Technology Adoption in Follower Countries
: With or Without Local R&D Activities?

by
Yasuyuki Todo

May 2004

Economic and Social Research Institute
Cabinet Office
Tokyo, Japan
Technology Adoption in Follower Countries: With or Without Local R&D Activities?

Yasuyuki Todo*

May, 2004

Abstract

This paper develops an endogenous growth model incorporating quality improvement, focusing on a follower country that lags behind the world technology frontier and adopts new technology with adaptation to local circumstances. We assume two forms of adaptation: inventive adaptation, which requires formal local R&D activities, and minor adaptation without R&D. Although current R&D activities expand local knowledge for future R&D, minor adaptation without R&D does not. The main result in the paper is that countries with sufficient local knowledge and skilled labor initially depend on technology adoption without R&D but then depend on local R&D, while other countries continue to depend on adoption without R&D. Switching regression using cross-country data supports the presence of multiple steady-state equilibria.

Keywords: technology adoption, inventive adaptation, multinational enterprises, local R&D activities, switching regression

JEL classifications: O33, O41

*Faculty of Economics, Tokyo Metropolitan University, 1-1 Minami-Osawa, Hachioji, Tokyo 192-0397 Japan (tel.: +81-426-77-2325; fax: +81-426-77-2304; e-mail: yastodo@comp.metro-u.ac.jp; URL: http://www.comp.metro-u.ac.jp/~yastodo/). I thank Richard Braun, Shinichi Fukuda, Yasuyuki Sawada and seminar participants at the University of Tokyo for helpful comments and suggestions, and Taichi Kobayashi and Kazuhiro Yoshiooka for excellent research assistance. Financial support from the Masayoshi Ohira Memorial Foundation and the Japan Society for the Promotion of Science is gratefully acknowledged.
1 Introduction

Countries lagging behind the world technology frontier, or follower countries,\(^1\) can benefit greatly from adopting new technology invented in countries at the frontier, or frontier countries. Evenson and Westpal (1995) argue that technology adoption is likely to require adaptation, since most technologies are sensitive to circumstantial differences between countries, such as those in climate, relative prices, and institutions. They also identify two distinct forms of adaptation: minor and inventive adaptation. Minor adaptation “involve(s) changes in the technique but leave(s) its core unaffected,” and is not associated with formal R&D activities. By contrast, inventive adaptation “make(s) use not of the (foreign) technique but of the knowledge that underlies it,” and hence requires formal local R&D activities. An example of minor adaptation is tightening bolts by hand rather than using robots. The modification of product designs to fit local circumstances should be defined as inventive adaptation.

In practice, the main contribution to technology adoption with minor adaptation is made by the foreign direct investment (FDI) of the multinational enterprises (MNEs) of frontier countries, particularly those MNEs that are not engaged in R&D activities in the host country. Local R&D activities for inventive adaptation are often undertaken by local firms that have licensing agreements with firms in frontier countries or by MNEs with R&D units in the host country.

Whether a follower country depends on technology adoption with or without local R&D activities is likely to affect its long-run level of technology and output. Hence, this paper theoretically investigates how the levels of these two forms of technology adoption are determined in an endogenous-growth framework, of the type developed in Acemoglu et al. (2002) and Aghion and Howitt (forthcoming). Furthermore, we investigate whether R&D subsidies help follower countries to catch up with frontier countries.

\(^1\)Follower countries include not only less developed countries but also include developed countries. Eaton and Kortum (1995) find that France, Germany, Japan, and the United Kingdom gain substantially from the innovations of other countries, particularly the United States.
Although there is much existing work on technology adoption in follower countries, to which we will refer later, a unique feature of our model is the following two assumptions on the differences between the two forms of adoption. First, adoption with minor adaptation does not require local knowledge in follower countries, whereas the extent of technology adopted by local R&D activities is positively correlated with the level of local knowledge. Second, current technology adoption through R&D expands local knowledge and hence the productivity of future R&D activities, whereas adoption without R&D does not affect the knowledge level.

To explain the second assumption, we compare licensing and FDI as examples of channels of technology adoption with and without R&D, respectively. Kim and Ma (1997) and Lall (2000) suggest that although production workers in MNEs can achieve operational capabilities, they cannot understand the principles of technologies. By contrast, R&D activities associated with licensing enable local workers to learn the knowledge of licensors. Furthermore, the knowledge spills over to other engineers through labor turnover, subcontracting, and formal and informal discussion. Hence, licensing expands knowledge in the economy. This assumption is also supported by Todo and Miyamoto (2002), who find, using Indonesian firm-level data, that the productivity of local firms is positively correlated with the magnitude of MNEs with local R&D but uncorrelated with the magnitude of MNEs without R&D.

Given these assumptions, the model obtains two major results. First, depending on initial conditions and parameter values, follower countries converge to a steady state in which there is either a positive level of local R&D activities or no R&D. If local knowledge is sufficiently unimportant in inventive adaptation, or if initial endowments of skilled labor and knowledge are sufficiently large, follower countries initially depend on technology adoption without local R&D but then increasingly depend on adoption with R&D as they catch up with frontier countries. By contrast, if the endowment of skilled labor is large but that of local knowledge is small, or if the endowment of skilled labor is small, follower countries converge to a steady state in which there are no local...
R&D activities, or in practice, in which there are only MNEs without R&D.

The reason for this result is that there is a dynamic externality in technology adoption with local R&D activities but not in adoption without R&D. Since current R&D activities expand local knowledge and the productivity of future R&D, the development of local R&D may generate a virtuous cycle. However, countries with limited knowledge or little skilled labor cannot benefit from the virtuous cycle, because dynamic gains from current R&D are limited.

This externality leads to the second major result that the decentralized equilibrium is inefficient. Because private firms are unaware of the externality, they underinvest in R&D activities. Therefore, subsidies for R&D could increase output per capita in the long run. This implies that promoting local R&D activities by MNEs and licensing agreements with foreign firms are socially beneficial for follower countries, whereas promoting FDI without encouraging local R&D is less useful. Note that some East Asian countries that have achieved rapid growth have adopted such policies. For example, the governments of Japan and Korea encouraged licensing in the early stages of their development (Kim and Ma, 1997), and the Chinese government currently requires MNEs in some sectors, such as automobiles, to set up R&D units in China (Yusuf, 2003).

We test the model’s major assumptions and main results by using cross-country data. Of particular importance is testing whether there are two dynamic patterns in the level of local R&D, for which we use a switching regression model with unobservable regime change developed by Quandt (1972) and introduced to the growth literature by Bloom et al. (2003). We find weak evidence that supports the presence of multiple steady-state equilibria. Countries with large endowments of skilled labor and knowledge have a large probability of converging to a steady state in which R&D expenditures are positive, whereas countries with small endowments tend to converge to a steady state in which there are no R&D expenditures.

Since large R&D expenditures correspond to large income per capita, this result is consistent with Bloom et al. (2003), who found two types of steady state in terms of income per capita in cross-section of countries. In addition,
it is consistent with Bloom et al. (2002) who find evidence of variation in the steady-state levels of countries’ total factor productivity (TFP), although they focus on geography and institutions as the major determinants of TFP levels, rather than, as in this paper, endowments of skilled workers and local knowledge. Multiple income-growth processes are also found in Quah (1993) and Fiaschi and Lavezzi (2003) who use Markov chain transition models.

This paper is closely related to the literature on technology transfer to less developed countries, which is extensive. However, some studies focus on a particular type of adoption, such as imitation through local R&D as in Grossman and Helpman (1991) and Barro and Sala-i-Martin (1997), and FDI as in Findlay (1978), Walz (1997), and Fosfuri et al. (2001). Although other studies such as Ethier and Markusen (1996) and Glass and Saggi (2002) incorporate two channels of technology transfer, FDI and licensing, they do not focus on the difference between these two channels in terms of the promotion of local knowledge. The model of Glass and Saggi (1999) combines FDI and imitation, but FDI is exogenous. The model of Saggi (1999), which assumes knowledge spillovers from licensing but not from FDI, is most closely related to our model. However, Saggi’s model is a two-period duopoly game, whereas ours is a growth model with an infinite horizon, and hence Saggi’s model does not feature multiple equilibria.

Our findings have significant implications for development policies. Until recently, FDI had been considered as the major source of technology transfer (Ito and Krueger, 2000, for example). Many studies have empirically tested for the effect of FDI on growth, including Borensztein et al. (1998), Sjöholm (1999), Haskel et al. (2002), among many others.\(^2\) However, this paper suggests that promoting FDI may not be as beneficial as the existing literature implies unless it is associated with local R&D activities.\(^3\) This conclusion accords with the

\(^2\)Keller (2001) and Saggi (2002) provide comprehensive surveys of the issue.

\(^3\)Some other theoretical studies suggest that promoting FDI may have little effect on growth in less developed countries. The reasons include the absence of learning in MNEs (Wang and Blomström, 1992), minimal linkages between MNEs and local firms (Rodriguez-Clare, 1996), and substitutability between FDI and imitation (Glass and Saggi, 1999).
argument of Yusuf (2003) that East Asian countries that have absorbed much knowledge through FDI need more local R&D for further growth.

The rest of the paper is organized as follows. Section 2 describes the theoretical model, and Section 3 show the equilibrium analysis. The empirical evidence supporting the model is presented in Section 4. Section 5 concludes the paper.

