8-2011

Risk and the Technology Content of FDI: A Dynamic Model

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SMU ECONOMICS & STATISTICS
WORKING PAPER SERIES

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August 2011

Paper No. 07-2011

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August 13, 2011

Abstract

This paper incorporates risk into the FDI decisions of firms. The risk of FDI failure increases with the gap between the South's technology frontier and the technology complexity of a firm's product. This leads to a double-crossing sorting pattern of FDI—firms of intermediate technology levels are more likely than others to undertake FDI. It is with the attempt to relax the upper bound of the technology content of FDI, we argue, that many FDI policies are created. The theory's predictions are consistent with the empirical pattern of FDI in China by US and Taiwanese manufacturing firms.

Key Words: Foreign Direct Investment; Technology; Risk; Spillover; Dynamic
JEL Classification: F21; F23; O24; O33

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1. INTRODUCTION

Risk assessment plays an important role in practice when firms decide whether or not to undertake foreign direct investment (FDI). When firms contemplate FDI in a relatively backward Southern country, they face the risk of failure in product quality control. The higher the technology content of their production blueprints, the higher the risk. Such risk consideration may outweigh the conventional cost-saving consideration and eliminate all FDI incentives. Analyses on how risk affects firms' FDI decisions, however, are generally absent from modern FDI theories with firm heterogeneity. This paper aims to fill this gap.

We introduce the risk of quality control failure into the Melitz-model with firm heterogeneity. To formalize the risk associated with FDI, we extend the idea of the O-ring theory by Kremer (1993). In essence, production using a more complex technology requires a greater number of intermediate steps. The risk of quality control failure by producing in the South, as a result, increases with the complexity of a firm's production technology, but decreases with the South's technology capacity. Thus, although a firm with a more advanced technology has a larger market share and gains more from the cheap labor in the South compared with a lower-technology firm, such an advantage is weakened by the higher likelihood of FDI failure. This offsetting factor can be strong enough to completely wipe out a firm's incentive to invest in the South.

Our model predicts a double-crossing sorting pattern of FDI by firm technology levels (endogenously equivalent to firm productivity levels). Specifically, the incorporation of risk consideration implies an upper bound on the technology content of FDI, in addition to the lower cutoff predicted by the conventional model: only firms of intermediate technology levels find FDI profitable. The determination of the lower cutoff for FDI is largely based on the conventional tradeoff between fixed and variable costs, as firms in the lower range of the technology spectrum face minimal risks of quality control failure. The risk consideration, however, plays a critical role in the determination of the upper bound when the quality control failure becomes a binding concern.

This double-crossing property of our model helps rationalize the underlying goals of high-tech targeted FDI policies. In particular, the aforementioned upper bound confines the technology content of multinationals and casts a limit on the extent to which the South can catch up through inward FDI. It is with the attempt to relax these upper bounds (but not the lower bounds, as inadvertently follows from the conventional model), we argue, that many FDI policies and interventions are created. See, for example, the industrial parks for

IT in China[1] and for biotechnology in Singapore.[2]

This prediction of a double-crossing FDI sorting pattern is in spirit consistent with the literature investigating the origin of comparative advantage. See, for example, Costinot (2009), Jones (2008), Krishna and Levchenko (2009), Nunn (2007), and Berkowitz et al. (2006), among others. They show that the South, limited by its environment of inadequate institutions, insufficient human capital, or incomplete contract enforcement, has a comparative disadvantage in producing goods requiring the use of more complex technologies.

Built on the risk factor, we go one step further to formalize the development process of the South along the ladder of technology capacity. Specifically, the South improves its technology capacity as its exposure to multinational production activities increases. If the South's initial technology capacity exceeds a minimum threshold such that the risk factor is not prohibitive, the first wave of FDI inflows takes place. This first wave helps the South build up experiences of producing for multinationals and pushes forward the technology frontier in the South. As the frontier moves out, the probability of FDI success rises, which relaxes the risk constraint and triggers another wave of FDI led by technologically more advanced firms. Our model thus predicts a self-reinforcing agglomeration process,[3] along which the spectrum of technology contents of FDI expands over time.

This self-reinforcing process leads to two important policy implications. First, the positive externality generated by firms leading in FDI is not internalized by individual firms when making FDI decisions, which justifies the use of intervention policies; see, for example, similar arguments (for government interventions based on externalities) made by Hausmann and Rodrik (2003), Hausmann et al. (2007), and others surveyed in Pack and Saggi (2006). Second, the agglomeration process amplifies the effectiveness of FDI promoting policies. It implies a potential persistent impact of one-time industrial policies on development as their initial effects are reinforced through the endogenous dynamic process. Overlooking this self-reinforcing feature could lead to a biased cost and benefit assessment of FDI policies.

We show that the set of steady state(s) of the above dynamic process is a lattice. It implies that if there are multiple steady states, the momentum propelling the South's technology frontier stops at the least element of the lattice, and the South is trapped at a relatively low level of technology frontier. Thus, an active FDI policy by the South could actually pull the South out of the development trap toward one of the higher steady-state development levels.

[1] http://www.globalmanufacture.net/home/IndustrialLocation/index.cfm

[2] http://www.edb.gov.sg/edb/sg/en_uk/index/industry_sectors/pharmaceuticals__/industry_background.html

[3] This self-reinforcing process is well documented by empirical studies. For example, Head et al. (1995) found that the location choice of FDI by Japanese firms in the U.S. is driven by the mass of existing Japanese firms in the same industry. Similarly, Cheng and Kwan (2000) found that FDI in China exhibits a strong self-reinforcing effect: existing FDI stock in a region tends to attract further FDI inflows.

We work out the effects of several important policies on the South's technology frontier at the steady state.

We compile two data sets to verify our theoretical predictions. The first data set consists of annual observations on the incidence of FDI entries into China by US manufacturing firms during 1980–2010. The second data set comprises quarterly observations on the incidence of FDI entries into China by Taiwanese manufacturing firms since 1991Q1 (when the Taiwanese government lifted its ban on westward FDI into China) until 2009Q4. We observe one salient pattern in both data sets. At any given point in time, the FDI entries tend to be made by firms of intermediate productivity levels (and not by the most or least productive firms)—a pattern consistent with the prediction of our model. We conduct panel analyses for each data set using a specification that allows possible nonlinear relationships between FDI propensity and firm productivity level, as well as dynamic effects of FDI. The findings provide support for our model.

2. MODEL

2.1 Production Technology and Risk

Consider a world consisting of two countries, the North and the South, with the world population normalized to be one. Consumer preferences are identical in the two countries and imply an isoelastic demand for a variety (good) i of an industry j as:

$$x_j(i) = p_j(i)^{-\frac{1}{1-\alpha}}, \ 0 < \alpha < 1, \tag{1}$$

where $p_j(i)$ is the price of variety i of industry j, and $\frac{1}{1-\alpha}$ corresponds to the price elasticity of demand for each variety of an industry.[4] We will often drop the variety and the industry index below to simplify presentation.

The production function for each variety in each industry is modeled after the O-ring theory of Kremer (1993). In particular, the production of each variety requires a continuum of steps $s \in [0, \theta]$, where θ is the measure of intermediate steps to be performed. The magnitude of θ thus reflects the complexity of the production technology. It is assumed that the blueprints of all production technologies are developed in the North. Each firm in the North is associated with one type of production technology θ, which is distributed according

[4]The demand function in (1) can be derived from a CES utility function, and the partial equilibrium framework presented below can be embedded in a general equilibrium framework to allow free entry without affecting the main predictions of the paper. The partial equilibrium framework is presented here for the sake of simplicity. The general equilibrium analysis can be obtained upon request from the authors.

to a cumulative distribution function $G(\theta)$ with $\theta \geq 1$.

For there to be valuable output and positive revenues, all steps must be performed successfully; otherwise, the final good is of no market value. That is,

$$x = \begin{cases} \left[\int_0^\theta \lambda(s)^\rho ds\right]^{\frac{1}{\rho}}, & \text{in case of success;} \\ 0, & \text{in case of failure,} \end{cases} \qquad 0 < \rho < 1, \tag{2}$$

where $\lambda(s)$ denotes the intensity of effort used to carry out step s, and $\frac{1}{1-\rho}$ corresponds to the elasticity of substitution between any two steps.

It is assumed that labor is the only factor of production and the wage rate in the North w^N is higher than in the South w^S.[5] One unit of labor is required for each unit intensity used to carry out a step regardless of the production location. Thus, conditional on the production location $l \in \{N, S\}$, a firm with a production technology θ chooses the intensity of each intermediate step to minimize its production cost, $\int_0^\theta w^l \lambda(s) ds$. The symmetry of the steps in their cost structure and in their contributions toward the final output implies that $\lambda(s) = \lambda = x\theta^{-1/\rho}$, $\forall s \in [0, \theta]$. Substituting $\lambda(s)$ into the cost function, one derives the minimized unit production cost as:

$$c^l(\theta) = w^l \theta^{\frac{\rho-1}{\rho}}, \tag{3}$$

where $\frac{\partial c^l(\theta)}{\partial w^l} > 0$, and $\frac{\partial c^l(\theta)}{\partial \theta} < 0$. These properties imply that firms enjoy a greater cost advantage either by relocating their production to the South or when they possess a more sophisticated production technology.

Note that the unit cost is incurred regardless of the quality of the output. A firm only learns whether or not the output is marketable after production is completed. The probability $\gamma^l(\theta)$ of successfully completing all intermediate steps for technology θ in a given

[5] Wage rates are taken to be given exogenously here, although they can be justified endogenously by introducing a freely traded numeraire good y_0, in which the North has an absolute advantage. Specifically, let the Northern (Southern) unit labor requirement in producing y_0 be $a^N (a^S)$, and $a^N < a^S$. Also assume that y_0 is produced in both countries. Then, the wages in the North and the South are "endogenously" pinned down at $w^N = \frac{1}{a^N}$ and $w^S = \frac{1}{a^S}$, respectively, with $w^N > w^S$. This modeling technique has been used by Antràs and Helpman (2004, p. 557) and Helpman et al. (2004, pp. 301 and 303, and footnote 11), and suggested by Melitz (2003, footnote 19).

production location l is assumed to take the following functional form:

$$\gamma^N(\theta) \triangleq 1, \qquad \forall\ \theta,\ \text{where } 1 \leq \theta, \tag{4}$$

$$\gamma^S(\theta) = \begin{cases} 1, & \text{if } 1 \leq \theta \leq T^S, \\ \left(\frac{T^S}{\theta}\right)^z, & \text{if } T^S < \theta, \end{cases} \tag{5}$$

where T^S ($T^S \geq 1$) denotes the South's technology frontier, and z ($z \geq 0$) measures the degree of risk sensitivity. In (4), we assume that there is no risk of failure if production is undertaken in the North. On the other hand, in (5), by choosing to carry out the production in the South via FDI, firms bear a risk of quality control failure if the South's technology frontier is lower than the required production technology level ($T^S < \theta$). The larger the technology gap ($\frac{\theta}{T^S}$), the smaller the probability of successfully producing the good in the South.

The risk sensitivity z reflects the elasticity of the success probability to the technology gap. Given a technology gap ($\frac{T^S}{\theta} < 1$), the higher the risk sensitivity z, the lower the success probability of production. In particular, the success probability approaches zero as z tends to infinity, and one as z reduces to zero. The degrees of risk sensitivity may differ across industries. For example, an accidental power failure is likely to have a much smaller impact on the yields of a firm in the textile industry than in the wafer fabrication industry.[6]

In practice, anecdotal examples abound where a firm from the North with an advanced technology blueprint encounters risks of quality control failure when producing in the South. For example, *The Economist* (2004) reported that Kenwood of Japan shifted its production of mini-disc players from Malaysia back to Japan in 2002, and as a result, saw its product's defect rate fall by 80%.

Firms of all technology levels also incur a fixed setup cost (in Northern labor units) to start production. By assumption, the fixed setup cost is higher in the South than in the North, $f^N < f^S$. Suppose as well that firms are risk neutral. Then, given the production location $l \in \{N, S\}$, the optimal output level that maximizes a firm's expected profit,

$$\max_x \pi^l(\theta) = \gamma^l(\theta)x^\alpha - c^l(\theta)x - w^N f^l, \tag{6}$$

is $x^l(\theta) = \left(\frac{\alpha\gamma^l(\theta)}{c^l(\theta)}\right)^{\frac{1}{1-\alpha}}$. It has an intuitive interpretation: a firm's output level decreases in its unit cost of production and increases in its success rate of production. Substituting (3),

[6] In a more general setting, we could allow z to be a function of θ or a random variable drawn jointly with θ. The qualitative results of the model will continue to hold so long as z is positively correlated with θ and takes on positive values.

(4), and (5) into $x^l(\theta)$, the optimal output level is:

$$x^N(\theta) = \Omega^N \theta^\nu, \qquad \forall\ \theta,\ \text{where } 1 \leq \theta, \tag{7}$$

$$x^S(\theta) = \begin{cases} \Omega^S \theta^\nu, & \text{if } 1 \leq \theta \leq T^S, \\ \Omega^S \left(\frac{T^S}{\theta}\right)^{\frac{z}{1-\alpha}} \theta^\nu, & \text{if } T^S < \theta, \end{cases} \tag{8}$$

where $\nu \equiv \left(\frac{1-\rho}{\rho}\right)\left(\frac{1}{1-\alpha}\right) > 0$, and $\Omega^l \equiv \left(\frac{\alpha}{w^l}\right)^{\frac{1}{1-\alpha}}$ with $\Omega^N < \Omega^S$. In the scenario where there is no FDI risk (either due to $z = 0$ or $\theta \leq T^S$), a firm with a more advanced blueprint will command a larger market share, and FDI always induces production expansion. With the possibility of FDI risk, however, firms will scale back their outputs from the risk-free scenario; this offsetting effect becomes larger, the more advanced a firm's production technology is. The resulting optimal expected profit is:

$$\pi^N(\theta) = \psi^N \theta^{\nu\alpha} - w^N f^N, \qquad \forall\ \theta,\ \text{where } 1 \leq \theta, \tag{9}$$

$$\pi^S(\theta; T^S, z) = \begin{cases} \psi^S \theta^{\nu\alpha} - w^N f^S, & \text{if } 1 \leq \theta \leq T^S, \\ \psi^S \left(\frac{T^S}{\theta}\right)^{\frac{z}{1-\alpha}} \theta^{\nu\alpha} - w^N f^S, & \text{if } T^S < \theta, \end{cases} \tag{10}$$

where $\psi^l \equiv (1-\alpha)\left(\Omega^l\right)^\alpha$ with $\psi^N < \psi^S$.

2.2 FDI Decision: To Stay or To Go?

A firm decides whether or not to undertake FDI by comparing $\pi^N(\theta)$ and $\pi^S(\theta; T^S, z)$. Such a comparison is shown in Figure 1. For illustrative purposes, we have converted the scale of production technology with $\tilde{\theta} = \theta^{\nu\alpha}$ and $\tilde{T}^S \equiv \left(T^S\right)^{\nu\alpha}$, and plotted the transformed profit functions $\tilde{\pi}^N(\tilde{\theta})$ and $\tilde{\pi}^S(\tilde{\theta}; \tilde{T}^S, z)$. The mapping from θ to $\tilde{\theta}$ (or from T^S to $\tilde{T}^S$) is a one-to-one, monotonic transformation; thus, we will often discuss results in the original scale even as we refer to the figure. It is immediately clear that $\tilde{\pi}^N$ is a linear function and increases in $\tilde{\theta}$. By choosing to produce in the North, firms face no risk of failure, and their profit increases monotonically with the technology level. On the other hand, the shape of $\tilde{\pi}^S$ depends on z and T^S. Panels (a)-(d) in Figure 1 illustrate the potential sorting patterns under different combinations of risk sensitivity and technology frontier in the South.

In the standard FDI literature, the risk of FDI failure is often assumed away. Examples include Antràs and Helpman (2004) and Helpman et al. (2004). This corresponds to the special case with $z = 0$ in our model. As shown in Figure 1(a), the profit function of producing in the South $\tilde{\pi}^S$ is a linear schedule, which crosses $\tilde{\pi}^N$ once from below at $\tilde{\theta}_{NS}$.

