An Application of Convergence Theory to Japan's Post-WWII Economic "Miracle"

Benigno Valdés

Abstract: The author provides an interpretation of the post-World War II economic "miracle" of Japan as a process of economic convergence within the framework of the neoclassical Solow–Swan model of economic growth. He shows how the predictions of the Solow–Swan model are qualitatively consistent with the actual economic record of Japan in the decades following World War II. The article is intended to help in the teaching of economic growth and the Japanese economic miracle, either as part of a macroeconomics course or in an advanced elective course in economic growth and development or in Japan's modern economic history.

Key words: economic growth and development, economic miracles, Japanese economy
JEL codes: N15, O11, O53

Japan is a prime example of what the economics literature defines as a *growth miracle*, that is, an economy that experiences high rates of per capita income growth for a long, sustained period of time that enables it to move from being poor to being rich in only a few decades. Today, Japan is (and has been for a number of years) an economic superpower, but in the aftermath of World War II (WWII), its economy was in shambles. However, between 1948 and 1972 (a period of 25 years) Japan's per capita income grew at an average annual rate of 8.2 percent, in real terms. Then it fell to levels more in line with the advanced capitalist countries of the West, but by that time, Japan had already joined the rich countries' club.

This is an impressive episode of sustained economic growth, but most economists do not regard it as a miracle because it can be explained within the framework of standard economics. It is true, however, that in some circles (economic and otherwise) the profound crisis that Japan is currently experiencing casts doubts not only on the validity of this assertion but also about the usefulness of mainstream economics to understand the post-WWII growth experience of the Japanese economy.

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Of course, the standard models of economics are only theory. There is no certainty that the explanations they give to these (or other) economic events are definite in the sense that they provide the true way such events have developed. But to go as far as saying that the standard economic theory cannot accommodate the high-growth behavior of the Japanese economy is, in my opinion, a mistake. I try to show that the main facts of the post-WWII economic development of Japan can be accommodated within the framework of the neoclassical model of economic convergence and that this model is a useful tool in teaching the economic history of Japan.[1]

NEOCLASSICAL THEORY OF ECONOMIC CONVERGENCE

Model of Economic Growth

The basic elements of the mainstream (neoclassical) analysis of economic growth were laid down in the contributions of Solow (1956) and Swan (1956) and were further developed by, among others, Solow (1957), Phelps (1961), Cass (1965), and Koopmans (1965) (in the last two cases recouping the pioneering work of Ramsey [1928]). A long period of stagnation in this subject followed, in part for lack of data on which to test the theory. The publication of the data banks compiled by Maddison (1989) and Summers and Heston (1991) opened a new wave of research in economic growth with a refreshing empirical flavor. Among the major modern contributions to the standard neoclassical model are Barro (1991) and Mankiw, Romer, and Weil (1992).[2] These contributions constitute the latest version of the neoclassical model of economic growth, which I refer to as the Solow–Swan model. This model provides a series of interesting theoretical results, among which the following are particularly useful to my purpose:

1. Every economy has its own steady state, that is, a kind of growth ceiling to its own possibilities of sustained per capita income growth. This state is determined by the economy's level of technology, rate of savings (therefore also of investment[3] in physical and human capital), rate of population growth, and rates of physical and human capital depreciation (which, for simplicity, are assumed to be approximately equal). These variables intervene as follows: a higher level of technology, a higher rate of saving, a lower population growth, and a lower rate of depreciation all raise the economy's steady state (and movements of these variables in the opposite direction lower it). Although each economy has its own steady state or growth ceiling, it is not the same for all economies because they do not have equal levels of technology, rates of saving, and so on; nor is the steady state immovable—it can be raised (lowered) by managing these variables adequately (inadequately).

This situation may be formalized as follows: Let the production of output Y_t be a Cobb-Douglas function with physical *and* human capital defined by K_t and of effective labor $A_t L_t$ so that

$$Y_t = F(K_t, A_t L_t) = K_t^{\alpha} (A_t L_t)^{1-\alpha}, \tag{1}$$

where (following the assumptions of the Solow–Swan model), the level of knowledge A_t and the labor force L_t grow at the exogenous exponential rates g and n, respectively. It can be shown (Jones 1998, 36) that the steady-state per capita income is given by

$$y_t^* = A_t\left(\frac{s}{n+\delta+g}\right)^{\alpha/(1-\alpha)}, \tag{2}$$

where s is the rate of saving, and δ is the rate of capital depreciation. Given that $A_t = A_0\, e^{gt}$, equation (2) can be written as follows:

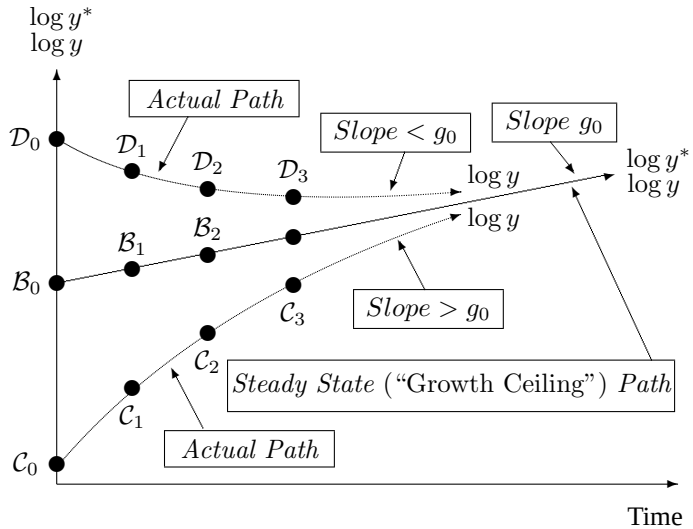
$$\log y_t^* = \left[\log A_0 + \frac{\alpha}{1-\alpha}\log s - \frac{\alpha}{1-\alpha}\log(n+\delta+g)\right] + gt. \tag{3}$$

As indicated in Figure 1, in the space $\{\log y_t^*, t\}$, this is a straight line of slope g, and the intercept is the expression in brackets. Given a country's specific values of s, n, δ, and g, I can interpret this line as the (logarithmic) representation of that country's growth-ceiling (steady-state) per capita income path.

