The Theory of Growth and Technology Transfer: Experience from the East Asian Economies*

Man-lui Lau
Texas Tech University
Henry Y. Wan, Jr.
Cornell University

Today, the East Asian economies are viewed as the role models for most of the LDCs and the formerly planned economies. Their rapid catching up with the DCs is achieved, to a great extent, with transferred technology. We discuss below the issues in modeling theoretically their experience. Specifically, we offer a theory which predicts a unimodal time profile for the growth rate as observed in Japan and Taiwan, and we identify the causal factors which may facilitate the "imitational component" for technical progress.

I. Introduction

A predominant portion of the human race today lags far behind their affluent brethren in their standard of living. The per capita GNP for the Swiss is $27,550 in 1988.[1] As shown in Figure 1, 60% (respectively, 83%) of the world population live in countries where the per capita GNP is less than 1.8% (respectively, 8%) of that figure. This raises two burning issues facing us, *why* the LDCs fall

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[1]The data used here are from the World Bank. According to Summers and Heston (1988), if exchange rate is replaced by purchasing power parities (PPP) as the means of converting GNP into a common currency, the gap between the richest country and the poorest country will be smaller.

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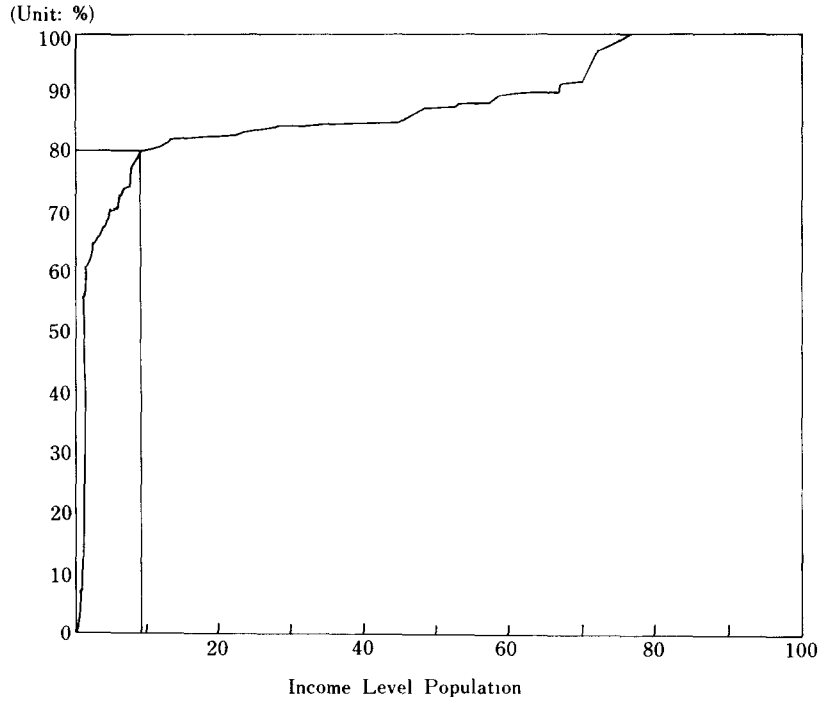

FIGURE 1
CUMULATIVE DISTRIBUTION OF POPULATION BY PER CAPITA INCOME
(SWISS P. C. INCOME = 100%)
Source: World Bank (1990).

behind and *how* they can catch up, fast.

Interest has recently been revived in these age-old issues for two reasons.

1) The sustained rapid growth of the East Asian economies, like Japan, the Asian NIEs and the ASEAN states. Their growth is apparently based upon technology transfers, facilitated by an outward-looking stance.
2) The rapid growing literature of the New Growth Theory, e.g., the contributions by Becker, Murphy and Tamura (1990), Lucas (1988), Romer (1986, 1990), Stokey (1988), Grossman and Helpman (1990a, b) etc. where fully analytic methods are mobilized to address issues in development economics.