We will refer to this scenario as the risk-free case.[7] It follows that firms are sorted according to their technology levels into firms of the lowest technology levels, with $\theta \in [1, \theta_N]$, who exit the market; firms of the lower technology levels, with $\theta \in [\theta_N, \theta_{NS}]$, who produce in the North; and firms of the highest technology levels, with $\theta \in [\theta_{NS}, \infty)$, who undertake FDI in the South.

This 'single-crossing' property in the risk-free case has some undesirable implications. First, it implies that firms of the highest technology levels are the ones to relocate production facilities to the South. Second, any policies by the South aimed to enhance FDI incentives only serve to attract firms of marginally lower technology levels than the existing inward FDI. Both predictions are contrary to what is observed in practice and what is aimed for by governments when providing FDI subsidies.

For example, *The Economist* (2004) reported that Canon of Japan, with a high-tech product line (ranging from precision photocopiers to optical components for digital cameras) was observed to maintain a majority of its worldwide production at home; similarly, at a time when other Japanese firms were shifting their manufacturing activities to China, Sharp chose to open its new "sixth-generation" plant (to make flat panels for televisions) in Japan in 2004.

Once FDI risk is incorporated into the standard model, richer implications are obtained. As suggested by (10), firms with a sufficiently low level of technology ($1 \leq \theta \leq T^S$) incur no FDI risk. These firms thus face the same tradeoff (between fixed and variable costs of FDI) as in the risk-free case. For firms with a relatively high level of production technology ($\theta > T^S$), the saving in unit cost by producing in the South is offset by the higher risk of quality control failure. The larger the technology gap is, the larger the offset relative to the risk-free scenario. Thus, the curve $\tilde{\pi}^S$ is linear and increasing in $\tilde{\theta}$ before $\tilde{T}^S$, coinciding with the risk-free case; it becomes a concave function after $\tilde{T}^S$. Hence, the expected profit from FDI will eventually be dominated by the profit of producing in the North for firms with sufficiently advanced technology. This implies an upper bound on the technology level of inward FDI.

As shown in Figure 1(b), for relatively low levels of technology capacity in the South and relatively mild levels of risk sensitivity, the curve $\tilde{\pi}^S$ crosses the curve $\tilde{\pi}^N$ twice, first from below at θ_0 and then from above at θ_1. Firms are sorted according to their technology levels into those of the lowest technology levels, with $\theta \in [1, \theta_N]$, who exit the market; those

[7] To ensure that, in the risk-free case, some firms will still produce in the North, the literature typically assumes that $\theta_N < \theta_{NS}$, where $\theta_N \equiv \left(w^N f^N / \psi^N\right)^{\frac{1}{\nu\alpha}}$ corresponds to the technology level where a firm will break even by producing in the North; $\theta_{NS} \equiv \left(w^N (f^S - f^N)/(\psi^S - \psi^N)\right)^{\frac{1}{\nu\alpha}}$ corresponds to the technology level where a firm will be indifferent between producing in the North and in the South.

of relatively low and relatively high technology levels, with $\theta \in [\theta_N, \theta_0] \cup [\theta_1, \infty)$, who stay behind in the North; and those of the intermediate technology levels, with $\theta \in [\theta_0, \theta_1]$, who undertake FDI.

The intuition behind this double-crossing property is straightforward. For firms of relatively low technology levels, $\theta \in [\theta_N, \theta_0]$, they face relatively low (or zero) probability of FDI failure; however, their market share is so small that they do not gain enough in variable profits to pay off the higher fixed setup cost by shifting production to the South. On the other hand, for firms of relatively high technology levels, $\theta \in [\theta_1, \infty)$, they gain relatively more from the lower wage in the South; however, their production technology levels are so advanced above the South's technology frontier that the higher likelihoods of FDI failure more than offset the wage saving. Hence, it is the firms of intermediate technology levels that may find FDI profitable.[8]

Figure 1(c) shows the scenario when the curve $\tilde{\pi}^S$ lies everywhere below the curve $\tilde{\pi}^N$, and as a result, no firms find it profitable to relocate production to the South. This occurs when the technology capacity in the South is relatively low but the degree of risk sensitivity is relatively high. Finally, when the South's technology frontier is relatively high ($T^S > \theta_{NS}$) as indicated in Figure 1(d), a double-crossing sorting pattern emerges as in Figure 1(b), except that now the lower bound coincides with the cutoff level in the risk-free case (θ_{NS}).

The discussions above suggest an interplay between the South's technology frontier and the degree of risk sensitivity in determining the profitability of FDI. This is formalized in the following proposition:

Proposition 1 *(i) For relatively low levels of technology frontiers $T^S \in [1, \theta_{NS}]$ in the South, there exists a unique risk sensitivity ceiling $z^*(T^S)$, such that positive amounts of FDI take place if and only if $z < z^*(T^S)$; for relatively high levels of technology frontiers $T^S \in (\theta_{NS}, \infty)$ in the South, FDI occurs regardless of z. (ii) Alternatively, for any given degree of risk sensitivity z, there exists a unique threshold $T^{S*}(z)$ for the technology frontier in the South, such that $T^{S*}(z)$ weakly increases in z and that positive amounts of FDI take place if and only if $T^S > T^{S*}(z)$.*

Proof of Proposition 1. The proof is provided in the appendix. ■

Proposition 1 is illustrated in Figure 2. The schedule $T^{S*}(z)$ partitions the (z, T^S) pa-

[8] This finding that FDI occurs in the middle range of the productivity spectrum shares some similarity with the product-cycle trade theory of Vernon (1966), Glass and Saggi (1998), Feenstra and Rose (2000), Antràs (2005), and Lu (2007). In essence, they argue that products/industries requiring the use of more advanced or skill-intensive technologies are not necessarily more profitable to be produced in the South, and as a result, product-cycle trade only occurs when a good's production technology becomes standardized or in industries with intermediate technology intensity.

rameter space into two areas—the upper-left area that implies a positive measure of FDI, and the lower-right area that implies a zero measure of FDI. Intuitively speaking, the higher the risk sensitivity, the higher the required minimum level of T^S for a positive measure of FDI to occur. The mapping from z to $T^{S*}(z)$ outlined by the curve CC' corresponds to the condition for a tangency between the South and the North profit functions. Relative to the tangency condition, a higher T^S or a lower z will make FDI more profitable than producing in the North for a positive measure of firms. The corner solutions occur in the scenarios where z is very low and T^S is not binding ($T^{S*}(z) = 1$), or where z is very high ($z \geq \bar{z} \equiv (1 - \psi^N/\psi^S)\nu\alpha(1-\alpha)$) and T^S has to meet the risk-free cutoff level θ_{NS} in order to ensure a positive measure of FDI.[9]

The implication that inward FDI in an industry will take place only if the South's technology frontier achieves a certain minimum threshold is consistent with the location choice of multinational firms documented by Kellenberg (2007), Fung et al. (2004), Globerman and Shapiro (2003), Wei (2000), and Cheng and Kwan (2000). Proposition 1 also implies a positive correlation between the risk sensitivity level and the required threshold of the South's technology frontier in order for FDI to take place. This implication fits well with the product-cycle (flying-geese) FDI pattern observed in empirical studies: for example, Feenstra and Rose (2000) document that more sophisticated industries often start production in the more advanced countries before moving to the less advanced countries; similarly, Makino et al. (2004) find that firms with a higher R&D intensity tend to choose the more developed countries as their FDI destination.

2.3 Extensive and Intensive Margins of FDI

In what follows, we focus on the cases where the technology capacity of the South meets the minimum threshold and FDI does take place. These are scenarios illustrated in Figures 1(b) and 1(d). Let $\Theta^S \equiv [\theta_0, \theta_1]$ denote the technology content of inward FDI. The upper and lower bounds of the technology content Θ^S can be defined formally as follows:

$$\pi^N(\theta_1) = \pi^S(\theta_1; T^S, z), \qquad \text{with } \pi^N_\theta(\theta_1) > \pi^S_\theta(\theta_1), \tag{11}$$

$$\pi^N(\theta_0) = \pi^S(\theta_0; T^S, z), \qquad \text{with } \pi^N_\theta(\theta_0) < \pi^S_\theta(\theta_0), \tag{12}$$

[9] The details are shown in the appendix. In essence, $\bar{z}$ is the risk sensitivity level such that the South's profit function has the same slope as the North's profit function at $\theta = T^S$. Since the slope of the South's profit function decreases with θ for $\theta > T^S$, the South's profit function will have a gentler slope than the North's profit function for all $\theta > T^S$ with $z \geq \bar{z}$. Thus, in order for FDI to occur, T^S cannot be lower than θ_{NS}.

where $\pi_\theta^l \equiv \partial\pi^l/\partial\theta$ for $l \in \{N, S\}$, and the signs follow from the fact that the curve $\tilde{\pi}^S$ crosses the curve $\tilde{\pi}^N$ from below at θ_0 and from above at θ_1 as seen in Figures 1(b) and 1(d).

Lemma 2 *The upper bound θ_1 of the technology content Θ^S of inward FDI increases, while the lower bound θ_0 of the technology content Θ^S of inward FDI decreases weakly, with the South's technology frontier T^S:*

$$\frac{\partial\theta_1}{\partial T^S} = \left[\pi_\theta^N(\theta_1) - \pi_\theta^S(\theta_1)\right]^{-1} \pi_{T^S}^S(\theta_1) > 0, \tag{13}$$

$$\frac{\partial\theta_0}{\partial T^S} \begin{cases} = \left[\pi_\theta^N(\theta_0) - \pi_\theta^S(\theta_0)\right]^{-1} \pi_{T^S}^S(\theta_0) < 0 & \text{if } 1 \leq T^S < \theta_{NS} \\ = 0, & \text{if } \theta_{NS} \leq T^S \end{cases} \tag{14}$$

where $\pi_{T^S}^S \equiv \partial\pi^S/\partial T^S$.

Proof of Lemma 2. Note that $\pi_\theta^N(\theta_1) - \pi_\theta^S(\theta_1) > 0$, $\pi_\theta^N(\theta_0) - \pi_\theta^S(\theta_0) < 0$. Also note that $\pi_{T^S}^S > 0$ for $\theta > T^S$ and $\pi_{T^S}^S = 0$ for $\theta \leq T^S$. The results therefore follow. ■

Let $X^S \equiv \chi(\theta_0, \theta_1, T^S) = \int_{\theta_0}^{\theta_1} x^S(\theta) dG(\theta)$ denote the aggregate production of the multinationals in the South in a given industry. Assume a Pareto distribution with shape k for the cumulative distribution function $G(\theta)$ such that $G(\theta) = 1 - (1/\theta)^k$ for $\theta \geq 1$ with $k > \nu$.[10] Given (8), it follows that

$$\chi(\theta_0, \theta_1, T^S) = \begin{cases} \frac{\Omega^S k}{a} \left(T^S\right)^{\frac{z}{1-\alpha}} \left[(\theta_0)^{-a} - (\theta_1)^{-a}\right], & \text{if } 1 \leq T^S < \theta_{NS}, \\ \\ \frac{\Omega^S k}{(k-\nu)} \left[(\theta_0)^{-(k-\nu)} - \left(T^S\right)^{-(k-\nu)}\right] & \\ \qquad + \frac{\Omega^S k}{a} \left(T^S\right)^{\frac{z}{1-\alpha}} \left[\left(T^S\right)^{-a} - (\theta_1)^{-a}\right], & \text{if } \theta_{NS} \leq T^S, \end{cases} \tag{15}$$

where $a \equiv \frac{z}{1-\alpha} + k - \nu > 0$ holds under the parameter restriction $k > \nu$, and hence the aggregate output in all scenarios is well defined.

Proposition 3 *The aggregate production X^S of the multinationals in a given industry increases with the South's technology frontier T^S:*

$$\frac{dX^S}{dT^S} = \left(\frac{\partial\chi}{\partial\theta_0}\frac{\partial\theta_0}{\partial T^S} + \frac{\partial\chi}{\partial\theta_1}\frac{\partial\theta_1}{\partial T^S} + \frac{\partial\chi}{\partial T^S}\right) \equiv \Lambda > 0. \tag{16}$$

Proof of Proposition 3. It is straightforward to verify that $\frac{\partial\chi}{\partial\theta_0} < 0$, $\frac{\partial\chi}{\partial\theta_1} > 0$, and $\frac{\partial\chi}{\partial T^S} > 0$. The result therefore follows by Lemma 2. ■

[10]The restriction on the shape parameter k ensures that the aggregate output of all firms is finite regardless of their production location even in the risk-free case.

Note that the aggregate production X^S of the multinationals increases with the South's technology frontier T^S at the rate Λ. This amount includes the increase in the production of the existing multinationals, $\frac{\partial \chi}{\partial T^S}$ (an intensive margin), because of the improved risk condition, as well as the increase in production due to new FDI entrants, $\frac{\partial \chi}{\partial \theta_0}\frac{\partial \theta_0}{\partial T^S} + \frac{\partial \chi}{\partial \theta_1}\frac{\partial \theta_1}{\partial T^S}$ (an extensive margin). Both margins work in the same direction to raise the aggregate output of the multinationals, with an improved technology capacity in the South.

2.4 FDI Spillover and the Dynamics of FDI

We model the catch-up process of the South to improve its technology frontier based on the learning function of Matsuyama (2002).[11] Specifically, we assume that the South improves its technology frontier in the following reduced form:

$$T_t^S \equiv T_0^S + \Gamma(Q_t^S), \tag{17}$$

where Q_t^S denotes the base of technology spillover. The function $\Gamma()$ is the mapping from Q_t^S to the improvement in the technology frontier, with the properties that $\Gamma(0) = 0$, $\Gamma_Q \equiv d\Gamma/dQ^S > 0$, and $\lim_{Q^S \to \infty} \Gamma(Q^S) \to \infty$. We define $Q_t^S \equiv \sum_{\tau=0}^{t} \left[1/(1+\delta_D)\right]^{t-\tau} X_\tau^S$. In other words, the aggregate discounted production activities of the multinationals in the South constitute the base of technology spillover. The South improves its technology frontier as its exposure to multinational production activities increases. The base of technology spillover depreciates (at a rate $\delta_D > 0$); thus, the more recent production activities of the multinationals play a more important role.

Such FDI spillover effects may occur through several possible channels: i) through labor turnover by workers who have worked for multinationals, ii) through backward linkages that improve the quality of the upstream suppliers for multinationals, and iii) through the feedback of incumbent multinationals to the local industries/governments who respond by investing in the types of infrastructure and human capital sought by multinationals. The improved technology capacity of the South helps lower the FDI risk in the coming period and benefits both existing and potential multinationals.[12]

We formalize the catch-up dynamic process below. In any given period t, firms face the state variable T_{t-1}^S and independently make their FDI decisions. Their decisions then

[11] Matsuyama (2002) aims to formalize the rise of mass consumption in a closed economy; he introduces the learning function to model the process of an industry to upgrade its productivity.

[12] Empirical support for the above formulation is found in Javorcik (2004) and Aitken and Harrison (1999), for example. The former study shows robust evidence of positive FDI spillover through backward linkages based on firm-level data from Lithuania. The latter study suggests positive spillover effects among *foreign affiliates* in the same industry, based on firm-level panel data from Venezuela.

collectively determine $(\theta_{0,t}, \theta_{1,t}, X_t^S)$. Specifically, the technology content of FDI, $\Theta_t^S = [\theta_{0,t}, \theta_{1,t}]$, is determined by (11) and (12) with $T^S = T_{t-1}^S$. The aggregate production of the multinationals is then determined according to (15) with $X_t^S = \chi(\theta_{0,t}, \theta_{1,t}, T_{t-1}^S)$, which in turn pins down the new level of technology frontier in the South T_t^S by (17).

To illustrate, starting from period $t = 1$ with a zero amount of prior FDI, it follows that $Q_0^S = 0$. Suppose that the South's initial technology frontier is at $T_0^S \in [1, \theta_{NS}]$. The first wave of FDI, Θ_1^S, takes place if the risk sensitivity z is smaller than the ceiling $z^*(T_0^S)$. The stock of multinational production activities starts to accumulate: $Q_1^S = X_1^S = \chi(\theta_{0,1}, \theta_{1,1}, T_0^S)$. Through FDI spillover, the South moves onto a higher level of technology frontier T_1^S. In period $t = 2$, as $T_1^S > T_0^S$, the expected profit of producing in the South increases for all firms with $\theta \in (T_0^S, \infty)$. This triggers a second wave of FDI entries made by a wider range of firms: $\Theta_2^S \supset \Theta_1^S$. Figure 3 illustrates this dynamic process of FDI inflows. In the case where the technology frontier is high to begin with such that $T_0^S > \theta_{NS}$, the dynamic process is similar except that the expansion of the technology content will take place only at the upper bound right from the beginning.