2. Each country necessarily converges to its own steady state, and, once on it, per capita income can only increase at the same rate as the level of technology (i.e., at the pace of technical progress). This may be shown as follows: the rate of growth of per capita income, γ_y, is given by (Valdés 1999, chap. 3)

$$\gamma_y = g + \lambda(\log y_t - \log y_t^*), \tag{4}$$

FIGURE 1
Convergence toward the Steady State



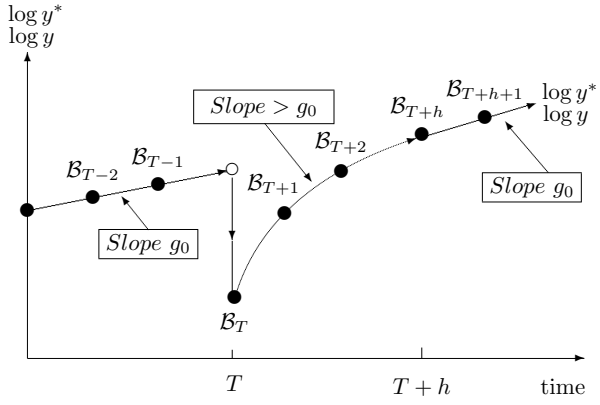
where y_t is the level of per capita income the country has in year t; y_t^*, the level of per capita income it would have if it were already in steady state (thus $\log y_t - \log y_t^*$ measures the distance that separates the economy from its steady state in year t); and $\lambda < 0$ is a parameter that represents the speed of convergence toward the steady state, that is, the percentage of the distance from the steady state that is closed in one year.[4] Three situations are possible: the economy is in steady state, is below it, or is above it. In the first case, $\log y_t - \log y_t^* = 0$, hence $\gamma_y = g$. In Figure 1, the economy moves along the steady-state path $\{B_1, B_2, B_3 \ldots\}$. In the second case, when the economy is below the steady state, $\log y_t - \log y_t^* < 0$ and, because $\lambda < 0$, it must be $\gamma_y > g$. As long as the economy is below its steady state, per capita income will grow at a higher rate than the level of technology but increasingly less so because in each successive period the value of $\log y_t - \log y_t^*$ will become smaller in absolute terms. Eventually, the economy will reach its steady state, and from then on, per capita income will grow at the same rate as the level of technology.[5] In Figure 1, per capita income follows the path $\{C_1, C_2, C_3 \ldots\}$ (see Appendix). The analysis is similar for the third case, when the economy is above its steady state. In Figure 1, per capita income follows the path $\{D_1, D_2, D_3 \ldots\}$.

Interesting Predictions

The preceding results lead to the following interesting predictions:

1. Imagine that a war destroys a large portion of a country's capital stock. Once the war is over and reconstruction begins, what does the Solow–Swan model predict regarding the rate of growth of per capita income? The answer is depicted in Figure 2. Prior to the war, the country had a rate of saving s_0, a rate of population growth n_0, a rate of depreciation δ_0, and a level of technology A_t growing each year

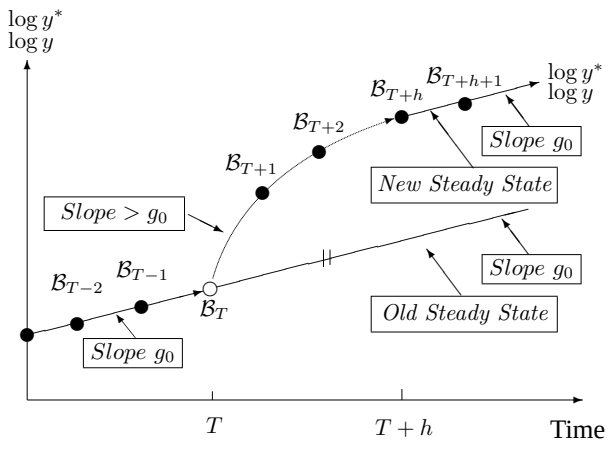
FIGURE 2
How a War Affects the Per Capita Income Rate of Growth



at the rate g_0. This amounts to saying that the country had the steady state corresponding to those values of *s*, *n*, δ, and *g*, represented by the straight line of slope g_0 in Figure 2. The war occurs at year *T* and, for simplicity, I assume that at the time the country is in steady state, its per capita income growing each year at the rate of technical progress g_0, following the path $\{\ldots B_{T-3}, B_{T-2}, B_{T-1}\}$. Because the war destroys a portion of the capital stock, *ceteris paribus* (with the same s_0, n_0, δ_0, and g_0), the level of per capita income in year *T* will be lower than it would have been had the war never occurred,[6] thus I have point B_T in Figure 2. This means that the destructive war situates the economy *below* its steady state. Hence, in subsequent years, its per capita income will grow at higher rates than the level of technology until the country again reaches its steady state, say in period $T + h$ in Figure 2, after which time the per capita income rate of growth returns to g_0.

2. Imagine that the country increases its rate of saving (and hence of investment in physical and human capital). What does the Solow–Swan model predict as a result of this policy action? The answer is depicted in Figure 3. To simplify, suppose that prior to this policy change the country was in the steady state corresponding to s_0, n_0, and so on, its per capita income growing at the rate g_0 along the growth-ceiling path $\{\ldots B_{T-3}, B_{T-2}, B_{T-1}\}$. In period *T*, say the current year, the rate of saving is increased to $s_1 > s_0$ and remains at this new value in the future. From equation (3), I know that this increases the intercept of the log y_t^* straight line, but the slope *g* remains the same because it is equal to the unchanged rate of technical progress. The increase in *s* lifts the economy's growth ceiling; the new steady-state path will be above the previous one but parallel to it because the slope continues to be g_0. Because of the policy change (the increase in the rate of saving), the country will be positioned below the corresponding new steady state, and therefore it begins to move toward it.

FIGURE 3
Per Capita Income Growth Following an Increase in the Rate of Saving

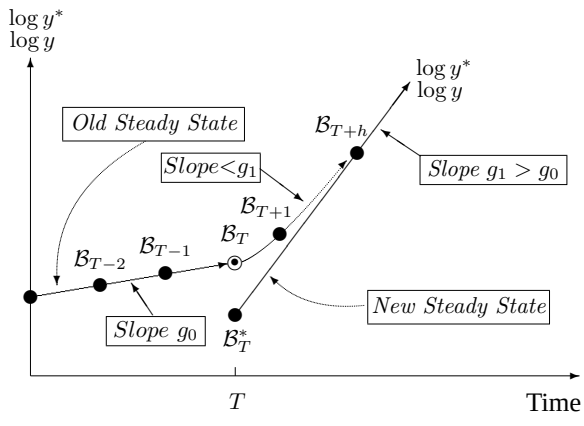


As long as the transition to the new steady state lasts, per capita income will grow at a rate higher than g_0 (the rate of technical progress). However, once the new steady state is reached (at future time $T + h$) and the economy settles on it, the growth rate of per capita income will return to g_0. Now, although the gain in growth is only temporary, the country will be better off than before the increase in the rate of saving, because it will now be moving along a higher steady-state path, thus enjoying each year higher per capita income levels than it would have otherwise had the increase in *s* not occurred.