Today the East Asian performances are widely perceived as role models for many economies in their policies reappraisal. How realis-

tic such perceptions are should be scrutinized systematically and analytically, case by case, in a manner parallel to the literature of the New Growth Theory, even though the latter is not designed to examine the East Asian experience. Our study below is a step in that direction.

Section II summarizes some facts of life as the background for our analysis. Section III sets up a catching-up model. The causes for growth are partitioned into three components: i) a catching-up mechanism, ii) the policy-influenced environment which decides the pace of catching-up, and iii) the "innovative" shocks. In this paper, we focus upon the first two components. Section IV illustrates how such a theory may help to explain reality. Section V contains some concluding remarks.

II. Lessons from Reality

Figure 2 summarized the growth rates of per capita real GNP, averaged over the 23-year period, 1965-1987, for all market economies for which data are available. Using each economy's status as a DC or LDC in 1987, these economies are displayed in two relative distributions, with dark line for the DCs, and the light line for the LDCs. We may conclude the followings.

1) By a F-test,[2] the null hypothesis H_0: both samples come from the same population is rejected at the 1% level of significance.
2) Any theory explaining the differences of sustained growth rates must presumably address the performances of the LDCs, with a larger dispersion among a much larger group (76 LDCs vis-a-vis 18 DCs).
3) The relative distribution of the LDCs presumably is governed by mechanisms significantly different from those for the DCs.

[2]For the two group of countries, DC and LDC, we have the following information.

	DC	LDC
Mean	2.35%	1.64%
Variance	0.6658%	5.3677%
No. of observations	18	76

We test the null hypothesis H_0: $\delta^2_{DC} = \delta^2_{LDC}$. We get a F-statistics of $8.0616 = 5.3677/0.6658$ which is larger than 2.80, the critical value for $F_{1\%}(75, 17)$. Hence we reject the H_0 that the two groups have the same variance at the 1% significant level.

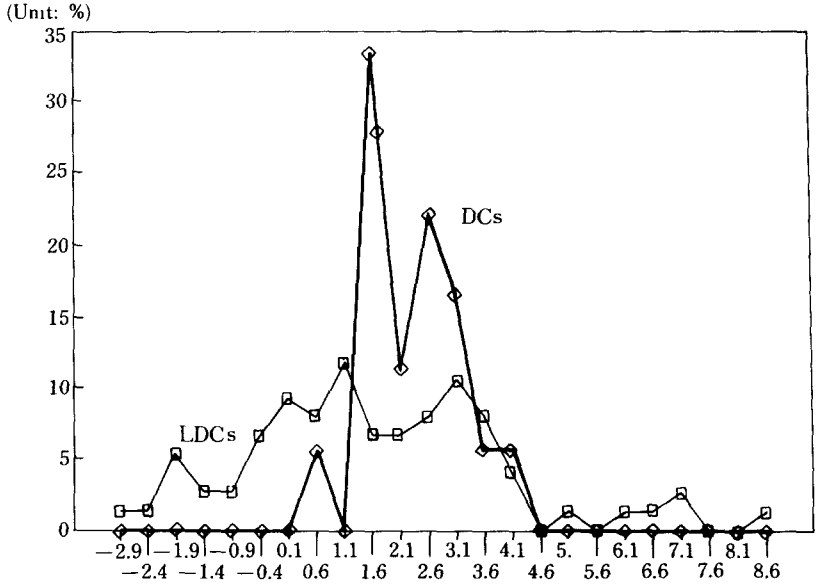

FIGURE 2

DISTRIBUTION OF THE GROWTH RATES OF PER CAPITA GNP: DC VS. LDC

Source: World Bank (1990), Republic of China (1989).

Note: Average annual growth rate for the period 1965–87.

The patterns observed are consistent with the observations of Lucas (1988, p. 4) in his seminal paper,

> "The poorest countries tend to have the lowest growth; the wealthiest next, the 'middle-income' countries highest."
> and "The richest...show little diversity.... Within the poor, ... enormous variability."