The above process implies a two-way causality between FDI inflows and the South's technology capacity. The amount of FDI inflows and the South's technology capacity reinforce each other: FDI inflows improve the South's technology capacity through the spillover effect; the higher technology capacity of the South in turn attracts further FDI inflows due to an improved risk condition. There thus arises a self-reinforcing agglomeration process.

2.5 Steady State

We characterize the steady state of the above dynamic process. It is straightforward to verify that at the steady state, $Q^S = \delta X^S$ where $\delta \equiv (1 + 1/\delta_D)$. Substitute δX^S for Q^S in (17) and the solutions implied by (11) and (12) into (15). The steady state conditions can be summarized by the following two simultaneous equations:

$$T^S = T_0^S + \Gamma\left(\delta X^S\right), \tag{18}$$

$$X^S = \chi(\theta_0(T^S), \theta_1(T^S), T^S). \tag{19}$$

Proposition 4 *Suppose an initial wave of FDI takes place. The subsequent dynamic process as described in Section 2.4 converges to a stable steady state.*

To show the above proposition, we start with (19). Let $\underline{X}^S$ and $\bar{X}^S$ denote the aggregate production levels of the multinationals when $T^S = T_0^S$ and when $T^S \to \infty$, respectively. Note that $\underline{X}^S \equiv \chi(\theta_0(T_0^S), \theta_1(T_0^S), T_0^S) > 0$ since by setup we start with a positive measure of FDI. Note as well that $\bar{X}^S \equiv \frac{\Omega^S k}{(k-\nu)} (\theta_{NS})^{-(k-\nu)}$, which is the largest amount of production that can ever take place by multinationals. This occurs when the risk factor is not binding ($T^S \to \infty$) and the output is equivalent to that in the risk-free scenario. Finally, recall that X^S increases in T^S at a rate $\Lambda > 0$ by Proposition 3. Together, these imply that the aggregate production X^S as a function of T^S has a positive lower bound $\underline{X}^S$ at $T^S = T_0^S$. It increases in T^S and approaches $\bar{X}^S$ from below as T^S tends to infinity. This relationship is illustrated in Figure 4(a) by the PP schedule, where PP stands for production.

Next, we characterize (18). Note that the level of technology frontier in the South T^S would stay at its initial level T_0^S if no multinational production took place ($X^S = 0$); it increases monotonically in X^S at a rate $\delta\Gamma_Q$, and reaches the upper bound $\bar{T}^S \equiv T_0^S + \Gamma(\delta \bar{X}^S)$ in the most optimistic scenario if all firms above the cutoff level θ_{NS} were to undertake FDI as in the risk-free case. This relationship is illustrated in Figure 4(a) by the LL schedule, where LL stands for learning.

As the LL curve starts below the PP curve and ends up above it, the two curves must cross at least once. In other words, there exists at least a steady-state equilibrium. If there is only one steady state as illustrated by point I in Figure 4(a), the steady state is also stable. In general, there could be multiple steady states, as illustrated in Figure 4(b). The set of steady states is a lattice. If we relabel the horizontal axis as T_{t-1}^S and the vertical axis as X_t^S, we could readily use Figure 4(b) to illustrate the dynamic process of FDI. Starting with the initial technology frontier T_0^S, the South's production for multinationals and the South's technology frontier grow (following the arrows) until they converge to the least element of the lattice. That is, if there are multiple steady states, the South is trapped into the lowest steady state with a relatively low level of inward FDI and a relatively low level of technology frontier.[13]

[13] The above prediction differs from Findlay (1978) on the relationship between the gap of the North-South development levels and the dynamics of FDI inflows. Findlay (1978) hypothesizes that the South catches up faster, the more backward its development level is relative to the North and the more exposed it is to FDI; moreover, the further behind the South's development level is, the more unexploited opportunity there exists and the more FDI inflows it will attract. Although we support the argument that inward FDI is an important channel through which less developed countries acquire the advanced technology developed abroad, by explicitly taking into account the FDI risk, we have arrived at contrasting predictions. First, our model implies that the development gap between the South and the North has a negative effect on the amount of FDI inflows, as a larger gap implies higher FDI risk. Second, similar to Parente and Prescott (1994) and Stokey (2009), our model differentiates between the growth *potential* indicated by the existing development gap and the *realized* growth that depends positively on the South's technology capacity. As a consequence of the reinforcing dynamic process, the initial technology backwardness of the South in our model has a negative and magnified long-run effect on the South's development. This helps account for why the relative backward countries (such as Kenya, Uganda and Mali) often find it difficult to attract FDI, and as a result, are trapped at a relatively low level of development.

Lemma 5 *At a stable steady state, the following property holds,*

$$\delta\Gamma_Q\Lambda < 1. \tag{20}$$

Proof of Lemma 5. At a stable steady state, the PP curve crosses the LL curve from above. This is equivalent to stating that $\frac{d\chi}{dT^S} < \left[\frac{d\Gamma}{dX^S}\right]^{-1}$ or $\frac{d\Gamma}{dX^S}\frac{d\chi}{dT^S} < 1$. Note that $\frac{d\Gamma}{dX^S} = \delta\Gamma_Q$ and that $\frac{d\chi}{dT^S} = \Lambda$. The result in (20) therefore follows. ■

Note that starting from a steady state, a positive disturbance to the technology frontier in the South T^S will lead to an increase in X^S by a rate Λ. For an increase in X^S, it in turn increases the technology frontier by a rate $\delta\Gamma_Q$. Lemma 5 says that at a stable steady state, the multiplier (as measured by $\delta\Gamma_Q\Lambda$) of a shock to the technology frontier must be smaller than one, so that the economy will gyrate back toward its initial state following a small disturbance to the endogenous variables. We focus on stable steady states below.

2.6 Comparative Static Analyses and Policy Implications

Let q denote one of the exogenous parameters $(T_0^S, \delta_D, w^S, f^S, z)$.[14] First, take the total differentiation of (19) with respect to X^S, T^S, and q; we have:

$$\frac{dX^S}{dq} = \Xi + \Lambda\frac{dT^S}{dq}, \tag{21}$$

where $\Xi \equiv \left(\frac{\partial\chi}{\partial\theta_0}\frac{\partial\theta_0}{\partial q} + \frac{\partial\chi}{\partial\theta_1}\frac{\partial\theta_1}{\partial q} + \frac{\partial\chi}{\partial q}\right)$ has the similar interpretation as Λ: the first two terms indicate the extensive-margin effect and the third term the intensive-margin effect of q on the aggregate production X^S. The change in the parameter q also affects X^S indirectly through its effect on the technology frontier, which in turn affects X^S by a rate Λ. Next, take the total differentiation of (18) with respect to X^S, T^S, and q, and substitute the expression in (21) for $\frac{dX^S}{dq}$; we get:

$$\frac{dT^S}{dq} = \delta\Sigma^{-1}\Gamma_Q\Xi + \Sigma^{-1}\Gamma_Q X^S\frac{\partial\delta}{\partial q} + \Sigma^{-1}\frac{\partial T_0^S}{\partial q}, \tag{22}$$

where $\Sigma \equiv 1-\delta\Gamma_Q\Lambda$. To see (22), note that a change in q could affect the technology frontier through three alternative channels. First, when $q = \{w^S, f^S, z\}$, a change in q has a direct

[14] The effects of the Northern wage w^N, the demand elasticity α, and the productivity dispersion measure k do not have definite signs. In the current setup, w^N affects not only the variable profits of operating in the North but also the fixed setup costs in both locations, which leads to the ambiguity. The effect of f^N is obviously the opposite of f^S shown below. Detailed analyses for these parameters are available upon request from the authors.

effect Ξ on the aggregate production X^S, which in turn affects the technology frontier by a rate $\delta\Gamma_Q$, and through the positive reinforcing feature of the dynamic process, generates a multiple Σ^{-1} of the initial effect on the technology frontier. Second, when $q = \delta_D$, the parameter has a direct effect on the base of spillover Q^S through δ. It then affects the technology frontier by a rate Γ_Q and generates another layer of multiplier effect on the technology frontier. Finally, when $q = T_0^S$, the initial technology frontier T_0^S affects the steady-state technology frontier directly through (18), which is similarly amplified by the reinforcing process.

We could also characterize the changes in the steady-state technology content of inward FDI, by taking the total differentiation of (11) and (12) to obtain:

$$\frac{d\theta_1}{dq} = \frac{\partial\theta_1}{\partial q} + \frac{\partial\theta_1}{\partial T^S}\frac{dT^S}{dq}, \tag{23}$$

$$\frac{d\theta_0}{dq} = \begin{cases} \frac{\partial\theta_0}{\partial q} + \frac{\partial\theta_0}{\partial T^S}\frac{dT^S}{dq}, & \text{if } 1 \leq T^S < \theta_{NS}, \\ \frac{\partial\theta_0}{\partial q}, & \text{if } \theta_{NS} \leq T^S. \end{cases} \tag{24}$$

The upper and lower bounds of the technology content can be directly affected by the exogenous parameter q if it appears in the profit functions; in addition, they will be indirectly affected through the change in the equilibrium technology frontier following a change in q. In the case that the lower bound θ_0 has already hit its lower limit θ_{NS}, the indirect effect will cease to operate, as is implied by Lemma 2.

Proposition 6 *The effects of general FDI promoting policies:*

$$(i) \quad \frac{dT^S}{dT_0^S} > 0, \frac{dX^S}{dT_0^S} > 0, \frac{d\theta_1}{dT_0^S} > 0, \frac{d\theta_0}{dT_0^S} \leq 0 \textit{ with equality when } \theta_{NS} \leq T^S;$$

$$(ii) \quad \frac{dT^S}{d\delta_D} < 0, \frac{dX^S}{d\delta_D} < 0, \frac{d\theta_1}{d\delta_D} < 0, \frac{d\theta_0}{d\delta_D} \geq 0 \textit{ with equality when } \theta_{NS} \leq T^S;$$

$$(iii) \quad \frac{dT^S}{dw^S} < 0, \frac{dX^S}{dw^S} < 0, \frac{d\theta_1}{dw^S} < 0, \frac{d\theta_0}{dw^S} > 0;$$

$$(iv) \quad \frac{dT^S}{df^S} < 0, \frac{dX^S}{df^S} < 0, \frac{d\theta_1}{df^S} < 0, \frac{d\theta_0}{df^S} > 0.$$

Proof of Proposition 6. Proof is provided in the appendix. ■

These results are quite intuitive. A policy raising the initial technology frontier in the South will attract a wider range of firms from the North, and hence a larger initial mass of multinational production. The larger initial base of spillover generates a bigger step forward by the South on the technology frontier and a steeper decline in the perceived risk of FDI failure. The effect of the initial difference is persistent and amplified by the self-reinforcing dynamics. This phenomenon is illustrated in Figure 5(a).

Second, a lower δ_D enhances the base for the spillover effect and the extent to which the South can catch up for a given amount of FDI inflows. This in practice may correspond to education policies that aim to improve the general human capital of the work force. The effect is illustrated in Figure 5(b). In the same figure, we also see that in the presence of multiple steady states, a deliberate FDI policy by the South could actually pull the South out of its development trap toward a higher steady state.

Third, an FDI policy that lowers the marginal labor cost, w^S, or fixed setup cost, f^S, in the South will increase the aggregate production of multinationals by encouraging new FDI entrants at the extensive margin. A reduction in w^S, in addition, also stimulates production at the intensive margin by all existing multinationals. The initial effects are then magnified by the agglomeration process. Figure 5(c) illustrates the effect of a decrease in w^S or f^S.

Proposition 7 *Risk-sensitivity and industry-targeted FDI policies:*

$$(i) \quad \frac{dT^S}{dz} < 0, \frac{dX^S}{dz} < 0, \frac{d\theta_1}{dz} < 0, \frac{d\theta_0}{dz} \geq 0 \text{ with equality when } \theta_{NS} \leq T^S.$$

Proof of Proposition 7. Proof is provided in the appendix. ■

Although not within the South's control to a large extent, the industry-specific risk sensitivity z has important effects on the South's industry-specific development. A lower degree of risk sensitivity z to the technology gap, by improving the success rate of FDI, raises both the extensive and intensive margins of FDI. This positive effect is further reinforced by the FDI agglomeration process. A lower z has very similar qualitative effects as a lower w^S and can be similarly illustrated by Figure 5(c).

This proposition implies that the extent to which the South can attract FDI (as measured by the extensive and intensive margins) and catch up (as measured by T^S) will vary across industries. This suggests that an FDI-promoting policy uniformly applied to all industries may be inefficient as it would be too generous for industries with a low degree of risk sensitivity while possibly not sufficient for highly risk-sensitive industries. Thus, a developing country may want to adopt industry-targeted FDI policies according to its development level, as aiming at high-tech industries may be very costly and unrealistic when its technology frontier lags far behind the North's.

3. EMPIRICAL EVIDENCE

Our theory leads to two major predictions: 1) among the firms that exist in an industry in an advanced Northern country, it is the firms with intermediate productivity levels (or intermediate production technology levels) that make an FDI entry in a relatively backward Southern country at any given point in time; 2) as the risk level decreases with a greater presence of multinationals in the South, the spectrum of the productivity levels of firms that undertake FDI expands over time. The first prediction follows from our static model and the second from our dynamic extension of the model.

3.1 Estimation Framework and Hypothesis

We propose an estimation framework to test our theoretical predictions formally. Let y_{it} be the FDI entry indicator of firm i in time period t, which equals unity if firm i makes an FDI entry into China during time period t and zero otherwise. The FDI entry decision depends on an underlying latent variable y_{it}^* of the form:

$$\begin{aligned} y_{it}^* &= \beta_0 + \beta_1 ROA_{i,t-1} + \beta_2 ROA_{i,t-1}^2 + \beta_3 ROA_{i,t-1} \times (t-1) + \sum_{j=1}^{k} \alpha_j d_{ij} + v_i + \epsilon_{it}, \\ y_{it} &= 1[y_{it}^* > 0], \end{aligned} \tag{25}$$

where $i = 1, 2, \ldots, n$; $t = 1, 2, \ldots, T$ (possibly missing in some periods for some i); $ROA_{i,t-1}$ is a measure of firm i's productivity in the previous period before the firm makes the FDI entry decision; d_{ij} for $j = 1, 2, \ldots, k$ are sector dummies, which equal one if firm i belongs to sector j and zero otherwise; v_i summarizes all the omitted variables or unobserved firm-specific effects that are time invariant (beyond the mean captured by β_0); and ϵ_{it} represents residual idiosyncratic errors.

The inclusion of sector dummies helps account for the possibility that the FDI propensity may differ across industries in a systematic manner. For example, in some sector, the degree of risk sensitivity, z, or the fixed setup cost of FDI, f^S, may be inherently higher than others. This will discourage FDI by firms from the sector in general. Alternatively, a lower industry-specific technology capacity in the South, T_0^S, may have similar negative effects on FDI propensity.

The quadratic term and the interaction term included in the estimation equation (25) represent a parsimonious specification to capture the nonlinearity (between FDI propensity and firm productivity) and the spillover effect of FDI in our model, respectively. We could recast the two major predictions of our theory in stochastic terms as: 1') in cross-section (at any given point in time), the probability of FDI is an inverted-U function of firm productivity; 2') the probability of FDI increases with time, but more for the higher-productivity firms. The last point can be seen by referring to equation (10), where if T^S increases over time, the profit of FDI will increase, but the marginal increase is bigger for firms with a higher θ. The above statements imply two joint testable hypotheses of our theory based on the estimation equation (25): (i) $\beta_2 < 0$, i.e., the most and least productive firms are less likely to undertake FDI, and (ii) $\beta_3 > 0$, i.e., there is a positive dynamic effect and it is intensified by the level of firm productivity. In contrast, the conventional FDI models without risk predict that $\beta_1 > 0$ and $\beta_2 = 0$; if dynamics were built into these models and similar spillover effects were allowed, the conventional models would also imply that $\beta_3 > 0$. In summary, the testable hypotheses corresponding to the current and the conventional theory are:

H1. Current FDI model with risk:	no restriction on β_1,	$\beta_2 < 0$,	$\beta_3 > 0$
H2. Conventional FDI model without risk:	$\beta_1 > 0$,	$\beta_2 = 0$,	$\beta_3 > 0$

3.2 Data

The first data set we compile consists of annual observations on US manufacturing firms' FDI entries into China during 1980–2010. The beginning time period is chosen based on the fact that China opened its doors to FDI in 1979. The US firms' financial information (e.g., assets and gross profits) is collected from the Compustat database, while the information on FDI entries is compiled from the *China Business Review* (CBR). The details of the data set are explained in the appendix. We use the annual return on assets (ROA, defined here as the ratio of annual gross profits to total assets at the end of the period) as a proxy for a firm's productivity level.[15] Thus, the lagged productivity level in (25) is measured by the lagged annual ROA of firm i ending in year $t-1$.