2 The Model

The model developed in this paper is a simple extension of a growth model incorporating quality-improving innovations such as those in Acemoglu et al. (2002) and Aghion and Howitt (forthcoming). This is a discrete-time model with overlapping generations, focusing on a small follower country that has a relatively low level of initial knowledge and adopts new technology developed at the world knowledge frontier.

2.1 Production

There are two types of worker, skilled and unskilled, in the follower country. Each worker lives for two periods, and the numbers of skilled and unskilled workers in each generation are constant and are denoted by $H$ and $L$, respectively. Each worker supplies inelastically one unit of labor in the first period of her life and retires in the second period.

The final good is produced competitively using a continuum in the 0–1 interval of intermediate goods according to the following production function:

$$Y_t = \left( \int_0^1 A_t(i)x_t(i)\alpha \, di \right)^{1/\alpha},$$  

(1)

where $A_t(i)$ and $x_t(i)$ are the quality of intermediate good $i$ and the flow of good $i$ used in period $t$, respectively, and $\alpha \in [0, 1]$. The final good is fully consumed by either the “young” or “old” generation in each period, and its price is unity.

The profit maximization for the final-good sector yields

$$p_t(i) = Y_t^{1-\alpha} A_t(i)^{\alpha} x_t(i)^{\alpha-1},$$  

(2)

where $p_t(i)$ is the price of good $i$ in period $t$. 
The market for each intermediate good is monopolized by a firm that improves the product quality using skilled workers\(^4\) and thus receives patents for the good of that quality. We assume that each patent lasts for only one period and that any firm can produce any good of a quality that was achieved in the previous period because of costless knowledge diffusion. Therefore, the monopoly of the incumbent firm would be eliminated in the next period without further quality improvement. Additionally, we assume that costs of quality improvement for the incumbent firm are always smaller than those for any other firm, because of the incumbent’s knowledge from its previous experiences. Accordingly, the incumbent firm in the initial period in each intermediate sector will engage in further quality improvement and monopolize the entire market in any period, as long as the profit from quality improvement is positive, as will be true in equilibrium under certain conditions.

Each of these intermediate firms produces one unit of its product from one unit of unskilled labor. Since production requires only unskilled labor whereas quality improvement requires only skilled labor, the decision of each intermediate firm on production is separable from its decision on quality improvement, which will be discussed later. Given equation (2) and \( A_t(i) \), the monopoly firm producing good \( i \) maximizes its profit from production at time \( t \), \( \pi_t(i) = (p_t(i) - w^L_t) x_t(i) \), where \( w^L_t \) is the wage rate of unskilled labor. The solution leads to mark-up pricing:

\[
p_t(i) = \frac{w^L_t}{\alpha}.
\]

These intermediate firms are owned by share holders, who receive the total monopoly profit as dividends. The behaviors of share holders will be described in detail in the consumption section.

The market clearing condition for unskilled workers yields \( \int_0^1 x_t(i)di = L \). Also, as we will find in the next subsection, the quality of any intermediate good is the same: \( A_t(i) = A_t \equiv \int_0^1 A_t(i) di \) for any \( i \), where \( A_t \) denotes the average

\(^4\)How new technologies can be adopted will be explained in detail in the next subsection.
quality of intermediate goods. Thus, we obtain

\[ Y_t = A_t L, \]  

(4)

and

\[ \pi_t(i) = (1 - \alpha)A_t(i)L. \]  

(5)

Equation (4) shows that given \( L \), output per capita is proportional to the quality of intermediate goods. Hence, the growth rate of per capita output is equal to the rate of quality improvement.

### 2.2 Quality Improvement

Each intermediate firm can improve the quality of its product by technology adoption using skilled labor. Technology adoption can occur with either inventive adaptation through local R&D activities or minor adaptation without R&D. There are two differences between the two types of technology adoption. First, adoption without R&D does not require local knowledge in the follower country, while adoption with R&D does, and the extent to which R&D improves quality increases as local knowledge expands. Second, current local R&D activities raise the productivity of future R&D activities by expanding local knowledge, whereas technology adoption without R&D does not. These assumptions are justified by several empirical studies, as explained in the introduction.

Thus, we assume that quality in intermediate good sector \( i \) is given by

\[ A_t(i) = \eta M(H_t^M(i)) \bar{A}_{t-1} + (1 + g) R(H_t^R(i)) \bar{A}_{t-1}^\phi \tilde{A}^{1-\phi}_{t-1}. \]  

(6)

The first term on the right-hand side of this equation represents quality improvement without R&D. \( \bar{A}_{t-1} \) is the quality level at the world knowledge frontier at time \( t - 1 \), which is assumed to be the same for all intermediate goods. Part of this frontier quality can be introduced through technology adoption with minor adaptation by, for example, MNEs without local R&D activities.\(^5\) This type of adoption requires local skilled labor as managers, rather than engineers, who

\(^5\) Note that this model does not consider financial aspects of FDI.
learn production processes and new operational techniques from foreign manuals. $H_t^M(i)$ denotes the number of these skilled workers in sector $i$ at time $t$. Because the degree of quality improvement is an increasing function of the number of skilled workers employed, we specifically assume

$$M(H_t^M) = \left( \frac{H_t^M}{\bar{H}} \right)^\mu,$$

where $\bar{H}$ is the total amount of skilled labor engaged in innovation at the world frontier, which is exogenously given, and $\mu \in (0, 1)$. Since we further assume $\eta \in (0, 1)$, $M(\bar{H}) = 1$ implies that even when the same amounts of skilled labor are engaged in quality improvement without R&D and innovation at the knowledge frontier, the follower country cannot achieve frontier quality. Note that the degree of quality achieved by this channel does not depend on the knowledge level of skilled workers, because their task, reading manuals, does not require a high level of knowledge.

The second term denotes quality improvement through local R&D activities. This type of technology adoption requires skilled labor and a combination of local and frontier knowledge for local R&D. $H_t^R(i)$ is the number of skilled workers engaged in local R&D, and we assume

$$R(H_t^R) = \left( \frac{H_t^R}{\bar{H}} \right)^\rho,$$

where $\rho \in (0, 1)$. $\bar{A}_{t-1}$, defined as the frontier quality at time $t - 1$, also represents the knowledge level of the frontier countries at time $t$. $\tilde{A}_{t-1}$ represents the knowledge level of local skilled workers at time $t$. We assume costless knowledge diffusion within the follower country, and thus each skilled worker shares the same local knowledge. Furthermore, since we assume that the local knowledge does not expand through technology adoption without local R&D, the local knowledge level is not equal to the total quality level achieved in the previous period, $A_{t-1}$. Rather, it should be represented by the quality level achieved by local R&D. Therefore, we assume

$$\tilde{A}_{t-1} = (1 + g) R(H_{t-1}^R(i)) \tilde{A}_{t-2} \tilde{A}_{t-2} = A_{t-1} - \eta M(H_{t-1}^M(i)) \bar{A}_{t-2}.$$
Constant parameter $\phi \in (0,1)$ represents the weight for local knowledge. The exogenous rate of quality improvement at the world frontier for any intermediate good is denoted by $g > 0$: $\bar{A}_t = (1 + g)\bar{A}_{t-1}$. Note that if $A_{t-1} = \bar{A}_{t-1}$ and $H_t^R(i) = \bar{H}$, i.e., if the follower country has the same knowledge level and employs the same amount of skilled labor as the frontier countries, the rate of quality improvement is $g$.

## 2.3 Consumption

Both skilled and unskilled workers are risk neutral, and the discount rate of any worker is $r$. In period $t$, each “young” worker born in that period receives her wage and consumes in the middle of that period. She may save part of her wage and purchase shares of intermediate firms at the end of period $t$ for future consumption. In the middle of period $t+1$, shares of each firm yield dividends, which is equal to production profits less costs of quality improvement. After that, “old” consumers sell all their shares to the “young” generation and consume the quantity of the sum of the dividends and the value of their shares.

Under these assumptions, the value of the total shares of intermediate firm $i$, $v_t(i)$, is determined by the arbitrage condition:

$$(1 + r)v_t(i) = v_{t+1}(i) + \pi_t(i) - w_t^H (H_t^M(i) + H_t^R(i)).$$

Since the producers’ solutions determine $v_t(i)$ whereas $v_t(i)$ does not affect the producers’ decisions, the equilibrium analysis in the next section focuses on the producers’ side of the model.

## 3 Equilibrium Analysis

### 3.1 Dynamic and Steady-State Equilibrium

The firm producing intermediate good $i$ chooses levels of $H^M(i)$ and $H^R(i)$ to maximize its monopoly profits from production, given by equation (5), less the cost of wages paid to skilled workers as follows:

$$\max_{H_t^M(i), H_t^R(i)} (1 - \alpha)A_t(i)L - w_t^H (H_t^M(i) + H_t^R(i)),$$

(7)
where $w_t^H$ is the wage rate of skilled labor at time $t$. The first-order conditions are
\[(1 - \alpha) \eta M'(H^M_t(i)) \bar{A}_{t-1} = w_t^H, \tag{8}\]
and
\[(1 - \alpha)(1 + g) R'(H^R_t(i)) \bar{A}_{t-1}^{\phi} \bar{A}_{t-1}^{1-\phi} = w_t^H. \tag{9}\]
These conditions suggest that intermediate good sectors are symmetric, and hence $H^J_t(i) = H^J_t \equiv \int_0^1 H^J_t(i) di$ for $J = M, R$ and $A_t(i) = A_t$. Thus, we obtain
\[
\frac{M_t'}{R_t'} = \frac{1 + g}{\eta} \left( a_{t-1} - \frac{\eta}{1 + g} M_{t-1} \right)^\phi. \tag{10}\]
where $M_t \equiv M(H^M_t)$, $R_t \equiv R(H^R_t)$, and $X'$ indicates the first-order derivative of any function $X$. In addition, $a_{t-1} \equiv A_{t-1}/\bar{A}_{t-1}$, or $a_{t-1}$ is the quality level of the follower country relative to the world frontier.

