Machinery Investment as a Key to American Growth

J. Bradford De Long
Harvard University and NBER

March 1992

Abstract

Examining economic growth in the post-World War II era and in the very long run reveals a strong association between growth and machinery investment: economies heavily investing in machinery see returns of twenty-five percent or more. A number of pieces of evidence—most importantly the correlation of growth and machinery investment with favorable machinery supply—suggest that machinery is a key factor in growth. Thus current low U.S. machinery investment rates are cause for concern. If they continue, U.S. productivity and standards of living are unlikely to remain among the world's highest for long.

I. Introduction

Machinery investment has been closely associated with economic growth since the beginning of the Industrial Revolution. New technologies were *embodied* in new types of machines: at the end of the eighteenth century steam engines were necessary for steam power, and automatic textile manufacture required power looms and spinning machines; in the early twentieth century, assembly line production was unthinkable without heavy investments in the new generations of high-precision metal shaping machines that made parts interchangable and assembly lines possible. Recent innovations fit the same pattern: basic oxygen furnace and continuous-casting steel-making technologies need oxygen furnaces and continuous casters. "Flexible system" implementations of mass production need numerically-controlled machine tools. Communication and data processing systems need fiber-optic connections.

Such investments in machinery have for the most part proven worthwhile: the productivity growth made possible has given the average American today more than ten times the wealth of the average American at the turn of the 20th century. In the industrial age those nations that have prospered—like early nineteenth century Britain, turn of the twentieth century Germany, or post-

World War II Japan—have been those that invested in machines and learned how to efficiently use machine technologies. Nations that fell behind—like turn of the twentieth century Britain or post-World War II Argentina—have been those that lagged in the accumulation and use of industrial machinery. Machinery investment, advances in technology, and economic prosperity have gone together in the industrial past. There is no reason to believe that things are different now, or will be different in the future.

Examining either the economic performance of industrial and industrializing nations in the post-World War II era or the very long-term experience of the entire twentieth century reveals that economies that heavily invested in machinery realized high rates of return indicates that economies that heavily invested in machinery realized high rates of return: on the order of twenty or thirty percent. National investments in machinery have thus been paid back in less than half a decade. Part of this rapid payback comes directly through immediate productivity gains from new machinery. But at least as much comes indirectly: workers and firms that install and use new generations of machinery gain valuable hands-on experience. Organizations learn how to adjust their routines to make efficient use of new technologies. Workers become more skilled and productive as well as they gain experience with modern machines.

Such increases in productivity arising indirectly out of machinery investment can be kept proprietary only with great difficulty. Workers who can use and adapt new technologies can and do demand higher wages, for their skills are as valuable to firms down the street as to their current employers. Firms copy operating procedures from path-breaking competitors. Thus the gainers from machinery investment include not only investing firms but their workers, and include competing firms and their workers as well. Moreover, one-third of increases in wealth flow to the government in higher tax payments: the room for tax cuts or spending increases provided spreads the benefits from machinery investment widely.

Three conclusions follow:

First, any nation wishing to be among the world's industrial leaders should shape its tax preferences and industrial policies to encourage the installation and use of machinery. The skills

learned and experience gained by utilizing modern technologies are very valuable assets. The wedge between the profits earned by investors and the value of machinery investment—counting the skills and expertise gained by the workforce—to society as a whole appears very large. Policies that increase machinery investment carry benefits far outweighing costs.

Second, nineteenth-century economists like David Ricardo and Karl Marx were wrong to fear that capitalists and corporations would extract more in excess profits than machinery could add in productivity. They feared that bosses would substitute machines for workers and erode workers' bargaining positions. The past century shows that this is not the case. As much of the benefits from machinery investment appear in the form of higher wages as of higher returns to capital. For most of the twentieth century American workers have been the most highly-paid in the world. They have been the most highly paid because—not in spite—of America's being a capital- and machinery-intensive economy.

Third, current very low U.S. national savings and net machinery investment rates are cause for extremely serious concern. As long as Americans do not save—or as long as the American government borrows as fast as Americans save in their private capacities—then Americans are not investing in the machinery that embodies new industrial technologies. American workers and firms will not learn how to efficiently use such new technologies. In such a situation a large trade deficit—the reverse side of a high rate of foreign investment in the U.S.—is to be welcomed: far better for citizens of Germany and Japan to be investing in America than for no one to be. But in such a situation the odds that American productivity levels and living standards will continue to be among the world's highest are slim.

II. Room for Improvement in American Economic Performance

In the late summer of 1990 the U.S. entered a recession. The unemployment rate, which had hovered near five percent, crept up to six and then seven and a half percent.[1] Bankruptcies

[1]By the yardstick of the unemployment rate, the 1990–92 recession was mild compared to the 1981–83 recession, during which the unemployment rate touched ten percent. However, this difference does not arise because

multiplied along with worries of excessive leverage and possible financial crises. Commentators spoke of how the Bush administration's economic failure placed in jeopardy the continuation of what had become a quarter-century of Republican presidential dominance.

But viewed from a perspective that takes in all of post–World War II American growth the 1990–1992 recession does not look very important. In fact, it is relatively hard to spot. Figure 1 plots U.S. production per worker (adjusted for inflation) from 1950 to the present.[2] These years saw productivity—gross domesticproduct divided by the number of workers—nearly double in real terms from $20,000 to almost $40,000 dollars of 1985 purchasing power.[3] The two percent or 750 dollar fall in output per worker from 1989 to 1991, or even the four percent decline of the Reagan-administration recession of 1981–1983, are small wriggles on a steeply upward-climbing graph.[4]

---

employment remained strong over 1990–92, but because more potential workers did not enter the labor force, or stopped searching for jobs. Both recessions have seen a fall in the rate of net job creation of approximately 1.5 million per year, relative to trend employment growth.