Clearly, what is summarized above cannot be a steady-state configuration in which country-specific growth rates take different constant values. If the observed configurations persist, surely the "middle-income" countries with their higher growth rates would overtake the high income countries, and they cannot be "middle-income" countries any more. It does suggest that for some countries with a given environment (the "policy-regime"), their growth rates may slow down after a phase of "trend-acceleration".[3] The high-

[3]This was first noted by Klein and Ohkawa (1968) for Japan, and then observed by Lucas (1988, p. 5) for the Asian NIEs.

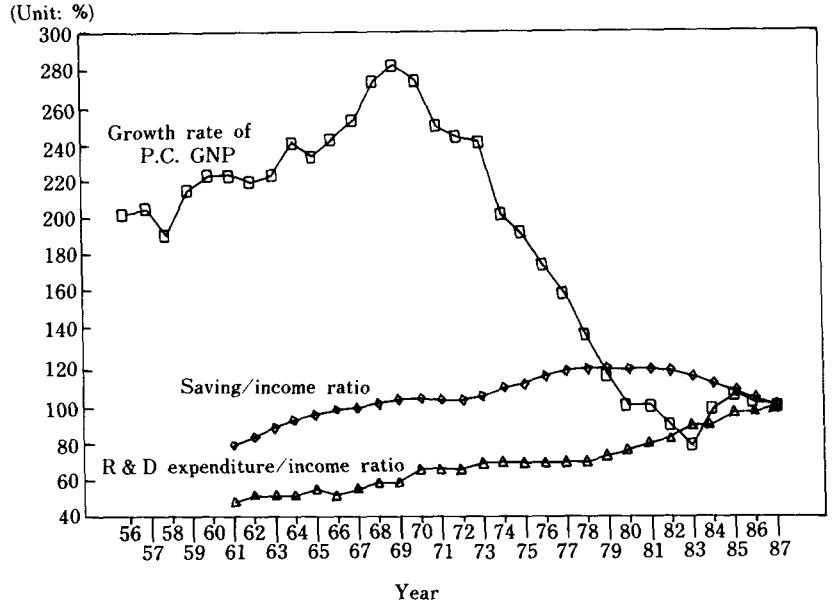

FIGURE 3
THE GROWTH PATTERN OF JAPAN

Source: The Economists (1989), National Science Foundation (1988), Economic Planning Agency, Government of Japan (1981, 1988).

Note: 10 year moving-average (data at 1970 is the average for the period 1960-70). Because of the lack of a complete time series, two overlapping time series of saving rate are employed and combined into a time series.

growth period corresponds to the proverbial "take-off point."

This does not suggest that all economies will be synchronized "in phase" over some longitudinal profile for growth. Baumol, Blackman and Wolff (1989) for example, showed that in the case of America, the growth rate of per capita real GNP apparently exhibits no trend. Moreover, economies under different policy-regimes may reach the "take-off" stage at different dates.[4]

We now turn to the record of Japan which is summarized in Figure 3, where both the 10-year moving average of the growth rate of per capita real GNP and the saving/income ratio exhibit a unimodal time-profile, while the R&D spending/income ratio increases

[4]The early phased-growth model of Tsiang (1964) hints as much.

