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**Abstract**

Focusing on technology spillover from foreign direct investment (FDI) inflows, this paper investigates the welfare implications of financial integration. Calibrations of a neoclassical growth model with international technology diffusion show that when technology catch-up due to FDI inflows is considered, the welfare gains from financial integration substantially increase, which contrasts with the small gains from additional, capital-accumulation effects of financial integration. The estimates suggest that by further enhancing financial integration, emerging Asian economies, such as the People's Republic of China (PRC) and the largest four Association of Southeast Asian Nations (ASEAN) countries, will experience substantial welfare gains.

*Keywords:* Foreign direct investment, financial integration, technology diffusion.

*JEL Classifications:* F21, F36, O33.

## I. Introduction

As emerging economies have deregulated their financial markets over recent decades, there has been a rapid increase in cross-border capital transactions. This continuous financial opening has left emerging market economies more financially integrated with global markets.

Despite the rapid financial developments in emerging markets, few researchers have investigated the welfare implications of financial integration in the regions. This study attempts to fill this gap by estimating the welfare gains from financial integration in emerging Asian economies.

In general, there have been two approaches in the literature attempting to quantify the welfare implications of financial integration. The first approach focuses on the manner by which financial integration enables a pooling of risks across countries. According to this approach, welfare gains are measured by the degree of consumption risk shared through financial integration (Cole and Obstfeld, 1991; Backus et al., 1992). The second approach emphasizes the production side and measures welfare gains by the degree of acceleration in growth due to foreign capital (Gourinchas and Jeanne, 2006). This approach shows in particular that financial integration speeds up capital accumulation through the inflow of foreign capital.

The welfare gains quantified by both approaches are generally small. The gains, reported as the permanent percentage increase in expected consumption equivalent to the increase in welfare gains through financial integration, vary from either less than 0.1% or up to 1%. Reported gains are small largely because the approaches focus mainly on the direct impact of financial integration, such as the sharing of consumption risk and capital accumulation. However, the welfare gains can be larger if we include other, indirect ways through which financial integration contributes to economic growth. In particular, foreign direct investment is considered an important channel for productivity growth through international technology diffusion.

Recent empirical studies show that disparities in the level of technology—and not in human or physical capital—explain the bulk of the difference in income or output per worker across economies (Hall and Jones, 1999; Easterly and Levine, 2001). Theoretical and empirical studies also show that technology diffusion plays an important role for technologically lagging economies to catch up with the global technology “frontier”. In particular, it is believed that inward foreign direct investment (FDI) is an important channel for the diffusion of technology across countries. Based on a simple calibration exercise, Hoxha and Kalemli-Ozcan (2007) recently showed that if technological improvement is also taken into consideration, the impact of capital integration on welfare is about twice as large as otherwise.

The main goals of our study are twofold. First, by using aggregate measures of productivity, we empirically test if FDI flows narrow the technology gap relative to the technologically advanced country. Second, by using our empirical estimates, we document the extent to which welfare in Asia is enhanced by financial integration. By assuming that financial integration leads to welfare improvement—not only through the direct effect of the rapid accumulation of capital but also through the indirect effect of technology diffusion—the calibration exercise is deeply rooted in our empirical findings. While Hoxha and Kalemli-Ozcan’s calibration is based on the findings of microeconomic studies on the impact of FDI on the productivity of firms, our calibration exercise is rooted in the empirical specifications used in our paper, which directly capture the extent of technology catch-up of a developing country with the frontier country.

The remainder of the paper is organized as follows. In section 2, we briefly review the literature on the relation between FDI and technology diffusion and illustrate the main features of the evolution of FDI flows in the data. Section 3 introduces a model of technology diffusion and section 4 empirically tests the effect of FDI on technology catch-up in Asia. Based on the empirical findings in section 4, we calibrate a model in section 5 to investigate the welfare implications of financial integration in Asia. Concluding remarks are in section 6.

## II. FDI and Technology Diffusion

### A. Literature Review

An economy's technological advancement depends on innovations of its own technology and the adoption of technologies produced elsewhere. For countries low on the technology ladder, the imitation and adoption of new technologies provide opportunity for catching up with technologically more advanced countries. This "advantage of backwardness" (Gerschenkron, 1962) implies that the larger the gap in the technology level relative to the advanced country, the faster the lagging economy can catch up with the global technology frontier. Recent growth models, such as those of Grossman and Helpman (1991, Chapters 11 and 12), and Barro and Sala-i-Martin (2004, chapter 8), incorporate the role of technology diffusion in economic growth.

While technology can diffuse through a variety of channels, FDI by multinational corporations (MNCs) is often regarded as one of the most important channels for international technology diffusion. MNCs themselves account for a substantial part of the world's research and development (R&D) investment, and can play a major role in the diffusion of new technology. Recent work on economic growth highlights the role of FDI in the technology diffusion process. Findlay (1978) postulates that FDI increases the rate of technical progress in the host country through a "contagion" effect from the more advanced technology, management practices, and other things etc., used by the foreign firms. Wang (1990) incorporates this idea into a neoclassical growth framework by modeling the increase in "knowledge" as a function of FDI. Borensztein, De Gregorio, and Lee (1998) provide a simple, endogenous growth model in which the more advanced "knowledge" embodied in FDI allows host countries to introduce new varieties of capital goods at lower cost, thereby leading to a higher rate of technology progress.

The adoption of advanced technologies by less-advanced countries is not free and requires effort and capability. Abramovitz (1986) uses the phrase "absorptive capacity" to denote domestic capability for absorbing foreign technology spillover. In particular, the lack of human capacity for adopting new technologies is considered a crucial factor that limits the absorptive capability of a nation. Nelson and Phelps (1966) construct a model in which the facilitation of new knowledge is only possible when a sufficient level of human capital is present in a developing country.

Many recent models also highlight the complementary effects between human capital and technology, as both human capital and technology investment are endogenous choices of society. Redding (1996), for instance, assumes that both forms of investments in human capital and technology (R&D) exhibit pecuniary externalities and are strategic complements. In his model, the incentives to invest in each are interdependent and, thus, multiple equilibria exist: an economy can either fall into a "low-education, low-technology" position or achieve a "high-education, high-technology" position. Acemoglu and Zilibotti (2001) point out that technologies invented in advanced countries are more skill-complementary. Hence, the mismatch between skills and technology leads to differences in productivity even when all countries have equal access to new technologies.

A substantial number of recent papers empirically investigate technology spillover from the presence of foreign firms at the firm, industry or economy levels (see the survey of Lim, 2001). The evidence based on firm- or industry-level data is not yet fully conclusive. Blomstrom (1986) and Kokko (1994) find a positive effect of FDI on productivity at the sectoral level in Mexico. In contrast, based on firm-level data from Venezuela, Aitken and Harrison (1999) find no evidence of a positive spillover from foreign to domestic firms. Similarly, Djankov and Hoekman (2000) find no significant technology spillover between foreign and domestic firms in the Czech Republic.

While these studies focus on the effect of FDI on horizontal spillover, that is, the effect multinational firms have on domestic firms in the same sector, recent studies examine vertical spillover from the presence of multinationals to their local suppliers or customers. For Indonesian and Lithuanian firms, Blalock and Gertler (2004) and Javorcik (2004) find evidence of positive FDI spillover through backward links, that is, spillover from the presence of multinationals in upstream sectors to domestic suppliers of intermediate inputs.

At the economy-wide level, Blomstrom, Lipsey, and Zejan (1994) find FDI has a significant positive effect on growth, but the effect is confined to high-income developing countries. But Blonigen and Wang (2004) provide contrasting evidence that FDI has a significantly positive effect only in less-developed countries.

Some studies find evidence that to have positive technology spillover through FDI the host country must have an absorptive capacity for new technologies that manifest in FDI. Using a panel dataset over 69 developing countries between 1970 and 1989, Borensztein et al. (1998) show that FDI contributes to productivity growth when the host economy has a minimum threshold stock of educated workers as an absorptive capacity for FDI technology spillover. Likewise, Xu (2000), using data on the affiliates of. multinationals in the United States (US), finds positive spillover from US multinationals on productivity growth in host countries that have a minimum stock of human capital. Subsequent empirical studies also establish the importance of various means of domestic absorptive capacities, other than human capital, for technology spillover from FDI. Durham (2002) and Alfaro, Chandra, Kalemli-Ozcan, and Sayek (2004) find that for a broad cross-section of countries, financial or institutional development in host economies of FDI plays an important role in absorptive capacity for technology spillover through FDI and economic growth.

### B. Evolution of FDI Flows

Figure 1 illustrates net FDI inflows as percentage of GDP for the world, Asia, and Latin America. The FDI data are collected from the World Development Indicator (WDI). The WDI reports FDI data for ten East Asian economies: China; Hong Kong; Indonesia; Japan; Korea; Malaysia; Philippines;Singapore;Taipei,China;and Thailand. The WDI's FDI data for Latin America also includes 31 countries. We use simple averages to represent each region.

Until 1985, the world average of net FDI inflows did not vary much, being around 1–2% of GDP. After 1985, it started to increase, reaching about 4% in 1992 and, following the European Exchange Rate Mechanism (ERM) crisis, plummeted to below 2% in 1993. FDI inflows started to increase again and exploded in the mid-1990s. The world average reached over 7% in 2002 and remained over 6% in 2005.