A visual impression of FDI propensity and its association with ROA is presented in Figure 6. A salient pattern is evident from the diagram: The observed FDI entries are made by firms of intermediate productivity levels (and not by the most or least productive firms). This is consistent with our static model's prediction. It is also clear from the diagram that FDI entries into China are rare among US firms. In detail, there are a total of 7,867 firms/96,400 observations in the sample, among which there are 352 firms/810 observations

[15] The accounting definition of gross profits corresponds closely to the definition of variable profits in our model. In our theory, a firm's variable profit is positively correlated with its productivity (technology) level θ. In the model, each firm incurs the same level of fixed costs; in practice, this is not the case. Thus, we normalize the empirical measure of gross profits by total assets to remove possible scale effects.

with FDI entries (that amounts to 4.5% of all firms and 0.8% of all observations). Most (7,515) of the firms do not make any FDI entry into China.[16]

The second data set we compile consists of quarterly observations on Taiwanese manufacturing firms' FDI entries into China during 1991Q1–2009Q4. Following the civil wars in the 1940s, Taiwan and mainland China remained in a hostile relationship. It was only in 1991 that the Taiwanese government lifted its historical ban on westward FDI into mainland China. This policy change serves as a natural experiment and starting point for examining Taiwanese firms' FDI entry decisions. The data set includes all Taiwanese firms in the manufacturing sectors listed on the Taiwan Stock Exchange (TSE) or the over-the-counter (OTC) market by the end of 2009. The information on FDI entries is compiled from the *Directory of Companies Investing in China* published by the Investment Commission, Taiwan Ministry of Economic Affairs (MOEA). The financial information on firms is retrieved from the Taiwan Economic Journal (TEJ) database. More details on the data set are provided in the appendix. Similarly, we use the annual ROA (spanning four quarters) as the proxy for a firm's productivity level. Specifically, for the Taiwanese data set with quarterly observations, the lagged productivity level in (25) is measured by the lagged annual ROA of firm i from the one year period ending in quarter $t-1$.[17] We opt to use the annual ROA, instead of the quarterly ROA, even in the case of quarterly observations, because of the concern that the quarterly ROA may be heavily influenced by seasonality in sales and hence a noisy measure of firm productivity.

Figure 7 presents a similar visual impression of FDI propensity and its association with ROA for the case of Taiwan. In contrast with the case of the US, by the end of 2009, most Taiwanese firms have made FDI entries into China. Of the 1,097 firms/42,357 observations in the sample, 854 firms/2,769 observations have FDI entries (that is 77.8% of all firms and 6.5% of all observations). Given the detailed counts of observations and FDI entries in the footnotes to Figures 6 and 7, we can also verify that the likelihood of FDI entries by Taiwanese firms into China is much higher than US firms right from the initial periods (say, 1982 for the US and 1992 for Taiwan). Notwithstanding the higher likelihood of making FDI entries into China, the association between FDI propensity and firm productivity has the same pattern as seen in the case of the US: firms making the FDI entries tend to be of intermediate productivity levels (and not the most or least productive firms). The higher likelihood of FDI entries in the case of Taiwan is reflected in a wider productivity spectrum of firms making FDI entries (relative to its population distribution). We can also make out

[16]The total sample size reported in Figure 6 is smaller than suggested above, as some observations have missing ROA information.

[17]For example, if the current quarter is 2001Q3, then $ROA_{i,t-1}$ is calculated from the total gross profits of 2000Q3, 2000Q4, 2001Q1, and 2001Q2 divided by the stock of total assets at the end of 2001Q2.

with bare eyes a gradual widening of the intermediate productivity spectrum of FDI firms over time. These patterns are consistent with the static and dynamic implications of our theory.[18]

In addition to providing extra empirical verification, the case of Taiwan presents a potentially interesting contrast with the US as a source of FDI. First, Taiwan is in many respects 'closer' to mainland China—in terms of geographical distance, language similarity, cultural background, and ethnic groups. In our theory, such a closer economic and social distance may imply an overall lower level of perceived FDI risk by firms in the static model and a greater speed of spillover in the dynamic model. Second, by 1991 when the Taiwanese firms were allowed to go west, it is likely that the overall technology frontier in mainland China had improved relative to its original state in 1980. These two factors suggest that relative to the US, a greater proportion of firms from Taiwan are likely to undertake FDI in the initial periods when FDI becomes possible; and firms that eventually have made FDI entries are likely to be the majority rather than the exception in Taiwan (as compared to the US). As we saw, these contrasts were observed in the two data sets.

We define sectors at the 3-digit NAICS level for the US data set and at the 2-digit TEJ sector classification for the Taiwanese data set. The list of sectors and the number of firms in each sector are given in the appendix.[19] We focus on the manufacturing industries here, because a disproportionate number of FDI entries into China are made by firms from these sectors (810 out of 1,198 FDI entries in the US data set with valid NAICS number; 2,769 out of 3,116 FDI entries in the Taiwanese data set). The manufacturing sectors' production process also fits more closely with our model than the other industries such as construction and finance.

3.3 Results

Given the specification (25), we perform five sets of estimation for each data set, based on three types of estimators (pooled, fixed-effects, and random-effects) and two types of probability distributions (logit and probit) for ϵ_{it}. Table 1 shows the estimation results under the assumption that the firm-specific effects v_i are independent of the regressors for the pooled and random-effects estimators, and Table 2 shows the results when we relax this

[18] We set the frequency of study at one year for the US data set and one quarter for the Taiwanese data set because of the much lower propensity of FDI entries into China by the US firms. There are very few observations with FDI entries (relative to the large number of firms) in any given quarter in the US data set.

[19] The TEJ sector classification at the 3 or 4-digit level is only available for some larger industries such as chemical/biotech and electronics industries. The level of disaggregation is chosen with a view to maintain a reasonable number of firms/observations within each sector. Given the larger number of firms in the US economy, we can afford a more disaggregated list of sectors (22 versus 13 sectors in the case of Taiwan).

assumption. The properties of these estimators in linear panels are well known. We highlight some issues peculiar to the binary (nonlinear) panels as is in our case before analyzing the estimation results.

First, we discuss the properties of the pooled estimator, which pools all observations and does not explicitly model the firm-specific effect v_i. Wooldridge (2002, Chapter 15.7.1) shows that the pooled estimator in essence estimates the average partial effect of the regressors (which is implicitly the average of the partial effects across all v_i in the population); in contrast, the panel estimates correspond to the partial effect when evaluated at $v_i = 0$. In linear panel models, these two effects are equivalent; in nonlinear panel models, however, they are in general different. For example, in probit models, one can verify that the pooled estimator is estimating the population parameter $\beta_a \equiv \beta/\sqrt{1+\sigma_v^2}$, instead of β, what the panel estimator estimates (Wooldridge, 2002, pp. 485–6). Both effects are of interest as argued by Wooldridge (2002, Chapters 15.7.1, 15.8.1–3); thus, we present information for both. Following the convention, the robust variance estimator is used (and reported in the tables) for the pooled estimator to account for possible correlations across observations of the same firm (due to the presence of v_i). Of course, if v_i has a degenerate distribution at zero (and thus $\sigma_v = 0$), the pooled estimator is equivalent to the panel estimator. This can be verified by a significance test of $\rho \equiv \frac{\sigma_v^2}{\sigma_v^2+\sigma_\epsilon^2}$ as reported in the tables.

Next, we discuss the fixed-effects (FE) and random-effects (RE) estimators. In linear panel models, the FE estimator is often preferred to the RE (and pooled) estimator on the ground that the former allows possible correlation between the regressors and the individual-specific effect v_i. The incidental parameters problem associated with the FE estimation when $n \to \infty$ is avoided by some sort of differencing that eliminates the individual-specific effect from the estimation. In binary panel models, however, eliminating v_i from the estimation is only possible in the logit model, and not in the probit model.[20] In addition, the FE estimator's drawback of not being able to identify the coefficients on time invariant regressors (e.g., the industry dummies in (25)) remains to be the case in the binary panel model. Thus, to generalize the RE (and pooled) estimator and retain the advantages associated with it, we relax the assumption that the firm-specific effects v_i are independent of the regressors following Mundlak (1978) in Table 2. This is to postulate that v_i may depend on the regressors such that: $v_i = \bar{\mathbf{x}}_i'\gamma + w_i$, where $\bar{\mathbf{x}}_i$ is the time averages of the (time-varying) regressors of firm i and w_i is the residual independent of $\bar{\mathbf{x}}_i$. Thus, estimations proceed as before but with the auxiliary regressors $\bar{\mathbf{x}}_i$ included in (25). This extension does not affect

[20] See, for example, Wooldridge (2002, pp. 491–2), Baltagi (2008, pp. 237–9), and Hsiao (2003, Chapter 7.3) for further discussions. In essence, in the FE logit model, a sufficient statistic exists that allows v_i to be conditioned out of the likelihood function, and permits the slope parameters β's to be consistently estimated.

the FE estimates, as the auxiliary regressors $\bar{\mathbf{x}}_i$ will be conditioned out of the likelihood function (and their coefficients not identifiable) as with the other time-invariant regressors. A test of $\gamma = \mathbf{0}$ in the RE (or pooled) model performs a similar function as the Hausman test.[21] A significance finding of γ rejects the null hypothesis that the firm-specific effects are uncorrelated with the regressors, and supports the generalized RE (and pooled) model.

First, let us look at the results for the US data set in Table 1. The signs of the coefficients based on the five sets of estimation results are consistent with H1 ($\hat{\beta}_2 < 0$ and $\hat{\beta}_3 > 0$), although not all estimates are significant. Specifically, $\hat{\beta}_3$ based on the pooled estimator and $\hat{\beta}_2$ based on the FE estimator are insignificant, and the sign of $\hat{\beta}_1$ is not robust.[22] The difference in findings between the FE and RE (or pooled) models suggests that the assumption of independence between v_i and the regressors may be violated. In Table 2, we relax this assumption and include the auxiliary regressors $\bar{\mathbf{x}}_i = \left(\overline{ROA}_i, \overline{ROA^2}_i, \overline{ROA \times (t-1)}_i\right)$.[23] The significance finding of the coefficients on $\bar{\mathbf{x}}_i$ suggests that the independence assumption for the pooled and RE models is indeed problematic and the finding presented in Table 2 more reliable.

As shown in Table 2, the results are now aligned across estimators. The signs and significance of the pooled and RE estimates are now consistent with the FE estimates with $\hat{\beta}_1 < 0$, $\hat{\beta}_3 > 0$ (both are significant), and $\hat{\beta}_2 < 0$ (insignificant). In words, for the US firms, the likelihood of making an FDI entry into China tends to increase over time, while the probability of FDI entry does not reveal a robust inverted-U relationship with firm productivity and instead tends to decrease with firm productivity.

One plausible explanation for the above findings could be that China's technology capacity is too low from the US firm's viewpoint and the degree of risk sensitivity perceived by the US firms is very high—a special scenario in our theory as characterized by Figure 1(c). Specifically, the South's profit function will have a gentler slope than the North's profit function for all $\theta > T^S$ if $z \geq \bar{z}$ (see footnote 9). Thus, if the South's technology frontier is also low such that $T^S \leq \theta_N$, it follows that $\pi^S - \pi^N$ decreases with θ for all firms present in the market ($\theta > \theta_N$). In other words, for all firms observed, the more productive firms are less likely to undertake FDI.[24] Although in theory the relationship is still concave (between

[21]See, for example, Wooldridge (2002, Chapter 10.7.3, pp. 487–8) and Cameron and Trivedi (2005, Chapters 21.4.3–4, pp. 786).

[22]The absolute magnitudes of the estimates in the logit model are naturally bigger than the probit model, as the former model's error term ϵ_{it} has a variance of $\pi^2/3$ and the latter a variance of one by normalization.

[23]Specifically, $\overline{ROA}_i \equiv (1/T_i)\sum_t ROA_{i,t-1}$, $\overline{ROA^2}_i \equiv (1/T_i)\sum_t ROA^2_{i,t-1}$, and $\overline{ROA \times (t-1)}_i \equiv (1/T_i)\sum_t (ROA_{i,t-1} \times (t-1))$, where T_i is the number of observations available for firm i.

[24]Strictly speaking, in this case with the FDI's profit function lies strictly below the North's profit function, no firms will undertake FDI in the first period, and as a result, the dynamic spillover effect will not take place ($\beta_3 = 0$). However, in a stochastic model such as (25), some firms may still undertake FDI given extreme positive idiosyncratic shocks and set off the spillover process. Alternatively, in the real world with

$\pi^S - \pi^N$ and θ), the curvature may be difficult to estimate if the variation in ROA is not big enough.

A closer look into the data finds our conjecture reasonable. First, as we documented earlier, most of the US firms did not make any FDI entry into China during the sampling period; thus, many observations (77,122 out of 84,129 observations) have to be dropped from the FE estimation that relies on within-firm variation. Second, the range and standard deviation of ROA reduce significantly from $[-1513, 25.73]$ and 6.28, respectively, for the whole sample to $[-2.22, 2.54]$ and 0.24 for the sub-sample of firms having made some FDI entries into China. This reduction in the range of ROA reflects trimming in both within-firm and cross-sectional variations; their standard deviations are down from 5.60 (within firm) and 4.04 (cross-section), respectively, in the whole sample to 0.13 and 0.22 in the sub-sample. This implies that most of the tail observations are thrown away and the remaining sample used in the FE estimation consists mostly of observations with intermediate ROA's. Thus, even if there is a nonlinear relationship between the probability of FDI and ROA in the population, it could be difficult to detect the curvature based on the selected sample with a much narrower range of ROA (relative to its population distribution). In the pooled or RE estimation, although the tail observations are included, the estimation suffers a similar loss in within-firm variation as the FE estimation: the observations on firms that do not undertake any FDI, although with possibly extreme ROA's, basically do not contribute to the estimation from within-firm variation.

Following the logic of our argument, one should expect to see a stronger (if exists) inverted U-relationship between FDI probability and firm productivity in the Taiwanese data set, given that its propensity of FDI in China is much higher. As we saw earlier, 77.8% of all firms have made some FDI entries into China by the end of the study period; as a result, only about a quarter of observations are dropped from the FE estimation. The spectrum of ROA for observations with FDI entries is fairly broad relative to its population distribution as indicated by Figure 7. Indeed, the variation in ROA in the sub-sample (of firms ever undertaking FDI in China) is almost the same as the whole sample.[25]

In Table 1, for the Taiwanese data set, we see that both the FE and RE logit estimators support the H1 hypothesis, while the pooled logit estimator finds a significant nonlinear relationship but not a dynamic FDI effect; the findings based on probit models are similar.

many countries investing in the same destination, the base of spillover can be contributed by multinational firms of other countries.

[25]The range of ROA remains the same, $[-1.63, 1.12]$, from the whole sample to the sub-sample, and the standard deviation decreases only slightly from 0.117 for the whole sample to 0.111 for the sub-sample. Similarly, there is as much within-firm and cross-sectional variation in the sub-sample (0.063 and 0.100, respectively) as in the whole sample (0.064 and 0.109, respectively). This suggests that the firms dropped are not systematically the least or most productive firms (alternately or consistently across periods).

In Table 2, the coefficients on the auxiliary terms are significant, rejecting the specification in Table 1 that assumes independence between firm-specific effects v_i and the regressors. This warrants us to focus on the results presented in Table 2. The results are now consistent across all estimators and both distributional assumptions, supporting the H1 hypothesis. That is, the most and least productive firms are less likely than firms of intermediate productivities to make FDI entries; and over time, the likelihood increases for all firms but more for the more productive firms.