3. Imagine that the country increases its rate of technological acquisition. What does the Solow-Swan model predict for the growth rate of per capita income as a result of this change? The answer is depicted in Figure 4. I assume, for simplicity, that prior to raising g the country is in steady state, its per capita income growing each year at the prevailing rate of technical progress g_0 along the steady-state path $\{\ldots B_{T-3}, B_{T-2}, B_{T-1}\}$. In the current year, T, g rises from g_0 to g_1. From equation (3), I know that this must tilt the steady-state per capita income path because the slope of $\log y_t^*$ increases. The increase in g also does something else, namely, it lowers the value of the steady-state per capita income for period T, that is, $\log y_T^*$ will be lower than it would have been if g had not increased. This is easy to see. From equation (3) we have

$$\left[\frac{\partial \log y_t^*}{\partial g}\right]_{t=T} = -\frac{\alpha/(1-\alpha)}{n+\delta+g} + T. \tag{5}$$

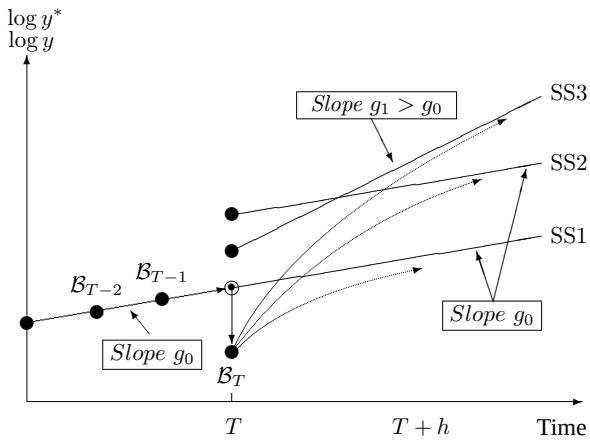
FIGURE 4
How an Increase in the Rate of Technical Progress Affects Per Capita Income Growth



Because the period $t = T$ in which the increase in g occurs is to be taken as the new initial period, I index $T = 0$, hence $[\partial \log y_t^*/\partial g]_{t=T} < 0$. Thus for period $t = T$, $\log y_t^*$ is lower than it would have been if g had not increased in that period. This result yields the new steady-state per capita income path in Figure 4. The actual level of per capita income must approach the new steady-state trajectory gradually. During the transition, the level of per capita income will grow at rates lower than g_1 but less so in each successive year. Once the new steady state is reached (at some future time $t = T + h$), per capita income will grow at the rate g_1. Moreover, this gain in growth will be permanent as long as the country is able to maintain the new, higher rate of technological acquisition, g_1. In this case, the per capita income gain is enormous, and there is no doubt that the best policy a country can design is to increase its rate of technical progress and sustain it. If it is unable to sustain the new, higher rate of technical progress g_1, its per capita income growth will decrease again, and so on.

4. Finally, imagine that the country experiences a war that destroys a portion of its capital stock and that, once the war is over, the country raises both its rate of saving and the pace of technical progress. What the Solow–Swan model would predict regarding the growth rate of per capita income in this case is depicted in Figure 5. Because this experiment is a combination of the preceding ones, the only comments needed are these: If the country had experienced only the destruction of its capital stock by the war, its per capita income would have converged to the steady-state path SS1 (Figure 5). If the increase in s was added, the convergence would have been to SS2; and if the increase in g was added, per capita income would have converged to SS3.

FIGURE 5
Effects on Per Capita Income Growth of a War that Destroys a Portion of the Country's Capital Stock, followed by an Increase in the Saving Rate and Rate of Technical Progress

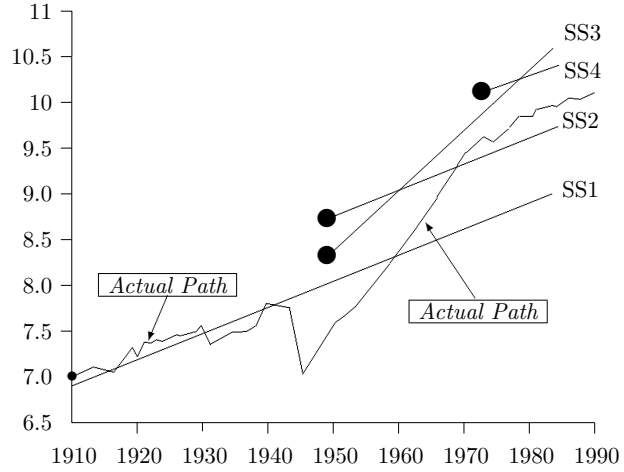


Similarity to Solow–Swan Model

This neoclassical model of economic growth provides a useful framework for understanding the basis of Japan's economic miracle. Consider the data in Figure 6. Specifically, the data show the actual evolution of Japan's per capita income since 1910. This evolution is strikingly similar to the one predicted by the Solow–Swan model for a country that had experienced the following events: a war destroying a large portion of the country's capital stock in the first half of the 1940s, an increase in the saving rate sometime afterward, and two changes in the rate of technological progress. The first change was upward, right after the war until the early 1970s, and the second was downward, from that time onward.

To make this similarity clear, I have superimposed plausible steady-state paths on the actual data, with turning points based on visual inspection. They are only hypothetical growth-ceiling paths, but they serve my purpose. If Japan had only experienced the destruction of a portion of its capital stock by war in the early 1940s, in the postwar era, its per capita income would have converged to the steady-state path SS1. If, beside the war, it had experienced an increase in the rate of saving, per capita income would have converged to a higher steady-state path, such as SS2. If it had also experienced an increase in the rate of technical progress, then per capita income would have converged to a steady-state path steeper than SS2, such as SS3. If this increase in the pace of technical progress had been truncated after (approximately) 1973, the convergence trajectory would have been deviated toward the flatter steady-state path SS4.

FIGURE 6
Japan's Real Per Capita Income, 1910–1985 (Logarithmic Scale)



Source: Data from Maddison (1991, Table A-5)

Actual Events

Did these events actually take place in Japan? Japan did participate in WWII, and a large portion of its capital stock was destroyed (early 1940s). The precise magnitude of the wartime destruction of Japan's capital stock is difficult to ascertain because the reported evidence is scant. Using the data in the *Hundred Year Statistics of the Japanese Economy* (1966), Maddison (1969) reported that about one-quarter of Japan's capital stock was destroyed during WWII. Hayashi (1997, 302) reported the same figure. An increase in Japan's rate of saving is also confirmed by the data. Japan's saving rate rose from an annual average of 19.8 percent for the period 1930–1948 to an annual average of 34 percent in the 1949–1980 period (the highest among the OECD countries).[7] Finally, the data also seem to confirm the existence of two major changes in Japan's rate of technical progress: one, upward, from the end of WWII to roughly 1973 and another one downward, thereafter. This follows from growth accounting exercises that show the Japanese index of total factor productivity (TFP) (a proxy for the level of technology) rising at an average annual rate of 6.4 percent between 1950 and 1973, well above the 4.4 percent average of the other G-7 countries, then falling to only 1.7 percent in the 1974–1988 period, compared to the 1.6 percent average for the other G-7 countries (Table 1).