The regional averages of East Asia and Latin America also track the world average quite closely, except during regional crises. When a crisis hit either of the regions, FDI inflows slowed, but eventually bounced back.

Figure 2 illustrates net FDI inflows as a percentage of GDP for subgroups classified by level of income. The WDI classified countries into four groups based on the per-capita level of income: low (50 countries); low-middle (50 countries); upper-middle (35 countries); and high (34 countries).

It is interesting to note that while FDI inflows generally expanded around the mid-1990s, the increase for high-income countries was markedly greater than for other countries.

Figure 3 shows FDI inflows as a percentage of GDP for each East Asian economy. The three bars represent average values for the 1980s, 1990s, and 2000s, respectively. FDI inflows to Hong Kong, China and Singapore, which ranged between 10 and 16%, by far surpass those of other countries. The PRC, Malaysia, and Thailand showed on average, FDI inflows of 2–4 %. In contrast, FDI inflows to Indonesia, Japan, Korea, and the Philippines were much lower and less than 2% throughout the whole period.

## III. A Model of Economic Growth with Technology Diffusion

We introduce a neoclassical growth model with international technology diffusion. We measure the disparities in the level of technology across economies and see how they evolve over time when FDI inflows from an advanced economy have an impact on the technology catch-up of a developing economy.

### A. Growth of a Reference Economy

We use a growth-accounting framework to decompose the level of output per worker into the levels of inputs and labor-augmented productivity. In this framework, the labor augmented productivity measures the level of technology.

We assume a Cobb-Douglas production function, that is,

$$Y = K^{1-\alpha}(AhL)^{\alpha} \tag{1}$$

In Eq. (1), $K$ denotes the stock of physical capital, $h$ is the amount of human capital per labor unit, $L$ is the number of workers, and $A$ denotes a measure of labor-augmented productivity. We assume that each worker inelastically supplies one unit of labor.

The production function is rewritten in terms of the output per worker, $y=Y/L$, as:

$$y = k^{1-\alpha}(Ah)^{\alpha} \tag{2}$$

In Eq. (2), $k$ $(=K/L)$ is the physical capital per worker. Let us assume that the labor share, $\alpha$, is constant across countries. Now, we distinguish between the reference country, which is denoted by an asterisk *, and a representative developing country by a subscript $i$. Then, the ratio of the output per worker between country $i$ and the reference country * is written as:

$$y_i / y^* = (k_i / k^*)^{1-\alpha} \cdot (h_i / h^*)^{\alpha} \cdot (A_i / A^*)^{\alpha} \quad (3)$$

Eq. (3) allows us to decompose the differences in the GDP per worker between the two countries into differences in: the capital-labor ratio; human capital, and labor-augmented productivity.

By taking logarithms of both sides of Eq. (3), the gap in output per worker between country $i$ and country * is written as an additive sum of three components, as shown in Eq. (4).

$$\ln(y_i / y^*) = (1-\alpha)\ln(k_i / k^*) + \alpha \ln(h_i / h^*) + \alpha \ln(A_i / A^*) ] \quad (4)$$

Human capital per worker is assumed to be related to years of schooling as follows.[1]

$$h = e^{\phi(E)} \quad (5)$$

In Eq. (5), $\phi(E)$ measures the efficiency of a unit of labor with $E$ years of education relative to one with no schooling. The derivative, $\phi'(E)$, is the marginal return from an additional year of schooling.

To investigate the dynamics of the reference economy, we explicitly introduce the time dimension in the subscript as follows.

$$Y_t^* = K_t^{*1-\alpha} (A_t^* L_t^* h_t^*)^{\alpha} \quad (6)$$

Now, we assume that labor grows at an annual rate $n$ and the annual labor-augmented productivity growth is $x^*$. In other words,

$$L_t^* = L_0^* e^{nt} \quad (7)$$

and

$$A_t^* = A_0^* e^{x^* t} \quad (8)$$

The production function can be rewritten as:

$$Y_t^* = K_t^{*(1-\alpha)} (A_0^* L_0^* e^{(n+x^*)t})^{\alpha} h_t^{*\alpha} \quad (9)$$

To work with variables that are constant in the long run, we define:

$$\tilde{z} = \frac{Z}{e^{(n+x^*)t}} \quad (10)$$

In Eq. (10), the symbol $\tilde{\bullet}$ denotes that the variable $\bullet$ is being measured in terms of efficiency

1 See Klenow and Rodriguez-Clare (1997), and Hall and Jones (1999).

units. We normalize the initial labor and level of technology to one, that is, $A_0^* = 1$ and $L_0^* = 1$. For simplicity, for the moment, we assume that human capital per worker, $h$, is fixed over time and normalized to one, that is, $h^* = 1$.

Then, the production function Eq. (1) becomes:

$$\tilde{y}_t^* = \tilde{k}_t^{*1-\alpha} \tag{11}$$

In this economy, the stock of capital in terms of efficiency units evolves by new investment less the portions that are due to: population growth (at a rate $n$); the increasing efficiency of labor (at a rate $x$*); and physical depreciation (at a rate $\delta$ ). In other words,

$$\dot{\tilde{k}}_t^* = \tilde{i}_t^* - \left(n + \delta + x^*\right)\tilde{k}_t^* \tag{12}$$

We assume that this economy is self-financed (autarky) and already has reached the steady state. Then, an equilibrium in this economy is characterized by a balanced-growth path in which output, consumption, and per-capita capital grow at a rate $x^*$.

Assuming a CRRA utility function with the relative risk-aversion coefficient, $\gamma$, we can show that, from an optimality condition for consumers, the consumption per efficiency-unit, $\tilde{c}_t^*$, satisfies the following Euler equation:

$$\tilde{c}_t^* = (\beta(1 + r_t))^{-1/\gamma}(1 + x^*)\tilde{c}_{t+1}^* \tag{13}$$

In Eq. (13), $\beta$ is the discount factor and $r_t$ is the real interest rate at time $t$. Hence, at steady state, the real interest is derived as follows.

$$r^* = (1 + x^*)^{\gamma} / \beta \tag{14}$$

The profit-maximization condition of the firm implies that the real interest also should be equal to the marginal productivity of capital less the depreciation rate.

$$r_t = (1 - \alpha)k_t^{*(-\alpha)} - \delta \tag{15}$$

In steady state, since the capital per efficiency-unit is constant, we ascertain the steady-state capital per efficiency-unit as follows.

$$\tilde{k}^* = (\frac{1 - \alpha}{r^* + \delta})^{1/\alpha} \tag{16}$$

We can also derive the steady-state output per efficiency-unit as follows.

$$\tilde{y}^* = (\frac{1 - \alpha}{r^* + \delta})^{(1-\alpha)/\alpha} \tag{17}$$

From Eq. (12), the steady-state investment per efficiency-unit is given by:

$$\tilde{i}^* = \left(n+\delta+x^*\right)\tilde{k}^* = \left(n+\delta+x^*\right)\left(\frac{1-\alpha}{r^*+\delta}\right)^{1/\alpha} \tag{18}$$

Finally, the steady-state consumption per efficiency-unit is:

$$\tilde{c}^* = \tilde{y}^* - \tilde{i}^* = \left(\frac{1-\alpha}{r^*+\delta}\right)^{(1-\alpha)/\alpha} - \left(n+\delta+x^*\right)\left(\frac{1-\alpha}{r^*+\delta}\right)^{1/\alpha} \tag{19}$$

In terms of the efficiency-units, this economy does not grow in the long run. Using lower-case letters for per-capita variables and uppercase letters for aggregate variables, we can easily verify that in the long run,

$$g_{k^*} = g_{y^*} = g_{c^*} = x^* \tag{20}$$

and

$$g_{K^*} = g_{Y^*} = g_{C^*} = n^* + x^* \tag{21}$$

Since we assume that the reference economy has already reached the steady state, the growth rates per worker and the aggregate growth rates are determined by Eqs. (20) and (21), respectively. In other words, the reference economy follows a balanced-growth path, that is, a situation where each variable grows at a constant rate.

### B. Growth of a Developing Country: The Case of a Closed Economy

Now, we turn to the growth of a developing country. Since we consider a representative developing country, we suppress the country-index $i$ in the subscript and instead explicitly introduce the time-dimension, $t$. We assume that the country's rate of growth of labor-augmented technology asymptotically approaches the growth-rate of the reference country, that is,

$$\lim_{t\to\infty} x_t = x^* \tag{22}$$

This assumption is commonly made in the empirical literature on growth. Since the advancement of knowledge is not country-specific in the long run, it is natural to assume that, in the limit, the technology in every country improves at the same rate as that in the reference country. If not, the entire global output will eventually be taken up by a particular country whose productivity grows permanently faster than other countries, which is not likely to happen.

It is important to note that while the limiting growth-rate of technology is the same, the level of technology can differ across countries. Differences in the level of technology in the long run reflect other differences, which are not explicit in the model, such as those of institutions, resource endowment, climate, and so on.[2] However, we will later assume that this long-run level of technology can change as technology diffuses across countries, especially from the

[2] See, among others, Hall and Jones (1999) for reasons that lead to differences in the level of technology across countries in the long run.

frontier country to a developing country. While technology diffusion causes technology to improve faster in the short run, the more important impact occurs in the long run.