Equation (6) can be written as
\[a_t = \frac{\eta}{1 + g} M_t + R_t(a_{t-1} - \frac{\eta}{1 + g} M_{t-1})^\phi. \tag{11}\]
Combining equations (10) and (11) yields
\[a_t = \frac{\eta}{1 + g} \left( M_t + \frac{M_t'}{R_t'} R_t \right). \tag{12}\]
Incorporating equation (12) and its first-order lag into equation (11) and the labor-market clearing condition $H^M_t + H^R_t = H$ for any $t$ yields
\[
\frac{M'_t}{R'_t} = \left( \frac{1 + g}{\eta} \right)^{1-\phi} \left( \frac{M'_{t-1}}{R'_{t-1}} R_{t-1} \right)^\phi. \tag{13}\]

Quality improvement generates a non-negative profit if $(1 - \alpha)A_t L - w_t^H H \geq 0$. Using equations (8), (9), and (12) to rewrite this yields
\[L > \frac{H}{M_t' + R_t'}. \]
The fact that the maximum value of the right-hand side of this inequality is either $\mu$ or $\rho$ yields the following proposition.
Proposition 1. (Profitability of Quality Improvement) All firms producing intermediate goods engage in quality improvement in every period if \( L \geq \mu \) and \( L \geq \rho \).

This proposition states that if the number of production workers, and hence the size of the market, is sufficiently large, quality improvement generates a non-negative profit. We assume that these conditions are met throughout this paper.

The equilibrium of the model can now be formally defined.

Definition 1. (Dynamic and Steady-State Equilibrium) Given \( a_0, H^R_1 \) is determined by equation (10) for \( t = 1 \), and the dynamics of \( H^R_t \) in equilibrium for \( t \geq 2 \) are determined by equation (13). \( H^R_t \) and equation (12) yield the equilibrium \( a_t \) for \( t \geq 1 \). The steady-state equilibrium is characterized by \( H^R_* \) and \( a_* \) such that \( H^R_* = H^R_t = H^R_{t-1} \) and \( a_* = a_{t-1} \).

To graph \( H^R_t \) as a function of \( H^R_t - 1 \) and analyze the dynamics of \( H^R \), we first consider the following equality satisfied in the steady state:

\[
q(H^R) = \left( \frac{R^*}{M^*} \right)^{1-\phi} R^* = \left( \frac{\eta}{1+g} \right)^{1-\phi},
\]

(14)

where \( M^* = M(H - H^R) \), \( R^* = R(H^R) \), and \( ^* \) indicates the first-order derivative of these functions evaluated at the steady state.

The shape of the function \( q \), and hence the characteristics of the equilibrium, depends on the parameter values. The left-side figures of Figure 1 illustrate this dependence. First, if \( \phi + \rho < 1 \), \( q(H^R) \) for \( 0 \leq H^R \leq H \) is monotonically decreasing between positive and negative infinity. Hence, equation (14) has a unique solution. Second, if \( \phi + \rho > 1 \) and \( H > \theta \), where

\[
\theta = [\rho - (1 - \phi)]\mu \left[ \frac{\hat{H}^\rho + \phi - 1 + \frac{\mu}{\rho} \frac{\eta}{1+g} (1-\phi)^{1-\phi}}{(\rho + \phi - 1)^{\rho+\phi-1} (1-\phi)^{(1-\rho)(1-\phi)}} \right]^{\frac{1}{\rho-1}},
\]

the function \( q \) is increasing in \( H^R \) for \( H^R < \frac{\rho-1}{\rho-1-\phi} \hat{H} \equiv \tilde{H} \) and decreasing for \( H^R > \tilde{H} \). Since the maximum of \( q \), \( q(\tilde{H}) \), is greater than \( \left( \frac{\eta}{1+g} \right)^{1-\phi} \),
equation (14) has two solutions. Third, if \( \phi + \rho > 1 \) and \( H < \theta \), no solution to equation (14) exists for \( 0 \leq H^{Rs} \leq H \).

In any of the three cases, equation (13) implies \( \frac{dH^R}{dH^R_{t-1}} \geq 0 \). The equilibrium \( H^R_t \) equals \( H \) when \( H^R_{t-1} = H \), and it is zero when \( H^R_{t-1} = 0 \). In addition, equation (13) implies

\[
\lim_{H^R_{t-1} \to 0} H^R_t(H^R_{t-1}) = \begin{cases} 
\infty & \text{if } \phi + \rho < 1 \\
0 & \text{if } \phi + \rho > 1.
\end{cases}
\]

By combining these results, we can graph \( H^R_t \) as a function of \( H^R_{t-1} \) for each case, as illustrated in the right-side figures of Figure 1.

These figures, in which \( H^R_S \) indicates a positive stable steady-state level of \( H^R \), while \( H^U \) indicates an unstable steady state, suggest the following proposition.

**Proposition 2. (Three Patterns of Equilibrium)**

(i) If \( \phi + \rho < 1 \), there is a unique stable steady state in which \( H^{Rs} \) is positive.

(ii) If \( \phi + \rho > 1 \) and \( H > \theta \), there are two stable steady-state equilibria. If the initial level of \( H^R \) is sufficiently small, \( H^R \) converges to a steady state in which \( H^{Rs} \) is zero. Otherwise, \( H^R \) converges to a steady state in which \( H^{Rs} \) is positive.

(iii) If \( \phi + \rho > 1 \) and \( H < \theta \), there is a unique stable steady state in which \( H^{Rs} \) is zero.

The key assumption that leads to the presence of multiple dynamic patterns and steady-state equilibria is a ‘biased’ dynamic externality that exists in technology adoption with local R&D but not in adoption without R&D. This externality results in a virtuous cycle in local R&D in some cases and a vicious cycle in others. If the externality is ‘unbiased,’ i.e., if the local knowledge expands through any type of adoption and \( \tilde{A}_{t-1} = A_{t-1} \), there is only one stable steady-state equilibrium regardless of parameter values and initial conditions.
Let us consider the characteristics of each case in more detail. In case (i),
the parametric condition, \( \phi + \rho < 1 \), implies that the weight assigned to local
knowledge in quality improvement through local R&D, \( \phi \), is small, and hence
the dynamic externality is relatively unimportant. As a result, there is a unique
steady state whatever the initial quality level.

In case (ii), the dynamic externality is relatively important. Hence, when the
initial quality level \( a_0 \), and hence the productivity of local R&D, is sufficiently
high, is also high. the number of skilled workers in R&D activities is also large in
the initial period. The subsequent knowledge improvement by the initial R&D
leads to a virtuous cycle in R&D and convergence to a positive steady-state
level of R&D. By contrast, if the follower country’s quality level is initially low,
gains from initial R&D are not sufficiently large for the country to enter the
virtuous cycle.

In case (iii), the total amount of skilled labor \( H \) is sufficiently small. Hence,
even when the current quality level is high, the quality improved by R&D, and
hence the productivity of R&D, is not sufficiently high. Thus, whatever the
initial conditions, the economy converges to the zero-R&D steady state.

### 3.2 Scale Effects

In equilibrium, equation (12) generates

\[
\frac{da_t}{dH_t} = \frac{\eta}{1 + g} \left( -\frac{M''_t}{M_t} \frac{R''_t}{R_t^0} \right) M'_t R_t > 0,
\]

where \( X'' \) denotes the second-order derivative of any function \( X \). Using this
and denoting \( a \) in the stable steady state in which \( H^R \) is positive by \( a^*_S \) yield

\[
\frac{\partial a^*_S}{\partial H} = \frac{\eta}{1 + g} \frac{M''_S R''_S}{R_S^0} \left( M''_S R''_S + M''_S R''_S + \frac{\phi}{1 - \phi} \left( \frac{R''_S}{R_S^0} \right)^2 \frac{M'_{S^*}}{R_S^0} \right) + \frac{\phi}{1 - \phi} \frac{M''_S R''_S}{R_S^0} > 0,
\]

since

\[
M''_S R''_S + M''_S R''_S + \frac{\phi}{1 - \phi} \left( \frac{R''_S}{R_S^0} \right)^2 \frac{M'_{S^*}}{R_S^0} < 0.
\]

Thus, we obtain the following proposition.
Proposition 3. (Scale Effects in Levels) An increase in the number of skilled workers in the follower country raises the country’s quality in the steady state relative to its level in the frontier countries.

Diminishing marginal products of skilled labor in technology adoption should have resulted in these scale effects in levels, as Jones (1998) discusses.

