ and $\beta$ on $\tilde{\theta}_N$, $\tilde{\theta}_0$ and $\tilde{\theta}_1$

In this section, we will examine how the magnitudes of knowledge spillovers, $\gamma$, and efficiency losses, $\beta$, affect the fraction of FDI firms. The threshold value of productivity level for being multinational firms ($\tilde{\theta}_0$, $\tilde{\theta}_1$, $\tilde{\theta}_N$ in Figures 3 and 4) satisfies $\Pi_{FDI} = \Pi_{NonFDI}$ such that

$$\Pi_{FDI} = \Pi_{NonFDI}$$

$$\psi_f \eta^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} \tilde{\theta}^{[1 + (\gamma - \beta)]} C_f^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} A - f_l = \psi_x \eta^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} \tilde{\theta} C_x^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} A$$

Denote $G = \psi_f \eta^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} \tilde{\theta}^{[1 + (\gamma - \beta)]} C_f^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} A - f_l - \psi_x \eta^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} \tilde{\theta} C_x^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} A = 0$, then

$$\frac{\partial G}{\partial \tilde{\theta}} = [1 + (\gamma - \beta)] \psi_f \eta^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} C_f^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} A \tilde{\theta}^{(\gamma - \beta)} - \psi_x \eta^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} C_x^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} A$$

From Figure 3 and Figure 4 we know that

$$\frac{\partial G}{\partial \tilde{\theta}_N} > 0$$
$$\frac{\partial G}{\partial \tilde{\theta}_0} > 0$$
$$\frac{\partial G}{\partial \tilde{\theta}_1} < 0$$

We also know that

$$\frac{\partial G}{\partial \gamma} = \psi_f \eta^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} \tilde{\theta}^{[1 + (\gamma - \beta)]} C_f^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} A ln(\tilde{\theta}) > 0$$
$$\frac{\partial G}{\partial \beta} = -\psi_f \eta^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} \tilde{\theta}^{[1 + (\gamma - \beta)]} C_f^{\frac{n}{\eta - \delta \sigma(\sigma - 1)}} ln(\tilde{\theta}) < 0$$
By L'Hôpital rule, we know that

\[
\frac{d\theta_N}{d\gamma} = -\frac{\partial G/\partial \gamma}{\partial G/\partial \theta_N} < 0, \quad \frac{d\tilde{\theta}_0}{d\gamma} = -\frac{\partial G/\partial \gamma}{\partial G/\partial \tilde{\theta}_0} < 0, \quad \frac{d\tilde{\theta}_1}{d\gamma} = -\frac{\partial G/\partial \gamma}{\partial G/\partial \tilde{\theta}_1} > 0
\]

\[
\frac{d\tilde{\theta}_N}{d\beta} = -\frac{\partial G/\partial \beta}{\partial G/\partial \theta_N} > 0, \quad \frac{d\tilde{\theta}_0}{d\beta} = -\frac{\partial G/\partial \beta}{\partial G/\partial \tilde{\theta}_0} > 0, \quad \frac{d\tilde{\theta}_1}{d\beta} = -\frac{\partial G/\partial \beta}{\partial G/\partial \tilde{\theta}_1} < 0
\]

Therefore, higher knowledge spillovers effect (\(\gamma\) increases) will raise the fraction of FDI firms. (i.e., \(\tilde{\theta}_N\) ↓ under the case of \((\gamma - \beta) > 0\), \(\tilde{\theta}_0\) ↓ and \(\tilde{\theta}_1\) ↑ under the case of \((\gamma - \beta) < 0\)) On the other hand, higher risk of knowledge diffusion (higher \(\beta\)) will reduce the fraction of FDI firms. (i.e., \(\tilde{\theta}_N\) ↑ under the case of \((\gamma - \beta) > 0\), \(\tilde{\theta}_0\) ↑ and \(\tilde{\theta}_1\) ↓ under the case of \((\gamma - \beta) < 0\)). Figure 7 depicts how \(\beta\) and \(\gamma\) affect the cutoff productivity levels.
Appendix 3: Productivity Measurement

We use Tornqvist multilateral total factor productivity (TFP) index developed by Caves, Christensen and Diewert and adopted by Aw, Roberts and Chen (2001). The productivity index is calculated separately for each of the two-digit industries in the manufacturing sector. The multilateral index relies on a single hypothetical firm that is constructed by the industry mean level of log output, log input, and input cost shares. Each firm’s log output and input levels are measured relative to the hypothetical firm. The TFP index for firm $i$ in year $t$ is calculated as:

$$\ln TFP_{it} = (\ln Q_{it} - \ln Q_{t}) + \sum_{s=2}^{t} (\ln Q_{s} - \ln Q_{s-1})$$

$$- \left[ \sum_{j} \frac{1}{2}(\alpha_{ijt} + \overline{\alpha_{jt}})(\ln X_{ijt} - \ln X_{jt}) + \sum_{s=2}^{t} \sum_{j} \frac{1}{2}(\alpha_{js} + \alpha_{j(s-1)})(\ln X_{js} - \ln X_{j(s-1)}) \right],$$

(9)

where $\ln Q_{it}$, $\ln X_{ijt}$ and $\alpha_{ijt}$ are the log output, input $j$ and the cost share of input $j$ for firm $i$ in year $t$. $\ln Q_{t}$, $\ln X_{jt}$ and $\overline{\alpha_{jt}}$ are the log output, input of factor $j$ and the cost shares of factor $j$ for the hypothetical firm in year $t$ which are measured by the mean of the corresponding variable over all firms in the industry in year $t$. The first term is the deviation of firm $i$’s output from the industry mean level in year $t$, and the second term captures the growth of industry output relative to the initial year, $t = 1$. The two terms in the second line are the same operations for the deviation of input usage from the hypothetical firms weighted by the corresponding cost shares of inputs.

Firm output is defined as production values deflated by a wholesale price index defined at the two-digit industry level. We use three inputs in production to construct the TFP: labor, capital, and materials. The labor input is measured as the number of employees. Labor
expenditures are measured as total salaries plus non-wage benefits paid by the firm. We use the book value of capital stock of the firm as the measure of capital input. The capital goods include plants, buildings and equipments. To control for price level changes in new capital goods that will cause the book value of firms to change over time as they invest in new equipment, we deflate the change in each firm’s book value by a price index for new capital goods. The cost shares on labor and materials are measured as the input expenses divided by the value of firm output. The firm’s expenditure share on capital is calculated as the residual after subtracting the expenditure on labor and material inputs from the firm’s output value.
References


Figure 1: Approved Taiwanese Outward FDI (1990-2006)

Figure 2: Kernel Distribution of TFP, by Year
Figure 3: Profits for Exporting and FDI Firms, $(\gamma - \beta) > 0$

Figure 4: Profits for Exporting and FDI Firms, $(\gamma - \beta) < 0$
Figure 5: Profits Gap between NonFDI and FDI at Productivity level $\tilde{\theta}^+, (\gamma - \beta) > 0$

Figure 6: Profits Gap between NonFDI and FDI at Productivity level $\tilde{\theta}^+, (\gamma - \beta) < 0$
Figure 7: Cutoff Productivity v.s. $\gamma$ and $\beta$

Table 1: Summary Statistics

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<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
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Table 2: Regression Results for Firms' Performance

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<tr>
<td>TFP_{2001} × Cluster</td>
<td>0.1487**</td>
<td>0.1664***</td>
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<td>R&amp;D × Textiles</td>
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