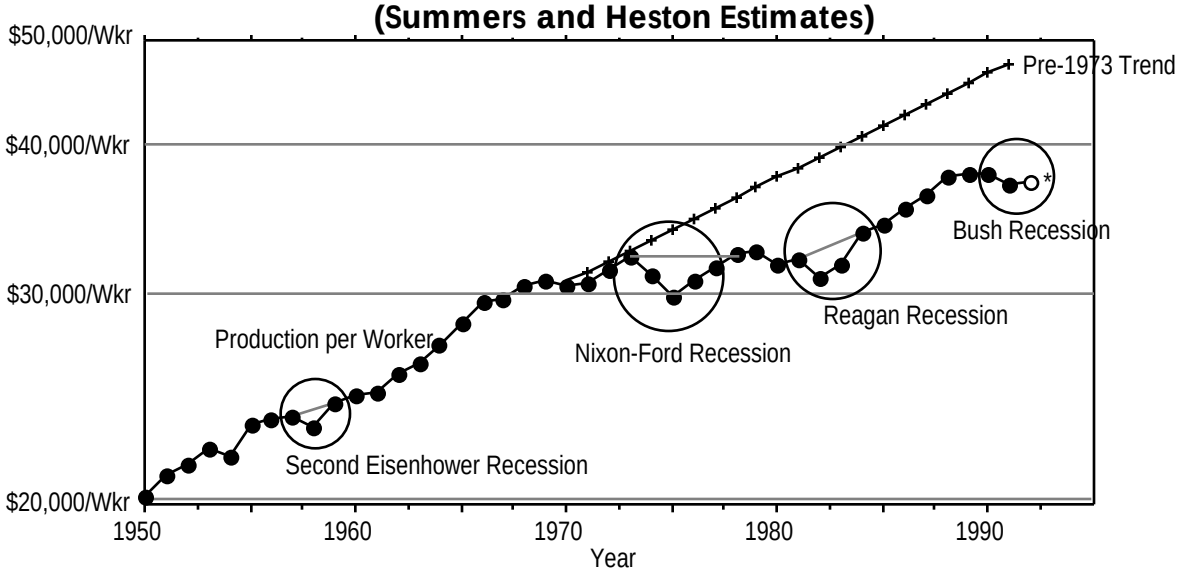
[2]The estimates shown in figure 1 were constructed by Robert Summers and Alan Heston. See "The Penn World Table V," *Quarterly Journal of Economics* (May 1991).

[3]Output *per capita* rose even more rapidly, as the share of the population in the labor force increased by an additional tenth.

[4]Although recessions are hard to see in figure 1, this does not mean that they are small. An economic policy that avoided the 1982-1983 recession and kept production growing smoothly from its 1981 to its 1984 level would have increased America's wealth by one tenth of a year's production—$350 billion dollars' worth of factories not built, highways not resurfaced, waste sites not cleaned up, children not educated, washing machines and automobiles not purchased, and meals not eaten. The 1981–1983 recession, and this current 1990–1992 recession, were expensive economic disasters for America.

Moreover, recessions reduce the general welfare by more than observed reductions in output and productivity would suggest because the burden of losses in a recession is so unequally distributed. Those who lose their jobs, or their businesses, can find themselves severely impoverished while their neighbors next door are unaffected. The point rather, is that recessions—while significant—are much, much less important than the engine of long-run economic growth. Recessions do economic damage to America, but the productivity slowdown has done magnitudes more damage.

Figure 1
Gross Domestic Product per Worker at 1985 Prices, and Pre-1973 Trend
(Summers and Heston Estimates)



*Projected.

Figure 1 shows that the business cycle is not the most important determinant of economic welfare. Instead, the most important determinant is the pace of the long-run upward climb of productivity. A decade that sees steep recessions of production below previous peaks but also a strong upward long-run productivity growth trend is much to be preferred over a decade that sees only shallow recessions but also stagnant long-run productivity growth.

Thus the dominant feature of figure 1—and the most important piece of bad economic news for America—is not any of the post-World War II recessions, but the relative retardation in the long-run growth trend of the past two decades. Had production per worker continued to grow at its pre-1973 pace, output per worker would now be nearly $50,000 per year (in 1985 dollars) instead of stalled below $40,000—as a country the U.S. would be a quarter richer than it in fact is today.

From 1973 to today the total economic loss from this retardation adds up to more than twelve trillion dollars—twenty-four times as much as the cost of the 1981–1983 recession, and if we have good luck this year perhaps fifty times the cost of the 1990–1992 recession. This

productivity slowdown, not any recession, is today's most serious economic problem.[5] Good economic policies will be made by keeping both eyes focused on the productivity trend and on what can be done to restore long-run growth—not by focusing on dealing with short-run recessions.

The productivity slowdown has created an "age of diminished expectations."[6] It has given rise to the widespread sense that this is not the country we hoped twenty years ago that we would live in today. Most voting Americans are distressed by the increase in relative inequality in the 1980's: it is the first business cycle expansion in memory in which the poorest fifth of Americans are worse off at the expansion's end than the poorest fifth were at its beginning.[7] But slow productivity growth over the past two decades means that Americans today are not as rich as they expected to be, and believe that they deserve to be. They feel under significant economic pressure themselves, and have become less generous. The past two decades have taught politicians that today's voters object strongly to expanding the welfare state to moderate the rise in inequality. They have taught those who—like me—want American politics to take a more social democratic turn that such a program cannot even be placed on the agenda while the productivity slowdown continues.

Many would argue that once underway the productivity slowdown was irreversible, that there is no option but to accept diminished expectations. They point to similar slowdowns in western European growth, and conclude that the magic of the 1950–1973 period cannot be recaptured. They believe we have no choice but to learn to live in this era in which the pace of long-run growth is slowed and it takes productivity not thirty but eighty years to double.

However, there is one powerful argument against this belief that the pre-1973 growth trend is out of reach. One country has reached it, at least as far as its productivity in producing

---

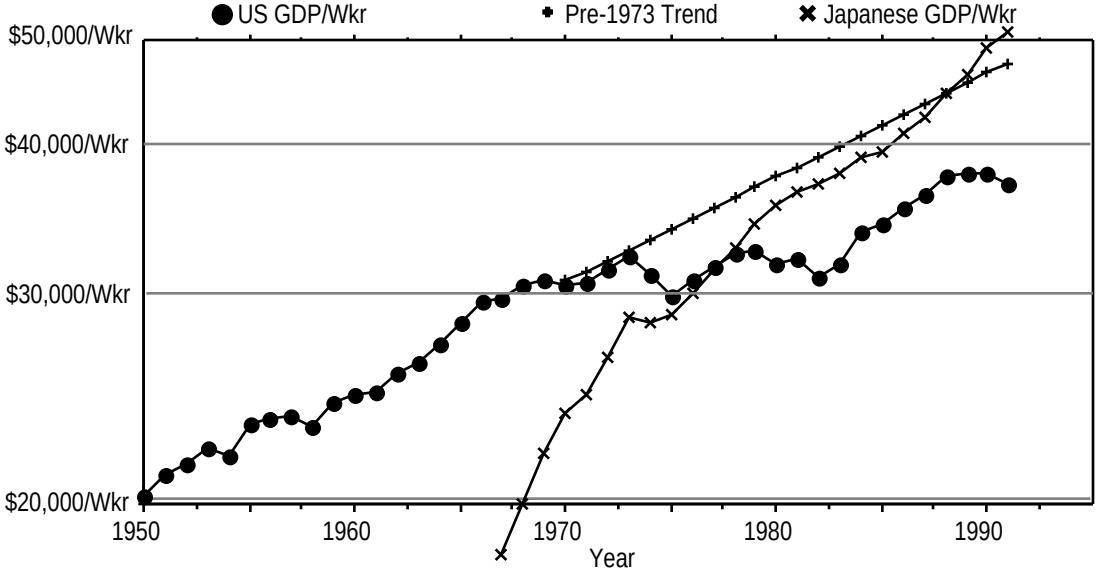
[5]It is traditional to blame the beginnings of the productivity slowdown on Richard Nixon and his administration. The rise of OPEC and the consequent high and unstable price of oil, the end of the Bretton Woods era and the shift to a régime of unstable exchange rates, the loss of confidence in price stability and the rise of a mentality fearful of inflation—all of these shocks played a role in the slowdown of long-run growth. But the growth slowdown has persisted too long for such explanations to be adequate.