3.3 Welfare

In this overlapping-generation model with two types of worker, it is not easy to define a social utility function for welfare analysis. Thus, we consider the welfare issue of whether subsidizing (or taxing) local R&D activities relating to inventive adaptation raises quality and output per capita in the steady state.\footnote{Per capita output is proportional to the average quality level, according to equation (4).}

Denoting the rate of the subsidy to wages of skilled workers engaged in local R&D activities by $\tau$, we rewrite equation (12) as

$$a_t = \frac{\eta}{1 + g} \left( M_t + (1 - \tau) \frac{M'_t}{R'_t} R_t \right).$$

(16)

Accordingly, the dynamics of $H^R$ are given by

$$\frac{M'_t}{R'_t} = \left( \frac{1 + g}{\eta(1 - \tau)} \right)^{1-\phi} \left( \frac{M'_{t-1}}{R'_{t-1}} R_{t-1} \right)^{\phi},$$

(17)

and its steady-state value is implicitly given by

$$q(H^R*S) = \left( \frac{\eta(1 - \tau)}{1 + g} \right)^{\frac{1-\phi}{\phi}},$$

(18)

where the function $q$ is defined by equation (14).

Figure 2 illustrates how Figure 1 should be modified in the case of an R&D subsidy. The left-side figures show graphically that the number of skilled workers engaged in R&D in the positive-R&D steady state, $H^R*S$, is increasing in $\tau$ in cases (i) and (ii) described above. In addition, $H^R*U$ in case (ii) is lower with the subsidy than without it. Therefore, although some follower countries in case (ii) converge to a zero-R&D steady state in the absence of intervention, those countries would converge to a positive-R&D steady state if an R&D subsidy were provided.
Case (iii) can be divided into two subcases when an R&D subsidy is provided. First, if \((1 - \tau)^{\frac{1 - \phi}{1 - \phi + \rho}} \theta < H < \theta\), a stable steady state with a positive level of R&D emerges, in addition to the zero-R&D state. We refer to this as case (iiiia). Second, if \(H < (1 - \tau)^{\frac{1 - \phi}{1 - \phi + \rho}} \theta\), the unique stable steady state remains the zero-R&D state even when a subsidy is provided. We refer to this as case (iiib).

In cases (i), (ii), and (iiiia), differentiating equations (16) and (18) with respect to \(\tau\) yields

\[
\frac{\partial a^*}{\partial \tau} = \frac{\eta \tau}{1 + g} M'\left(\frac{(1 - \tau)\phi}{\tau(1 - \phi)} - 1\right) \frac{\partial H^R}{\partial \tau} \begin{cases} 
> 0 & \text{if } \tau < \phi \\
= 0 & \text{if } \tau = \phi \\
< 0 & \text{if } \tau > \phi .
\end{cases}
\]

This and the fact that \(\frac{\partial a}{\partial H^R} > 0\) if \(\tau < \phi\) derived from equation (16) lead to the following proposition.

**Proposition 4. (Efficiency Gains from R&D Subsidies)** Subsidizing skilled workers engaged in local R&D activities at the rate \(\phi\) maximizes output per capita in the steady state if the subsidy leads to a stable steady state in which there is a positive level of local R&D activities; i.e., in cases (i), (ii), and (iiiia).

The reason for the efficiency gains from an R&D subsidy is again the biased dynamic externality. Since private agents do not appropriate the future gains from current R&D, they underinvest in R&D activities in the decentralized equilibrium.

**4 Empirical Analysis**

This section tests the assumptions of the model described by equation (6) and its main prediction, presented in Proposition 2, that there are two patterns of equilibrium dynamics.

**4.1 Data**

For this empirical investigation, we need proxies for the variables in the model. First, technology adoption with minor adaptation is often conducted by MNEs...
without R&D activities in the host country, as we have already argued. Therefore, the number of skilled workers engaged in technology adoption with minor adaptation, \( H^M \), is represented by FDI inflows as a percentage of GDP, and denoted by \( FDI \). Strictly speaking, we should use FDI inflows that are not associated with R&D activities, but such data are not available for most countries. The data on FDI inflows are taken from UNCTAD (2003), and GDP data are from the World Bank (2003).

Second, the number of skilled workers engaged in technology adoption with inventive adaptation through local R&D activities, \( H^R \), is represented by the R&D expenditures as a percentage of GDP (\( R\&D \)). These data come from UNESCO (1999).\(^7\)

Third, the total number of skilled workers in the economy, \( H \), is represented by the number of workers with a secondary-school degree or higher educational qualifications. This is constructed by multiplying the proportion of the population who are over 25 years of age and have a secondary-school degree from Barro and Lee (2001) by the number of workers from the Penn World Tables Mark 6.0, which updates Summers and Heston (1991).

Finally, the follower country’s average quality relative to the frontier level, \( a \), is represented by the level of TFP relative to that of the United States. Following Hall and Jones (1999), the TFP of each country at time \( t \) is defined as

\[
TFP_t = \frac{Y_t}{K_t^{\alpha} (W_t e^{\kappa(s)})^{1-\alpha}},
\]

where \( Y, K, \) and \( W \) are real GDP, the real capital stock, and the number of workers, respectively. \( Y \) and \( W \) are from the Penn World Tables Mark 6.0, while observations on \( K \) are obtained from data on real investment from 1950 (from the same source), assuming a five-percent depreciation rate. \( s \) is average years of schooling from Barro and Lee (2001). \( \kappa(s) \) indicates effective units of labor, in which we assume \( \kappa' = 0.134 \) for \( s < 4 \), \( \kappa' = 0.101 \) for \( 4 \leq s < 8 \), and \( \kappa' = 0.068 \) for \( s \geq 8 \), on the basis of micro evidence from Psacharopoulos

\(^7\)The updated version is available at http://www.unesco.org.
In addition, we assume $\bar{\alpha} = 1/3$.

We collected these data for those countries for which they are available for the period 1970–1999 to generate a panel data set covering three 10-year periods. The sample does not include the United States, which is assumed to be at the world technology frontier. FDI and R&D are averages per period, while values for $H$ and $a$ from the beginning of each period are used to represent initial conditions. The data for the last two periods, 1980–1989 and 1990–1999, are presented in the Appendix Table. Since the data for R&D expenditures are rarely available before 1980, we omit pre-1980 R&D. In addition, since R&D data are missing on some countries for some years after 1980, R&D may be based on only a few annual observations, rather than on all 10.

**4.2 Testing the Assumptions of the Model**

Denoting the rate of quality improvement by $g_t \equiv \frac{A_t}{A_{t-1}} - 1$, we obtain from equation (6) that indicates the assumptions on quality improvement:

$$\frac{\partial g_t}{\partial H^M_t} = \frac{\partial g_t}{\partial H^R_t} > 0, \quad (19)$$

and

$$\frac{\partial^2 g_t}{\partial H^M_t \partial a_{t-1}} = (1 - \phi) \frac{\partial^2 g_t}{\partial H^R_t \partial a_{t-1}} < \frac{\partial^2 g_t}{\partial H^R_t \partial a_{t-1}} < 0. \quad (20)$$

Inequality (19) implies that the number of skilled workers engaged in technology adoption has a positive effect on the growth of average quality, whether adoption involves local R&D or FDI without R&D. In addition, inequality (20) implies that the effect diminishes as $a$ increases or as the follower country catches up with the frontier countries. This is because less new technology is available to the follower country the larger is $a$. Furthermore, the effect of skilled labor on growth declines by more when technology adoption is without R&D than when adoption is with R&D. In other words, the effect of FDI without R&D on growth is greater than the effect of R&D when the follower country is far behind the knowledge frontier, and *vice versa*.

These implications of the assumptions can be tested by the following TFP-
growth regression:

\[ \ln TFP_{i,t+1} - \ln TFP_{it} = \beta_0 + \beta_1 a_{it} + \beta_2 \ln FDI_{it} + \beta_3 (\ln FDI_{it} \times a_{it}) \\
+ \beta_4 \ln R& D_{it} + \beta_5 (\ln R& D_{it} \times a_{it}) + u_{it}, \]

where subscript \( i \) denotes country \( i \), subscript \( t \) denotes the 10-year period starting from year \( t \), and \( u \) is the error term. If the assumptions of the model are satisfied so that inequalities (19) and (20) hold, we expect \( \beta_1 < 0, \beta_2 > 0, \beta_4 > 0, \) and \( \beta_3 < \beta_5 < 0. \)

The constant term, \( \beta_{0i} \), is assumed to be country specific because of the geographic and linguistic proximity to the frontier countries, particularly the United States. Recent empirical papers such as Branstetter (2001), Conley and Ligon (2002), and Keller (2002), have found that geographic, economic, and linguistic distance significantly influence the degree of international knowledge diffusion. To eliminate \( \beta_{0i} \), we take first differences to obtain the following estimable equation:

\[ \Delta (\ln TFP_{i,t+1} - \ln TFP_{it}) = \beta_1 \Delta a_{it} + \beta_2 \Delta \ln FDI_{it} + \beta_3 \Delta (\ln FDI_{it} \times a_{it}) \\
+ \beta_4 \Delta \ln R& D_{it} + \beta_5 \Delta (\ln R& D_{it} \times a_{it}) + \Delta u_{it}, \] (21)

where \( \Delta x_{it} \equiv x_{it} - x_{i,t-1} \) for any variable \( x \).