Overall, the empirical FDI patterns we observed in the US and Taiwanese data sets are supportive of our theory in the highly risk-sensitive scenario and in the intermediate risk-sensitive scenario, respectively.

4. CONCLUSION

This paper contributes to the FDI literature by modeling the effect of risk on the FDI decisions of firms. Contrary to conventional views, our model predicts an upper bound on the technology content of FDI. The presence of this upper bound highlights the rationale of many FDI-promoting policies used by the South—to attract firms of advanced production technologies constrained by the risk consideration. The effect of any one-time FDI policy is further reinforced through the agglomeration dynamics of FDI. The paper's static prediction (of an upper bound on the productivity spectrum of multinational firms) and dynamic prediction (of an expanding upper bound) are supported by firm-level data on FDI in China by US and Taiwanese firms.

Admittedly, the model presented in the paper bears certain limitations. For example, for simplicity, we adopt a reduced-form formulation of the spillover effect, and for tractability, a stylized functional form of FDI risk. In future work, the ability to characterize the mechanisms of spillover effects will rely to a large extent on the advancement of empirical work in this area. On the other hand, our theory can be extended in several possible dimensions to address other interesting issues. First, one could allow the degree of risk sensitivity to depend not only on industry characteristics but also to evolve over time. In particular, in line with the product-cycle theory, the degree of risk sensitivity is likely to decrease as the product matures. Provided that firms could have multiple product lines, such extension could help us to learn more about the endogenous length of product cycles and the optimal product scope of firms. Second, one could allow for firms to have multiple production stages in multiple countries and ask how the level of transaction cost affects the pattern of fragmentation. Third, one could allow for firms to modify the blueprint (in particular to water down the complexity of their production technology) to meet the technology frontier of the

South and analyze the impact of this option on the industry aggregate productivity.

5. APPENDIX

Proof of Proposition 1. We first show the existence and uniqueness of $z^*(T^S)$ for given $T^S \in [1, \theta_{NS})$. The proof is equivalent to showing that there exists a unique z^* such that $\tilde{\pi}^S(\tilde{\theta}; \tilde{T}^S, z)$ is tangent to $\tilde{\pi}^N(\tilde{\theta})$. Let $\tilde{\theta}^\dagger$ define the technology level where the two profit functions have the same slope. It follows that

$$\tilde{\theta}^\dagger(\tilde{T}^S, z) = \left[\left(1 - \frac{z}{\nu\alpha(1-\alpha)}\right)\frac{\psi^S}{\psi^N}\right]^{\frac{\nu\alpha(1-\alpha)}{z}} \tilde{T}^S. \tag{26}$$

Note that $\tilde{\theta}^\dagger$ exists (which implies $\tilde{\theta}^\dagger > \tilde{T}^S$) and is bounded if and only if $0 < z < \bar{z}$, where $\bar{z} \equiv \left(1 - \frac{\psi^N}{\psi^S}\right)\nu\alpha(1-\alpha)$. Let $\phi(\tilde{T}^S, z)$ denote the distance between $\tilde{\pi}^S(\tilde{\theta}; \tilde{T}^S, z)$ and $\tilde{\pi}^N(\tilde{\theta})$ at the technology level $\tilde{\theta}^\dagger$; we have:

$$\phi(\tilde{T}^S, z) \;=\; \psi^N \tilde{\theta}^\dagger(\tilde{T}^S, z)/g(z) - w^N(f^S - f^N), \tag{27}$$

where $g(z) \equiv \frac{\nu\alpha(1-\alpha)}{z} - 1$. Note that for $\tilde{T}^S \in [1, \tilde{\theta}_{NS})$ and $z \in (0, \bar{z})$,

$$\frac{\partial \phi(\tilde{T}^S, z)}{\partial z} < 0, \;\; \lim_{z \to 0} \phi(\tilde{T}^S, z) \to \infty, \;\; \lim_{z \to \bar{z}} \phi(\tilde{T}^S, z) = \tilde{T}^S\left(\psi^S - \psi^N\right) - w^N(f^S - f^N) < 0, \tag{28}$$

where the first limit follows by applying L'Hospital's Rule to $\tilde{\theta}^\dagger$ and $g(z)$, and the sign of the second limit follows by the fact that $\tilde{\pi}^S(\tilde{\theta}; \tilde{T}^S, z)$ is strictly dominated by $\tilde{\pi}^N(\tilde{\theta})$ at $\tilde{\theta} = \tilde{T}^S < \tilde{\theta}_{NS}$. Thus, by the fixed point theorem, there exists a unique $z^* \in (0, \bar{z})$, such that

$$\phi(\tilde{T}^S, z^*) = 0 \tag{29}$$

and $\tilde{\pi}^S$ is tangent to $\tilde{\pi}^N$. For $z < z^*$, it follows from (28) that $\phi(\tilde{T}^S, z) > 0$, and as a result, a positive measure of FDI takes place.

For $T^S = \theta_{NS}$, the South profit function will lie everywhere below the North profit function with overlapping only at θ_{NS} when $z \geq \bar{z}$. In other words, if and only if $z < \bar{z}$, will the South profit function rise above the North profit function to the right of $T^S = \theta_{NS}$ so that a positive measure of firms undertake FDI. Thus, $z^*(\theta_{NS}) = \bar{z}$. For $T^S \in (\theta_{NS}, \infty)$, the South profit function lies strictly above the North profit function at least for $\theta \in (\theta_{NS}, T^S + \epsilon]$, where $\epsilon > 0$, so FDI occurs regardless of z.

We next show the existence and uniqueness of $T^{S*}(z)$ for all z. From the above, we know that $z^*(1)$ is the cap of the risk sensitivity when the South's technology frontier is at the lowest level ($T^S = 1$). For z below the cap $z^*(1)$, FDI takes place necessarily, which is equivalent to saying that $T^{S*}(z) = 1$ for $z \in [0, z^*(1)]$. For sufficiently large degrees of risk sensitivity such that $z \geq \bar{z}$, the South profit function is flatter than the North profit function for all $\theta > T^S$; thus, FDI will take place if and only if the technology frontier exceeds the risk-free cutoff level θ_{NS}, so $T^{S*}(z) = \theta_{NS}$ for $z \geq \bar{z}$.

For $z \in (z^*(1), \bar{z})$, to show the existence of a unique $T^{S*}(z)$ is equivalent to showing the existence of a unique technology frontier level $T^{S*} \in (1, \theta_{NS})$ such that $\tilde{\pi}^S$ is tangent to $\tilde{\pi}^N$, or equivalently,

$$\phi(\tilde{T}^{S*}, z) = 0. \tag{30}$$

One can verify that for $\tilde{T}^S \in (1, \tilde{\theta}_{NS})$ and $z \in (z^*(1), \bar{z})$,

$$\frac{\partial \phi(\tilde{T}^S, z)}{\partial \tilde{T}^S} > 0, \quad \lim_{\tilde{T}^S \to 1} \phi(\tilde{T}^S, z) < 0, \quad \lim_{\tilde{T}^S \to \tilde{\theta}_{NS}} \phi(\tilde{T}^S, z) > 0. \tag{31}$$

The sign of the first limit is implied by the fact that $\phi(1, z^*(1)) = 0$ and $\frac{\partial \phi(1,z)}{\partial z} < 0$. To obtain the sign of the second limit, note that $\phi(\tilde{T}^S, z)$ is the unique maximum of $\tilde{\pi}^S(\tilde{\theta}; \tilde{T}^S, z) - \tilde{\pi}^N(\tilde{\theta})$. Because $\tilde{\pi}^S(\tilde{\theta}; \tilde{T}^S, z) - \tilde{\pi}^N(\tilde{\theta}) = 0$ holds at $\tilde{\theta} = \tilde{T}^S = \tilde{\theta}_{NS}$ and that $\tilde{\theta}^\dagger > \tilde{T}^S$, the sign of the second limit follows. Thus, by the fixed point theorem, there exists a unique $\tilde{T}^{S*} \in (1, \tilde{\theta}_{NS})$ for $z \in (z^*(1), \bar{z})$, such that (30) is satisfied.

To show the relationship between T^{S*} and z, take the total differentiation of (30) to obtain:

$$\frac{d\tilde{T}^{S*}}{dz} = -\left.\frac{\frac{\partial \phi(\tilde{T}^S, z)}{\partial z}}{\frac{\partial \phi(\tilde{T}^S, z)}{\partial \tilde{T}^S}}\right|_{\tilde{T}^S = \tilde{T}^{S*}} > 0.$$

It follows that $dT^{S*}/dz = \left(d\tilde{T}^{S*}/dz\right)\left(dT^{S*}/d\tilde{T}^{S*}\right) > 0$ for $z \in (z^*(1), \bar{z})$. It is obvious that $dT^{S*}/dz = 0$ for $z \in [0, z^*(1)]$ and for $z \geq \bar{z}$. ■

Proof of Propositions 6–7. To determine the signs of (21)–(24), first note that $\Sigma > 0$ holds at a stable steady state. Also recall the signs for $\Lambda > 0$ and $\Gamma_Q > 0$, and for $\frac{\partial \theta_1}{\partial T^S}$ and $\frac{\partial \theta_0}{\partial T^S}$ from Lemma 2. Finally, note that based on the definition in (11)–(12) for the upper and lower bounds of the technology content, it follows that:

$$\frac{\partial \theta_1}{\partial q} \equiv \left[\pi_\theta^N(\theta_1) - \pi_\theta^S(\theta_1)\right]^{-1}\left[\pi_q^S(\theta_1) - \pi_q^N(\theta_1)\right], \tag{32}$$

$$\frac{\partial \theta_0}{\partial q} \equiv \begin{cases} \left[\pi_\theta^N(\theta_0) - \pi_\theta^S(\theta_0)\right]^{-1}\left[\pi_q^S(\theta_0) - \pi_q^N(\theta_0)\right], & \text{if } 1 \leq T^S < \theta_{NS}, \\ \left[\pi_\theta^N(\theta_{NS}) - \pi_\theta^S(\theta_{NS})\right]^{-1}\left[\pi_q^S(\theta_{NS}) - \pi_q^N(\theta_{NS})\right], & \text{if } \theta_{NS} \leq T^S, \end{cases} \tag{33}$$

where $\pi_q^l \equiv \frac{\partial \pi^l}{\partial q}$ for $l \in \{N, S\}$. Recall that $\frac{\partial \chi}{\partial \theta_0} < 0$ and $\frac{\partial \chi}{\partial \theta_1} > 0$. Thus, to determine the sign of Ξ, it remains to show the signs of the derivatives $\frac{\partial \theta_1}{\partial q}$, $\frac{\partial \theta_0}{\partial q}$, and $\frac{\partial \chi}{\partial q}$, using the profit functions (9)–(10), and the FDI aggregate production function (15), for each parameter. We show the detailed derivations below.

(i) $q = T_0^S$: As the parameter T_0^S does not appear in the profit functions (9) and (10), nor in the FDI aggregate production function (15), it follows that $\frac{\partial \theta_1}{\partial T_0^S} = 0$, $\frac{\partial \theta_0}{\partial T_0^S} = 0$, and $\frac{\partial \chi}{\partial T_0^S} = 0$. Thus, $\Xi = \ominus 0 + \oplus 0 + 0 = 0$, and

$$\begin{aligned} \frac{dT^S}{dT_0^S} &= \Sigma^{-1}\frac{\partial T_0^S}{\partial T_0^S} = \Sigma^{-1} > 0, \\ \frac{dX^S}{dT_0^S} &= \Xi + \Lambda \frac{dT^S}{dT_0^S} = 0 + \oplus\oplus > 0, \\ \frac{d\theta_1}{dT_0^S} &= \frac{\partial \theta_1}{\partial T_0^S} + \frac{\partial \theta_1}{\partial T^S}\frac{dT^S}{dT_0^S} = 0 + \oplus\oplus > 0, \\ \frac{d\theta_0}{dT_0^S} &= \begin{cases} \frac{\partial \theta_0}{\partial T_0^S} + \frac{\partial \theta_0}{\partial T^S}\frac{dT^S}{dT_0^S} = 0 + \ominus\oplus < 0, & \text{if } 1 \leq T^S < \theta_{NS}, \\ \frac{\partial \theta_0}{\partial T_0^S} = 0, & \text{if } \theta_{NS} \leq T^S. \end{cases} \end{aligned}$$

(ii) $q = \delta_D$:

Similarly, the parameter δ_D does not appear in the profit functions (9) and (10), nor in the FDI aggregate production function (15). It follows that $\frac{\partial \theta_1}{\partial \delta_D} = 0$, $\frac{\partial \theta_0}{\partial \delta_D} = 0$, and $\frac{\partial \chi}{\partial \delta_D} = 0$. Thus, $\Xi = \ominus 0 + \oplus 0 + 0 = 0$, and

$$\begin{aligned} \frac{dT^S}{d\delta_D} &= \Sigma^{-1}\Gamma_Q X^S \frac{\partial \delta}{\partial \delta_D} = \oplus\ominus < 0, \\ \frac{dX^S}{d\delta_D} &= \Xi + \Lambda \frac{dT^S}{d\delta_D} = 0 + \oplus\ominus < 0, \\ \frac{d\theta_1}{d\delta_D} &= \frac{\partial \theta_1}{\partial \delta_D} + \frac{\partial \theta_1}{\partial T^S}\frac{dT^S}{d\delta_D} = 0 + \oplus\ominus < 0, \\ \frac{d\theta_0}{d\delta_D} &= \begin{cases} \frac{\partial \theta_0}{\partial \delta_D} + \frac{\partial \theta_0}{\partial T^S}\frac{dT^S}{d\delta_D} = 0 + \ominus\ominus > 0, & \text{if } 1 \leq T^S < \theta_{NS}, \\ \frac{\partial \theta_0}{\partial \delta_D} = 0, & \text{if } \theta_{NS} \leq T^S. \end{cases} \end{aligned}$$

(iii) $q = w^S$:

Using (9) and (10), note that

$$\begin{aligned}
\pi^S_{w^S}(\theta) - \pi^N_{w^S}(\theta) &= \frac{\partial \psi^S}{\partial w^S} \left(T^S\right)^{\frac{z}{1-\alpha}} \theta^{\nu\alpha - \frac{z}{1-\alpha}} < 0, \text{ for } T^S < \theta, \\
\pi^S_{w^S}(\theta) - \pi^N_{w^S}(\theta) &= \frac{\partial \psi^S}{\partial w^S} \theta^{\nu\alpha} < 0, \text{ for } \theta \leq T^S.
\end{aligned}$$

Plug the above signs into (32) and (33); it follows that $\frac{\partial \theta_1}{\partial w^S} < 0$ and $\frac{\partial \theta_0}{\partial w^S} > 0$. Next, using (15), note that

$$\frac{\partial \chi}{\partial w^S} = \frac{\partial \Omega^S}{\partial w^S} \frac{\chi}{\Omega^S} < 0,$$

as $\frac{\partial \Omega^S}{\partial w^S} < 0$. As a result, $\Xi = \ominus \oplus + \oplus \ominus + \ominus < 0$, and

$$\begin{aligned}
\frac{dT^S}{dw^S} &= \delta \Sigma^{-1} \Gamma_Q \Xi = \oplus\ominus < 0, \\
\frac{dX^S}{dw^S} &= \Xi + \Lambda \frac{dT^S}{dw^S} = \ominus + \oplus\ominus < 0, \\
\frac{d\theta_1}{dw^S} &= \frac{\partial \theta_1}{\partial w^S} + \frac{\partial \theta_1}{\partial T^S} \frac{dT^S}{dw^S} = \ominus + \oplus\ominus < 0, \\
\frac{d\theta_0}{dw^S} &= \begin{cases} \frac{\partial \theta_0}{\partial w^S} + \frac{\partial \theta_0}{\partial T^S} \frac{dT^S}{dw^S} = \oplus + \ominus\ominus > 0, & \text{if } 1 \leq T^S < \theta_{NS}, \\ \frac{\partial \theta_0}{\partial w^S} > 0, & \text{if } \theta_{NS} \leq T^S. \end{cases}
\end{aligned}$$

(iv) $q = f^S$:

Using (9) and (10), note that

$$\pi^S_{f^S}(\theta) - \pi^N_{f^S}(\theta) = -w^N < 0.$$

Plug the above signs into (32) and (33); it follows that $\frac{\partial \theta_1}{\partial f^S} < 0$ and $\frac{\partial \theta_0}{\partial f^S} > 0$. Furthermore, note that $\frac{\partial \chi}{\partial f^S} = 0$. Thus, $\Xi = \ominus \oplus + \oplus \ominus + 0 < 0$, and

$$\begin{aligned}
\frac{dT^S}{df^S} &= \delta \Sigma^{-1} \Gamma_Q \Xi = \oplus\ominus < 0, \\
\frac{dX^S}{df^S} &= \Xi + \Lambda \frac{dT^S}{df^S} = \ominus + \oplus\ominus < 0, \\
\frac{d\theta_1}{df^S} &= \frac{\partial \theta_1}{\partial f^S} + \frac{\partial \theta_1}{\partial T^S} \frac{dT^S}{df^S} = \ominus + \oplus\ominus < 0, \\
\frac{d\theta_0}{df^S} &= \begin{cases} \frac{\partial \theta_0}{\partial f^S} + \frac{\partial \theta_0}{\partial T^S} \frac{dT^S}{df^S} = \oplus + \ominus\ominus > 0, & \text{if } 1 \leq T^S < \theta_{NS}, \\ \frac{\partial \theta_0}{\partial f^S} > 0, & \text{if } \theta_{NS} \leq T^S. \end{cases}
\end{aligned}$$

(v) $q = z$:

Using (9) and (10), note that

$$\begin{aligned}
\pi_z^S(\theta) - \pi_z^N(\theta) &= \frac{1}{1-\alpha}\psi^S \left(T^S\right)^{\frac{z}{1-\alpha}} \theta^{\nu\alpha - \frac{z}{1-\alpha}} (\ln T^S - \ln\theta) < 0, \text{ for } T^S < \theta, \\
\pi_z^S(\theta) - \pi_z^N(\theta) &= 0, \text{ for } \theta \leq T^S.
\end{aligned}$$

Plug the above signs into (32) and (33); it follows that $\frac{\partial\theta_1}{\partial z} < 0$, while $\frac{\partial\theta_0}{\partial z} > 0$ if $1 \leq T^S < \theta_{NS}$ and $\frac{\partial\theta_0}{\partial z} = 0$ if $\theta_{NS} \leq T^S$. Next, using (15), note that if $1 \leq T^S < \theta_{NS}$,

$$\frac{\partial\chi}{\partial z} = -\frac{1}{1-\alpha}\frac{\Omega^S k}{a}\left(T^S\right)^{\frac{z}{1-\alpha}} [J(\theta_0) - J(\theta_1)],$$

where $J(\theta) \equiv \left(\frac{1}{a} - \ln\frac{T^S}{\theta}\right)\theta^{-a}$, which is flat at $\theta = T^S$ and everywhere decreasing for $\theta > T^S \geq 1$. In the current case, $T^S < \theta_0 < \theta_1$, it follows that $J(\theta_0) - J(\theta_1) > 0$ and $\frac{\partial\chi}{\partial z} < 0$. Alternatively, if $T^S \geq \theta_{NS}$,

$$\frac{\partial\chi}{\partial z} = -\frac{1}{1-\alpha}\frac{\Omega^S k}{a}\left(T^S\right)^{\frac{z}{1-\alpha}} [J(T^S) - J(\theta_1)].$$

Given the property of $J(\theta)$ and that $T^S < \theta_1$, it follows that $\frac{\partial\chi}{\partial z} < 0$ in this case as well. Hence, $\Xi = \ominus\oplus + \oplus\ominus + \ominus < 0$, if $1 \leq T^S < \theta_{NS}$, and $\Xi = \ominus 0 + \oplus\ominus + \ominus < 0$, if $\theta_{NS} \leq T^S$ as well. As a result,

$$\begin{aligned}
\frac{dT^S}{dz} &= \delta\Sigma^{-1}\Gamma_Q\Xi = \oplus\ominus < 0, \\
\frac{dX^S}{dz} &= \Xi + \Lambda\frac{dT^S}{dz} = \ominus + \oplus\ominus < 0, \\
\frac{d\theta_1}{dz} &= \frac{\partial\theta_1}{\partial z} + \frac{\partial\theta_1}{\partial T^S}\frac{dT^S}{dz} = \ominus + \oplus\ominus < 0, \\
\frac{d\theta_0}{dz} &= \begin{cases} \frac{\partial\theta_0}{\partial z} + \frac{\partial\theta_0}{\partial T^S}\frac{dT^S}{dz} = \oplus + \ominus\ominus > 0, & \text{if } 1 \leq T^S < \theta_{NS}, \\ \frac{\partial\theta_0}{\partial z} = 0, & \text{if } \theta_{NS} \leq T^S. \end{cases}
\end{aligned}$$

■

Data Appendix: The US data set

The firm data are extracted from the "Compustat North America Fundamental Annual dataset". The range of data retrieved is from fiscal year 1980 to 2010, using the "search the entire database" option. An observation records a company's identification number, name (*conm*), North American Industry Classification (NAICS) code, fiscal year of the data, and financial information (e.g., total assets and gross profits). Not all firms appear in all years, and even if they appear, some financial information can be missing. This search results in 26,557 firms/287,183 observations.

On the other hand, FDI entries into China by US firms during 1980–2010 are compiled from *China Business Review* (CBR), a bi-monthly trade journal published by the US-China Business Council that archives foreign business activities in China. There is a lag of about two months between the date of transactions and publishing (e.g., transactions in January are typically only reported in the Mar/Apr or later issue). In the 1980 issues, there was no section on FDI. From Jan/Feb 1981 to May/Jun 1987, FDI transactions are located under the "Joint Ventures/Direct Investments" heading. From Jul/Aug 1987 onwards, FDI transactions are located under the heading "Investments in China". Each entry in the journal includes a brief description of the transaction made, the parties involved, and the year and month of the transaction. We regard entries which describe "contracts signed", "facilities/factory built", "joint venture established" as an official FDI entry, and disregard entries that report negotiations in progress. For each observation, we record the name of the US firm (*firmname*), and the year and month of the FDI transaction, among other information. This results in an effective sample of 1,506 firms/2,560 observations. This indicates that some firms make multiple FDI entries over the years.

We then merge the two data sets by matching the company names from the two data sets. A firm from the CBR data set finds a matching firm from the Compustat data set if: 1) *firmname* = *conm*, or *firmname* is very similar to *conm* and there is no evidence to suggest that *firmname* is a separate entity; 2) *firmname* has undergone a name change (not due to a merger or acquisition) with its current name = *conm*, or *firmname* is an international brand name of *conm* outside the US; 3) *firmname* is a (local, regional, or international) subsidiary or business unit/division of *conm*; 4) *firmname* has undergone a merger/acquisition with the new entity known as *conm*. This matching process requires extensive search on the internet for company histories and organizational structures. Following this, 1,708 (out of 2,560) observations from CBR find a matching firm from Compustat, and most of them (1,502) fall into the first and second categories of exact match. The remaining observations from CBR without a match from Compustat are dropped from the study, as their financial information is not available.

This merging process results in 26,209 firms/280,742 yearly observations, among which there are 662 firms/1,348 yearly observations with FDI entries. In manufacturing sectors alone, there are 7,867 firms/96,400 observations, among which there are 352 firms/810 observations with FDI entries. In the numbers reported above, we have dropped observations that correspond to subsequent FDI entries by the same firm in the same year, since in the panel analysis, we cannot have multiple observations on the same firm in the same time period (in any case, these multiple FDI entries are associated with the same lagged annual ROA). We have also dropped the observations on FDI entries in 1980, as they do not have the data on the lagged annual ROA, which is required in the panel analysis. In any case, there is no FDI entry into China in 1980 by US manufacturing firms (and only one by US non-manufacturing firms). The financial data of 1980 are used only as the input to calculate the lagged annual ROA for 1981.

The list of manufacturing sectors (and the number of firms in the sample) at the 3-digit NAICS level are: 311–food manufacturing (314); 312–beverage and tobacco product manufacturing (128); 313–textile mills (79); 314–textile product mills (28); 315–apparel manufacturing (193); 316–leather and allied product manufacturing (59); 321–wood product manufacturing (84); 322–paper manufacturing (159); 323–printing and related support activities (106); 324–petroleum and coal products manufacturing (117); 325–chemical manufacturing (1,458); 326–plastics and rubber products manufacturing (220); 327–nonmetallic mineral product manufacturing (131); 331–primary metal manufacturing (223); 332–fabricated metal product manufacturing (276); 333–machinery manufacturing (713); 334–computer and electronic product manufacturing (2,213); 335–electrical equipment, appliance, and component manufacturing (296); 336–transportation equipment manufacturing (381); 337–furniture and related product manufacturing (94); 339–miscellaneous manufacturing (593); and 33–that cannot be classified into sub-sectors (2).

Data Appendix: The Taiwanese data set

The data on FDI entries into China by Taiwanese firms are based on a Chinese publication, the *Directory of Companies Investing in China*, published by the Investment Commission, Taiwan Ministry of Economic Affairs (MOEA).[26] The publication chronicles the date (e.g., 1991/7/16) when a TSE or OTC firm received approval from the MOEA for their outward FDI in China. For each FDI entry approved, the publication also provides details on the investment and company details. The data are available since 1991, until the end of January 2010 in the version of the file we downloaded. Thus, we set the study period to 1991Q1–2009Q4.

The firm data are retrieved from the "Taiwan Economic Journal (TEJ) Data Bank", combining the results from the "Company Basic Information" and the "Finance" data bank. In particular, the sample of study includes all Taiwanese firms listed on the Taiwan Stock Exchange (TSE) or the over-the-counter (OTC) market by the end of 2009.[27] Their uncon-

[26] http://www.moeaic.gov.tw/system_external/ctlr?PRO=PublicationLoad&id=43

[27] To be precise, a few firms listed later than 2009 have their financial information available as early as 2009Q1 and so appear in the data set. However, as explained in the main text, the annual ROA from the

solidated (i.e., parent firm only) financial data are used, which are available at a quarterly basis from 1986Q1. An observation records a company's TSE identification number, ban code (Taiwanese company tax ID), name, TEJ industry classification, year and quarter of the data, financial information, and other company details.

We then merge the financial and FDI data sets at a quarterly basis by the company's ban code, which is available in both data sets and is a unique identifier of a Taiwanese company. This merging process results in 1,332 firms/53,692 quarterly observations, among which there are 959 firms/3,116 quarterly observations with FDI entries. In manufacturing sectors alone, there are 1,097 firms/42,357 observations, among which there are 854 firms/2,769 observations with FDI entries. Similarly to the US data set, subsequent FDI entries by the same firm in the same time period of analysis (quarter here) have been dropped in the tally above. The financial data of 1990 are used to calculate the lagged annual ROA for 1991Q1.

By the TEJ industry classification, of the 1,097 firms in the manufacturing sectors, there is a large concentration of firms in the M2300–electronics industry (752), reflecting Taiwan's strong comparative advantage in this sector in this time period. The remaining 12 industries have relatively few firms each: M1100–cement (7), M1200–foods (22), M1300–plastics (27), M1400–textiles (56), M1500–electric machinery (62), M1600–electrical appliance and cable (15), M1700–chemical and biotechnology (88), M1800–glass and ceramics (5), M1900–paper and pulp (7), M2000–iron and steel (40), M2100–rubber (11), and M2200–automobile (5).

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previous four quarters is required to study the FDI entry decision of a current quarter. For example, to study the FDI entry decision of the last period 2009Q4, financial data from 2008Q4 to 2009Q3 are required. Therefore, none of these firms have effective observations on lagged annual ROA's, and as a result, they are not used in the final analysis.

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Figure 1: Expected Profits of FDI versus Production in the North