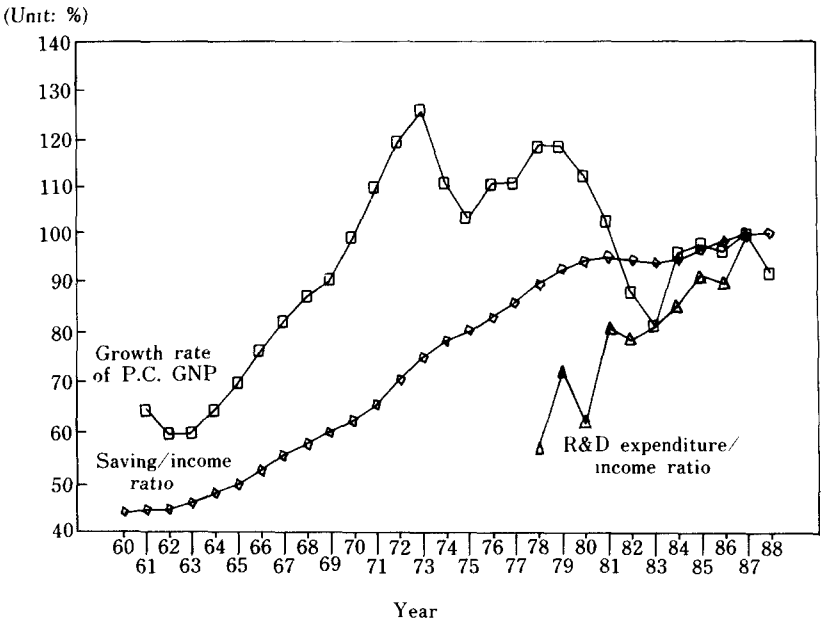

FIGURE 4
THE GROWTH PATTERN OF TAIWAN

Source: Republic of China (1989).
Note: See the note of Figure 2.

steadily. To facilitate comparison, we set the 1987 values to be 100 for all the three series.

It is clear from the data that the "high growth period" of Japan has passed into history. This slowing down cannot be explained by the series for saving propensity, nor any steadily rising series like the R&D propensities (or education, etc.). Nor can it be due to some world-wide influences. Some Asian economies[5] enjoy their own "trend acceleration" just as Japanese growth slows down.

Last we consider the Japanese record a fluke. The Taiwanese data in Figure 4 show similar patterns, except that the series for saving propensities have not peaked yet.

The explanation of the Japanese growth curve may be sought in the catching up process, to be discussed below.

[5]For example, Thailand currently.

III. The Process of Technology Diffusion

We shall now go back to the Neo-classical growth theory,[6] and consider an aggregate production function which is of first order homogeneous in both capital and labor, the latter being measured in efficiency units. Let y_t be the output per worker (in natural units), A_t be the labor-augmenting efficiency index, and f_t be the function relating the capital/efficiency labor ratio k_t to the output/efficiency labor ratio, all for economy i. Hence

$$y_t = A_t f_t(k_t),\ f' > 0,\ f'' < 0. \tag{1}$$

In an open economy, k_t is determined by investment opportunities, and not by domestic saving so that

$$A_t f_t'[k_t(t)] = r(t) \tag{2}$$

where $r(t)$ is the world interest rate. Thus, among the Asian NIEs, Taiwan has an export surplus in recent decades, with domestic savings exceeding domestic investment, while in South Korea, everything in just the reverse. In such a world, saving does not explain growth, while growth potentials explain investments via (2).

Take logarithmic derivative of (1) with respect to time, one may write

$$\begin{aligned} y_t'/y_t &= A_t'/A_t + c_t, \\ \text{where } c_t &\equiv (rk_t/y_t)(k_t'/k_t). \end{aligned} \tag{3}$$

Let us now adopt the Schumpeterian[7] distinction between "imitation" and "innovation." Let the component in A_t'/A_t which is related to transferred technology be b_t and the rest be a_t, we then have

$$y_t'/y_t = a_t + b_t + c_t. \tag{4}$$

Denote economy 1 as the economy with the highest per capita output:

$$y_1 = \max_i \{y_t\}$$

we then refer $y_1 - y_i$ as the "technology backlog" for economy i, in the sense of Gerschenkron (1962). In what follows, $b_t y_i$ and $b_t y_t/(y_1$

[6]See, for example, Solow (1956, 1957).
[7]See Schumpeter (1942).

$-y_i$) will be referred to as the *absolute* and the *relative* rates of imitation.

It is to be noted that although the "technology backlog" is defined in such a manner, the actual source of technology for economy i may well be some economy $j \neq 1$. The controlling factor here is from where one can acquire the appropriate technology at the least cost.