Major problems relating to the estimation of this equation are the potential endogeneity of FDI and R&D and autocorrelation in the error term. Hence, although we start with ordinary least squares (OLS), the optimal generalized method of moments (GMM) is also used to alleviate these potential problems. Since \( FDI_{it} \) and \( R& D_{it} \) are determined by \( a_{i,t-1} \), a suitable instrument for estimating equation (21) is \( \Delta a_{i,t-1} \). Other suitable instruments are the lagged regressors. However, because of the limitation of the R&D data, we assume that the R&D variables are exogenous. Consequently, we instrument \( \Delta \ln FDI_{it} \) and \( \Delta (\ln FDI_{it} \times a_{it}) \) by \( \Delta a_{i,t-1} \), \( \Delta \ln FDI_{i,t-1} \) and \( \Delta (\ln FDI_{i,t-1} \times a_{i,t-1}) \). In addition, robust standard errors are used in all regressions because of potential heteroscedasticity and/or autocorrelation in the error terms.

The estimation results are reported in Table 1. The OLS results in the first column are consistent with the theoretical assumptions to some extent.
The estimated coefficients of $\Delta a$, $\Delta \ln FDI$, and $\Delta(\ln FDI \times a)$ are negative, positive, and negative, respectively, and all are statistically significant at the five-percent level. Column (2) shows that the optimal GMM estimates are qualitatively the same, but the sizes of the latter two are substantially larger than the corresponding OLS estimates.

The coefficients of $\Delta \ln R&D$, and $\Delta(\ln R&D \times a)$ are statistically insignificant for both OLS and GMM, although their signs are consistent with theoretical predictions. This is puzzling because Griffith et al. (2000) and Guellec and de la Poiteire (2001) find a positive and significant effect of R&D. A possible explanation for this difference is that these studies focus on OECD countries whereas this paper includes all countries except for the United States.

Although the effect of R&D is unclear, we can still examine the relevance of inequality (19) by testing $\beta_3 < \beta_5$. The $F$ statistics for the null hypothesis that $\beta_3 \geq \beta_5$ against the alternative that $\beta_3 < \beta_5$ are 1.70 (in OLS) and 4.06 (in GMM). Thus, at the five-percent level, the null hypothesis is not rejected in OLS but is in GMM.

To test whether the R&D variables are endogenous, we apply the test for strict exogeneity suggested by Wooldridge (2002, p. 285). We re-estimate equation (21), using the level data on $a_{it}$, $\ln R&D_{it}$, and $\ln R&D_{it} \times a_{it}$ as additional regressors and compute the $F$ statistic for the null hypothesis that the coefficients of the additional variables are jointly zero. Given an $F$ statistic of 0.55, we cannot reject strict exogeneity at the five-percent level. This justifies the GMM estimation without lagged first-differences of the R&D variables as instruments.

Moreover, we test the strict exogeneity of the FDI variables by using the same method. The $F$ statistic is 2.34, and therefore, strict exogeneity of the FDI variables cannot be rejected at the five-percent level but can at the 10-percent level. Thus, it is not clear whether the FDI variables are exogenous or whether the OLS or GMM is favored.

As a robustness check, we use a limited sample that includes countries with a TFP level less than the level of the United States in 1980. Columns (3) and (4) of Table 1 report the OLS and GMM results, respectively, using the limited
sample. The results are similar to the previous results to a great extent. In summary, FDI has a positive estimated effect on quality improvement but this diminishes as the relative quality level increases. Although the evidence on the effect of R&D is unclear, we find some evidence to support the hypothesis that the quality improvements that are due to R&D are larger than those that are due to FDI when the quality level is close to the frontier level.

4.3 Testing the Predictions of the Model

Proposition 2 of the model suggests that there are two types of country. Countries with large endowments of skilled labor and knowledge converge to a steady state in which the level of R&D is positive, whereas others converge to a steady state characterized by FDI without local R&D activities. Figure 3 presents broad empirical support for these results. In this figure, one segment shows changes in FDI inflows and R&D expenditures from the 1980s to the 1990s for each country, and one end of a segment with a country code denotes averages for the 1980s while the other without a code denotes averages for the 1990s. Countries are divided into two groups, one of which comprises countries with low TFP in 1980, while the other comprises those with high TFP.

Included in the top figure for countries with low initial TFP are countries such as Costa Rica (country code, CRI), Indonesia (IDN), Thailand (THA), Togo (TGO), and Trinidad and Tobago (TTO), in which FDI inflows increased while R&D expenditures remained low or declined. Moreover, the number of skilled workers, represented by the number of workers with a secondary-school degree, in countries such as Costa Rica and Togo is relatively small, as predicted by the theoretical model. By contrast, as the bottom figure shows, R&D expenditures increased or were stable at a high level in most countries with high initial TFP, with exceptions such as Mexico (MEX) and Argentina (ARG).

Furthermore, we tested theoretical predictions by using formal regression analysis. The difficulty is that the data do not clearly distinguish between the

---

8 See Appendix Table for the detailed data.
9 The author gratefully acknowledges discussion with and suggestions from Yasuyuki Sawada that were helpful in developing this idea and running the regression.
two types of country. One approach is to classify countries by the growth rate of R&D expenditures. However, this exogenous division may not reflect the true difference between the countries. Therefore, this paper uses the switching-regression model with unobservable regime change developed by Quandt (1972) and introduced to the growth literature by Bloom et al. (2003). Specifically, the empirical model is constituted by the following three equations.

\[ z^* = \eta_0 + \eta_1 \ln a_{i,t-1} + \eta_2 \ln H_{it} + \epsilon_{c,it}, \]  

where \( z^* \) is a latent variable, and

\[
\Delta \ln R&D_{it} = \gamma_{r0} + \gamma_{r1} \ln R&D_{i,t-1} + \gamma_{r2} \ln H_{it} + \epsilon_{r,it}, \quad \text{if} \quad z^* \geq 0, \tag{23}
\]

\[
\Delta \ln R&D_{it} = \gamma_{m0} + \gamma_{m1} \ln R&D_{i,t-1} + \gamma_{m2} \ln H_{it} + \epsilon_{m,it}, \quad \text{if} \quad z^* < 0. \tag{24}
\]

Equation (22) indicates that countries are classified according to their endowments of skilled labor and knowledge. Equation (23) represents the dynamics of R&D expenditures for the type of country that converges to a positive-R&D steady state, while equation (24) represents the dynamics for the type of country that converges to the zero-R&D steady state. Assuming that the variance–covariance matrix for the disturbances of the empirical model is given by

\[
\Sigma = \begin{pmatrix}
\sigma_{rr} & \sigma_{rm} & \sigma_{rc} \\
\sigma_{rm} & \sigma_{mm} & \sigma_{mc} \\
\sigma_{rc} & \sigma_{mc} & 1
\end{pmatrix},
\]

we can estimate equations (22), (23), and (24) jointly by maximum likelihood (ML).

Although our approach is similar to that of Bloom et al. (2003), their empirical model is regression of levels of income per capita whereas ours is regression of the growth in R&D expenditures. This is because we assume that the ratio of R&D expenditures to GDP does not reach its steady state in many countries. In addition, although Bloom et al. (2003) avoid to use endogenous variables

---

\[ ^{10}\text{See Dickens and Lang (1985) for the likelihood function. For the initial values of the coefficients in equations (23), and (24), } \sigma_{rr} \text{ and } \sigma_{mm}, \text{ we use the OLS estimates, in which we assume no regime change. For the initial values of the coefficients in equation (22), we use the results from a probit regression, assuming } z = 1 \text{ when the growth rate of R&D expenditures is positive and } z = 0 \text{ otherwise.} \]
as regressor, this paper uses the number of skilled workers and the TFP level, which are endogenous. However, using lagged regressors should alleviate the endogeneity problem.

The results of the model imply the following predictions for the coefficients of the equations. First, since countries converging to a positive-R&D steady state should have sufficiently large endowments of skilled labor and knowledge according to Proposition 2, we expect $\eta_1 > 0$ and $\eta_2 > 0$. Second, the standard convergence argument suggests $\gamma_{r1} < 0$ and $\gamma_{m1} < 0$: a country well below its steady-state level grows quickly. Third, since Proposition 3 suggests that a larger endowment of skilled labor $H$ leads to a larger level of R&D activities in the positive-R&D steady state, we expect $\gamma_{r2} > 0$. However, since $H$ does not affect R&D activities in the zero-R&D steady state, we expect $\gamma_{m2} = 0$. Finally, equation (23) implies that the share of R&D expenditures in GDP in the positive-R&D steady state for country $i$ is given by $\exp\left(-\left(\gamma_{r0} + \gamma_{r2} \ln H_i\right)/\gamma_{r1}\right)$, which is expected to be positive. However, its value in the zero-R&D steady state, given by $\exp\left(-\left(\gamma_{m0} + \gamma_{m2} \ln H_i\right)/\gamma_{m1}\right)$, is expected to be zero.