EXPLAINING THE ACTUAL EVENTS

It appears that the Solow–Swan model accommodates the post-WWII rapid pace of Japan's economic growth in the sense that high growth is precisely what the model predicts for the events that took place in Japan. This raises two questions: First, why did the Japanese society, whose prewar saving rate was not high by international standards, choose to increase it so much afterward, taking upon itself a sacrifice in consumption beyond the one imposed by the war's destruction of its productive capacity? Second, why was the Japanese rate of technical progress so high from 1950 to 1973, in comparison with other OECD countries, and why did it decline so much thereafter?

TABLE 1
The Slowdown in TFP Growth Around the World

Country	1950–1973	1974–1988	Change
France	4.9	2.3	–2.6
Germany	5.6	1.9	–3.7
Japan	6.4	1.7	–4.7
United Kingdom	2.3	1.7	–0.6
United States	2.6	0.6	–2.0
Average	4.4	1.6	–2.8

Sources: Blanchard (1997) and Maddison (1991).
Note: TFP stands for total factor productivity.

The High Saving Rate

The answer to the first question may lie in a combination of factors, but to explain them, I need to dig a little deeper into the theory of economic convergence. Because by definition it is $c = y - i$, where c and i represent consumption per capita and investment per capita, respectively, and because $I = sy$ (account taken of the qualification made in note 3), I have $c = (1 - s)y$. Thus, the per capita consumption path mirrors the per capita income path scaled down by a factor $1 - s$ (Figure 7). On the other hand, from $c = (1 - s)y$ we have $\gamma_c = \gamma_y$, that is, the level of per capita consumption grows at the same rate as the level of per capita income, as indicated in equation (1). From the previous discussion, I know that an increase in s raises the steady-state per capita income path, and so it enlarges the distance that currently separates the level of per capita income from its steady-state level, which is now higher. Thus, y will grow faster than before the increase in s and so will c, because $\gamma_c = \gamma_y$. But whereas y will begin to grow faster starting from the level represented by point B_T, c will *not* begin to grow faster starting from the level represented by C_T, for the rate of saving cannot be raised without giving up the corresponding amount of consumption. Thus, c will begin to grow faster starting from a level below C_T, such as the one represented by point C'_T in Figure 8. By raising the rate of saving, both y and c more rapidly reach the levels they would have had if the war had not occurred. This speeding-up of convergence toward the hypothetical no-war levels of welfare is not gratis, because it implies a tradeoff between present and future consumption (Figure 8).

FIGURE 7
How a War Affects the Per Capita Income and Per Capita Consumption Paths

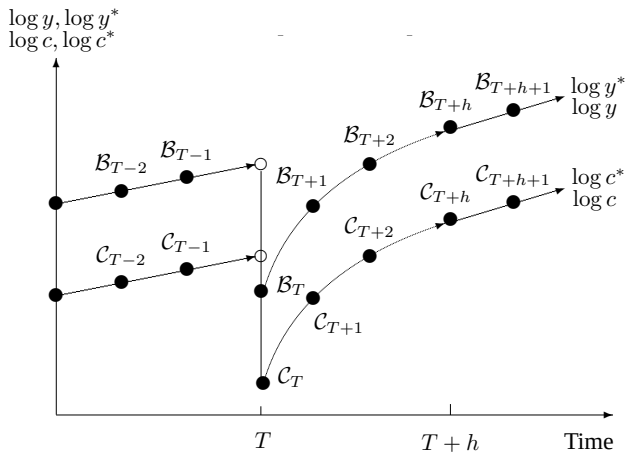
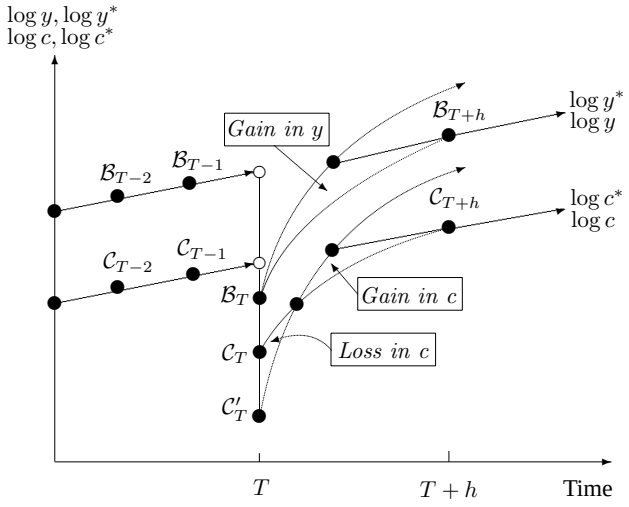


FIGURE 8
Gain and Loss in *y* and *c* from a Temporary After-War Increase in *s* Aimed at Speeding up Convergence Toward the Living Standards that Would Have Prevailed if the War Had Not Occurred



The logic behind this result is quite simple. Attached to each rate of saving is a corresponding stream of future investment, capital stock, production, and, therefore, consumption. A higher rate of saving today must at some point raise future consumption above the level achievable with the current rate of saving because it implies relatively higher levels of investment, stocks of physical and human capital, and production. In this sense, a higher rate of saving represents a decision to forgo present consumption to raise the possibilities of future consumption.

On the other hand, every society attaches a higher value to present than to future consumption. If offered to receive a candy *either* today *or* ten years from now, we would choose to have the candy today, because we are uncertain whether we will still be around in the year 2013. In valuing future consumption, we apply to it a rate of discount (the time-preference rate) that will be higher the less we value future consumption relative to present consumption. For any two societies, the one whose time-preference rate is higher will be less willing to save, because it gives a higher value to present than to future consumption. Although each rate of saving is attached to a corresponding stream of future consumption, it is also attached to the value society gives to future-relative-to-present consumption, that is, to its time-preference rate.