[6]Paul Krugman, *The Age of Diminished Expectations* (Cambridge, MA: M.I.T. Press, 1990).

[7]David Cutler and Larry Katz, "Macroeconomic Fluctuations and the Disadvantaged," *Brookings Papers on Economic Activity* (Fall 1991).

tradeable manufactures is concerned. Figure 2 is a graph that we in the United States are going to see increasingly often over the next decades. We should get used to it. It shows U.S. and Japanese output per worker in constant prices (converting yen into dollars at the average of 1987–1991 real exchange rates). Figure 2 shows that Japanese productivity today is at, or is even a little above, where the U.S. would have been had the pre-1973 trend continued.

Figure 2
U.S. and Japanese GDP per Worker in 1985 Dollars
(Yen Converted at Average 1987–1991 Exchange Rates)



Two different figure 2's could be drawn. The other would compare GDP's using purchasing power parities, and would show the U.S. still "ahead" of Japan. In the U.S. goods that are not internationally traded—think of houses, or land, or agricultural products, or the services of those who work in wholesale and retail trade—are much cheaper in relative terms than they are in Japan. Comparisons made at purchasing power parities show the U.S. richer by a substantial margin: the average American lives better than the average Japanese.[8]

But this alternative figure 2 would answer not a question about relative productivities but a question about relative living standards. Comparisons at average exchange rates measure

[8]In large part because the United States was "born rich" with its abundant land and natural resources. .

production by how many internationally traded goods it would buy. Comparisons using purchasing power parities are appropriate for assessing relative living standards—how well-off in relative terms Americans are. Comparisons, like figure 2, that use average exchange rates measure what countries have managed to do with the land and resource bases that they possess. If you are interested in comparing relative standards of living, make comparisons using purchasing power parities; if you are interested in comparing productivities at making the manufactured goods that enter world trade, make comparisons using average exchange rates.

Figure 2, and the economic accomplishments of Japan, are useful yardsticks. They show what America should be accomplishing. They suggest that the post-1973 productivity slowdown was not in fact inevitable, and that with proper policies could be reversed. They pose a challenge that should be met by accelerating American economic growth to match the benchmark provided by our own pre-1973 growth trend, and by the accomplishments of the Japanese.

III. Machinery Investment and Productivity Growth

What has distinguished successful from unsuccessful economies, measured in terms of their rates of economic growth? Both the very long run record of relative growth rates over the past century, and the record of post-World War II growth in a much broader sample of nations, show a key difference: the rapidly-growing economies were those that had high rates of investment in machinery.

The Very Long Run Record

Figure 3 plots the association of machinery investment rates (as a share of total output) against the growth rates of output per capita for seven nations—Argentina, Canada, Germany (the *Bundesrepublik* after World War II), Italy, Japan, the United Kingdom (including southern Ireland until 1913), and the United States—over the past century.[9] Each point shows the

[9]See J. Bradford De Long, "Productivity Growth and Machinery Investment: A Long Run Look 1870–1980," *Journal of Economic History* (forthcoming June 1992). The investment estimates used in this paper are equal to new

economic growth and machinery investment experience of one economy over an approximately fifteen year period,[10] with some period start and end dates offset in order to match major historical events. For example, the period that begins in 1900 ends not in 1915 but in 1913, before the beginning of World War I.

Figure 3 shows a strong association between machinery investment and growth: more than half the variability in output per capita growth can be accounted for by differences in rates of machinery investment. Moreover, machinery investment has a closer association with output per capita growth than do other factors—like literacy or school attendance, rates of total investment or investment in categories other than machinery, or the potential for "catch up" by closing the gap between a country's productivity and the world's best-practice productivity level.

Adding additional factors related to productivity to regression equations does not produce a much better fit than does machinery investment alone: even simultaneously adding a large number of such variables—secondary school enrollment rates, population growth rates, non-machinery investment rates, and the current degree of relative economic backwardness—does not significantly add to predictive power. Collectively, such factors only account for an additional ten percent of the variability of productivity growth.

---

investment less retirements. It is thus larger than is calculated according to the "net investment" concept, which subtracts depreciation on currently-installed and useful capital. This sample of nations is dictated by data availability: these are the nations for which national income and product accounts of sufficient reliability to construct figure 3 exist. And among these nations, Argentinian long run national income and product accounts data are of lower quality. See Alan Taylor, "External Dependence, Demographic Burdens, and Argentine Economic Decline After the *Belle Époche*" (Cambridge, MA: Harvard University CFIA Working Paper 92-1) for a detailed discussion of the Argentine experience.

[10]The use of fifteen-year periods as the units of observation reduces the potential confusion between short-run business cycle fluctuations and long-run shifts in rates of economic growth. If the data were grouped in five year periods, or examined year-by-year, then a substantial proportion of variability would come from business cycle fluctuations. In recessions output drops, but because productive resources have become slack, and not because the reduced pace of investment has significantly reduced the output that could be produced if capacity utilization and employment were at their normal levels. Such business cycle fluctuations would generate a spurious association between investment and short-run growth, unrelated to the true underlying links between investment and long-run growth. The fifteen-year frequency of observation reduces such contamination. It does not eliminate it. Note that the bottom left points in figure 3 are due to the short-run effects of the Great Depression, and not to the long-run relation of investment to growth.