Column (1) in Table 2 reports the results from a simple ML estimation in which we assume no regime change, while columns (2), (3), and (4) indicate the results for equations (22), (23), and (24), respectively. The likelihood ratio statistic from the values of the likelihood functions of the two models is 64.3, rejecting the null hypothesis that the model without regime change is the true specification.\footnote{Bloom et al. (2003) suggest that this likelihood ratio statistic does not have the usual chi-squared asymptotic distribution. Hence, they obtain its critical values from a Monte Carlo study, which are approximately 1.5 times as large as those using the chi-squared distribution. However, since the value of the likelihood ratio statistic in this paper, 64.3, is likely to be larger than any critical value, we do not undertake a Monte Carlo study.}

Column (2) shows that the coefficients of $\ln a_{i,t-1}$ and $\ln H_{it}$ in equation (22) are positive and significant, as the theory predicts. The estimated coefficients suggest that the probability of converging to the zero-R&D steady state is, for example, 0.98 for Togo, 0.45 for Thailand, and 0.15 for Korea.

In addition, column (4) indicates that the predictions relating to countries
that converge to the zero-R&D steady state are supported. The coefficient of ln R&D is negative and significant, while the coefficient of ln H is insignificant. According to these results, in the zero-R&D steady state for a country with the average number of skilled workers (11.1 million), R&D expenditures are estimated to be 0.08 percent of GDP. A Wald statistic reported in the last row of Table 2 indicates that this point estimate is not significantly different from zero.

The results relating to countries that converge to the positive-R&D steady state presented in column (3) are not clearly consistent with the theoretical predictions. Although the coefficient of ln R&D is negative, it is not significantly different from zero. The coefficient of ln H is negative and significant, rather than positive as predicted. According to the results, in the positive-R&D steady state, R&D expenditures for the average country are estimated to be 9.54 percent of GDP. The fact that this estimated R&D share is much greater than the corresponding share in the zero-R&D steady state supports the theoretical prediction of multiple equilibria. However, a Wald test cannot reject the hypothesis that the R&D share in the positive-R&D steady state is zero, probably because of the large standard error of the coefficient of ln R&D.

A possible reason for this partial inconsistency with the theoretical predictions may be the use of the absolute number of skilled workers as the key regressor in the estimation. Although this is justified by Propositions 2 and 3, one may derive another conclusion that the share of skilled workers in the total labor force, rather than the number, influences the equilibrium of the model. This is possible by assuming that the number of intermediate goods produced in each country is proportional to the size of its total labor force.\(^{12}\)

Thus, using the share of H in the total labor force, denoted by \(h\), we replicate the estimations above. The results reported in columns (5)-(8) in Table 2 show evidence that is generally consistent with the model. First, the likelihood statistic from the ML regression without regime change and the switching re-

\(^{12}\)This is a standard assumption to eliminate scale effects in growth that is used in Aghion and Howitt (1998, Ch.12), Dinopoulos and Thompson (1998), Peretto (1998), and Young (1998).
gression suggests that the latter is the true specification. The results from the regime equation shown in column (6) indicates that the initial TFP level is a significant factor for the classification of countries into two regimes, while the impact of the share of skilled labor is insignificant. The estimated probability of converging to the zero-R&D steady state is 0.65 for Togo, 0.41 for Thailand, and 0.19 for Korea. Second, in contrast to the result in column (3), the effect of skilled labor in equation (23) is positive, although it is significantly different from zero only at the 10 percent level. Third, the share of R&D expenditures in GDP in the positive-R&D steady state implied from the estimation for the average country is 2.79 percent. The $p$ value from a Wald test is 5.3 percent, suggesting that this is different from zero at a reasonable significance level. The magnitude of the estimate is plausible, since the share of R&D expenditures in the U.S. has been stable around 2.5-3 percent. The share of R&D expenditures in the zero-R&D steady state is smaller and 0.17 percent, and its $p$ value is 9.2 percent. The estimated shares in the positive- and zero-R&D steady states are equal to each other with a $p$ value of 7.3 percent.

In conclusion, although the empirical tests do not provide full support for the theoretical predictions, they do provide some support. Countries with large endowments of knowledge and skilled labor have a large probability of converging to a steady state in which R&D expenditures are positive, whereas countries with small endowments tend to converge to a steady state in which there are no R&D expenditures.

5 Conclusions

This paper has developed an endogenous growth model that incorporates quality improvement, and focuses on follower countries behind the world technology frontier that adopt new technology with adaptation to local circumstances. There are two forms of adaptation, minor and inventive, which constitute adaptation with and without local R&D activities, respectively. In practice, the adoption of new technology with minor adaptation is often undertaken by MNEs
that do not engage in R&D activities in the host country, while inventive adaptation involves R&D activities by either MNEs or local firms that have licensing agreements with foreign firms. We assume that adoption without local R&D does not require local knowledge, whereas the degree of technology adopted through R&D is positively correlated with the level of local knowledge. Furthermore, we assume that technology adoption with local R&D expands future local knowledge, while adoption with R&D does not.

Our main finding is that countries with large endowments of local knowledge and skilled labor depend on adoption without local R&D activities initially but then increasingly depend on local R&D. When endowments of local knowledge and skilled labor are sufficiently small, dependence on adoption without R&D persists, and countries converge to a steady state in which there are no local R&D activities. The reason for the multiple dynamic processes is that there is a ‘biased’ positive dynamic externality in local R&D in the sense that current R&D improves the productivity of future R&D, whereas there is no externality in technology adoption without R&D. Moreover, because of this externality, subsidizing R&D is likely to increase output per capita in the long run.

Empirical evidence from country-level panel data was used to test the main assumptions and predictions of the theoretical model. In particular, we use a switching-regression approach with unobservable regime change to test for multiple steady-state equilibria in R&D expenditures. The empirical results generally support the theoretical predictions, although some results are not statistically significant or consistent with the theory.
References


29


Table 1: Testing the Assumptions of the Model

Dependent variable: $\Delta$ (growth rate of TFP)

<table>
<thead>
<tr>
<th>Sample</th>
<th>All countries</th>
<th>Countries with low initial TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td></td>
<td>OLS</td>
<td>Efficient GMM</td>
</tr>
<tr>
<td>$\Delta a$</td>
<td>-0.1111</td>
<td>-0.1180</td>
</tr>
<tr>
<td></td>
<td>(0.0179)**</td>
<td>(0.0219)**</td>
</tr>
<tr>
<td>$\Delta \ln FDI$</td>
<td>0.0149</td>
<td>0.0329</td>
</tr>
<tr>
<td></td>
<td>(0.0039)**</td>
<td>(0.0137)*</td>
</tr>
<tr>
<td>$\Delta (\ln FDI \times a)$</td>
<td>-0.0163</td>
<td>-0.0404</td>
</tr>
<tr>
<td></td>
<td>(0.0065)*</td>
<td>(0.0178)*</td>
</tr>
<tr>
<td>$\Delta \ln R&amp;!D$</td>
<td>0.0055</td>
<td>0.0082</td>
</tr>
<tr>
<td></td>
<td>(0.0049)</td>
<td>(0.0108)</td>
</tr>
<tr>
<td>$\Delta (\ln R&amp;!D \times a)$</td>
<td>-0.0032</td>
<td>-0.0070</td>
</tr>
<tr>
<td></td>
<td>(0.0069)</td>
<td>(0.0138)</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.0072</td>
<td>-0.0056</td>
</tr>
<tr>
<td></td>
<td>(0.0036)</td>
<td>(0.0042)</td>
</tr>
</tbody>
</table>

Observations 41 41 23 23

R-squared 0.673 0.498 0.689 0.615

Hansen’s J 0.006 0.026

Note: The dependent variable and all the regressors are first differenced. Standard errors are in parentheses. * denotes statistical significance at the 5% level, while ** denotes statistical significance at the 1% level.
### Table 2: Testing the Predictions of the Model

<table>
<thead>
<tr>
<th></th>
<th>(1) ML regression without regime change</th>
<th>(2) Switching regression</th>
<th>(3) Positive-R&amp;D steady state</th>
<th>(4) Zero-R&amp;D steady state</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>3.076</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.272)**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnH</td>
<td>0.319</td>
<td>0.395</td>
<td>-0.787</td>
<td>-1.718</td>
</tr>
<tr>
<td></td>
<td>(0.654)</td>
<td>(0.172)**</td>
<td>(0.255)**</td>
<td>(1.883)</td>
</tr>
<tr>
<td>lnR&amp;Ds</td>
<td>-2.400</td>
<td>-0.615</td>
<td>-11.091</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.017)**</td>
<td>(0.551)</td>
<td>(1.914)**</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-2.583</td>
<td>-4.720</td>
<td>8.722</td>
<td>-12.419</td>
</tr>
<tr>
<td></td>
<td>(5.3389)</td>
<td>(2.011)**</td>
<td>(2.166)**</td>
<td>(10.854)</td>
</tr>
<tr>
<td>Observations</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-164.342</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implied S.S. R&amp;D</td>
<td>9.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wald statistic</td>
<td>0.21</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>(5) ML regression without regime change</th>
<th>(6) Switching regression</th>
<th>(7) Positive-R&amp;D steady state</th>
<th>(8) Zero-R&amp;D steady state</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a$</td>
<td>2.028</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.979)**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnH</td>
<td>7.016</td>
<td>0.190</td>
<td>2.034</td>
<td>4.279</td>
</tr>
<tr>
<td></td>
<td>(1.495)**</td>
<td>(0.472)</td>
<td>(1.217) *</td>
<td>(2.440) *</td>
</tr>
<tr>
<td>lnR&amp;Ds</td>
<td>-3.736</td>
<td>-2.120</td>
<td>-11.868</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.879)**</td>
<td>(0.870)**</td>
<td>(1.432)**</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-25.975</td>
<td>-1.295</td>
<td>-5.427</td>
<td>-36.798</td>
</tr>
<tr>
<td></td>
<td>(5.612)**</td>
<td>(1.390)</td>
<td>(4.663)</td>
<td>(5.442)**</td>
</tr>
<tr>
<td>Observations</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-155.396</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implied S.S. R&amp;D</td>
<td>2.79</td>
<td></td>
<td></td>
<td>0.17</td>
</tr>
<tr>
<td>Wald statistic</td>
<td>3.72</td>
<td></td>
<td></td>
<td>2.83</td>
</tr>
</tbody>
</table>