The theory of economic growth shows that the saving rate that leads to the highest stream of future (steady-state) consumption per capita is the one that results from a time-preference rate equal to zero, that is, the one that would be chosen by a society valuing present and future consumption equally. However,

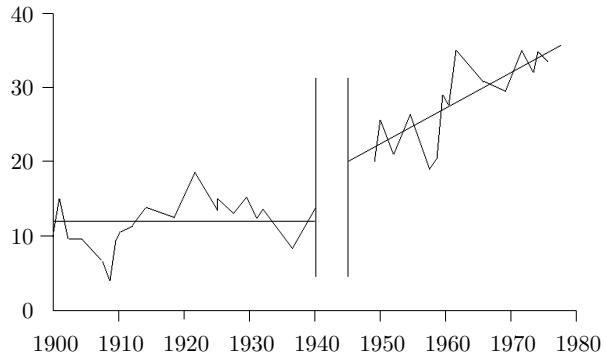
all societies have a strictly positive time-preference rate, so that their rate of saving is lower than the one required to settle on their corresponding highest path of future (steady-state) consumption per capita, and this shows that human beings are everywhere rational. After all, an increase in the rate of saving means a sacrifice in terms of lower consumption today but only an uncertain benefit in terms of higher consumption in the future. More saving today will, at some future time, allow for a higher consumption path than the one waiting for us under current saving, but no one knows if by then we will be alive to enjoy it!

Given a society's rate of time preference, there must be a threshold higher rate of saving for which the gain and the loss of welfare depicted in Figure 8 balance each other. Therefore we could expect that after a destructive war society would instinctively increase its rate of saving for the purpose of speeding up the process of convergence toward the level of welfare it would have enjoyed had the war not taken place.[8]

But then one would also expect the saving rate to return to its prewar value when the intended goal was attained, that is, the increase in *s* would be only temporary. However, this did *not* happen in Japan. In fact, the Japanese economy reached the level of welfare that it would have had in the absence of WWII (other things equal) by around 1960, yet the saving rate did not revert to its prewar value nor did it stabilize at the circa 1960 value, but, as shown in Figure 9, it kept on rising (Maddison 1992). Thus, whatever the weight of this *welfare recovery effect*, in the case of Japan, it is clearly not sufficient to explain the extent of the high post-WWII savings. What else was there?

A possible explanation is the *bequest* (Hayashi 1986, 1997) or *intergenerational generosity* (Valdés 1999) motive. The idea is that although a relatively high rate of time preference (and hence a relatively low rate of saving) can be interpreted as rational behavior in light of an uncertain future, it can also be interpreted as a proof of our selfishness, for it implies that we value present con-

FIGURE 9
Japan's Saving (Investment) Ratio, 1900–1975



sumption (ours) more than future consumption (our children's). It may be taken to mean that the current adult population is not willing to sacrifice more present consumption to leave a better legacy for its descendants (in terms of higher levels of consumption than the ones they will have based on our current saving effort). Obviously, the implication of this theory is that the rate of saving has been higher in Japan than in other OECD countries because the degree of intergenerational generosity is higher in Japan than anywhere else![9]

One might be tempted to ask why, if the Japanese are so intergenerationally generous, they did not show it before when Japan's prewar saving rate was not high by international standards. A plausible answer is that the war provided information they did not have before, namely, that their level of welfare, however high they might have thought it to be, was very low compared with the level attained by the developed Western nations. The Japanese society had largely ignored this fact because until WWII Japan lived with its back to the world.[10] In fact, one major consequence of the war was to bring an end to Japan's traditional isolationism. It was only then that Japanese society knew what a great effort would have to be made to reach the high living standards of the West. As a prominent Japanese economist has said, "Japan's saving rate has been high because the Japanese desired to accumulate wealth in order for their children to live as well as Americans do" (Hayashi 1986; 1997, 374).

The intergenerational generosity motive should not be taken lightly because, as an explanation for Japan's post-WWII high-saving behavior, there may be much truth in it.[11] This does not exclude, however, the possibility that other factors specific to Japan's postwar social and economic environment might also have influenced its saving behavior. In fact, there are additional (complementary rather than alternative) explanations. In the first place, Japan is a small country in surface and is densely populated; thus land is a scarce resource. Not only is there no land to support a large agricultural sector, but little is available for real estate building. Because land is scarce, it is expensive, and as a result, so is housing. This was also the case in the prewar years, of course; but the problem of high housing prices has been exacerbated in the postwar period by demographic expansion, by a steady flow of young people from agricultural villages to already crowded cities,[12] and by housing-supply speculation by real estate trades. Besides, the postwar Japanese banking system, generous as it has been for business financing (too generous, as the current wave of bank runs produced by the many bad loans given to firms clearly proves), has not shown much flexibility in lending to families. In Europe and the United States, families have been able to buy their homes with down payments as low as 15–20 percent (that is, they could borrow as much as 80–85 percent of the homes' value). For the Japanese, it has been much more difficult to borrow for the same purpose; in fact, down payments of 40 percent have often been needed to buy a home. Quite logically, a borrowing constraint of this magnitude, coupled with the high real estate prices, have forced home buyers in Japan to save a larger proportion of their incomes than the typical European or U.S. family.

The post-WWII Japanese system of labor compensation is based on a scheme of deferred payments that ties wages to seniority: low when the workers are

young and higher as they age within the firm. This system might also have contributed to the high aggregate savings–income ratio. There are many reasons for young workers to consume but fewer as they age. The lack of synchronization between labor incomes and spending needs might have been bridged with a flexible credit system, but the Japanese banks were not prone to family lending. Besides, only risk-taking individuals borrow against their future expected income, and, according to most accounts, the Japanese are risk averse (Hayashi 1986). Finally, it is often argued that Japan's tax system, by taxing capital gains lightly, has encouraged savings.

These reasons can help to explain why following WWII the saving rate was so much higher in Japan than in the other OECD countries. How then could Japan, with such high domestic savings and therefore low propensity to consume, manage to keep its economy operating at full capacity? The short answer is, because the Western countries, and in particular the United States, opened their domestic markets to Japan and allowed it to erect import barriers so that it could protect its industries from foreign competition in its own domestic market. Of course, this is something a country would not allow any other countries to do under normal circumstances. From the U.S. point of view, however, the situation in Southeast Asia was special at that time. Communism had been established in China and North Korea and was trying to move into Vietnam, Cambodia, and Laos. The possibility that it threatened South Korea, Taiwan, the Philippines, and possibly Japan itself if its economic well-being did not keep improving, seemed more than a mere thought. This situation, and a bit of guilt for having dropped the A-bomb on Hiroshima and Nagasaki, can explain why the United States allowed Japan to maintain balance of trade surpluses in their bilateral exchange and how Japan managed to keep its economy working at full capacity in spite of high domestic savings.[13] This situation was perfect for Japan: low interest rates at home owing to both the high domestic saving and the liquidity from international trade[14]; a high level of economic activity and hence a low rate of unemployment; and a high and growing foreign demand tempered by a relatively low domestic consumption, resulting in a tolerable rate of inflation.