Figure 3
Machinery Investment and Economic Growth in Seven Countries, 1870–1990

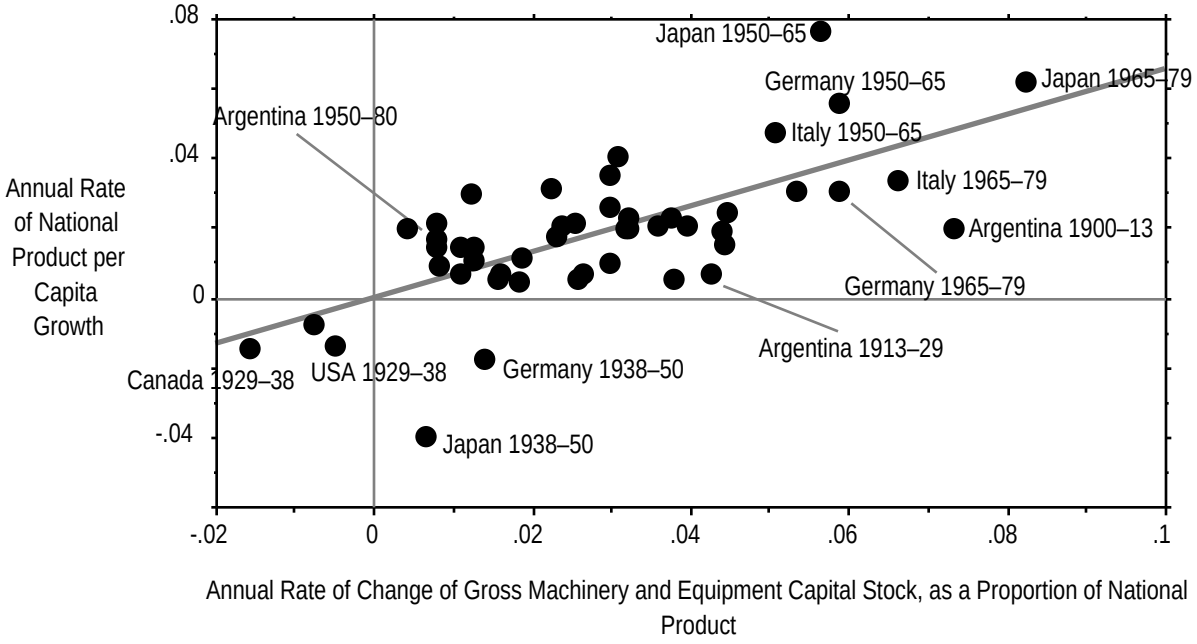
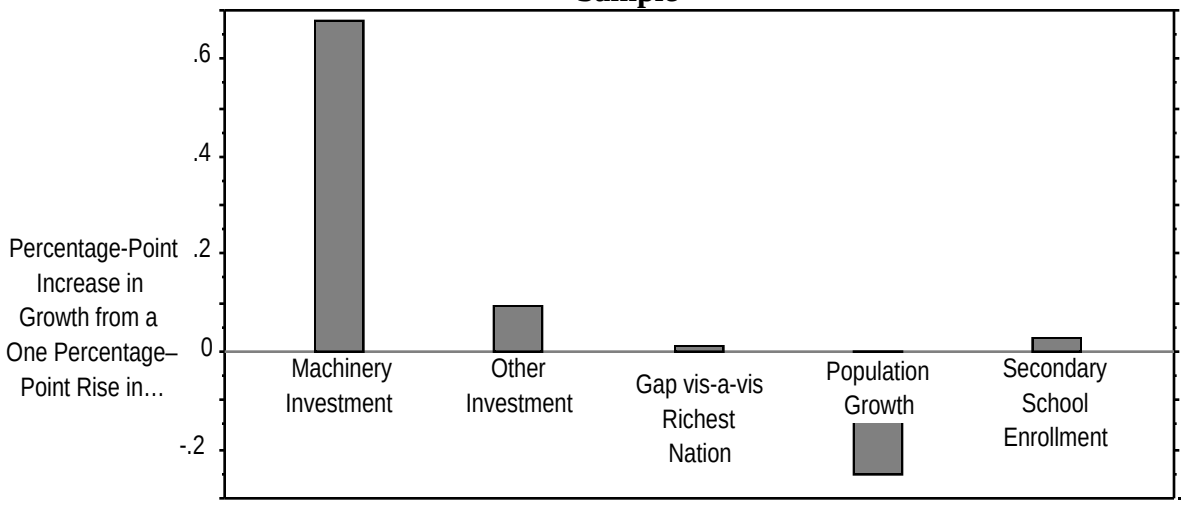


Figure 4 presents typical regression results, reporting increases in economic growth rates associated with one percentage point rises in a number of growth-related factors.[11] A one percentage point rise in the machinery investment share of output is associated with an increase of more than 0.5 percentage points per year in the rate of economic growth; an equal rise in non-machinery investment is associated with a growth rate increase of less than 0.1 percent per year.[12]

[11]Standard errors of the regression coefficients are as follows: 0.117 (machinery investment), 0.095 (other investment), 0.010 (productivity gap vis-a-vis richest nation), 0.463 (population growth), and 0.028 (secondary school enrollment). The squared multiple correlation is 0.605. The standard error of the regression is 1.4 percentage points per year.

[12]The highest-growth highest-investment points plotted in figure 3 (with the exception of 1900–1913 Argentina) come after World War II. The post-World War II era has seen growth more rapid than any previous period. But the association of machinery investment and output growth does not stem from the contrast between the pre- and post-World War II eras. In the sample underlying figure 3, post-1950 growth has been no more rapid on average than what would have been predicted from the pre-1950 relationship.

Figure 4
Dominance of Machinery Investment as a Correlate of Economic Growth in the Long-Run Sample



The Argentinian Example

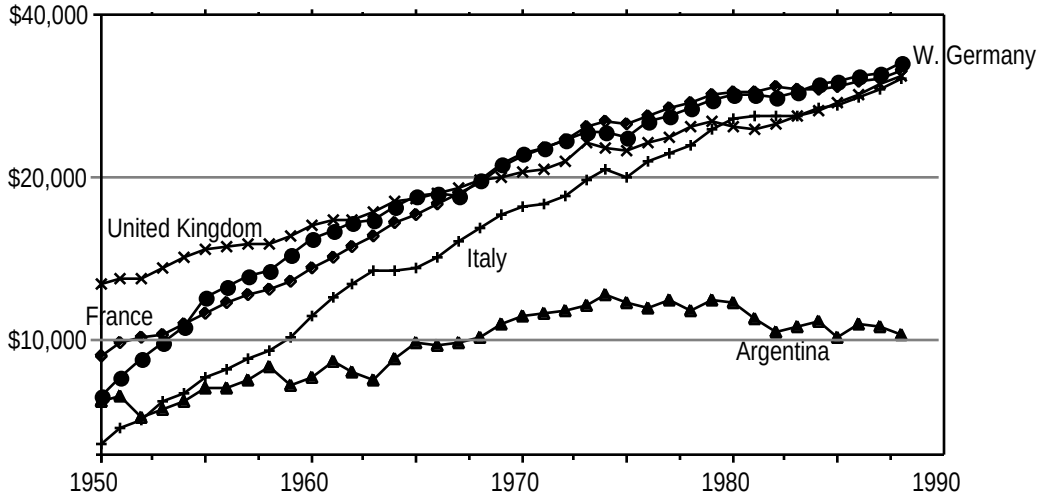
Moreover, one nation in figure 3 has failed to share in the post-World War II boom. Six of the nations in figure 3 are currently counted as among the industrial economies. The seventh—Argentina—is today part of the third world. Yet it was a first world nation until the mid-1950's. Argentinian post-World War II machinery investment is unimpressive. One of the richest nations in the world in 1900, it is now poorer than Brazil, South Korea, and Taiwan—and far poorer than the OECD nations that were its peers at the turn of the century. Figure 5 shows Argentina's relative economic stagnation and decline since World War II.