Clearly, the rate of imitation increases with the technical competence of economy i, which may be represented as:

$$z_i \equiv y_i/y_1. \tag{5}$$

In fact, imitation is an activity producing externalities, since imitation leads to further domestic imitations. All this may be captured in

Assumption 1

$$b_i y_i/(y_1 - y_i) \equiv b_i z_i/(1 - z_i) = b_i^* z_i^{\alpha}, \qquad \alpha > 1 \tag{6}$$

where b_i^* is a multiplicative scalar.

Now (6) may be rewritten as:

$$b_i = b_i^*(1 - z_i)z_i^{\alpha - 1}. \tag{7}$$

An implication of the above formulation is that:

$$b_1 = 0, \tag{8}$$

since the technology leader has nothing to learn from itself.

One may compare the growth rate of any economy i and the growth rate of economy 1, the technical leader, by means of (4), (5) and (7):

$$\begin{aligned} y_i'/y_i - y_1'/y_1 &= (a_i - a_1) + (c_i - c_1) + b_i^*(1 - z_i)z_i^{\alpha - 1} \\ &= D_i(t) + b_i^*(1 - z_i)z_i^{\alpha - 1} \end{aligned} \tag{9}$$

where $D_i \equiv (a_i - a_1) + (c_i - c_1)$

Equivalently:

$$z_i'/z_i = D_i(t) + b_i^*(1 - z_i)z_i^{\alpha - 1} \tag{10}$$

To decide the time-path of z_i, and hence, y_i, one must specify $D_i(t)$ and $b_i^*(t)$, under some plausible conditions. Adopt now:

Assumption 2

$$b_i^*(t) \equiv \beta(\pi_i) \text{ for all } t \tag{11}$$

where π_t is the policy regime prevailing for economy i.

This means, once a policy is adopted, it is instantly understood by the agents so that correspondingly b_i^* takes a constant value over time.

Assumption 3[8]

$$r(t) = r^* \text{ for all } t \tag{12}$$

Under the assumed technology, this implies a constant capital/efficiency labor ratio, and hence $k_i'/k_i = 0$, for all i and t. Assumption 3 approximates the fact that there is no trend for the interest rate.

Assumption 4

$$a_1(t) = a_1^* \text{ for all } t \tag{13}$$

$$a_i(t) = 0 \text{ for all } t \text{ and } i > 1. \tag{14}$$

Assumption 4 approximates the fact that 1) for the United States (the technology leader for much of the post-WWII years), there is no trend for its growth rate, and 2) none of the Asian NIEs has every produced a single major product which is completely based upon local invention and design.

By (12)–(14), (10) becomes

$$z_i'/z_i = -a_1^* + \beta(\pi_i)(1 - z_i)z_i^{\alpha-1} \tag{15}$$

IV. A Graphical Illustration

To illustrate how the above model works, let us consider an example with five economies in the world, with:

$$a_1^* \in (0, 1/4), \quad \alpha = 2, \quad z_i(0) = z(0) \in (0, 1/2) \text{ for } i = 2, 3, 4, 5$$

$$\beta(\pi_5) < \beta^* = \beta(\pi_4) < \beta(\pi_3) < \beta(\pi_2)$$

$$\text{where } \beta^* = a_1^*/[z(0)\{1 - z(0)\}]$$

First, from (15) plot z_i'/z_i as a function of z_i for $i = 2, 3, 4$ in a modified phase diagram. This is depicted as Figure 5a. The solid line, the broken line and the dotted line correspond to the situations

[8]Data do not reveal any trend in the movement of interest rate. Since there is no trend, interest rate may be considered to consist of a constant term and a stochastic term. Here, in order to simplify the argument, we depress the stochastic term and assume that interest rate is constant.