The Changing Pace of Technical Progress

Concerning the second fundamental question, "Why was the Japanese rate of technical progress so high from 1950 to 1973 by comparison with other OECD countries, and why did it decline so much afterward?", the following is a plausible answer. By the end of WWII, the frontier of knowledge was not in Japan but in the United States, and any doubts the Japanese might have had about that were dissipated by the U.S. victory in the war. Possibly from the point of view of the Japanese, the defeat took on a clear meaning: If the Americans had won the war, it must have been that they were the best in the world, and the best ought not to be hated but imitated.[15] This Japan did after the war, well and fast (often showing little regard for patent laws[16]) and perhaps because imitation is easier, and usually cheaper, than invention, Japan closed the technological gap with Europe and the United States very quickly. The Japanese should be proud of this achieve-

ment. Anyone can disassemble a machine of the latest technological vintage, but few can uncover its structure and replicate the original to the point of making an even better machine. To do this, appropriate human capital is needed, and that can only be obtained with effort, sacrifice, and resilience, all of which the people of Japan supplied steadily.

Measuring a country's stock of human capital is difficult because economists have only recently begun to see this variable as essential for economic growth, and no appropriate measures for it have been constructed. Traditionally, economics has treated the individual as so many units of *jelly*-labor (all labor is treated the same), but distinguishing skilled from unskilled labor, a healthy population from an unhealthy one, and so on is essential to understanding the process of economic development. To circumvent the lack of appropriate data on human capital, I proxied it with variables such as *number of years of formal education*, and *life-expectancy*. This approximation leaves much to be desired,[17] but I think of it as being better than nothing. Recent research on the determinants of economic growth has shown that it is education at the secondary and higher levels (increasingly the latter) rather than at the primary level that has a considerable positive effect on economic growth (Barro 1997). This empirical finding does not mean that high school and primary educations are losing importance for economic growth. No one can pursue university studies without prior knowledge obtained at the high school and primary levels. It means that the level of knowledge needed to operate productively in today's world (the "standard" knowledge) is increasingly provided by the university.[18] Because this empirical finding comes from the analysis of the 1960–1990 period, I assumed that the new standard began to take effect as early as the 1950s. Japan worked hard to catch up with the countries that were highly endowed with human capital. In the 1950s in Japan, only 17.2 percent of the high school graduates entered a university, not a lot considering that only 47 percent of the youth with elementary education entered high school. The situation improved very quickly (Table 2), and the data reported in Table 3 give an understanding of the effort made by Japan on the educational front during the miracle.[19] Equally impressive was the improvement in the population's health during the same period (Table 4). Clearly, much of Japan's saving effort (sacrificed consumption) was devoted to human-capital for-

TABLE 2
Education Enrollment in Japan, Selected Years, 1955–75

Year	Elementary school educated youth entering high school (%)	High school graduates entering university (%)
1955	47.4	17.2
1970	79.4	24.2
1975	91.9	38.4

Source: Kosai (1997).

TABLE 3
Average Years of Formal Education of Population Aged 15–64, 1950 and 1984

Country	Total			Secondary and higher		
	1950	1984	% Change	1950	1984	% Change
France	8.18	10.79	32	3.22	5.79	79.8
Germany[a]	8.51	9.48	11	4.51	5.48	21.5
Japan	8.12	11.5	42	2.24	5.16	130.3
United Kingdom	9.40	10.9	16	3.40	4.92	44.7
United States	9.46	12.5	32	3.85	6.72	74.5

Source: Maddison (1987, Table A-12).
Note: The data refer to full-time formal schooling.
[a]The educational levels for Germany are understated because Germany has an intensive system of postformal training combined with formal education.

TABLE 4
Life Expectancy at Birth in 1960 and 1985

Country	1960	1985	Change (in years)	% Change
France	70.4	76.6	6.2	8.8
Germany	69.4	74.3	4.9	7.0
Japan	67.7	77.3	9.6	14.1
United Kingdom	70.8	74.7	3.9	5.5
United States	69.8	74.9	5.1	7.3

Source: Barro and Sala-i-Martin (1995, Table 10.1).

mation, and this, as suggested in the theory of technological diffusion (Nelson and Phelps 1966), which assumes that more human capital increases a nation's ability to absorb new technologies, surely contributed to its rapid TFP growth.

However, the imitation-based possibility of rapid technological improvement dies out as the imitating country uses up the worldwide stock of knowledge. In the end, its level of knowledge cannot increase faster than the technological frontier, that is, not more rapidly than the pace of new inventions (its own or someone else's) and no doubt more slowly than during the years of unbounded imitation, for it is always easier to imitate than to invent (that is, to add to the worldwide stock of scientific knowledge).

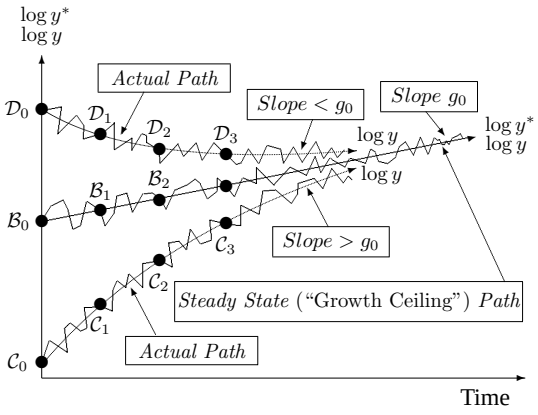
There could have been little doubt (but was Japan conscious of it?) that without moving from imitation to invention, at some point the rate of technical progress surely had to slow down, and this started to happen roughly in 1973. Indeed, for reasons that are still a bit mysterious, TFP growth began to fall all over the world, a phenomenon known as the worldwide TFP slowdown (Valdés 1999, chap. 6). The decline was particularly acute in Japan (Table 1), a clear sign that its imitation-based policy of technological improvement was beginning to face diminishing returns.