Carlos Díaz-Alejandro analyzed Argentina's decline.[13] The Great Depression left Argentina suspicious of free-trade: its trading partners had shut it out to reduce their unemployment. In this environment Juan Perón gained support for a program of national assertion and populist redistribution. Perón's program of economic stimulation, price controls, wage increases, and trade restrictions produced almost half a decade of rapid growth. But then exports began to fall.

---

[13]Carlos F. Díaz-Alejandro, *Essays on the Economic History of the Argentine Republic* (New Haven, CN: Yale University Press, 1970).

Figure 5
Post-World War II Argentine and European Real GDP per Worker Levels
(Summers and Heston Estimates, 1985 Dollars)



The resulting foreign exchange shortage gave Perón only unattractive options. He chose to further restrict imports, believing that a continuation of redistributions to urban workers, and a reduction in dependence on the world economy was in Argentina's interest. First priority for foreign exchange went for materials; second priority for consumption to keep living standards high; last priority went to investment. In spite of healthy national savings, machinery investment in Argentina has been low since World War II because of the resulting difficulty of importing foreign-made industrial capital goods. In Díaz-Alejandro's view, Argentina became a third world nation because it followed populist policies that crippled machinery investment, and made its workforce unable to learn how to use new generations of modern industrial technologies.

The Post-World War II Era[14]

For the post-World War II era reliable machinery investment and economic growth estimates are available for many more countries: approximately nine times as many.[15] This

[14]This section is based on J. Bradford De Long and Lawrence H. Summers, "Equipment Investment and Economic Growth," *Quarterly Journal of Economics* (May 1991).

[15]Chiefly as a result of the United Nations International Comparison Project. See Irving Kravis, Alan Heston, and Robert Summers, *World Product and Income* (Baltimore, MD: Johns Hopkins University Press, 1982); United Nations, *International Comparisons of Prices and Purchasing Power in 1980* (New York: United Nations, 1985);

larger sample shows the same pattern as did the longer-run seven-nation sample. Figure 6 presents the scatter of machinery investment and growth using a "high productivity" sample, made up of 25 nations that in 1960 were already relatively rich and possessed the human and material infrastructures necessary to take advantage of modern industrial technologies.[16]

Figure 7 presents the same scatter diagram using a larger 61-nation sample. And figure 8 presents coefficients from regression equations using both the high productivity and the larger samples.

In figure 6 differences in machinery investment rates account for five-ninths of the total variability in 1960–85 growth rates. Other plausible factors related to economic growth—like population growth, non-machinery investment rates, and the level of productivity relative to the U.S. level—account for less than one-eighth of the variability. In a statistical sense the growth miracles or disasters of the post-World War II period among the industrial nations are associated with high or deficient machinery investment.[17]

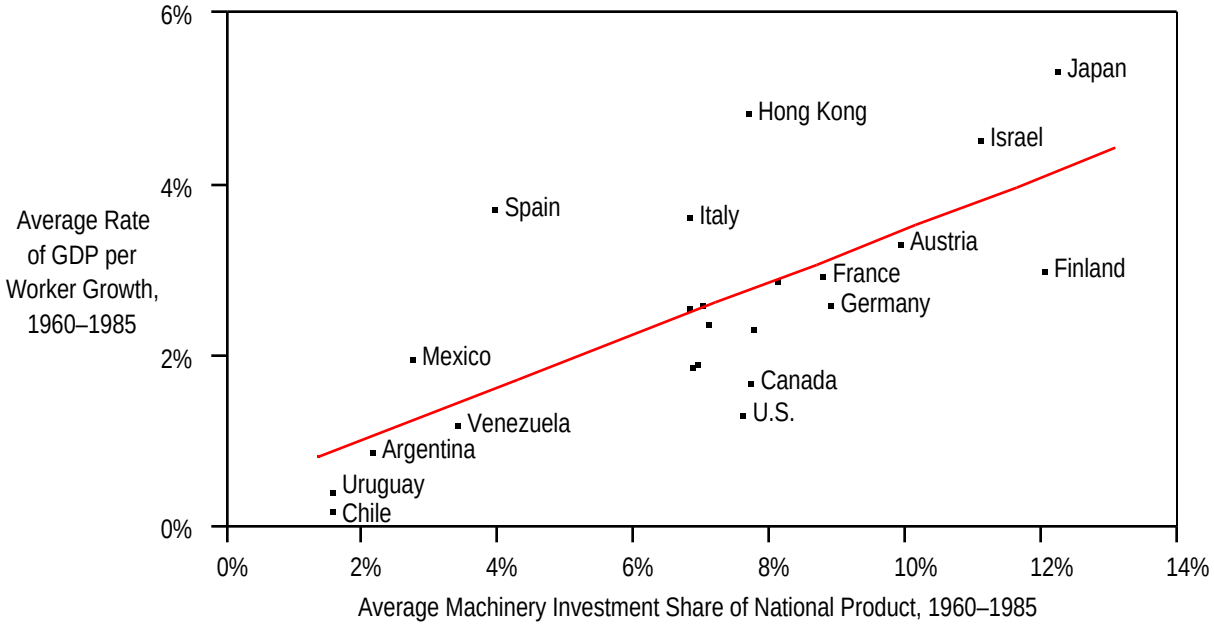
---

and Robert Summers and Alan Heston, "A New Set of International Comparisons of Real Product and Prices," *Review of Income and Wealth* (March 1988), as well as Summers and Heston, "The Penn World Table V."

[16]This sample was selected by taking all nations for which data were available that had levels of GDP per worker greater than 25 percent of the U.S. level in 1960.

[17]In the 25 nation sample, the large effect of machinery investment is largely driven by the contrast between the experience of South America—Argentina, Chile, and Uruguay—and the experience of the rapidly-growing economies of East Asia—Japan and Hong Kong. This raises the possibility that differences in growth rates that the regression interprets as due to different rates of machinery investment are in fact due to differences in "culture" and attitudes toward "enterprise." But the three countries in the bottom left corner of figure 6 were all rich and industrialized in 1950: they had, in the previous three quarters of a century, demonstrated that they did not have significant cultural barriers that prevented industrialization or growth. Díaz-Alejandro's analysis suggests that their slow growth in the post-World War II era was the result of an unfortunate concatenation of circumstances in which certain politico-economic weaknesses had disastrous effects.