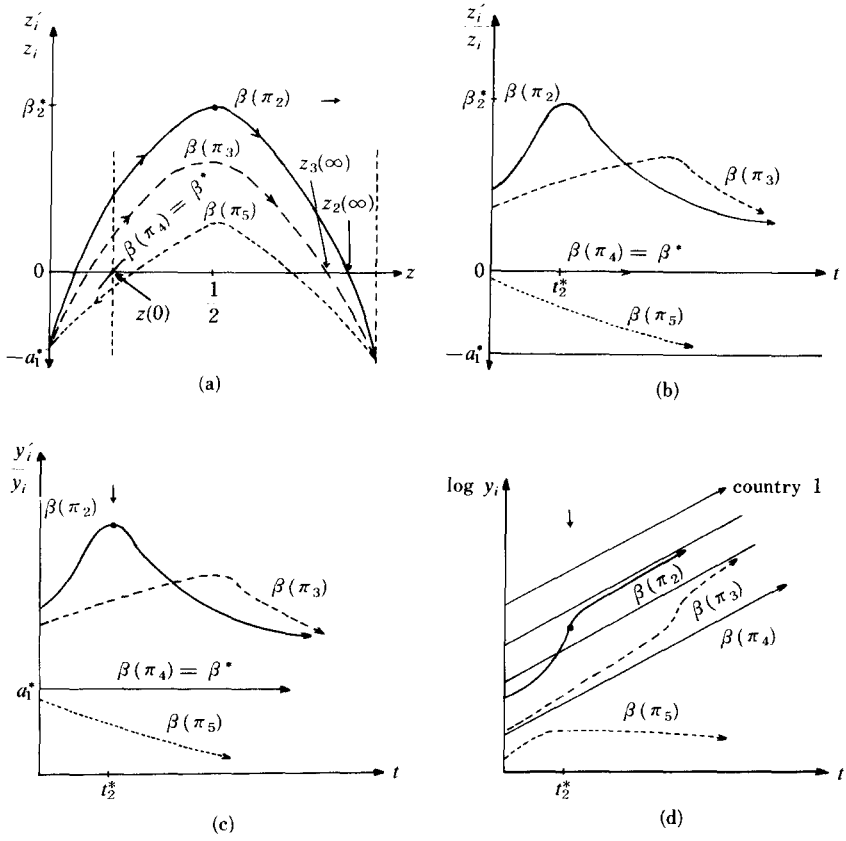

FIGURE 5

THE ANATOMY OF THE CATCHING-UP PROCESS

Note: Panels a, b, c, and d are aligned. For example, for economy 2, the peak growth rate for industrial competence is β_2^*, occuring when $z_2 = 1/2$ (see panel a) at time t_2^* (see panel b). At that instant, t_2^*, the growth rate of economy 2 also reaches its peak (see panel c), which means the time path of per capita output y_2 in log scale has its steepest slope, at an inflection point (see panel d).

pertaining to countries 2 $[b_2^* = \beta(\pi_2)]$, 3 $[b_3^* = \beta(\pi_3)]$ and 5$[b_5^* = \beta(\pi_5)]$, respectively. Starting from the same initial condition, $z_i(0) = z(0)$, the respective trajectories head toward the steady states $z_2(\infty)$, $z_3(\infty)$ and $z_5(\infty) = 0$, with $z_2(\infty) > z_3(\infty) > z(0) > 0 = z_5(\infty)$. On the other hand, country 4 will stay at the initial point $z(0)$ forever. Thus, the technological gap $1 - z_i$ narrows for country 2 as well as country 3, but widens for country 5, and remains the same for country 4. Further, the eventual gap is smaller for country

2 than that for country 3.

Next, we can integrate the trajectories in Figure 5a by quadrature, and plot the time-profiles of the growth rates of technical competence, z'_2/z_2, z'_3/z_3, z'_4/z_4 and z'_5/z_5. These are shown in Figure 5b. By an upward translation for a distance of a_1^*, we get the time-profiles of the growth rates of per capita output of these four economies in Figure 5c. Both countries 2 and 3 have unimodal growth profiles which approach asymptotically the limit of a_1^* from above. The profile for country 4 is a horizontal straight line and that of country 5 is a monotonically downward sloping curve approaching the horizontal axis.