By that time, Japan had already joined the rich countries' club, and its achievements were too numerous to be overshadowed by a fuzzy development, as the TFP slowdown was seen to be. As of the late 1970s, could anyone have questioned the fact that Japan, having started from so low, had moved up by so much? Could it have been asked for more? On the surface, the answer was surely no, and as always happens when things seem to go well, no deeper scrutiny was undertaken. In retrospect, it should have been done. For below the rosy surface, Japan was building a risky economic infrastructure, an institutional framework suitable to let it grow in the worldwide environment in which the miracle took place, but not in the one that was to emerge three decades later. But that, which is the true cause of Japan's current economic troubles, is also another story.[20]

APPENDIX

A commentator of a previous draft of this article pointed out that although the use of the words "growth ceiling" to describe the steady-state trajectory is appealing, it might mislead students into thinking that, for the given values of s, n, δ, and g, under no circumstances the level of per capita income can rise above (or fall below) the steady-state path $\{B_1, B_2, B_3 \ldots\}$ (or, when in transition toward the steady state, above or below the smooth paths $\{C_1, C_2, C_3 \ldots\}$ or $\{D_1, D_2, D_3 \ldots\}$). This interpretation, of course, is not true because both along the steady-state path and during the trajectory toward it, the economy is subjected to transitory shocks of either a demand or supply nature (or both) that temporarily deviate the level of per capita income from the smooth paths described in Figure 1. This is of course clear to instructors of economics, but the warning about students being possibly misled must be recognized. Perhaps the solution is to start any course on growth theory by clarifying that all macroeconomic time-series variables exhibit long-run trends and short-run cycles. The analytical methods employed in growth theory (at least in the kind of growth theory used in this article) abstract from the short-run cycles and focus on the long-run, steady-state trends (and on the underlying [smooth] trajectories between different steady-state trends). Students will then surely see that whereas Figure 1 refers to the underlying long-run trajectories, the actual paths are like the ones represented in Appendix Figure 1.

APPENDIX FIGURE 1



NOTES

1. By saying that the main facts of the Japanese post-WWII economic development can be accommodated within the framework of the neoclassical Solow–Swan model, I mean that the model's predictions are qualitatively consistent with those facts. Whether the Solow–Swan model also provides a good econometric fit of such facts is beyond the scope of this article.
2. The 1990s have also witnessed the development of models of economic growth outside the mainstream (neoclassical) current, namely the literature known as *endogenous* or New Growth Theory, a very promising research agenda. These models also may be used to enlighten the Japanese experience, and I resort to them in some instances. The neoclassical Solow–Swan model and the New Growth Theory are not opposing analytical frameworks but rather complements (Valdés 1999, chap. 9; Barro, 1999). For a fairly comprehensive, nontechnical survey of the recent literature, see Jones (1998); for a more technical but readable survey, see Valdés (1999); finally, for more complete and technical surveys, see Barro and Sala-i-Martín (1995), and Aghion and Howitt (1998).
3. The reader might have noticed that the rate of saving is one thing and the rate of investment, which is what really counts, another. In a closed economy, they coincide, but in an open economy, they may differ: the investment ratio will be higher (lower) than the saving ratio if foreign investment in the home country exceeds (falls short of) the country's investment abroad. However, up to the 1980s (a period that covers the miracle's time span), Japan neither diverted much of its domestic savings abroad nor absorbed much direct foreign investment. Hence, it is no surprise that its domestic rate of investment (32 percent for 1949–1980) practically coincides with its domestic rate of saving.
4. Most empirical studies have found this parameter to be about –0.03, the same for all economies. This means that approximately 3 percent of the per capita income gap that currently separates an economy from its steady state is eliminated in one year; hence, it would take approximately 14 years to close one-half of the gap, 35 years to close two-thirds of it, and so on. Although there is some dispute as to whether the value of λ is –0.03 or higher (some studies have found it to be as high as –0.11), what really surprises everyone is its constancy. Indeed, given the variety of worldwide steady states, the uniformity of λ is a puzzling empirical finding.
5. Strictly speaking, the level of per capita income reaches the steady-state level only asymptotically, of course. I proceed as if the arrival of the steady state actually takes place at some finite future time.
6. Obviously, assume that the war reduces the capital stock in a higher proportion than it reduces the population (war also kills people).
7. Hayashi (1989) made a good case that some of the reported increase in Japan's saving rate is a statistical illusion. He argued that the official Japanese national accounts have an upward bias. He endeavored to correct this bias and arrived at a new estimation of the saving rate that is certainly smaller than the official report but nonetheless still considerably higher than that of the other OECD countries for the same period.
8. My analysis seems to imply that according to the neoclassical theory Japan's saving rate should have increased immediately after the war, yet as reported by Kosai (1997, 172–73), it actually fell for a few years before it began to rise:

   > [T]he consumption expenditures of the average urban worker household in 1946–7 amounted to more than 100 percent of his or her income. By 1955 that had dropped to a level similar to that of the prewar period [. . .], the propensity to consume continued to decline, and the saving rate increased to twice the prewar rate.

   Does this evidence contradict the theory? The neoclassical theory does seems to imply that after a destructive event like a war the saving rate should immediately increase for the purpose of bringing the economy back on its prewar steady-state path. However, the fact that in Japan (as in other countries in a similar situation) the rate of saving actually fell for a few years immediately after WWII does not contradict the theory. In fact, it reinforces the value of that theory as an analytical tool, for it makes it congenial with common sense. This is so because, immediately after a very destructive war (or, for that matter, an earthquake, a flood, and so on), the surviving households are so distressed with hunger that their rate of time preference should temporarily increase, that is, they temporarily value present consumption *vis-à-vis* future consumption much more than usual, hence the rate of saving must be expected to fall for a while. Only afterward, when life slowly evolves into business as usual, will savings rise to bring the economy back on its prewar steady-state path. That is all very neoclassical. To my knowledge, Christiano [1989] was first to put forth this argument, precisely in the context of analyzing Japan's post-WWII saving behavior.

   For the purpose of this article, however, the short-lived decrease in the Japanese rate of saving immediately after WWII is a minor theme. That is so because, as predicted by the theory, it was

bound to be overturned by the subsequent and much longer rising course of the rate of saving during the period of the miracle. (That is what the kind of long-run economic analysis that I am using demands from us, namely to focus on the economy's tendencies, rather than on its short-run dynamics.)

9. For a discussion of this analysis, see Valdés (1999, chap. 5).
10. [I]n 1637, following a bloody revolt known as the Shimbara Uprising, Japan was hermetically sealed off from the outside world. No Japanese was allowed, under pain of death, to leave the country, and any Japanese who was foolish enough to return from abroad was executed in a rather unpleasant manner. Foreigners were not permitted to enter the country at all; if they did, they were beheaded. In 1640, a band of brave but foolhardy Portuguese appeared, bearing presents and hoping that the *shogun*, Iemitsu, might relent. He did not. The whole crew of the Portuguese boat, with the exception of 13 people, was beheaded; the vessel with its cargo, including all the gifts brought to the *shogun*, was burnt. (Mikes 1970, 13)