We also assume that the steady-state values of all variables in per-efficiency units are the same across countries. This assumption implies that, in addition to the same rate of technological growth, the preference, the rate of population growth, and the rate of depreciation are the same across countries.

If a developing country is closed, the only difference in growth performance between the reference country and the developing country is that the developing country grows faster as long as it approaches the steady state. In the transition, the capital stock in terms of efficiency-units evolves according to the following equation.[3]

$$\dot{\tilde{k}}_t = -(n + x^* + \delta)\alpha(\tilde{k}_t - \tilde{k}^*) \quad (23)$$

Hence, in the vicinity of the balanced-growth path, $\tilde{k}_t$ approaches $\tilde{k}^*$ at a rate that is proportional to its distance from $\tilde{k}^*$. Using the previous expressions for per-capita growth, during the transition period, we have:

$$g_k = x^* - (n + x^* + \delta)\alpha \frac{\tilde{k}_t - \tilde{k}^*}{\tilde{k}_t} \quad (24)$$

By considering that $y=Ak^{1-\alpha}h^{\alpha}$, we can easily show that $\tilde{y}_t$ moves toward $\tilde{y}^*$ at the same rate as $\tilde{k}_t$ moves toward $\tilde{k}^*$. That is,

$$\dot{\tilde{y}}_t = -(n + x^* + \delta)\alpha(\tilde{y}_t - \tilde{y}^*) \quad (25)$$

In a similar way, we can show that during the transition period, the rate of growth of per-capita output is:

$$g_y = x - (n + x^* + \delta)\alpha \frac{\tilde{y}_t - \tilde{y}^*}{\tilde{y}_t} \quad (26)$$

Thus, Eqs. (25) and (26) imply conditional convergence: provided that economies converge to the same steady state, less-developed countries should grow faster. The greater the distance of an economy from the long-run capital per effective labor, the faster the economy grows.

Note that the model allows the level of technology to differ across countries even at the steady state. In other words, while the developing country catches up with the reference country by accumulating capital, the model does not consider another important avenue for catching-up through technology spillover from advanced countries.

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[3] This is derived by a first-order Taylor series approximation of $\dot{\tilde{k}}_t$ around the steady state, $\tilde{k}^*$. See Barro and Xala-i-Martin (2004) and Gourinchas and Jeanne (2006).

## C. Opening Capital Market: Capital Inflows and Technology Catch-up

In the previous case, where the economy's capital market is closed, the developing country grows faster than the reference country as it accumulates capital faster over the period in which it approaches the steady state. Since the economy's capital market is closed, it should approach the steady state by accumulating capital through its own savings. Once it reaches the steady state, however, it grows at the same rate as the rate of labor-augmented technological progress, which is common across countries. Also, note that we allowed the level of technology to differ across countries even at the steady state.

Now we turn to the effects of international financial integration on the economy's growth and welfare. We assume that there are no impediments to financial flows across countries under financial integration. When the developing country opens its capital market to foreign countries, the evolution of the economy experiences two important changes. First, if financial integration is in effect, since the return to capital is greater when the economy is away from the steady state, foreign capital continuously flows in until the economy moves to its steady state. We assume that the capital movements are fully and immediately made. To the extent that this transition period is shortened, the economy grows faster and its welfare improves.[4] Following Hoxa and Kalemli-Ozcan (2007), we call this first channel of financial integration the *capital-accumulation* effect. Note that while the level of technology differs, since capital in efficiency-units is the same across countries at the steady state, no further movements of capital will occur once the economy reaches the steady state.

Second, the developing country grows faster as it narrows the technology gap between itself and the reference country, which is the technologically most enhanced country. Here, we focus on the role of foreign direct investment (FDI), and assume that it is the main channel through which technology diffuses across countries. As capital flows in from the reference country to the developing country, especially in the form of FDI, workers in the developing country have the opportunity to learn the advanced technology. When the labor-augmented technology improves, the growth rate of the economy rises due to not only faster productivity growth but also additional capital inflows, as the level of technology permanently increases. We will call this second channel of financial integration the *technology catch-up* effect. Recently, Hoxha and Kalemli-Ozcan (2007) emphasized this second channel while estimating the welfare effect of financial integration.

How large is the technology catch-up effect? We believe that the answer is entirely an empirical matter. For empirically investigating the extent of the technology catch-up effect, while Hoxha and Kalemli-Ozcan (2007) adopted the value that was estimated from firm-level micro-data, we model the dynamics of the aggregate technology catch-up in the following form.

$$x_t \equiv \frac{\dot{A}_t}{A_t} = x^* + G\left( \ln(A_t / A_t^*), \frac{FDI_t}{K_t}, h_t \right) \qquad (27)$$

In Eq. (27), $G$ is assumed to approach 0 as $t \to \infty$ (or $\lim_{t\to\infty} x_t = x^*$). Since learning takes time, we assume that the growth rate of labor-augmented technology is greater than $x^*$ in the short run and gradually approaches $x^*$ until technology catch-up is completed.

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[4] This is exactly the approach followed by Gourinchas and Jeanne (2006). However, they did not incorporate other benefits of financial integration such as technological diffusion; this lowered their estimate of welfare improvement.

According to Eq. (27), the extent to which the growth-rate of the labor-augmented technology of the developing country exceeds the steady-state growth rate of the labor-augmented technology of the reference country depends upon the technology gap, $\ln(A_t / A_t^*)$, the proportion of the aggregate capital that the FDI capital accounts for, $\frac{FDI}{K}$, and the per-capita human capital of the developing country, $h$. In general, we expect that the following inequalities hold.

$$\frac{\partial G}{\partial(\ln(A / A^*))} < 0 \tag{28}$$

$$\frac{\partial G}{\partial(\frac{FDI}{K})} > 0 \tag{29}$$

and

$$\frac{\partial G}{\partial h} > 0 \tag{30}$$

Eq. (28) implies that, ceteris paribus, the wider the gap, the faster the technology gap narrows.

Note that our specification allows the technology gap to narrow even without FDI inflows. This is clear from Eqs. (27) and (28) that allow the rate of technology improvement to depend upon the technology gap even when $FDI=0$. We believe that it is more realistic to assume that even a closed economy catches up with the country that is at the frontier of technology. For example, if the level of technology is low, it is relatively easier for the closed economy to create innovations by itself without the transmission of technology from other foreign countries. Hence, it is likely that technology improves faster when the level of technology is lower. In other words, the technology growth rate is still negatively associated with the technology gap. However, as will be shown below, the extent to which the gap narrows in the steady state depends only upon the proportion of FDI capital and the level of human capital.

Eq. (29) implies that the rate at which the technology gap closes also depends on the proportion of FDI capital. Finally, Eq. (30) suggests that as the level of human capital of the developing country rises, the country learns faster and, therefore, the technology gap narrows faster.

We will further assume that the following inequality holds.

$$\frac{\partial^2 G}{\partial(\frac{FDI}{K})\partial h} > 0 \tag{31}$$

This inequality suggests that the same increase in FDI capital has a larger impact on the technology catch-up if the level of human capital in the developing country is greater.

Note that, in general, the technology catch-up may not be complete. According to Eq. (27), technology catch-up ceases as $G$ approaches $0$ in the limit. If the technology catch-up ceases, the technology of the developing country advances at the rate x*, which is the rate at which the reference country's technology improves. Given the amount of FDI inflows needed in the steady state and the level of human capital, we can derive the technology gap in the steady state by solving for *G=0*.

$$G\left(\ln(A/A^*), \frac{FDI}{K}, h\right) = 0 \Leftrightarrow \ln(A/A^*) = g\left((\frac{FDI}{K})^*, h\right) \tag{32}$$

In Eq. (32), $(\frac{FDI}{K})^*$ is the proportion of FDI capital in the steady state and $g$ is the explicit solution for $\ln(A/A^*)$, as a function of $\frac{FDI}{K}$ and $h$. Eq. (32) clearly shows that the extent of technology catch-up in the long run depends upon the level of human capital as well as capital inflows.

Unlike the capital-accumulation effect, since the technology catch-up effect requires some time for completely blowing up, the growth rate of output does not immediately reach the steady state and the short run dynamics of technology are characterized as follows.

$$x_t = x^* + G(\ln(A_t / A^*), (\frac{FDI}{K})_t, h_t) \tag{33}$$

## IV. Empirical Tests of the Effect of FDI on Technology Catch-up

### A. Empirical Specification

For the empirical investigation, we set up the following basic specification.[5]

$$d\log TFP_{it} = \alpha_o + \alpha_1 * Gap(TFP_{it}) + \alpha_2 * H_{it} + \alpha_3 FDI_{it} + \alpha_4 * H_{it} * FDI_{it} + \eta_i + \varepsilon_{it} \tag{34}$$

In Eq. (34), $d\log TFP_{it}$ is the (average annual) growth rate of the total factor productivity for country $i$ at time $t$, $Gap(TFP_{it})$ is the initial gap of the level of technology of country $i$ relative to the US, $H$ is the initial stock of human capital, which is measured by the initial-year level of the average number of years of secondary and tertiary education for the population that is aged 15 and above, $FDI$ is a measure of FDI inflows, $\eta$ is an unobserved country-specific effect, $\varepsilon$ is the error term, and the subscripts $i$ and $t$ represent countries and time-periods. We also include period dummies to control for unobserved period-specific fixed effects.