Note: Standard errors are in parentheses. †, *, and ** denote statistical significance at the 10, 5, and 1 percent level, respectively.
Figure 1: Dynamic and Steady-State Equilibrium

Case (i): \( \phi + \rho < 1 \)

Case (ii): \( \phi + \rho > 1 \) and \( H > \theta \)

Case (iii): \( \phi + \rho > 1 \) and \( H < \theta \)
Figure 2: Dynamic and Steady-State Equilibrium with R&D Subsidies

Case (i): $\phi + \rho < 1$

Case (ii): $\phi + \rho > 1$ and $H > 0$

Case (iii): $\phi + \rho > 1$ and $(1 - \tau)^{1/\gamma} \theta < H < \theta$

Case (iiia): $\phi + \rho > 1$ and $(1 - \tau)^{1/\gamma} \theta < H < \theta$

Case (iiib): $\phi + \rho > 1$ and $H < (1 - \tau)^{1/\gamma} \theta$
Figure 3: Changes in FDI inflows and R&D Expenditures from the 1980s to the 1990s

(1) Low initial TFP

(2) High initial TFP

Note: One end of a segment with a country code shows averages during the period 1980–1989, and the other end without a code indicates those during 1990–1999.
### Appendix Table: Cross-Country Data

<table>
<thead>
<tr>
<th>Country</th>
<th>Code</th>
<th>$a_{1980}$</th>
<th>$a_{1990}$</th>
<th>$FDI_{1980}$</th>
<th>$FDI_{1990}$</th>
<th>$R&amp;D_{1980}$</th>
<th>$R&amp;D_{1990}$</th>
<th>$H_{1980}$</th>
<th>$H_{1990}$</th>
<th>$h_{1980}$</th>
<th>$h_{1990}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>ARG</td>
<td>1.03</td>
<td>0.54</td>
<td>0.65</td>
<td>2.59</td>
<td>0.45</td>
<td>0.40</td>
<td>2.717</td>
<td>4.259</td>
<td>26.5</td>
<td>37.3</td>
</tr>
<tr>
<td>Australia</td>
<td>AUS</td>
<td>1.09</td>
<td>0.99</td>
<td>1.71</td>
<td>1.75</td>
<td>1.21</td>
<td>1.59</td>
<td>4.634</td>
<td>5.781</td>
<td>68.7</td>
<td>71.0</td>
</tr>
<tr>
<td>Austria</td>
<td>AUT</td>
<td>1.16</td>
<td>1.10</td>
<td>0.31</td>
<td>1.06</td>
<td>1.27</td>
<td>1.59</td>
<td>2.196</td>
<td>2.433</td>
<td>65.1</td>
<td>66.3</td>
</tr>
<tr>
<td>Belgium</td>
<td>BEL</td>
<td>1.28</td>
<td>1.14</td>
<td>1.77</td>
<td>9.30</td>
<td>1.67</td>
<td>1.74</td>
<td>1.583</td>
<td>1.908</td>
<td>40.2</td>
<td>45.9</td>
</tr>
<tr>
<td>Brazil</td>
<td>BRA</td>
<td>1.12</td>
<td>0.75</td>
<td>0.65</td>
<td>1.51</td>
<td>0.50</td>
<td>0.81</td>
<td>5.285</td>
<td>8.828</td>
<td>11.9</td>
<td>16.3</td>
</tr>
<tr>
<td>Canada</td>
<td>CAN</td>
<td>1.05</td>
<td>1.00</td>
<td>0.99</td>
<td>1.76</td>
<td>1.41</td>
<td>1.66</td>
<td>8.950</td>
<td>10.557</td>
<td>74.2</td>
<td>76.3</td>
</tr>
<tr>
<td>Chile</td>
<td>CHL</td>
<td>0.60</td>
<td>0.52</td>
<td>1.85</td>
<td>5.11</td>
<td>0.40</td>
<td>0.66</td>
<td>1.287</td>
<td>2.215</td>
<td>34.1</td>
<td>46.2</td>
</tr>
<tr>
<td>China</td>
<td>CHN</td>
<td>0.19</td>
<td>0.21</td>
<td>0.52</td>
<td>4.11</td>
<td>0.67</td>
<td>0.69</td>
<td>122,318</td>
<td>249,920</td>
<td>22.7</td>
<td>36.4</td>
</tr>
<tr>
<td>Colombia</td>
<td>COL</td>
<td>0.66</td>
<td>0.57</td>
<td>1.30</td>
<td>2.14</td>
<td>0.12</td>
<td>0.37</td>
<td>1,878</td>
<td>2,968</td>
<td>21.3</td>
<td>26.0</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>CRI</td>
<td>0.73</td>
<td>0.53</td>
<td>1.78</td>
<td>3.13</td>
<td>0.19</td>
<td>0.20</td>
<td>146</td>
<td>282</td>
<td>18.7</td>
<td>27.0</td>
</tr>
<tr>
<td>Cyprus</td>
<td>CYP</td>
<td>0.84</td>
<td>0.91</td>
<td>2.48</td>
<td>2.52</td>
<td>0.10</td>
<td>0.20</td>
<td>101</td>
<td>162</td>
<td>35.4</td>
<td>51.2</td>
</tr>
<tr>
<td>Denmark</td>
<td>DNK</td>
<td>1.05</td>
<td>0.90</td>
<td>0.25</td>
<td>2.57</td>
<td>1.35</td>
<td>1.90</td>
<td>1,645</td>
<td>1,989</td>
<td>60.8</td>
<td>69.5</td>
</tr>
<tr>
<td>Egypt, Arab Rep.</td>
<td>EGY</td>
<td>0.45</td>
<td>0.45</td>
<td>2.66</td>
<td>1.38</td>
<td>0.20</td>
<td>0.21</td>
<td>1,501</td>
<td>3,450</td>
<td>13.5</td>
<td>23.7</td>
</tr>
<tr>
<td>El Salvador</td>
<td>SLV</td>
<td>0.51</td>
<td>0.37</td>
<td>0.33</td>
<td>1.28</td>
<td>1.54</td>
<td>2.20</td>
<td>182</td>
<td>257</td>
<td>12.0</td>
<td>16.1</td>
</tr>
<tr>
<td>Finland</td>
<td>FIN</td>
<td>1.10</td>
<td>1.06</td>
<td>0.26</td>
<td>1.19</td>
<td>1.73</td>
<td>2.50</td>
<td>1,162</td>
<td>1,599</td>
<td>48.8</td>
<td>64.8</td>
</tr>
<tr>
<td>France</td>
<td>FRA</td>
<td>1.30</td>
<td>1.17</td>
<td>0.50</td>
<td>1.62</td>
<td>2.20</td>
<td>2.34</td>
<td>10,413</td>
<td>12,837</td>
<td>43.0</td>
<td>48.3</td>
</tr>
<tr>
<td>Greece</td>
<td>GRC</td>
<td>1.28</td>
<td>0.89</td>
<td>1.14</td>
<td>0.87</td>
<td>0.29</td>
<td>0.50</td>
<td>1,002</td>
<td>1,452</td>
<td>27.3</td>
<td>37.4</td>
</tr>
<tr>
<td>Iceland</td>
<td>ISL</td>
<td>1.34</td>
<td>1.06</td>
<td>0.46</td>
<td>0.61</td>
<td>0.78</td>
<td>1.58</td>
<td>41</td>
<td>62</td>
<td>35.0</td>
<td>45.8</td>
</tr>
<tr>
<td>India</td>
<td>IND</td>
<td>0.25</td>
<td>0.27</td>
<td>0.04</td>
<td>0.40</td>
<td>0.75</td>
<td>0.83</td>
<td>42,848</td>
<td>60,411</td>
<td>16.2</td>
<td>18.2</td>
</tr>
<tr>
<td>Indonesia</td>
<td>IDN</td>
<td>0.37</td>
<td>0.43</td>
<td>0.37</td>
<td>1.06</td>
<td>0.31</td>
<td>0.07</td>
<td>5,743</td>
<td>13,376</td>
<td>10.4</td>
<td>19.1</td>
</tr>
<tr>
<td>Ireland</td>
<td>IRL</td>
<td>0.89</td>
<td>0.92</td>
<td>0.65</td>
<td>4.92</td>
<td>0.86</td>
<td>1.28</td>
<td>600</td>
<td>788</td>
<td>47.7</td>
<td>58.3</td>
</tr>
<tr>
<td>Israel</td>
<td>ISR</td>
<td>1.11</td>
<td>0.95</td>
<td>0.39</td>
<td>1.21</td>
<td>2.97</td>
<td>2.65</td>
<td>863</td>
<td>1,084</td>
<td>59.7</td>
<td>59.5</td>
</tr>
<tr>
<td>Italy</td>
<td>ITA</td>
<td>1.55</td>
<td>1.35</td>
<td>0.30</td>
<td>0.35</td>
<td>1.05</td>
<td>1.12</td>
<td>7,226</td>
<td>9,315</td>
<td>33.3</td>
<td>40.5</td>
</tr>
<tr>
<td>Japan</td>
<td>JPN</td>
<td>1.02</td>
<td>1.05</td>
<td>0.02</td>
<td>0.06</td>
<td>2.62</td>
<td>2.90</td>
<td>39,228</td>
<td>51,414</td>
<td>54.3</td>
<td>65.7</td>
</tr>
<tr>
<td>Korea, Rep.</td>
<td>KOR</td>
<td>0.67</td>
<td>0.87</td>
<td>0.27</td>
<td>0.67</td>
<td>1.30</td>
<td>2.39</td>
<td>6,747</td>
<td>12,016</td>
<td>45.8</td>
<td>67.3</td>
</tr>
<tr>
<td>Malaysia</td>
<td>MYS</td>
<td>0.71</td>
<td>0.70</td>
<td>3.18</td>
<td>6.64</td>
<td>0.10</td>
<td>0.32</td>
<td>1,137</td>
<td>2,226</td>
<td>21.3</td>
<td>29.9</td>
</tr>
<tr>
<td>Mauritius</td>
<td>MUS</td>
<td>0.52</td>
<td>0.58</td>
<td>0.61</td>
<td>0.81</td>
<td>0.36</td>
<td>0.28</td>
<td>127</td>
<td>200</td>
<td>24.2</td>
<td>33.0</td>
</tr>
</tbody>
</table>