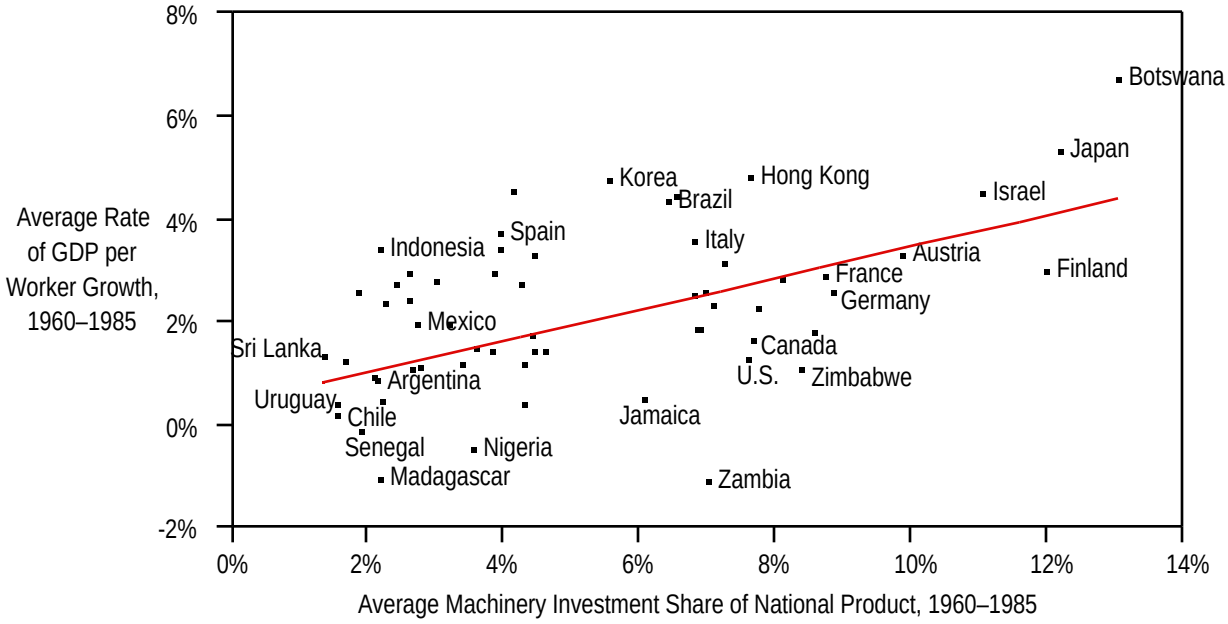
Figure 6
Post-WWII Growth and Machinery Investment, Rich Nations



In the larger post-World War II sample, including very poor as well as rich nations, other systematic factors—initial GDP per worker levels, labor force growth rates, and non-machinery investment rates—do not play a larger role. They account for less than one-twentieth of the variability of output per capita growth rates. Machinery investment rates, by contrast, account for more of the variability of growth rates—a quarter—although for a smaller fraction than in the 25 nation sample.[18]

[18]See De Long and Summers, "Equipment Investment and Economic Growth," for details of the regression equations. The machinery investment coefficient is estimated with high precision. In both samples its standard error is less than .065. Note that the relationship between machinery and growth is significantly stronger for the sample of nations relatively rich in 1960 than for the larger sample as a whole. Differences in machinery investment rates are not the only important determinant of growth in relatively poor economies. Fast-growing poor nations must avoid the growth of large public sectors that would place a heavy load on their economies. They must also create the educational and material infrastructures to support development if they are to acquire, install, and learn how to use the modern machinery that embodies industrial technologies.

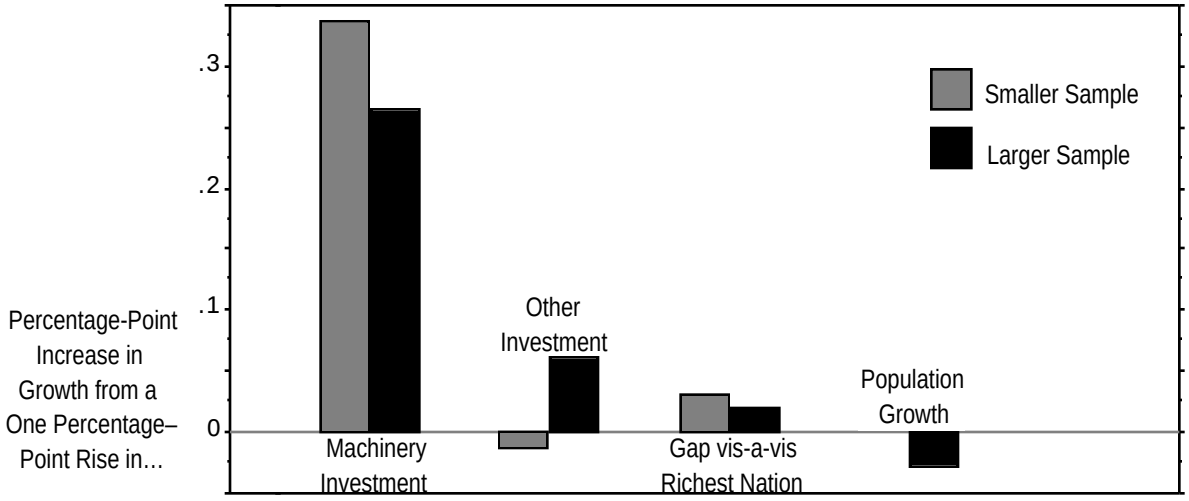
Figure 7
Post-WWII Growth and Machinery Investment, Larger Sample



The regression coefficients shown in figure 8 suggest that an increase of between 3 and 4 percentage points in the share of national output devoted to machinery investment is associated with an increase in the growth of GDP per worker of 1 percent per year. Over the 25 years of the sample, such an increase in growth rates cumulates to a difference of 30 percent in the final level of GDP per capita.

This implies that differences in machinery investment account for essentially all of the extraordinary post-World War II growth performance of Japan relative to the sample as a whole, and for essentially all of the deficient growth performance of a country like Argentina. Argentina has achieved a relative GDP per worker growth rate deficit of 2.1 percent per year over 1960–85 relative to the average pattern seen in the sample of 25 relatively rich nations. This growth rate deficit has seen Argentina's 1985 level of GDP per capita fall thirty percent in relative terms compared to the average of the sample of 25 relatively rich nations. In both the case of Argentina and the case of Japan, more than four-fifths of this difference is accounted for by their rates of machinery investment.

Figure 8
Dominance of Machinery Investment as a Correlate of Economic Growth Rates in the Post-World War II Era



III. Does High Machinery Investment Cause Rapid Growth?

The existence of a strong association between rates of machinery investment and economic growth does not, of course, by itself mean that a high rate of machinery investment causes rapid growth. Rather than the chain of causation running from machinery investment to growth, it could run from growth to machinery investment. Wealthy nations on average see more running shoes purchased than do poor nations. But this does not mean that subsidies for running shoes are the key to accelerating growth.

This section argues that the association between machinery investment and growth does in fact arise because machinery investment is a key factor causing economic growth. The argument has three steps.