Since we have assumed the Cobb-Douglas production function, the labor-augmented technology, $A_{it}$, is related to the total factor productivity, $TFP_{it}$, in the following way.

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[5] This specification closely follows Borensztein et al. (1998), who test a complementary effect between FDI and human capital in technological diffusion and economic growth. However, while they used GDP growth as an indicator for technological progress, we use direct measures of the technological gap and technological growth by measuring the total factor productivity.

$$A_{it}^{\alpha} = TFP_{it} \quad \Leftrightarrow \quad \alpha \times d\log A_{it} = d\log TFP_{it} \qquad (35)$$
$$\Leftrightarrow \quad \alpha \times Gap(A_{it}) = Gap(TFP_{it})$$

The measure of technological growth is the average annual rate of total factor productivity. To conduct the decomposition of the output, we measure the output per worker by the level of GDP per working-age population aged between 15 and 64. GDP data are taken from the Penn-World Tables (PWT) 6.1 of Heston et al. (2002). We have used the working-age population as a measure of the number of workers, considering that the available cross-country sources of labor forces or employees are less reliable than those of working-age populations. We use the data on physical capital stock, constructed by Lee (2005), by using the perpetual inventory method that is based on aggregate investment data in the Penn-World Tables (PWT) 6.1. For the labor-share parameter, $\alpha$, we assume a value of 0.65. To construct a measure of the stock of human capital, we assume that in Eq. (5), $\phi(E)$ is linear and the average marginal return from an additional year of schooling is 7%, as in Bernanke and Gurkaynak (2001) and Bosworth and Collins (2003).[6] The years of schooling are measured by the average years of schooling for the population aged 15 and over, as constructed by Barro and Lee (2001).

The gap in technology is measured by the log difference in the level of total factor productivity between each country and the US, as constructed by Lee (2005). For our preferred approach of representing FDI flows as a proportion of the aggregate capital, we would need to convert one of these values into the units of the other. Instead, in the empirical setting, we characterize FDI flows as a proportion of GDP, averaged over a five-year period. Further, note that the theory presented in the previous section implies that the extent of technology spillover is more associated with the ratio of FDI capital stock, not FDI flows, to total capital stock. Hence, we need to switch FDI flows to FDI stock as well. The ratio of FDI flows to GDP can be converted to FDI stock as a share of the total capital stock in the following way.

$$\frac{FDI_t}{k_t} = \frac{FDI_t^F}{y_t}\frac{FDI_t}{FDI_t^F}\frac{y_t}{k_t} = (\frac{FDI}{y})^*(\frac{FDI}{FDI^F})(\frac{r^*+\delta}{1-\alpha}) \qquad (36)$$

In Eq. (36), $FDI_t$ and $FDI_t^F$ are FDI stock and FDI flows at time $t$, respectively. The second equality holds at steady state. $\frac{FDI}{FDI^F}$ is the ratio of FDI stock to FDI flows at steady state.

Our regression of specification (34) applies to a panel set of cross-country data over six five-year periods from 1970 to 2000, which correspond to the intervals, 1970–75, 1975–80, 1980–85, 1985–90, 1990–95, and 1995–2000. Some studies have used annual observations but the high-frequency variations of TFP (total factor productivity) are more likely to result from business fluctuations than from technological change. Others have used cross-sectional regressions, using period-average data, but they are more likely subject to bias from omitted country-specific variables.

Our panel consists of 491 observations ranging from a minimum of 68 countries in the 1970–75 period to a maximum of 88 countries in 1985–90 and 1990–95. Table 1 summarizes descriptive statistics of the data.

6 The results are not sensitive to alternative assumptions.

The empirical technique we use here is the fixed-effects estimation to control for unobservable country fixed-effects. The estimation also uses instrumental-variable (IV) regressions to control for the potential endogeneity bias of FDI.

### B. Estimation Results

Columns (2.1)~(2.3) of Table 2 summarize the regression results from the fixed-effects OLS panel estimation. Regression 2.1 shows that the coefficient of the technology gap is statistically significant, with the expected negative sign, indicating that more technologically backward countries experienced faster technological progress over time. The average years of schooling at secondary and tertiary levels has a positive, though not strong, effect on TFP growth. FDI also has a positive effect on technology growth, but the coefficient is only marginally significant at the 10% level. If viewed causally, the estimated coefficient, 0.099 (at a standard error of 0.055), implies that an increase of 0.023 per year in the ratio of FDI to GDP (about one standard deviation) leads to an increase in the growth rate of TFP of about 0.2 percentage points per year.

The theory outlined above suggests that the effect of FDI on technological growth interacts with the level of human capital stock. The specification in regression 2.2 replaces the FDI variable by the interactive term between FDI and human capital. The interactive term is positive and statistically significant. Regression 2.3 extends this specification by adding the FDI variable. In this way, we test if FDI affects technological growth by itself or through its interaction term. The result shows that the interaction term is positive and statistically significant, while the coefficient of FDI is negative and insignificant. The regression coefficients indicate that all countries with post-primary school attainment above 0.32 years will benefit from FDI. In our sample, 362 out of the total 491 (country-year) observations satisfy this threshold. The estimates indicate that, for instance, in an economy with a post-secondary attainment of 2.2 years (which is the average value for the sample countries in 2000), an increase of 0.023 per year in the ratio of FDI to GDP (equivalent to one standard deviation) raises the growth rate of TFP of the host economy by about 0.5 percentage points per year.

### C. Instrumental Variables Estimation

While the estimation results in section B are indicative, they do not necessarily mean that more FDI raises the growth rate of TFP; it is possible that the causality runs in the opposite direction, that is, FDI flows into those countries that exhibit fast technological improvement. To control for this endogeneity problem, we use instrumental variables (IV) panel estimation by using as instruments for FDI the lagged value of FDI, the log value of GDP, and a measure of nominal exchange-rate volatility.[7]

The results of the IV estimation are reported in Columns (2.4)~(2.6) of Table 2. In regressions 2.4 and 2.5, the FDI variable and the product of the FDI and human-capital terms individually enter positively and are statistically significant. The coefficients are an order of magnitude larger in IV panel estimation than in the fixed-effects panel. The specification of regression 2.6 includes two variables together. The result shows that the interaction term is positive, though marginally significant, while the coefficient of FDI is insignificant. The FDI variable and its interaction term with human capital are jointly significant (p-value = 0.004). Hence, FDI has a

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[7] Most previous studies use lagged values of FDI flows as instruments. Wei (2001) finds that a measure of nominal exchange-rate volatility has a significant explanatory power on the variation of FDI inflows. The nominal exchange-rate volatility is measured by the coefficient of variation of the nominal exchange-rate over the time-interval.

positive effect on TFP growth and the magnitude of the effect depends on the stock of human capital that is available in the host economy. The point estimate of the interactive term indicates that in a country with an average stock of human capital of 2.2 years, an increase of 0.023 per year in the ratio of FDI to GDP raises the growth rate of TFP by about 1.1 percentage points per annum year, which is about twice as large as in the OLS case.

## D. Estimation with FDI Stocks

The model outlined in Section 3 suggests that the effect of FDI on productivity growth is captured by FDI stocks rather than FDI flows. In fact, it is not expected that technology spillover is positively related to the current FDI flows alone. Given that it takes time to learn new technology, the existing FDI stock is also expected to continuously transmit new technology. Our empirical specifications so far are inconsistent with the model in this sense because we have adopted FDI flows as an explanatory variable.

In this section, we remedy this problem by replacing the FDI-flow variable with the FDI-stock variable in the empirical analyses. In Table 3, we report the results. Regression results 3.1-3.3 are based on OLS estimation and 3.4-3.6 are based on IV estimation.

In regression 3.1, which shows the basic estimation results, the technology gap enters statistically significantly, with the expected sign. The coefficient of schooling is marginally significant at the 10% level, but the coefficient of the FDI-stock variable is not statistically significant. The specification in regression 3.2 replaces the FDI variable by the interactive term between FDI and human capital. The interactive term is positive and statistically significant at the 5% level. Regression 3.3 extends this specification by adding the FDI-stock variable. In this way, we test if FDI affects productivity growth by itself or through its interaction term. The result shows that the interaction term is positive and statistically significant at the 10% level, while the coefficient of FDI is negative and insignificant. Though the evidence is somewhat weaker, we reconfirm the hypothesis that FDI contributes to productivity growth by interacting with the stock of human capital. The estimated coefficients imply that in a country with an average stock of human capital of 2.3 years, an increase of 0.15 per annum in the ratio of FDI-stock to GDP raises the growth rate of TFP by about 0.4 percentage points per annum in the 1970-2000 period.

In regressions 3.4-3.6, we report the estimation results with the same specification as 3.1-3.4, but with the` instrumental-variables technique. The instrumental variables are constructed in the same way as in the IV estimation with the FDI-flow variable, reported in Table 3. The results are generally consistent with those of the OLS estimation. When either the FDI stock or the interactive term between FDI stock and human capital is included, it is significant at the 5% level. However, when both are included in regression 3.6, the associated coefficients are both positive but insignificantly different from zero.