Note: See text for the definitions of the variables.
Appendix Table: Cross-Country Data (continued)

<table>
<thead>
<tr>
<th>Country</th>
<th>Code</th>
<th>(a_{1980})</th>
<th>(a_{1990})</th>
<th>(FDI_{1980})</th>
<th>(FDI_{1990})</th>
<th>(R&amp;D_{1980})</th>
<th>(R&amp;D_{1990})</th>
<th>(H_{1980})</th>
<th>(H_{1990})</th>
<th>(h_{1980})</th>
<th>(h_{1990})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>MEX</td>
<td>1.13</td>
<td>0.70</td>
<td>1.16</td>
<td>2.29</td>
<td>0.38</td>
<td>0.33</td>
<td>3,644</td>
<td>9,128</td>
<td>17.2</td>
<td>32.6</td>
</tr>
<tr>
<td>Netherlands</td>
<td>NLD</td>
<td>1.29</td>
<td>1.12</td>
<td>1.45</td>
<td>4.11</td>
<td>2.07</td>
<td>2.01</td>
<td>3,025</td>
<td>3,834</td>
<td>55.4</td>
<td>61.5</td>
</tr>
<tr>
<td>New Zealand</td>
<td>NZL</td>
<td>0.85</td>
<td>0.77</td>
<td>3.04</td>
<td>4.04</td>
<td>0.95</td>
<td>1.07</td>
<td>1,015</td>
<td>963</td>
<td>76.7</td>
<td>63.2</td>
</tr>
<tr>
<td>Norway</td>
<td>NOR</td>
<td>1.25</td>
<td>1.00</td>
<td>0.48</td>
<td>1.73</td>
<td>1.46</td>
<td>1.72</td>
<td>1,005</td>
<td>1,891</td>
<td>51.2</td>
<td>87.5</td>
</tr>
<tr>
<td>Panama</td>
<td>PAN</td>
<td>0.80</td>
<td>0.43</td>
<td>0.00</td>
<td>5.77</td>
<td>0.01</td>
<td>0.26</td>
<td>206</td>
<td>394</td>
<td>31.5</td>
<td>45.5</td>
</tr>
<tr>
<td>Peru</td>
<td>PER</td>
<td>0.70</td>
<td>0.41</td>
<td>0.20</td>
<td>2.96</td>
<td>0.28</td>
<td>0.06</td>
<td>1,694</td>
<td>2,598</td>
<td>31.5</td>
<td>37.7</td>
</tr>
<tr>
<td>Philippines</td>
<td>PHL</td>
<td>0.47</td>
<td>0.33</td>
<td>0.57</td>
<td>1.92</td>
<td>0.18</td>
<td>0.18</td>
<td>5,981</td>
<td>10,588</td>
<td>34.1</td>
<td>45.9</td>
</tr>
<tr>
<td>Portugal</td>
<td>PRT</td>
<td>1.09</td>
<td>1.03</td>
<td>1.09</td>
<td>1.99</td>
<td>0.38</td>
<td>0.64</td>
<td>606</td>
<td>1,001</td>
<td>14.1</td>
<td>22.5</td>
</tr>
<tr>
<td>Rwanda</td>
<td>RWA</td>
<td>0.15</td>
<td>0.14</td>
<td>1.00</td>
<td>0.22</td>
<td>0.28</td>
<td>0.04</td>
<td>62</td>
<td>72</td>
<td>2.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Singapore</td>
<td>SGP</td>
<td>1.69</td>
<td>1.65</td>
<td>10.00</td>
<td>11.51</td>
<td>0.57</td>
<td>1.30</td>
<td>201</td>
<td>527</td>
<td>18.0</td>
<td>36.0</td>
</tr>
<tr>
<td>South Africa</td>
<td>ZAF</td>
<td>0.96</td>
<td>0.69</td>
<td>0.01</td>
<td>0.59</td>
<td>0.86</td>
<td>0.81</td>
<td>2,598</td>
<td>3,205</td>
<td>28.5</td>
<td>26.9</td>
</tr>
<tr>
<td>Spain</td>
<td>ESP</td>
<td>1.35</td>
<td>1.21</td>
<td>1.28</td>
<td>1.91</td>
<td>0.58</td>
<td>0.88</td>
<td>2,636</td>
<td>4,787</td>
<td>20.4</td>
<td>33.9</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>LKA</td>
<td>0.23</td>
<td>0.28</td>
<td>0.75</td>
<td>1.24</td>
<td>0.18</td>
<td>0.19</td>
<td>2,157</td>
<td>2,692</td>
<td>35.2</td>
<td>38.1</td>
</tr>
<tr>
<td>Sweden</td>
<td>SWE</td>
<td>0.99</td>
<td>0.94</td>
<td>0.47</td>
<td>5.45</td>
<td>2.79</td>
<td>3.52</td>
<td>2,431</td>
<td>2,775</td>
<td>58.4</td>
<td>62.3</td>
</tr>
<tr>
<td>Switzerland</td>
<td>CHE</td>
<td>1.26</td>
<td>1.14</td>
<td>0.96</td>
<td>1.73</td>
<td>2.20</td>
<td>2.68</td>
<td>2,018</td>
<td>2,385</td>
<td>65.3</td>
<td>66.8</td>
</tr>
<tr>
<td>Thailand</td>
<td>THA</td>
<td>0.49</td>
<td>0.57</td>
<td>0.98</td>
<td>2.62</td>
<td>0.30</td>
<td>0.14</td>
<td>2,297</td>
<td>4,656</td>
<td>9.7</td>
<td>15.8</td>
</tr>
<tr>
<td>Togo</td>
<td>TGO</td>
<td>0.23</td>
<td>0.17</td>
<td>1.05</td>
<td>1.61</td>
<td>0.79</td>
<td>0.48</td>
<td>114</td>
<td>195</td>
<td>10.0</td>
<td>13.7</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>TTO</td>
<td>0.81</td>
<td>0.53</td>
<td>1.75</td>
<td>7.24</td>
<td>0.80</td>
<td>0.13</td>
<td>104</td>
<td>174</td>
<td>26.6</td>
<td>36.7</td>
</tr>
<tr>
<td>Turkey</td>
<td>TUR</td>
<td>0.56</td>
<td>0.57</td>
<td>0.20</td>
<td>0.46</td>
<td>0.57</td>
<td>0.46</td>
<td>2,347</td>
<td>4,116</td>
<td>12.3</td>
<td>16.9</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>GBR</td>
<td>0.89</td>
<td>0.87</td>
<td>1.61</td>
<td>2.57</td>
<td>2.22</td>
<td>2.03</td>
<td>12,049</td>
<td>14,900</td>
<td>44.7</td>
<td>52.4</td>
</tr>
<tr>
<td>United States</td>
<td>USA</td>
<td>1.00</td>
<td>1.00</td>
<td>0.78</td>
<td>1.12</td>
<td>2.67</td>
<td>2.64</td>
<td>101,861</td>
<td>109,972</td>
<td>92.7</td>
<td>89.6</td>
</tr>
<tr>
<td>Venezuela</td>
<td>VEN</td>
<td>1.09</td>
<td>0.69</td>
<td>0.29</td>
<td>2.60</td>
<td>0.33</td>
<td>0.40</td>
<td>1,457</td>
<td>1,613</td>
<td>23.9</td>
<td>23.8</td>
</tr>
</tbody>
</table>

Note:  
- Code = the country code used in Figure 3.  
- \(a\) = the TFP level relative to the U.S.’s.  
- \(FDI\) = the ratio of FDI inflows to GDP (%).  
- \(R\&D\) = the ratio of R&D expenditures to GNP (%).  
- \(H\) = the number of workers with a secondary-school degree.  
- \(h\) = the ratio of \(H\) to the total labor force.