First is an examination of the association between machinery investment and "intensive" productivity growth (holding the number of workers constant) as opposed to "extensive" labor force growth (holding productivity per worker constant). "Intensive" (productivity) growth and

machinery investment are more closely associated than “extensive” (labor force) growth and machinery investment. This would not be the case if increasing GDP were the cause that increased the demand for machinery investment. Then both intensive and extensive growth would be correlated with machinery investment.

Second is an analysis of the joint behavior of prices and quantities: growth is associated with high quantities and low prices of machinery investment. If the high quantity of machinery investment in rapidly growing countries were due to some other factor, that both caused rapid growth and increased the demand for machinery, we would expect to see high machinery investment and machinery prices go together: as underlying growth rates varied, countries would find themselves at different points on an upward-sloping machinery supply curve and rapid-growth nations would have both high quantities and relatively high prices of machinery. This is not so. Instead, as GDP per worker varies countries appear to find themselves at different point on a downward-sloping machinery demand curve.

Third is a survey of the links between the process of innovation and rgw macroeconomic associations documented above. Studies of innovation stresses that expertise in handling and modifying new technologies is the result of experience—that the best way to learn how to use a new technology efficiently is to practice using it. Such micro processes would naturally lead to the macro pattern of a strong association of machinery investment and growth that we see.

Intensive and Extensive Growth

If faster growth leads to higher investment because faster growth generates a larger and richer market, we would expect investment to respond equally to “intensive” increases in output generated by productivity and to “extensive” increases generated by population. It should not matter much whether the larger and richer market comes from having more consumers or richer consumers.

Figure 9
Machinery Investment and "Intensive" as Opposed to "Extensive" Growth in the Post-World War II Period

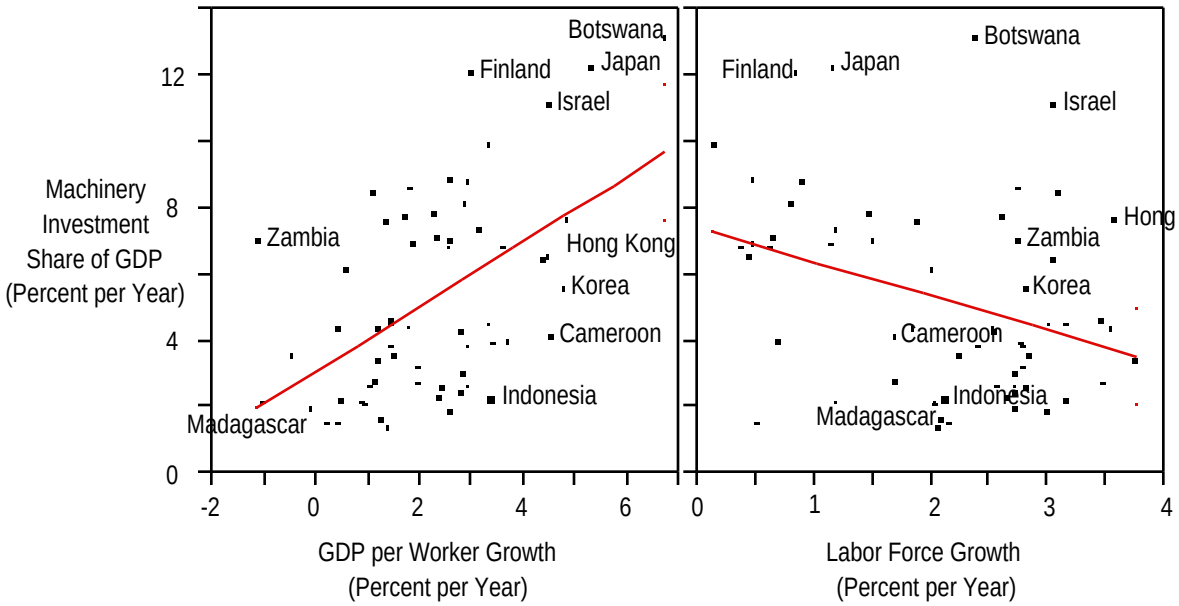
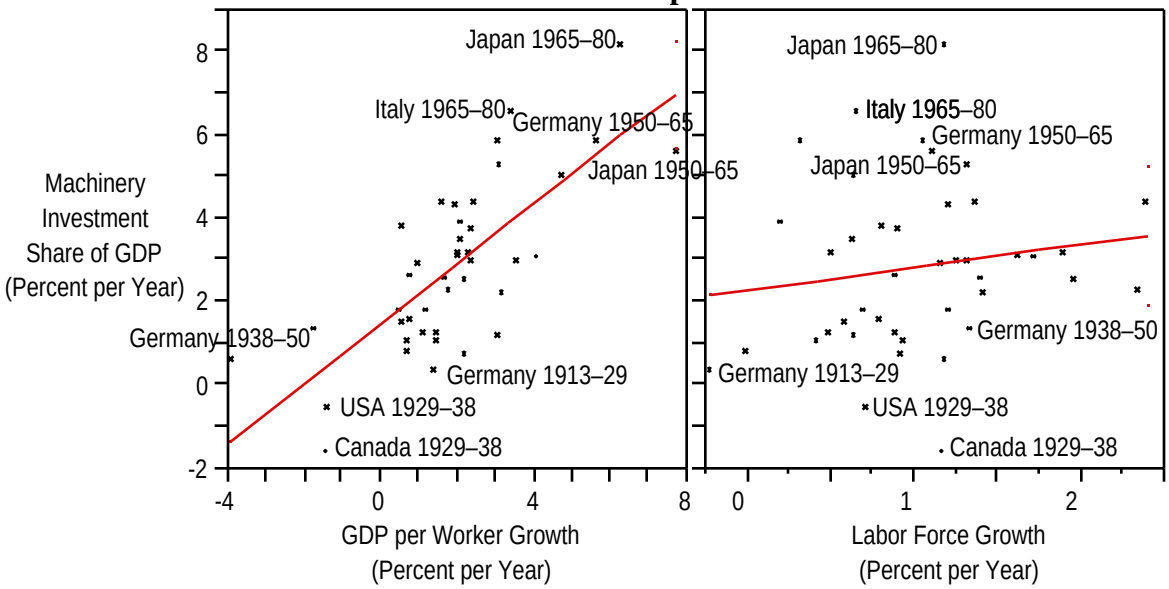


Figure 9 plots the association in the post-World War II period between machinery investment and the two "intensive" and "extensive" components of GDP growth—the rate of growth of GDP per worker, and the rate of growth of the labor force. Machinery investment is strongly associated with increases in GDP that come from increasing productivity (holding the labor force constant). It is weakly—even *negatively*—associated with increases in total output that come from increasing the labor force (holding productivity constant).

A similar close relationship between machinery investment and intensive growth holds as well for the long run, seven-nation sample, as figure 10 shows. Rapid growth is associated with higher rates of machinery investment. But it is *intensive* growth that is especially strongly associated.