Overall, we conclude that our results do not change even if we use the FDI-stock variable rather than the FDI-flow variable. Interestingly, the estimated coefficients of other variables change little, with only the coefficient of the FDI-stock variable scaled down by a factor of approximately 10. This reflects the fact that the FDI-flow variable is approximately one tenth of the FDI-stock variable in the data.

### E. Checks for Robustness and Additional Exercises (Summary of Findings That Are Not Reported in the Tables)

We have carried out a broad set of empirical exercises that investigate the robustness of our results. We briefly summarize the results.[8]

(i) *Consideration of only the years 1970–95*. The results are stronger. The interactive term becomes significant at a 1% level in IV estimation. If we use a more balanced dataset, for example., a sample of countries that has complete TFP data, the results are the same.

(ii) *Restriction to Organisation for Economic Co-operation and Development (OECD) countries without high incomes.* The results are qualitatively the same, although they become weaker.

(iii) *Effects in East Asia*. We have examined whether there were differences for East Asia in the effects of FDI on technology progress by including multiplicative terms of FDI variables with East Asia region-dummies. There is no evidence that the effects are different for East Asia.

(iv) *Addition of other missing variables*. The possible determinants of TFP include government consumption, trade openness, institutions, and financial depth. When we add all these variables to the regressions, the main results are qualitatively the same. However, the sample size shrinks.

(v) *Consideration of differing absorptive capacities*. We try other measures such as institutional quality (a measure of property rights or the 'investment climate'), openness, and financial depth. There is evidence that institutional quality*FDI has some significance. However, there are some problems; in particular, the data are available only from 1982.

## V. Estimation of the Welfare Effects of Financial Integration

Based on the growth model and estimation results of the previous sections, we can undertake a calibration exercise to assess the welfare effects of financial integration. As explained in section 3, if a country opens up the capital market, the welfare of the country increases through two channels: the capital-accumulation effect and the technology catch-up effect. In this section, we apply our methodology to East Asian countries and investigate how the welfare level improves as financial markets are completely integrated with the financial market of an advanced economy.

<u>Benchmark case</u>

In the benchmark case, we assume that financial markets are completely closed. Since the economy relies only on domestic savings, it takes time for the economy to reach the steady-state. We can think of two versions of the benchmark case. In the first version, there is no technology catch-up, besides the closed nature of financial markets. This version of the

[8] The results are available upon request.

economy was described in detail in section 3.B. However, as explained earlier, it is more realistic to assume that even a closed economy catches up with the country at the technology frontier. In the second version of the benchmark case, the technology is assumed to evolve following the same dynamics that are estimated by Eq. (34). where the level of FDI is set to zero. As explained in section 3, if a country opens its capital market, the welfare level of the country increases through two channels: the capital-accumulation effect and the technology catch-up effect. We consider three cases of full financial integration.

Case 1 (the capital-accumulation effect)
We assume that capital movements from foreign countries are immediately made. However, there is no additional technology catch-up due to the inflow of foreign capital.

Case 2 (the technology catch-up effect with 40% FDI inflows)
We allow additional technology catch-up through FDI inflows. However, the FDI stock is assumed to constitute only 40% of the total foreign capital.[9] Hence, the extent of technology catch-up is low.

Case 3 (the technology catch-up effect with 100% FDI flows)
As in Case 2, we allow additional technology catch-up through FDI inflows. The FDI stock is assumed to constitute 100% of the total foreign capital. Hence, the extent of technology catch-up is high.

In Table 4, we report the calibration results for eight Asian countries. In calibrating the model, the estimated coefficients reported in regression specification 2.3 in Table 2 are used to set the parameter values, except that the coefficient of FDI flows is scaled down by a factor of 10. This modification reflects the fact that while the empirical specification in Table 2 is based on FDI flows, the model specification is based on the FDI-stock variable rather than the FDI-flow variable (see Eq. (36)).[10]

While we devised two versions of the benchmark case, the welfare implication of additional technology improvement due to financial integration is the same, irrespective of which version we use as a benchmark. However, for evaluating Case 1, it is easier to use the first version of the benchmark. In other words, we focus on the capital-accumulation effect without worrying about technology changes by assuming the absence of technology catch-up both before and after financial integration. In contrast, it is easier to use the second version of the benchmark case while evaluating Cases 2 and 3. In this instance, the additional technology catch-up due to financial integration is defined by comparing the technology catch-up under complete financial integration to the technology catch-up that prevails in the absence of foreign capital inflow. The extent of technology catch-up when capital integration is complete can be estimated from Eq. (34) by substituting the appropriate value of FDI that is supposed to flow in.

On the other hand, the extent of technology catch-up when there is no financial integration is obtained by setting FDI to zero. According to Eq. (34), a low-technology country catches up with the country at the technology frontier as long as the technology gap is less than 1. Therefore, when we evaluate Cases 2 and 3, the additional welfare improvement due to financial

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9 As noted in Hoxha and Kalemli-Ozcan (2007), FDI flows constitute about 40% of total capital flows.

10 The reason why we report the calibration results on the basis of estimates of the flow specification is that the FDI-stock values are much more subject to measurement errors. Our results do not significantly change if we use the estimated coefficients of the regression specification 4.3 where the FDI-stock variable is used, in which case the coefficients do not need to be scaled down.

integration is captured by using the second version of the benchmark case.

It is important to note that as long as technology improves, additional FDI continuously flows in. For example, in Korea, the initial capital per efficiency-unit is 93% of its steady-state value. This is because, while the per-capita initial capital is low, since the level of technology is also low, the initial capital per efficiency-unit becomes higher at the level close to its steady-state value. Hence, the initial inflow of FDI is small. However, as technology subsequently improves, the capital per efficiency-unit is lowered. In other words, the capital per efficiency-unit becomes lower than its steady-state value. In this case, we assume that foreign capital immediately flows in again so that the capital per efficiency-unit is equalized to its steady-state value. In other words, we assume that foreign capital flows in not only at the beginning of capital liberalization, but also continuously flows in as long as technology subsequently improves. This additional FDI further improves technology and the improved technology induces further FDI inflows and so on.

The calibration results are reported in Table 4. For the calibration of the model, we assume that any country's steady-state values of $\tilde{k}$ and $\tilde{y}$ are equivalent to those of the US. The levels of per-capita output and capital for each country in 2000, as a ratio of the country's level to that of the US, are reported in rows 1 and 2. In terms of the output per-capita, Hong Kong, China (0.73) and Singapore (0.72) are the most advanced countries, followed by Korea (0.47) and Malaysia (0.32). Interestingly, however, the level of per-capita capital is much higher in Singapore (1.10) than in Hong Kong, China (0.80). In fact, it is higher in Singapore than even the US

We convert the ratio of per-capita capital into the ratio of capital per efficiency-unit in the following way.

$$\frac{\tilde{k}_i}{\tilde{k}^*} = \frac{k_i / A_i}{k^* / A^*} = \frac{k_i}{k^*}\frac{A^*}{A_i} = \frac{k_i}{k^*}\left(\frac{TFP^*}{TFP_i}\right)^{1/\alpha} \qquad (37)$$

In row 3 of Table 4, we report the ratio of the capital per efficiency-unit for each country. If we take into consideration the productivity level (0.88), the level of capital per efficiency-unit in Singapore becomes much higher than that in the US. In Korea, while the per-capita capital (0.53) is much lower, since the productivity level is also low (0.57, as reported in row 5), its capital per efficiency-unit is higher than that in the US We interpret this as evidence that capital markets in these two countries are completely open to global markets. Since no additional foreign capital is supposed to flow in these two countries, the benefit of financial integration is nil. In the other countries, the level of capital per efficiency-unit is lower than that in the US If these countries further open their capital markets, we will assume that the ratio becomes one, which is the source of welfare improvements that arise from financial integration.

The level of human capital in 2000 is reported in row 4. It is highest in Korea, followed by Hong Kong, China and the Philippines. For the calibration of the model, we assume that the level of human capital is fixed throughout at the level of 2000.

The initial level of TFP ("Initial gap"), which is constructed as the ratio of each country's TFP level to that of the US, is reported in row 5. The initial TFP level is also the highest in Hong Kong, China and Singapore, followed by Malaysia and Korea.

As explained earlier, in the second version of the benchmark case, the developing country can catch up with the reference country in terms of technology, without FDI flows. In this case, the technology evolves along the same dynamics that are estimated by Eq. (34), where the level of FDI is set to zero. We can also calculate the steady state of the technology gap, when FDI flows are zero, by solving the following equation.

$$\ln\left(A / A^{*}\right) = g(0, h) \tag{38}$$

We can easily show that the steady-state level of technology is lower than that under positive FDI flows.