Figure 5d presents the per capita output in logarithm scale for all the five economies. The asymptotic growth rate of countries 2 and 4 are the same as the growth rate of country 1. The growth rate of country 4 is the same as that of country 1 at any moment, while the growth rate of country 5 slows down towards zero.

The implications of the above example are as follows.

1) For economies which can tap into the "technological backlog" from abroad, the "high growth period" is a transient phase. Thus, it is impossible to expect the United States to achieve growth rates attained by Korea.
2) There can be differences in steady state growth rates between country 4 (say, Malawi) and countries 2 and 3 (say, Korea and the Philippines). Such differences are what motivate the contributions of Lucas (1988) etc.
3) Although the long-run growth rates of country 2 and country 3 tend to converge, the welfare implication is different. The fact that the steady state technical competence, $z_2(\infty)$ and $z_3(\infty)$, differ does not tell the whole story. As Figure 5d suggests, the fact that the high growth phase of country 2 leads that of country 3 for many years (say, 25 years) implies that the population of country 3 will have to suffer from poverty for one full generation or more. That is a fact no policy maker can ignore.

V. Concluding Remarks

What policies would stimulate technology transfer? Intuitively, "openness" to the outside world matters. Anecdotal evidence indi-

cates that competitive pressure, learning-by-others-doing, as well as factor mobility all have roles to play. Firms competing against foreign suppliers in markets of the advanced economies tend to learn more about production scheduling, sales promotion and after-sales service in remote locations. Firms cooperating with foreign investors may learn by osmosis, if the economy serves as an export platform for some advanced foreign markets. Labor mobility across firms can speed up information diffusion. Policies which encourage such activities should improve the imitative potential of an economy. Hopefully, factual data may be used to test these intuitive observations, but this will not be dealt with here.

A key component of our formulation is that the developing economy in question faces a perfect world capital market. This may apply to economies struggling with the debt crises. Yet, in principle, this is an achievable goal, judging from the experience of Korea, or Mauritius. Even for those economies with persistent export surplus today, e.g. Japan and Taiwan, they also had their days of foreign exchange shortage, in the not too distant past.

Our model may be generalized somewhat to allow for international interest differentials reflecting the risk premium. The essential point is that with international capital flows, the investment need not be equal to the saving of the same country.

What we try to explain in this paper is the observed unimodal profile of growth rate as in Japan and Taiwan. In such a study, matters can be simplified greatly if the interest rate has no trend, just as it is observed in real life. Such "trendlessness" is taken as given in this paper. This approach is quite different from the New Growth Theory, where every phenomenon is explained in term of the rational behavior of forward-looking agents. Of course, we could have adopted an approach as in Wan (1971), with the time-path of the interest rate decided endogenously. But that leaves open the questions: why should the observed interest rate series be trendless. One may try to explain this observed phenomenon as the implications of agents' preference, or production technology, etc. But then, such efforts may be misplaced. Since the trendless phenomenon comes from a world where some central bankers (e.g. the Fed of the US, the Bundesbank, and the Bank of Japan) matters greatly. Therefore,' a serious study may call for a N-person hierarchial differential game in which developing economies (including those undergoing the catching-up process) are interest rate takers, but the central bankers of some DCs behave strategically. This is clear-

ly beyond the scope of the current study.

In the mean time, as the world is paying full attention to the East Asian drama, some attempt at an analytical study presumably is better than none at all.

Finally, we note that our formulation here is consistent with a model where a large number of identical producers coexist in each country, each maximizes the present value of his own profit stream, and where any learning-by-imitation accrues only to individual workers. Imitation is an activity which diverts labor input from direct production, but it also enhances the value of marginal product of labor. Producers must select the pace of imitation to maximize his own current profit. In so doing, labor productivity also rises over time.

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