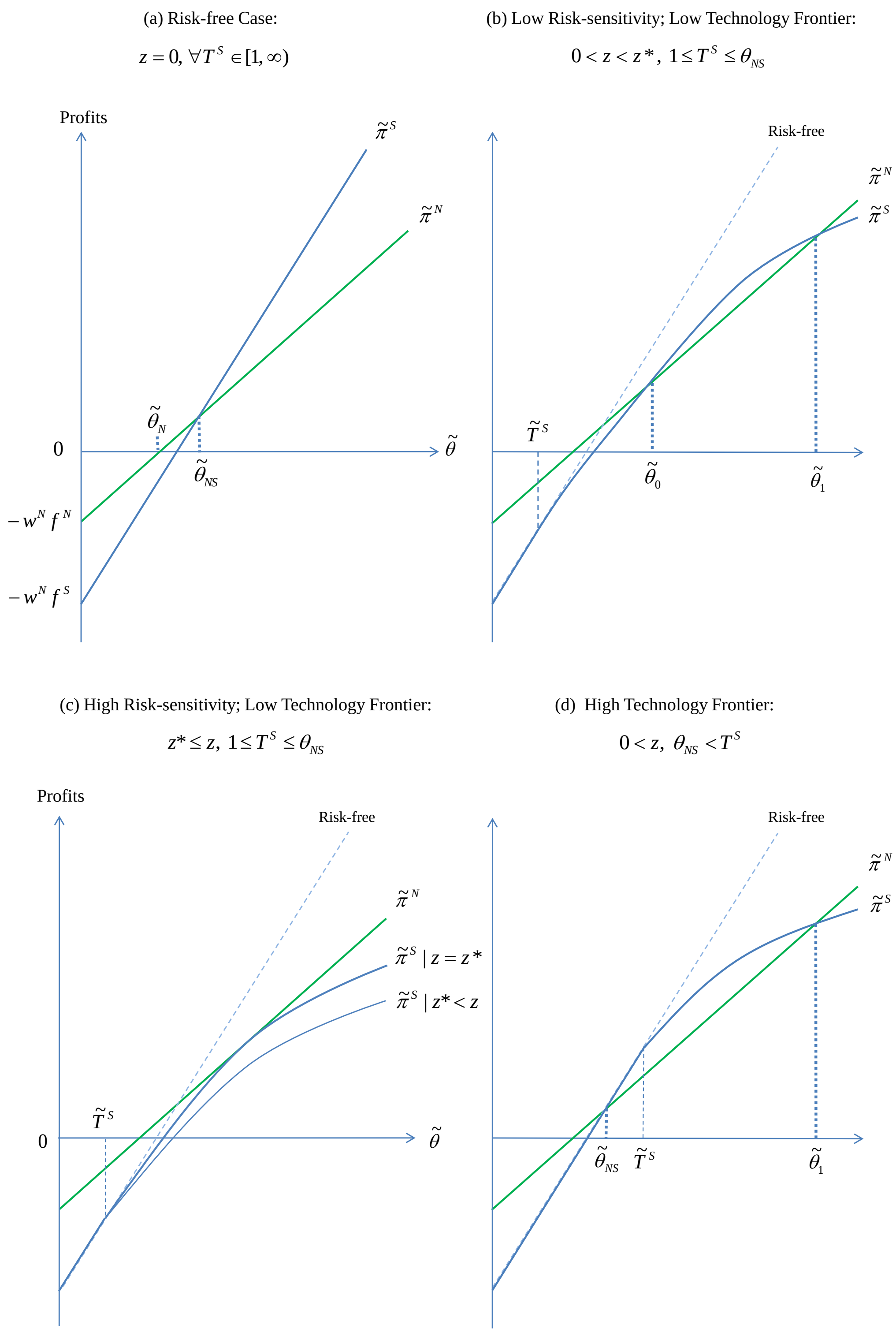


Figure 2: Threshold Technology Frontier for Inward FDI

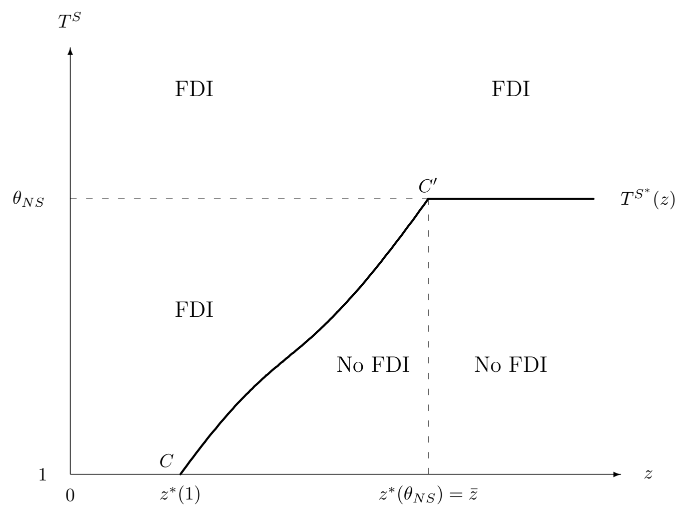


Figure 3: Dynamics of FDI

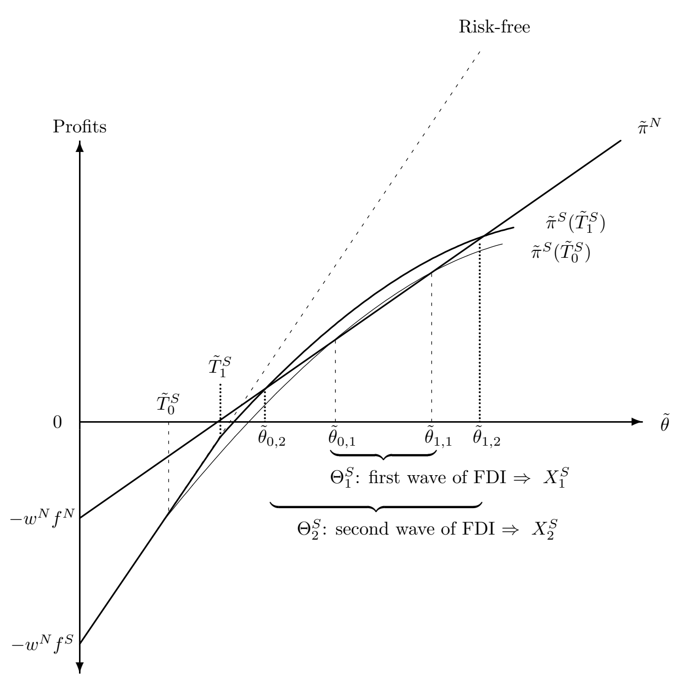
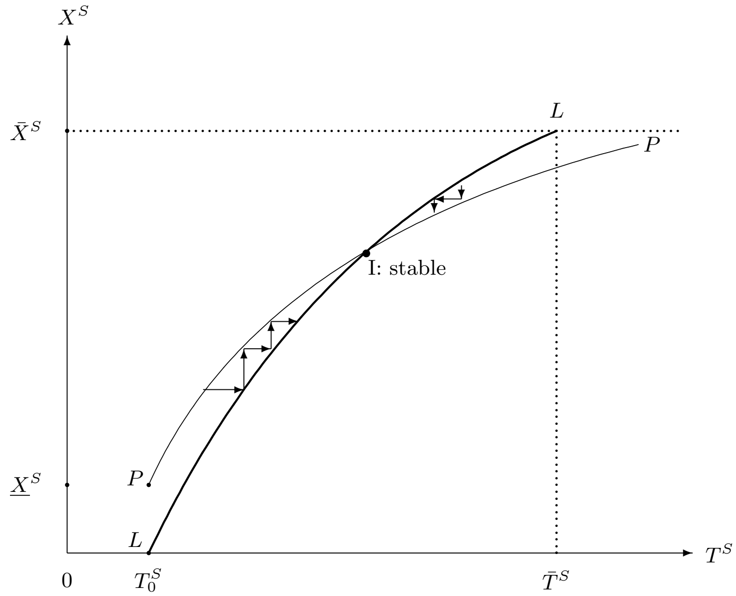


Figure 4: Existence and Stability of Steady State

(a) Unique Equilibrium



(b) Multiple Equilibria

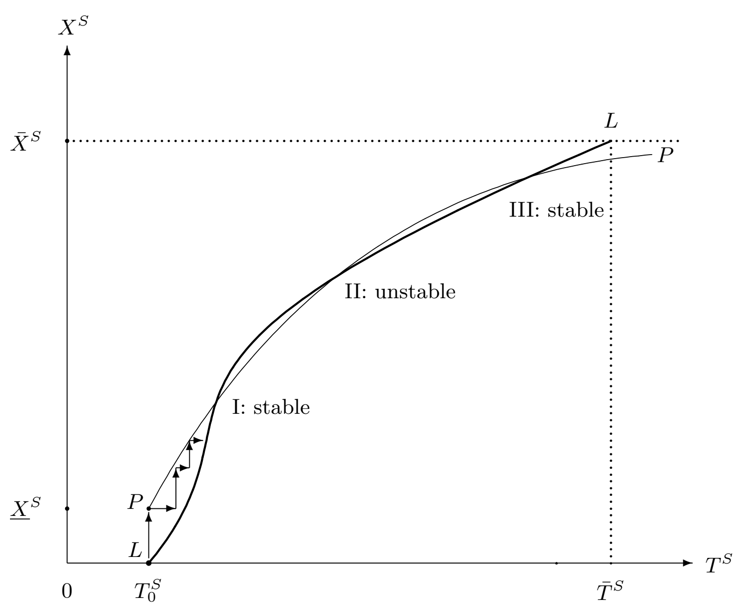
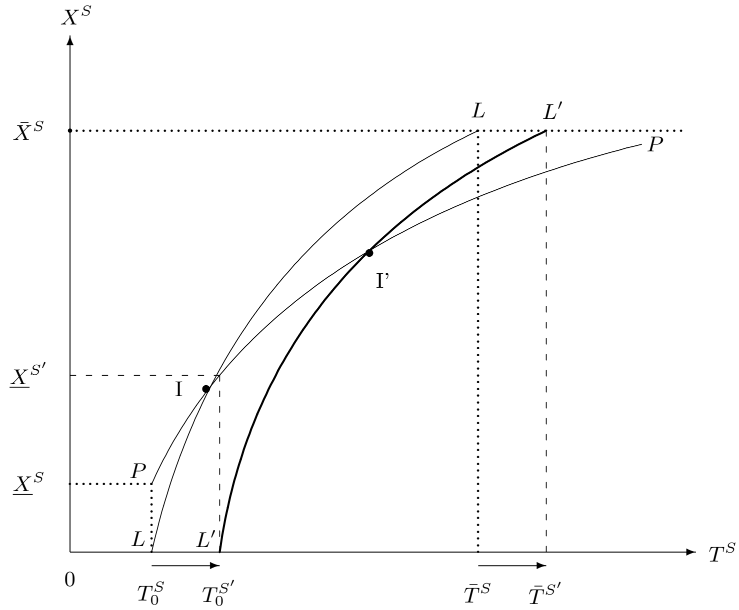


Figure 5: Comparative Static Analysis

(a) $T_0^S < T_0^{S\prime}$



(b) $\delta_D > \delta_D{}'$

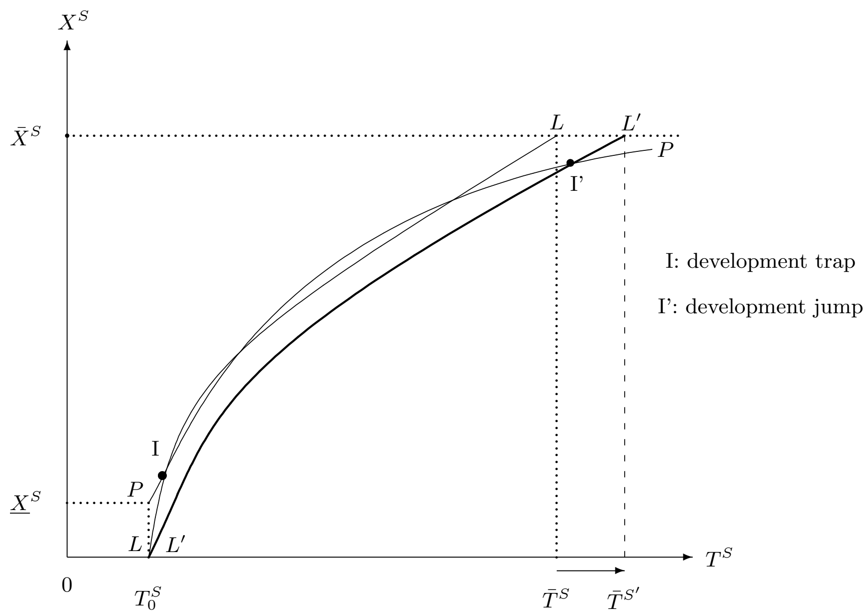


Figure 5: Comparative Static Analysis Continued

(c) $w^{S'} < w^S$; $f^{S'} < f^S$; $z' < z$

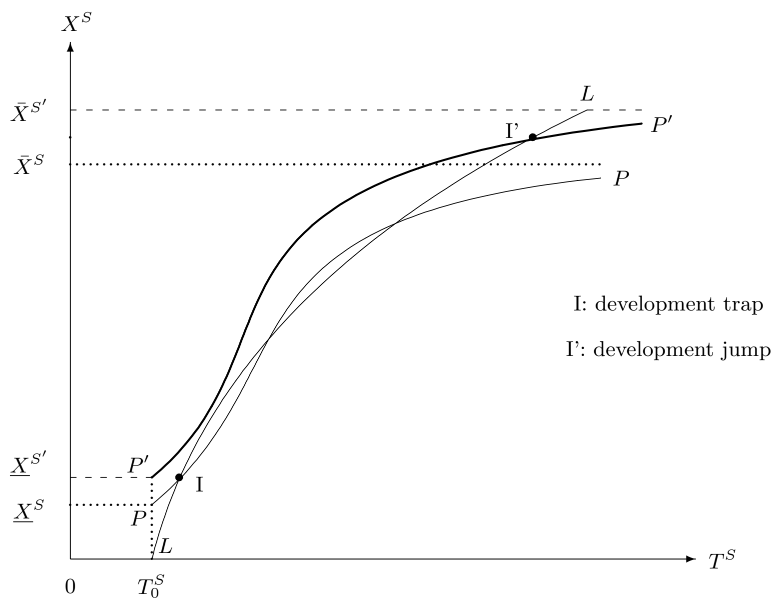
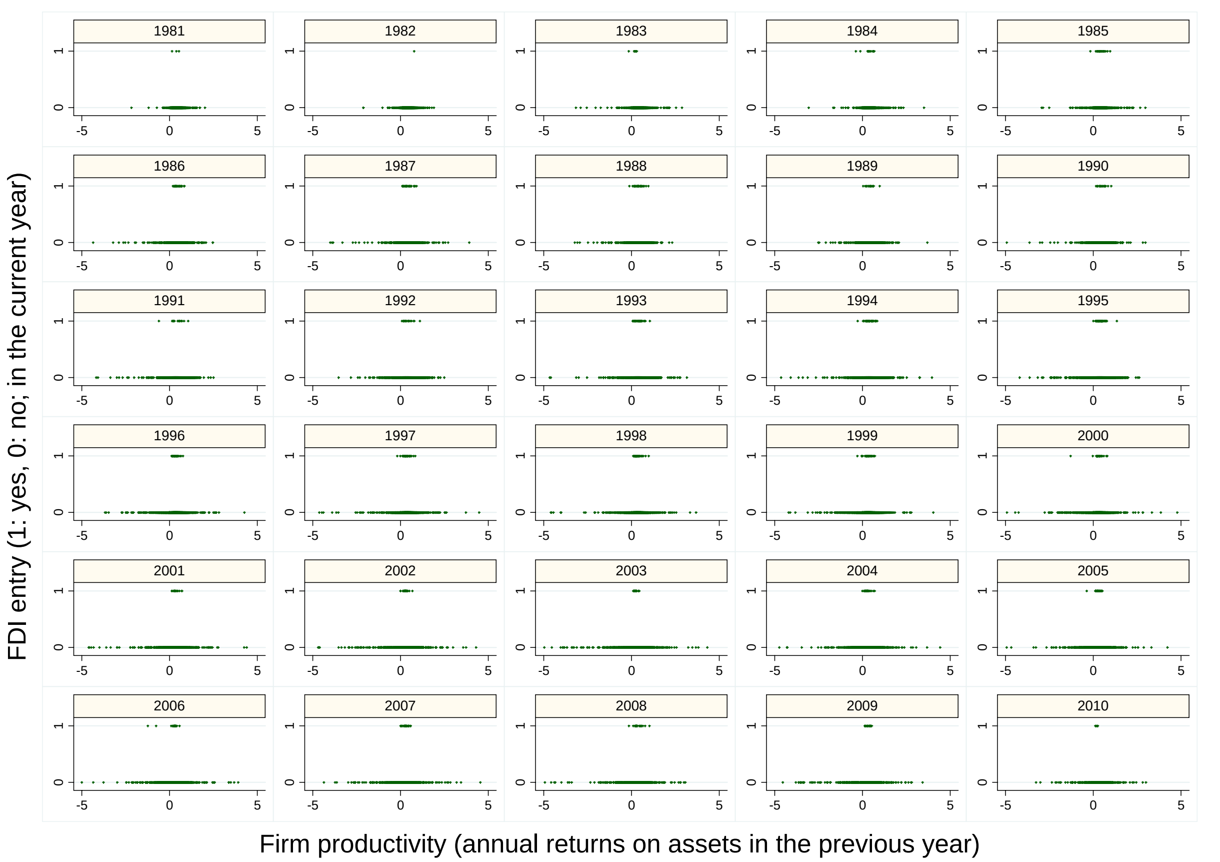
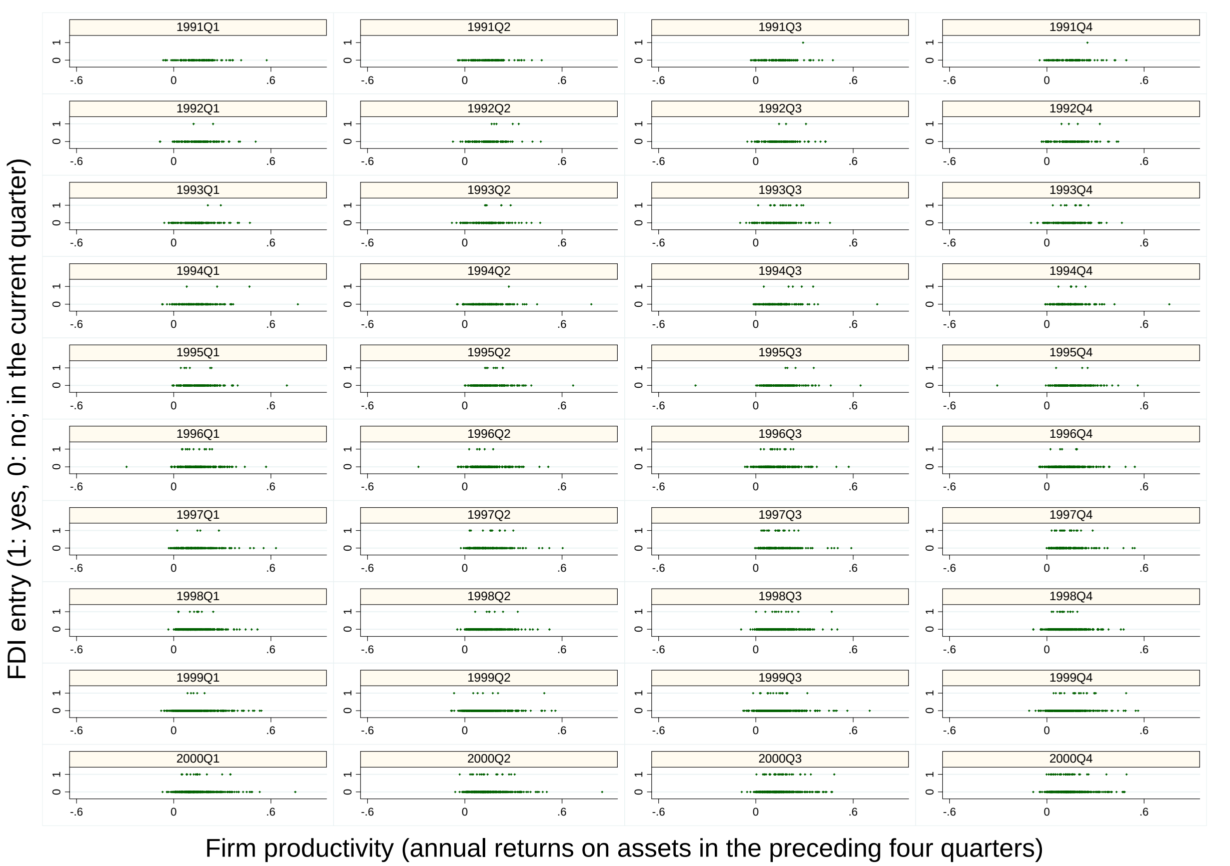