Depending on the assumption about the share of FDI flows (either 40% or 100%) of the total foreign capital, we report two steady-state levels of the technology gap: "steady-state gap (40%)" and "steady-state gap (100%)". As expected, generally, the higher the steady-state level of technology, the lower the initial level of capital per efficiency-unit is. For example, the initial levels of capital per efficiency-unit are 0.33 and 0.36 in Indonesia and The PRC, respectively, and the technology increases to 0.58 if the two countries do not open the capital markets. If they completely open the capital markets, the steady-state level of technology increases to 0.67 and 0.68 (40% FDI) or 0.82 and 0.86 (100% FDI), respectively. While Indonesia's initial level of capital per efficiency-unit is lower, implying more FDI inflows, the PRC's technology in the steady state after financial integration is higher because the PRC's human capital is greater. If the two countries do not open the capital markets, the steady-state level of technology stops at 0.58 for both. In contrast, since no foreign capital flows in either Korea or Singapore, there is no additional technology improvement even if capital integration is complete in these countries. Hong Kong, China also exhibits the absence of additional technology catch-up following financial integration. In the remaining five countries, the technology improves after financial integration. In Figure 4, the evolution of technology in these countries is described. Figure 4.A is the case where FDI flows constitute 40 % of foreign capital and Figure 4.B is the case where FDI flows constitute 100 % of foreign capital. In all these countries, the steady-state level of technology is higher in the latter case than in the former case.

We report three measures of the welfare improvement that arises from financial integration. The welfare improvements in Cases 1, 2, and 3, are denoted as "Welfare improvement 1," "Welfare improvement 2," and "Welfare improvement 3," respectively. The welfare gains from financial integration are reported as the permanent percentage increase in the expected consumption that is equivalent to the increase in welfare gains from financial integration in each case.

As argued by Gourinchas and Jeanne (2006), even for countries whose initial capital per efficiency-unit is quite low, if there is no additional technology improvement, the benefit from financial integration is generally low. For example, in Case 1, the welfare gains for Indonesia, which is the country with the lowest initial level of capital per efficiency-unit, are 4.8%. For other countries, the welfare gains are even lower. In Korea and Singapore, the welfare gains are nil.

If we allow for FDI's role in technology improvement, the welfare gains become larger. In Case 2, the welfare gains are about 1.5 to 4 times higher in the PRC, Indonesia, Malaysia, and the Philippines. In Case 3, where FDI constitutes 100 % of foreign capital, welfare gains are much larger. The welfare gains in the PRC, Indonesia, Malaysia, and the Philippines are 23.5%, 22.0%, 21.2%, and 25.3%, respectively. These values are substantially higher than those obtained without additional technology improvement.

## VI. Conclusion

Using data from 88 countries for the period 1970–2000, we find evidence that inward FDI is an important channel for international technology diffusion among countries. Our result also confirms a strong complementary effect between FDI and human capital.

Based on our empirical results, we calibrate a simple model and apply it to Asian countries. Our calibration results illustrate that welfare gains from financial integration are not large if we do not consider the technology catch-up that is due to FDI inflows. This is true even for those countries where the initial level of capital per efficiency-unit is low. However, if additional capital contributes to technology spillover, the welfare gains substantially increase for those countries whose initial level of capital per efficiency-unit is low. Given that there is strong evidence that FDI is an important channel for the transmission of technology, overall our results suggest that, by enhancing further financial integration, there is some room for welfare improvement in Asian countries.

Some caveats are in order while interpreting our results. First, our model assumes that capital movements are completely made until the steady state is reached. But if there are other impediments (not present in the financial market) that prevent capital movements, the measures of welfare improvement can be substantially reduced. Second, our calibrations are based on the assumption that all FDI inflows come entirely from the advanced economy, which has the highest level of technology. However, FDI can come from various source countries. For instance, regional financial integration would have different welfare implications compared to global integration. Third, our calibration is based on a one-sector model. Recently, on the basis of a multi-sector model, Caselli and Feyrer (2007) showed that the physical rate of return to capital is almost equalized across countries. They argue that for those countries with low levels of capital, the rate of return is low due to the high costs of implementing capital. If this is the case, capital movements will be minimal even if the capital market is completely open, which in turn implies much less welfare improvement.

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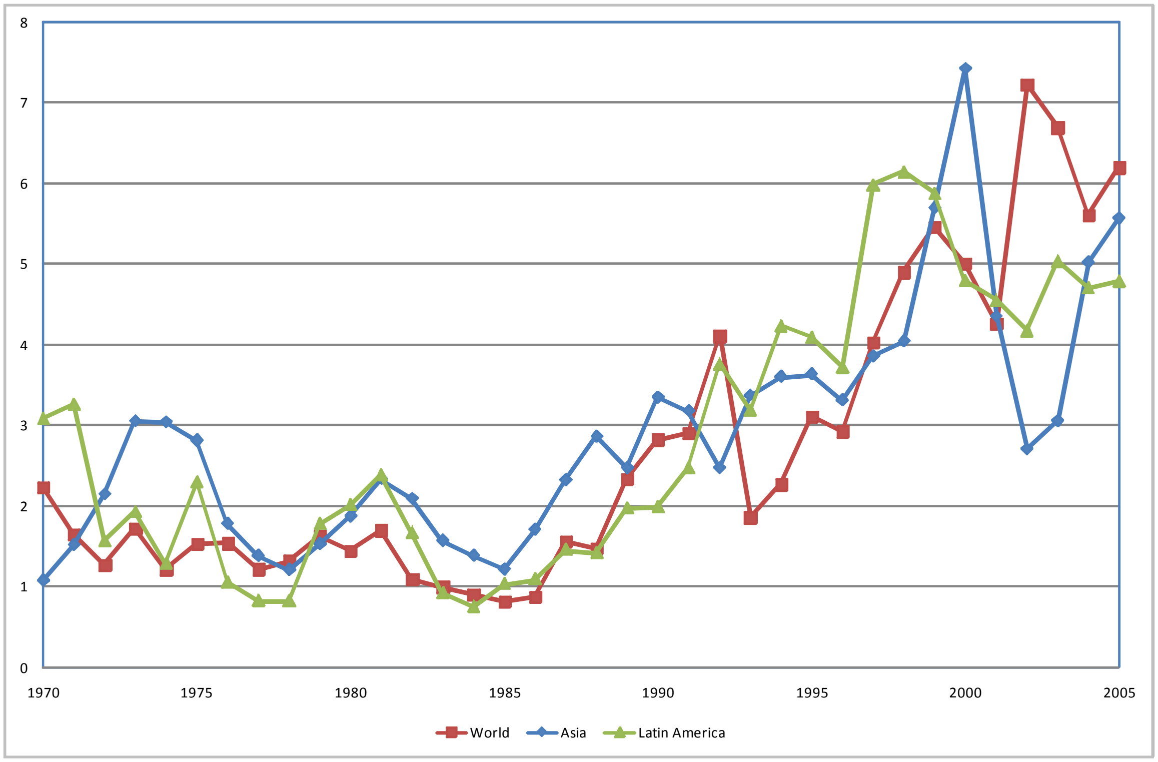
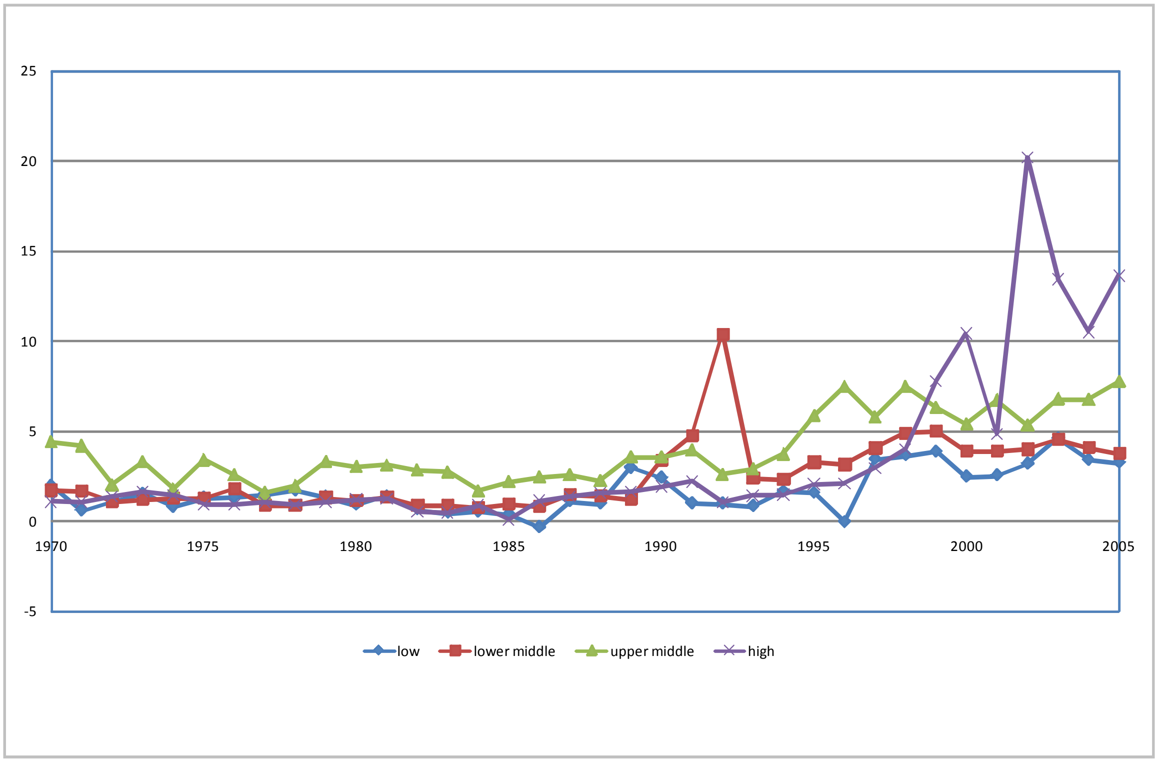
**Figure 1: The FDI Inflows** (% of GDP)




Note: The foreign direct investment (FDI) flows and gross domestic product (GDP) are measured in current US dollars and the ratios are constructed by dividing the value of FDI flows by the value of GDP for each country. The world, Asia, and Latin American values are constructed by simple averages across the countries that belong to the respective regions.