    The 13 people saved from the killing were sent back to Macau with an explicit assignment, namely, to let the world know that the Japanese did not wish to meet anyone. In fact, "[b]efore they departed they were addressed by an official in these terms: 'You are witnesses that I even caused the clothes of those who were executed to be burned; let them [the Portuguese] think no more of us; just as if we were no longer in the world'" (Mikes 1970, 13). The message got across: after that singular event, not many *gaijin* (foreigners) had the courage to stop by until Commodore Perry of the U.S. Navy tried again, in 1853 (no presents this time), to open Japan to the world. He was slightly more successful (see note 15).
11. Hayashi (1986; 1997) seems fully convinced that this has been the main force behind Japan's saving effort.
12. To give an example, the share of the economically active population engaged in agriculture fell from 45.2 percent in 1950 to 26 percent in 1965 and to 12.6 percent in 1975.
13. As early (or as late!) as 1970, George Mikes, one of the finest Western observers of modern Japan, wrote the following:

    [J]apan has had good luck. First, she lost the war and before losing it her industry was, fortunately, destroyed. This is no facetious remark or frivolous joke, but a sober assessment, shared by most Japanese economists. Of course the loss of the war meant a great deal of suffering, humiliation and tragedy; but it also made efficient rebuilding much easier. Japan had to start from scratch and received all the help she needed. Without the war and the destruction which followed in its wake, Japanese industry could not possibly be half as up-to-date as it is. That was the Second World War. Further wars meant further strokes of luck. The Korean War was a godsend, coming just at the right moment. It was fought on Japan's doorstep and money galore poured in. The blessings of the Korean War had not even been fully counted when the Americans—Japan's best friends—obliged with the Vietnam War, another huge source of income. [Besides,] Japan is one of the most protectionist countries in the world. Japanese industry still plays the part of the little boy who has recently started from scratch and needs very gentle treatment. They cannot let foreign competitors in because their industry is too fragile. If it is, it is a fragile giant . . . The motor-car industry is the worst of the lot; but in every field the Japanese make concessions to foreign competitors only when their own export is threatened—and even then always the minimum concessions. Every advantage which they are never slow to claim for themselves—such as, say, landing rights of foreign aircraft—has to be fought for tooth and nail and is resisted to the last ditch. Japan claims all rights and facilities for her own exports but she has discovered that it is better to sell than to buy; better to export than to import . . . Perhaps the same thoughts have—at least *en passant*—occurred to other nations too, but they know better by now . . . Japan can still get away with her pose of weakness, particularly in America where the guilt of the atom bomb still lingers on. So poor little Japan—the third largest industrial power in the world—has to be helped and nursed . . . . (Mikes 1970, 123–25)
14. Recall that I am referring to a period in which the fixed-exchange-rate mechanism approved at Bretton-Woods at the end of WWII was still in use, and that, under one such system, the balance of payments disequilibria are automatically corrected via movements in the interest rate. For instance, a balance of payments surplus raises the reserves of the banking system and, in absence of "sterilization" measures, the money supply increases, thereby lowering the interest rate. Hence, under a fixed-exchange-rate mechanism, a balance of payments surplus is equivalent to a monetary expansion. Of course, the balance of payments is not the same thing as the trade balance; but if a current account surplus adds to a capital account surplus, or exceeds a capital account deficit, then a balance of payments surplus follows. As one would expect of a coun-

try recovering from a devastating war and heavily relying on imports, Japan experienced balance of trade deficits in the early post-WWII years, but the United States always came to the rescue, and although the balance of payments occasionally showed deficits—it did, in 1954, 1957, 1961, and 1963—the monetary tightening that it implied was not big enough to be a hindrance to growth.

15. Japan had experienced the same sentiment before. In the summer of 1853, Commodore Perry, of the U.S. Navy, traveled to Japan (with his fleet!). He carried a letter from President Fillmore for the *Shogun*, demanding that Japan (then fully isolated from the rest of the world by its own choice) open trade relations with the West. Perry delivered the letter and said he would return for an answer the following year; but "[b]efore leaving, he made a show of force by sailing up Yedo (Tokyo) Bay in defiance of the Japanese government. The Japanese had never seen a steamship before and were duly impressed. When Perry returned in February 1854, they capitulated, and a few weeks later a trade agreement was signed. . . ." (Mikes 1970, 24). Most nations would have reacted in anger, but the Japanese knew better than that;

    > [t]hey said: "If the *gaijin* (foreigner) can force us to do things we do not want to do, then the *gaijin* is stronger and more successful than we are. The *gaijin*, indeed, must be better. So we must learn his ways . . . If the *gaijin* has steamships we have never seen before, then we must learn how to build steamships . . . ". And they did, in almost no time. (Mikes 1970, 14)

    Japan sent people to Europe and the United States, learned what was new and did it fast, took it home and improved on it. Japan benefited from this episode of *imitation* so effectively that half a century later it was able to engage in various wars never losing one, so it did not occur to it that in WWII it would be on the losing side. But Japan was, and its main conclusion was that it had higher technical knowledge than its Asian neighbors but not as high as needed to win over the industrial powers of the West. Back to *imitating* them.
16. But then, who does (or did, particularly in those days)? The Japanese, too, made contributions to technical knowledge that their Western competitors took up completely gratis, as in the case of the "just-in-time production" managerial blueprint. It was introduced by Toyota in 1956, and soon afterward almost everyone was using it in Europe and the United States.
17. For instance, one year of formal education at a very good university is not the same as at a very bad one, yet they both count as one year. On the other hand, formal education is not the only means to increase a country's level of knowledge: experience, too, is important.
18. Perhaps it was the high school's level some 50 years ago but not any longer, so technical has the world become.
19. To add more significance to this achievement, it may be useful to mention that tertiary education, from its late introduction (Tokyo in 1877; Kyoto in 1897; Kyushu in 1909) to WWII, was characterized not only by the low number of graduates but also by its nontechnical orientation. For the aim of the scarce university education provided in Japan before WWII really was not to produce technicians and engineers but lawyers and generalist administrators who found their way mainly into the government's bureaucracy. Technical education was to be obtained by means of a master-apprentice system carried out at the shop floor (Crawcour 1997, 67; Yamamura 1997, 342). However, we now know that the possibility of achieving technical progress through this learning-by-doing method is definitely bounded and almost nil unless it starts from a minimum threshold of knowledge—the standard knowledge of the time. That is why, although the system of within-the-firm training has continued to this day in Japan, the apprentices are now largely university graduates.
20. For a brief, but thoughtful hint to this effect, see Noguchi (1998). An interesting point that is often raised regarding the peculiar institutional framework developed in Japan during the period of the miracle is the dual character of its economy: on the one hand, a highly competitive, exports-driven and very modern sector, using the latest technology; on the other hand, a technologically backward sector oriented to the domestic market, with a clear oligopolistic structure, shielded from foreign competition, and very much dependent on subsidies. Among other problems, this setting provided no incentives for innovation in the inward-oriented sector of the Japanese economy, thus creating one form of what Parente and Prescott (1994, 2000) called "barriers to technology adoption." This probably contributed to the reported post-1973 severe slowdown in productivity growth.

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