Figure 6: Incidence of FDI entries into China by US firms in the manufacturing industries across years



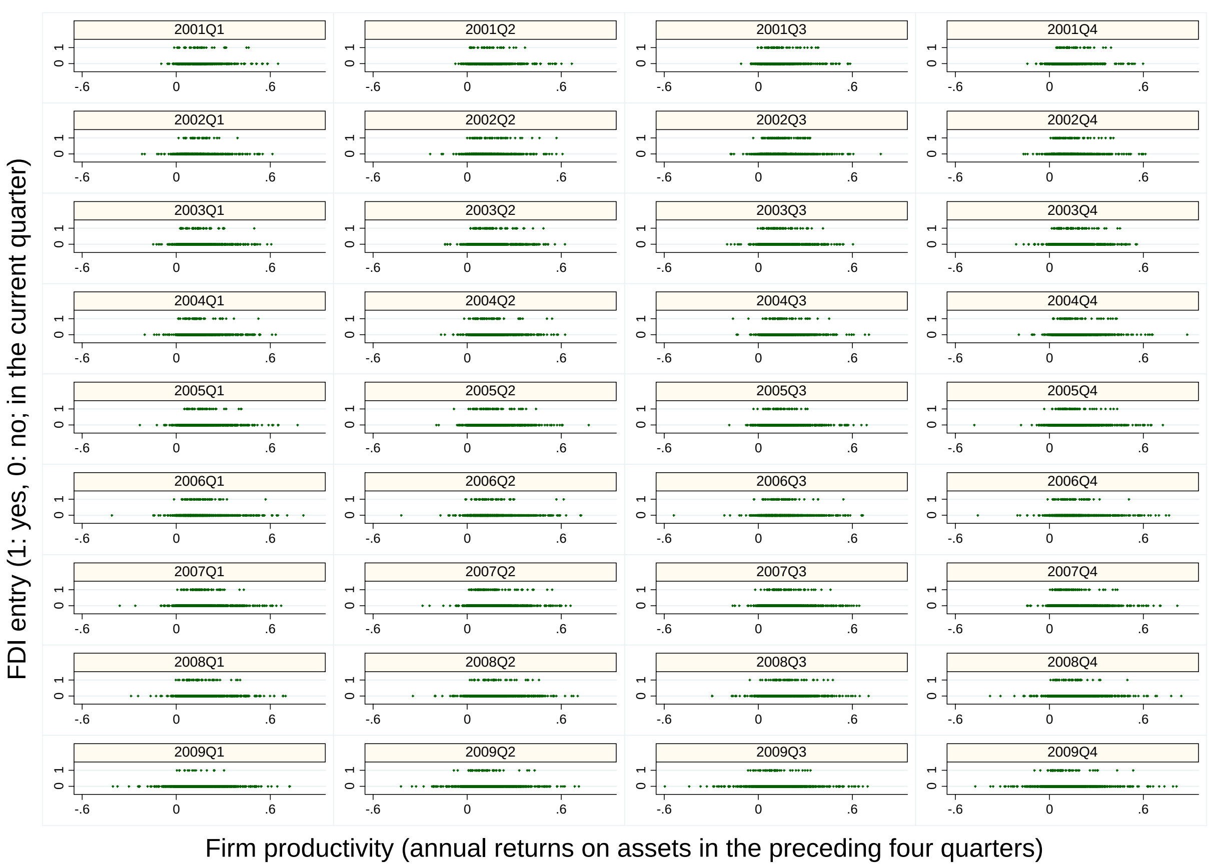
Note: In 1980, there is no FDI entry. The numbers of observations (and FDI entries) in each year are: 2,023 (3) in 1981; 2,115 (1) in 1982; 2,309 (7) in 1983; 2,451 (16) in 1984; 2,560 (28) in 1985; 2,666 (28) in 1986; 2,776 (30) in 1987; 2,757 (32) in 1988; 2,664 (17) in 1989; 2,644 (20) in 1990; 2,695 (15) in 1991; 2,779 (19) in 1992; 2,981 (39) in 1993; 3,099 (47) in 1994; 3,227 (57) in 1995; 3,544 (37) in 1996; 3,580 (39) in 1997; 3,388 (47) in 1998; 3,401 (33) in 1999; 3,324 (35) in 2000; 3,248 (17) in 2001; 3,083 (32) in 2002; 3,010 (21) in 2003; 2,939 (28) in 2004; 2,856 (33) in 2005; 2,779 (26) in 2006; 2,659 (31) in 2007; 2,518 (28) in 2008; 2,491 (21) in 2009; 1,563 (5) in 2010. Outliers with $|ROA| > 5$ are not included in the above diagrams to harmonize the scale. These observations are small in number (196), and all of them are observations without FDI entries; thus, this does not bias the presentation in any way in favor of our theory.

Figure 7: Incidence of FDI entries into China by Taiwanese firms in the manufacturing industries across quarters (continued on the next page)



Note: The numbers of observations (and FDI entries) in each quarter are: 104 (0) in 1991Q1; 104 (0) in 1991Q2; 110 (1) in 1991Q3; 112 (1) in 1991Q4; 126 (2) in 1992Q1; 126 (5) in 1992Q2; 131 (3) in 1992Q3; 131 (4) in 1992Q4; 140 (2) in 1993Q1; 140 (6) in 1993Q2; 142 (16) in 1993Q3; 143 (9) in 1993Q4; 152 (3) in 1994Q1; 152 (1) in 1994Q2; 154 (5) in 1994Q3; 157 (5) in 1994Q4; 169 (6) in 1995Q1; 169 (8) in 1995Q2; 173 (4) in 1995Q3; 175 (3) in 1995Q4; 196 (11) in 1996Q1; 196 (6) in 1996Q2; 204 (13) in 1996Q3; 207 (5) in 1996Q4; 235 (4) in 1997Q1; 235 (10) in 1997Q2; 243 (19) in 1997Q3; 249 (19) in 1997Q4; 287 (9) in 1998Q1; 287 (7) in 1998Q2; 303 (12) in 1998Q3; 303 (13) in 1998Q4; 369 (5) in 1999Q1; 369 (7) in 1999Q2; 378 (17) in 1999Q3; 381 (21) in 1999Q4; 444 (17) in 2000Q1; 444 (17) in 2000Q2; 455 (37) in 2000Q3; 461 (36) in 2000Q4. Outliers with $ROA > 0.9$ or $ROA < -0.6$ are not included in the above diagrams to harmonize the scale. These observations are small in number (11 in total during 1991Q1–2009Q4), and all of them are observations without FDI entries; thus, this does not bias the presentation in any way in favor of our theory.

Figure 7: Incidence of FDI entries into China by Taiwanese firms in the manufacturing industries across quarters (continued from the previous page)



Note: The numbers of observations (and FDI entries) in each quarter are: 527 (36) in 2001Q1; 527 (38) in 2001Q2; 540 (54) in 2001Q3; 542 (49) in 2001Q4; 635 (41) in 2002Q1; 635 (55) in 2002Q2; 667 (83) in 2002Q3; 669 (68) in 2002Q4; 711 (49) in 2003Q1; 711 (59) in 2003Q2; 747 (64) in 2003Q3; 747 (71) in 2003Q4; 808 (54) in 2004Q1; 808 (60) in 2004Q2; 832 (56) in 2004Q3; 833 (54) in 2004Q4; 861 (47) in 2005Q1; 862 (62) in 2005Q2; 890 (53) in 2005Q3; 891 (72) in 2005Q4; 907 (56) in 2006Q1; 907 (50) in 2006Q2; 933 (56) in 2006Q3; 935 (57) in 2006Q4; 964 (58) in 2007Q1; 964 (68) in 2007Q2; 996 (68) in 2007Q3; 997 (64) in 2007Q4; 1,015 (58) in 2008Q1; 1,015 (45) in 2008Q2; 1,029 (54) in 2008Q3; 1,029 (45) in 2008Q4; 1,041 (15) in 2009Q1; 1,041 (44) in 2009Q2; 1,055 (44) in 2009Q3; 1,055 (55) in 2009Q4. Outliers with $ROA > 0.9$ or $ROA < -0.6$ are not included in the above diagrams to harmonize the scale. These observations are small in number (11 in total during 1991Q1–2009Q4), and all of them are observations without FDI entries; thus, this does not bias the presentation in any way in favor of our theory.

Table 1: Panel analysis of the probability of FDI in China by US and Taiwanese firms of the manufacturing industries

	US (1981–2010)			Taiwan (1991Q1–2009Q4)		
logit	pooled	FE	RE	pooled	FE	RE
$ROA_{i,t-1}$	**2.180**	**-0.984**	0.269	**3.254**	-0.625	1.181
	(0.784)	(0.393)	(0.402)	(0.880)	(0.814)	(0.733)
$ROA^2_{i,t-1}$	**-2.608**	-0.039	**-1.111**	**-9.320**	**-3.170**	**-6.936**
	(0.865)	(0.280)	(0.366)	(1.787)	(1.706)	(1.490)
$ROA_{i,t-1} \times (t-1)$	0.014	**0.064**	**0.051**	0.002	**0.060**	**0.029**
	(0.011)	(0.014)	(0.013)	(0.009)	(0.009)	(0.008)
constant	**-4.410**		**-6.860**	**-2.339**		**-2.512**
	(0.343)		(0.359)	(0.284)		(0.358)
$\rho \equiv \frac{\sigma_v^2}{\sigma_v^2+\sigma_\epsilon^2}$			**0.622**			**0.171**
			(0.022)			(0.012)
probit	pooled		RE	pooled		RE
$ROA_{i,t-1}$	**0.603**		0.052	**1.514**		**0.732**
	(0.240)		(0.161)	(0.401)		(0.350)
$ROA^2_{i,t-1}$	**-0.734**		**-0.415**	**-4.226**		**-3.297**
	(0.253)		(0.136)	(0.772)		(0.685)
$ROA_{i,t-1} \times (t-1)$	0.005		**0.021**	0.001		**0.011**
	(0.004)		(0.006)	(0.004)		(0.004)
constant	**-2.218**		**-3.315**	**-1.344**		**-1.428**
	(0.135)		(0.157)	(0.144)		(0.174)
$\rho \equiv \frac{\sigma_v^2}{\sigma_v^2+\sigma_\epsilon^2}$			**0.524**			**0.138**
			(0.023)			(0.010)
no. of obs.	81,929	7,007	84,129	39,382	30,566	39,382
no. of firms	7,522	338	7,716	1,055	732	1,055
no. of periods per firm (min.)		2	1		6	2
no. of periods per firm (avg.)		20.70	10.90		41.80	37.30
no. of periods per firm (max.)		30	30		76	76

Note:
1. The regression function is as specified in (25); sector-specific effects are not reported (and not identifiable in the FE estimation, because they are time invariant). Standard errors are in parentheses; robust standard errors (clustering by firms) are reported for the pooled estimator. An estimate in boldface indicates that it is statistically significant at the 10% level.
2. In the FE logit model, a sufficient statistic exists that allows v_i to be conditioned out of the likelihood function, and permits the slope parameters β's to be consistently estimated; this is not possible in the FE probit model. See Wooldridge (2002, pp. 491–2), Baltagi (2008, pp. 237–9), and Hsiao (2003, Chapter 7.3).
3. In the RE logit model, it is assumed that the error components have the following distributions: v_i are i.i.d. $N(0, \sigma_v^2)$, and ϵ_{it} are i.i.d logistic distributed with mean zero and variance $\sigma_\epsilon^2 = \pi^2/3$, independently of v_i. In the RE probit model, similar assumptions are made, except that ϵ_{it} are i.i.d. $N(0,1)$. To evaluate the likelihood function for the RE model, the Gaussian-Hermite quadrature procedure with 20 integration points is used. Robustness checks based on 16 or 24 integration points lead to similar results.
4. In the RE model, the ratio ρ indicates the proportion of the total variance contributed by the firm-level variance component. The pooled estimator is no different from the panel estimator if $\rho = 0$. The significance of the estimate $\hat{\rho}$ reported in the table is determined based on the likelihood-ratio test.
5. As explained in the data appendix, the US data set does not have the data on the ROA of 1979, and thus the observations on FDI entry in 1980 are dropped from the estimation. In any case, there is no FDI entry into China in 1980 by US manufacturing firms.

Table 2: Panel analysis of the probability of FDI in China by US and Taiwanese firms of the manufacturing industries (with Mundlak (1978) auxiliary regressors)

	US (1981–2010)			Taiwan (1991Q1–2009Q4)		
logit	pooled	FE	RE	pooled	FE	RE
$ROA_{i,t-1}$	**-1.145**	**-0.984**	**-1.074**	-0.318	-0.625	-0.425
	(0.461)	(0.393)	(0.402)	(0.980)	(0.814)	(0.786)
$ROA^2_{i,t-1}$	-0.095	-0.039	-0.078	**-3.516**	**-3.170**	**-3.604**
	(0.359)	(0.280)	(0.300)	(2.134)	(1.706)	(1.655)
$ROA_{i,t-1} \times (t-1)$	**0.075**	**0.064**	**0.071**	**0.049**	**0.060**	**0.057**
	(0.017)	(0.014)	(0.014)	(0.010)	(0.009)	(0.009)
$\overline{ROA}_i$	**5.551**		**3.930**	**13.017**		**12.148**
	(1.200)		(0.768)	(2.936)		(1.973)
$\overline{ROA^2}_i$	**-4.321**		**-2.911**	**-9.573**		**-6.610**
	(1.279)		(0.661)	(3.983)		(2.464)
$\overline{ROA \times (t-1)}_i$	**-0.127**		**-0.103**	**-0.180**		**-0.184**
	(0.028)		(0.032)	(0.039)		(0.028)
constant	**-4.551**		**-6.933**	**-2.726**		**-2.925**
	(0.352)		(0.375)	(0.303)		(0.359)
$\rho \equiv \frac{\sigma_w^2}{\sigma_w^2+\sigma_\epsilon^2}$			**0.613**			**0.164**
			(0.022)			(0.012)
probit	pooled		RE	pooled		RE
$ROA_{i,t-1}$	**-0.417**		**-0.511**	-0.086		-0.039
	(0.152)		(0.172)	(0.454)		(0.375)
$ROA^2_{i,t-1}$	-0.033		-0.035	**-1.819**		**-1.825**
	(0.105)		(0.119)	(0.923)		(0.759)
$ROA_{i,t-1} \times (t-1)$	**0.027**		**0.031**	**0.024**		**0.025**
	(0.006)		(0.007)	(0.005)		(0.005)
$\overline{ROA}_i$	**1.762**		**1.630**	**5.844**		**5.607**
	(0.362)		(0.319)	(1.315)		(0.919)
$\overline{ROA^2}_i$	**-1.245**		**-1.135**	**-3.613**		**-2.739**
	(0.367)		(0.255)	(1.524)		(1.024)
$\overline{ROA \times (t-1)}_i$	**-0.047**		**-0.044**	**-0.085**		**-0.087**
	(0.010)		(0.014)	(0.018)		(0.013)
constant	**-2.254**		**-3.359**	**-1.520**		**-1.619**
	(0.137)		(0.165)	(0.151)		(0.175)
$\rho \equiv \frac{\sigma_w^2}{\sigma_w^2+\sigma_\epsilon^2}$			**0.518**			**0.132**
			(0.023)			(0.010)
no. of obs.	81,929	7,007	84,129	39,382	30,566	39,382
no. of firms	7,522	338	7,716	1,055	732	1,055
no. of periods per firm (min.)		2	1		6	2
no. of periods per firm (avg.)		20.70	10.90		41.80	37.30
no. of periods per firm (max.)		30	30		76	76

Note:
The end notes for Table 1 apply here with the following modifications.
1. The regression function is as specified in (25), augmented by the Mundlak (1978) auxiliary regressors. The coefficients on the auxiliary terms are not estimable in the FE model because they are time invariant.
2. Let w_i indicate the component of firm-level specific effects not accounted for by the auxiliary regressors: i.e., $v_i = \gamma_1 \overline{ROA}_i + \gamma_2 \overline{ROA^2}_i + \gamma_3 \overline{ROA \times (t-1)}_i + w_i$. The residual error w_i (and its variance σ_w^2) now replaces v_i (and its variance σ_v^2) wherever referred to in the end notes of Table 1.