Source: World Bank, World Development Indicator.

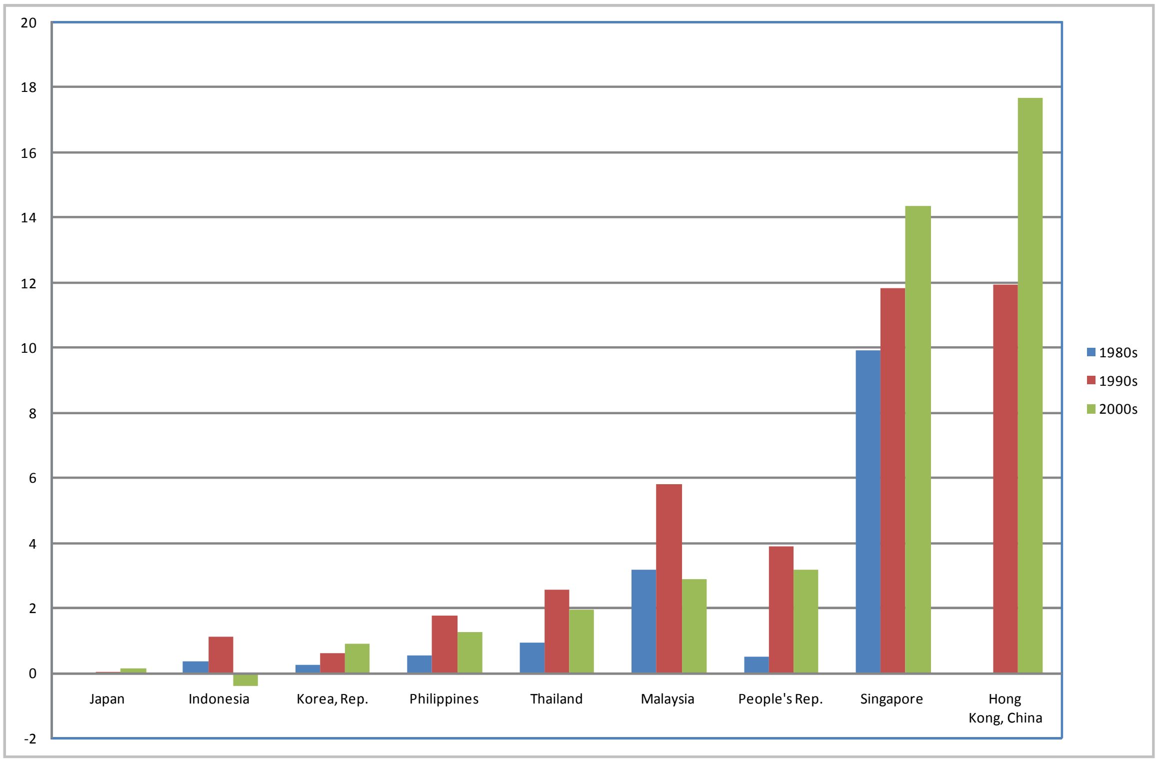
**Figure 2: The FDI Inflows** (% of GDP) **by Income Level**




Note: Countries are classified into four groups based on the per-capita income level: low (50 countries); low-middle (50 countries); upper-middle (35 countries); and high (34 countries). This figure plots the average net inflows (% of gross domestic product) of foreign direct investment in each group.

Source: World Bank, World Development Indicator.

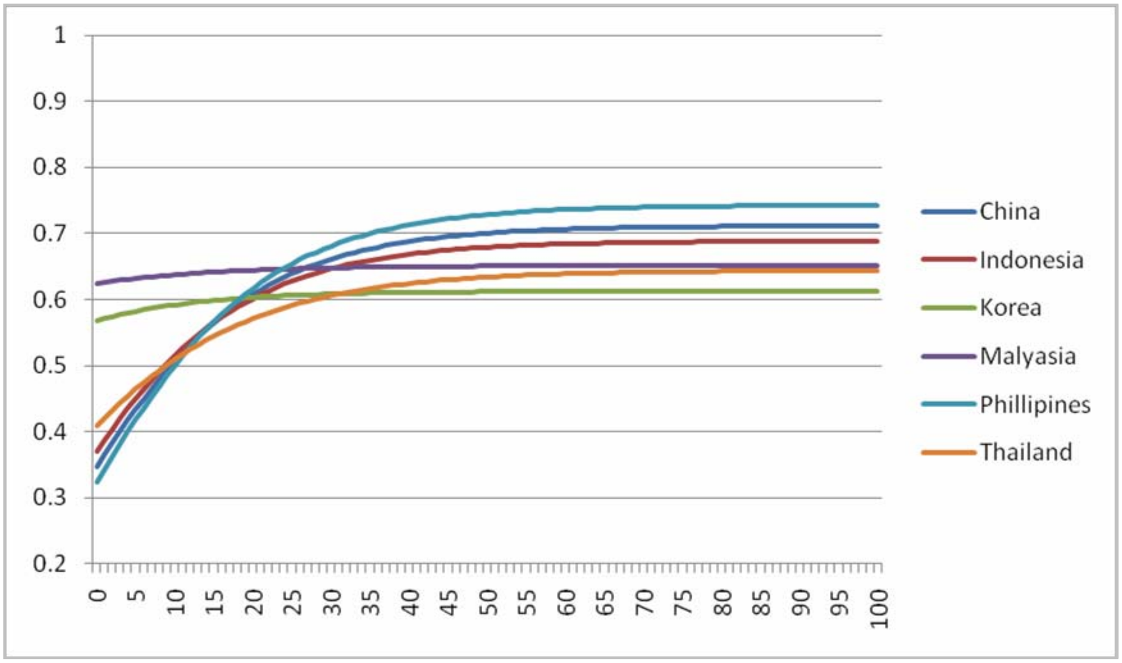
**Figure 3: FDI Inflows** (% of GDP) **in East Asia**




Note: The simple average in the corresponding decade is reported.

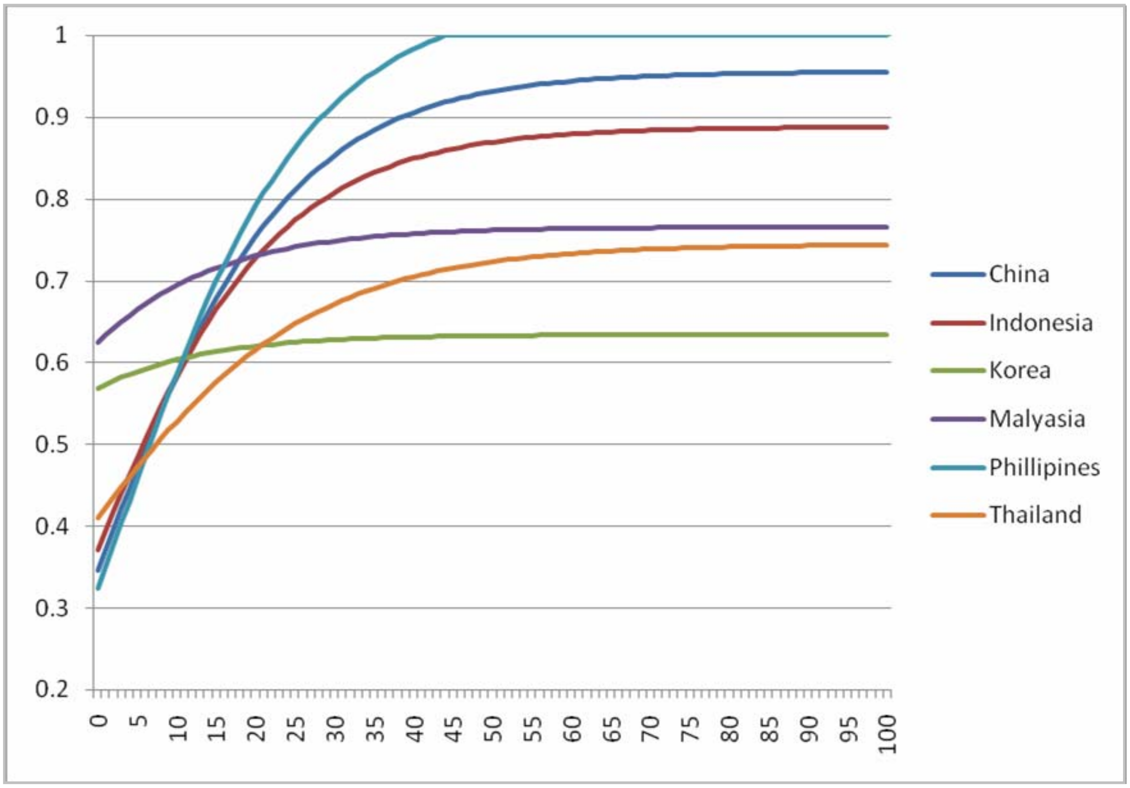
**Figure 4: Technology Catch-up**

**A. FDI Constitutes 40% of Capital Inflows**




Note: Technology catch-up is modeled as in Eq. (34) in the main text. We use the estimated coeffcients of specfication (2.6) in Table 2. The initial TFP is measured by using the constructed data on capital stock, output, labor, and human capital for each country. We assume that, as a country opens its capital market, foreign capital immediately flows into that country, and that foreign direct investment flows constitue 40% of the foreign capital inflows.

**B. FDI Constitutes 100% of Capital Inflows**




Note: We assume that FDI flows constitute 100% of the foreign capital inflows. For other details, see the notes for Table A.

**Table 1: Descriptive Statistics**

| Period | TFP growth (annual average) | TFP gap (initial year) | FDI to GDP (period average) | Schooling year (secondary and higher) | No of Obs. |
|---|---|---|---|---|---|
| 1970–75 | 0.0027 | -0.637 | 0.009 | 0.91 | 68 |
| | (0.0254) | (0.389) | (0.018) | (0.97) | |
| 1975–80 | 0.0025 | -0.602 | 0.009 | 1.19 | 83 |
| | (0.0275) | (0.385) | (0.0105) | (1.05) | |
| 1980–85 | -0.0004 | -0.556 | 0.010 | 1.50 | 86 |
| | (0.0204) | (0.395) | (0.014) | (1.23) | |
| 1985–90 | 0.0017 | -0.657 | 0.009 | 1.62 | 88 |
| | (0.0237) | (0.420) | (0.016) | (1.23) | |
| 1990–95 | 0.0011 | -0.708 | 0.016 | 1.87 | 88 |
| | (0.0280) | (0.449) | (0.023) | (1.33) | |
| 1995–2000 | 0.0095 | -0.720 | 0.032 | 2.09 | 78 |
| | (0.0175) | (0.471) | (0.037) | (1.38) | |
| All periods | 0.0021 | -0.646 | 0.014 | 1.55 | 491 |
| | (0.0242) | (0.422) | (0.023) | (1.27) | |

Note: The rate of growth of total factor productivity (TFP) is based on the growth accounting that is described in the text. The gap in technology is measured by the log of the difference in the level of total factor productivity between each country and the US The sample consists of 491 observations of the panel data over six five-year periods (1970 to 2000) that are used for the regressions in Table 2.

**Table 2: FDI and Rate of Growth of TFP**

(Panel of six five-year periods over 1970-2000: Number of observations (N) =491)

| Regression No. | OLS Estimation 2.1 | 2.2 | 2.3 | IV Estimation 2.4 | 2.5 | 2.6 |
|---|---|---|---|---|---|---|
| TFP gap | -0.0745 | -0.0762 | -0.0768 | -0.0682 | -0.0768 | -0.0727 |
| | (0.0074)*** | (0.0072)*** | (0.0073)*** | (0.0082)*** | (0.0074)*** | (0.0084)*** |
| Schooling | 0.0055 | 0.0035 | 0.0030 | 0.0077 | 0.0008 | 0.0032 |
| | (0.0035)* | (0.0034) | (0.0036) | (0.0038)** | (0.0039) | (0.0044) |
| FDI | 0.0985 | | -0.0396 | 0.5544 | | 0.2785 |
| | (0.0545)* | | (0.0797) | (0.1821)*** | | (0.2095) |
| FDI*Schooling | | 0.1046 | 0.1237 | | 0.2887 | 0.2185 |
| | | (0.0356)*** | (0.0524)** | | (0.1076)*** | (0.1167)* |
| R2 | 0.253 | 0.262 | 0.263 | 0.269 | 0.268 | 0.269 |

Note: The estimation in Columns (2.1)-(2.3) is based on OLS estimation with fixed effects, controlling for unobserved country-specific factors. The estimation in columns (2.4)~(2.6) adopts instrumental variables (IV) panel estimation with fixed effects, using as instruments for FDI: the lagged value of FDI; the log value of total GDP; and a measure of the nominal exchange-rate volatility. The interactions of these variables with the schooling variable are used as instruments for the FDI*schooling variable. Year-dummies and constant terms are included and not reported. Standard errors are reported in parentheses. One, two, and three * indicate significance at the 10%, 5%, and 1% levels, respectively.

**Table 3: FDI Stocks and TFP Growth Rate: Fixed Effects OLS and Instrumental Variables Estimation**
(Panel of six five-year periods over 1970-2000: Number of observations (N) =488)

| | OLS Estimation | | | IV Estimation | | |
|---|---|---|---|---|---|---|
| | **3.1** | **3.2** | **3.3** | **3.4** | **3.5** | **3.6** |
| TFP gap | -0.0750 | -0.0757 | -0.0757 | -0.0835 | -0.0783 | -0.0830 |
| | (0.0073)*** | (0.0073)*** | (0.0073)*** | (0.0124)*** | (0.0076)*** | (0.0110)*** |
| Schooling | 0.0060 | 0.0044 | 0.0041 | 0.0137 | 0.0016 | 0.0089 |
| | (0.0034)* | (0.0035) | (0.0036) | (0.0067)** | (0.0038) | (0.0066) |
| FDI | 0.0153 | | -0.0054 | 0.3220 | | 0.2260 |
| | (0.0127) | | (0.0188) | (0.1615)** | | (0.1478) |
| FDI*Schooling | | 0.0148 | 0.0169 | | 0.0480 | 0.0281 |
| | | (0.0073)** | (0.0105)* | | (0.0179)** | (0.0221) |
| R2 | 0.007 | 0.007 | 0.007 | 0.006 | 0.007 | 0.007 |

Notes: The estimation is based on panel estimation with fixed effects, controlling for unobserved country-specific factors. Year-dummies and constant terms are included and not reported. The FDI-stock variable is measured by the ratio of the stock of direct investment liabilities to GDP. Columns (3.1)-(3.3) are estimated by fixed-effects OLS and columns (3.4)~(3.6) by fixed-effects instrumental variables. Standard errors are reported in parentheses. One, two, and three * indicate significance at the 10%, 5%, and 1% levels, respectively.

**Table 4: Welfare Implications of Financial Integration**

| | China, People's Rep. of | Hong Kong, China | Indonesia | Korea, Rep. of | Malaysia | Philippines | Singapore | Thailand |
|---|---|---|---|---|---|---|---|---|
| $y / y^*$ | 0.11 | 0.73 | 0.11 | 0.47 | 0.32 | 0.11 | 0.72 | 0.2 |
| $k / k^*$ | 0.08 | 0.8 | 0.08 | 0.53 | 0.3 | 0.08 | 1.1 | 0.26 |
| $\tilde{k} / \tilde{k}^*$ | 0.36 | 0.94 | 0.33 | 1.19 | 0.59 | 0.40 | 1.32 | 0.93 |
| $h$ | 1.53 | 1.92 | 1.37 | 2.09 | 1.58 | 1.74 | 1.6 | 1.53 |
| Initial gap | 0.35 | 0.90 | 0.37 | 0.57 | 0.62 | 0.32 | 0.88 | 0.41 |
| Steady-state gap (0%) | 0.58 | 0.90 | 0.58 | 0.60 | 0.62 | 0.59 | 0.88 | 0.58 |
| Steady-state gap (40%) | 0.68 | 0.90 | 0.67 | 0.60 | 0.65 | 0.70 | 0.88 | 0.59 |
| Steady-state gap (100%) | 0.86 | 0.90 | 0.82 | 0.60 | 0.76 | 0.90 | 0.88 | 0.60 |
| Welfare improvement 1 | 3.2% | 0.3% | 3.5% | 0 | 1.6% | 2.9% | 0 | 0.2% |
| Welfare improvement 2 | 19.1% | 0.3% | 16.7% | 1.4% | 4.3% | 22.3% | 0 | 6.9% |
| Welfare improvement 3 | 54.3% | 0.3% | 46.5% | 3.6% | 21.7% | 63.4% | 0 | 18.2% |

Notes: The steady state values, $\tilde{k}$ and $\tilde{y}$, are assumed to be equivalent to those of the United States (US) "Initial gap" represents the initial technology gap, which is constructed as the ratio of each country's factor productivity (TFP) level to the US' TFP level in 2000. "Steady-state gap (0%)" represents the level of steady-state technology when the economy is closed. Depending on the assumption about the proportion of the total foreign capital that comprises foreign direct investment (FDI) flows (either 40% or 100%), we report two steady-state levels of technology: "Steady-state gap (40%)" and "Steady-state gap (100%). We report three measures of the welfare improvement that arises from financial integration, which is expressed as the permanent percentage increase in the expected consumption that is equivalent to the increase in welfare gains from financial integration in the year 2000. "Welfare improvement 1" is the case where there is no technology catch-up and financial integration has only the additional capital-accumulation effect. "Welfare improvement 2" is the case where technology catch-up is considered, but FDI flows constitute only 40% of foreign capital. Finally, "Welfare improvement 3" is the case where technology catch-up is considered and FDI flows constitute 100% of foreign capital.

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About the paper

In this paper, Jong-Wha Lee and Kwanho Shin investigate the impact of technology spillover from foreign direct investment inflows on financial integration. They find welfare gains can be had through greater financial integration in emerging Asian economies, such as the People's Republic of China and the four largest Association of Southeast Asian Nations.

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