Figure 10
Machinery Investment and "Intensive" as Opposed to "Extensive" Growth in the Long-Run Sample



Prices and Quantities

The inverse association of machinery prices and growth is powerful evidence that high machinery investment is primarily a cause and only secondarily a result of rapid growth. If high rates of investment were a consequence rather than a cause of growth, the price of machinery would be relatively high in rapidly-growing countries: strong demand would press on the limits of supply, and raise prices. Fast growth would increase machinery investment by raising profits and the demand for machinery. This would move the economy upward and outward along a machinery supply curve, as shown in the first panel of figure 11. Rapid growth would go with high machinery investment rates, and relatively high machinery prices.

But this is not so. Rapid growth is associated with low, not high, machinery prices. High machinery investment countries for the most part do not have an extraordinarily strong derived demand for machinery investment, but instead favorable supply conditions.

Figure 12 plots machinery relatively prices (compared to levels expected given a country's

current level of economic development)[19] against machinery investment. The symbol plotted for each point distinguishes relative growth rates: the fastest-growing fourth, the second quartile, the third quartile, and the slowest-growing fourth of nations are plotted with different symbols. The faster growing nations do indeed have both high machinery investment quantities and low machinery investment prices.

Figure 11
Supply, Demand, and the Correlation of Machinery Prices and Quantities

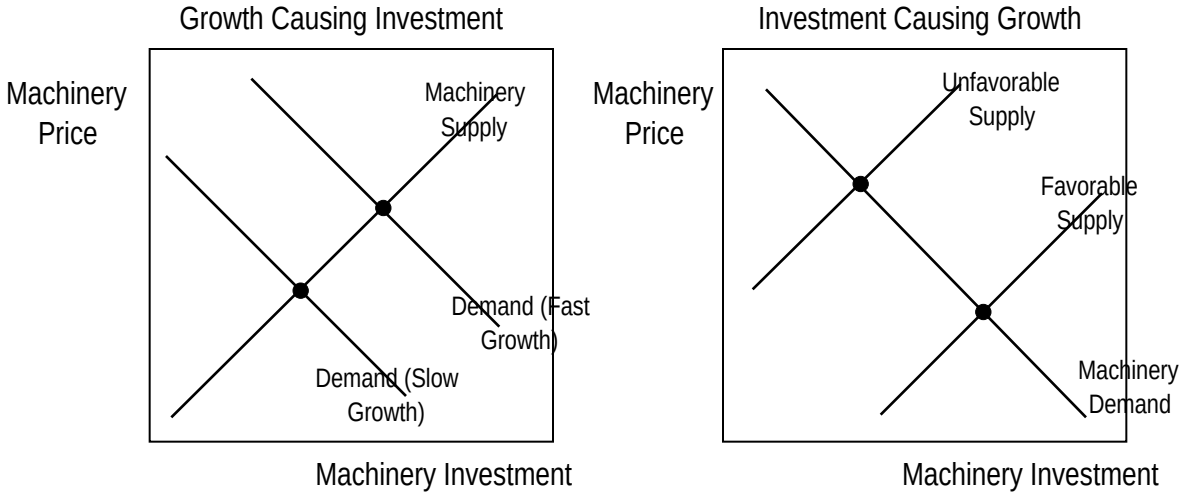


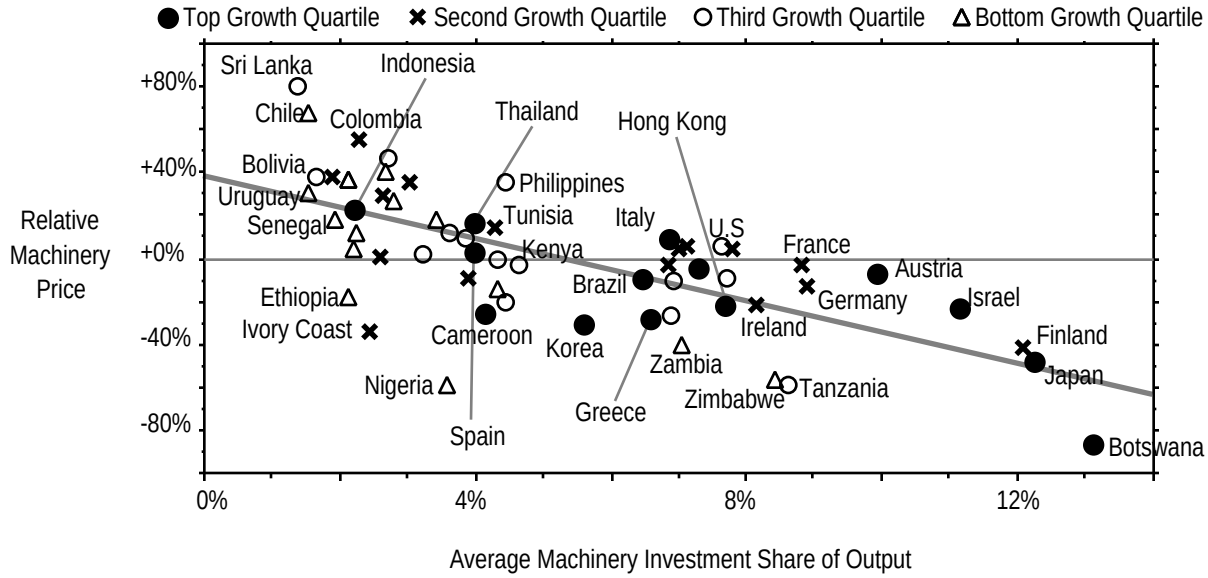
Figure 12 shows different countries positioned at different points on a downward-sloping machinery demand, not on an upward-sloping machinery supply curve.[20] This indicates that fast-growing nations are those which have had favorable machinery supply conditions—and that high rates of machinery investment are primarily a cause, not a consequence of rapid growth.

---

[19]The relative machinery price plotted on the vertical axis of figure 12 is the difference between the real relative price of machinery and what the price is expected to be given the strong relationship between the level of productivity and machinery prices. Machinery prices are markedly lower in richer countries.

[20]There is one group of countries in figure 12 that are anomalous in view of the experience of the rest of the sample: African outliers like Zambia, Zimbabwe, and Tanzania have relatively high machinery investment shares, relatively low machinery prices, and growth rates that have been extraordinarily slow given either their machiy prices or their machinery investment shares. One possibility is that the reported investment shares and prices are inaccurate because of widespread corruption. A second possibility is that investment has been misdirected into areas where it has low value because decision makers in these largely state-owned economies have their eyes on the problem of maintaining political support for the current government rather than on the problem of increasing production or making profits.

Figure 12
Prices, Machinery Investment, and Output Growth, 1960–85



In figure 12 the relative price of machinery is low where the machinery investment share is high. The points in the lower right of figure 12, with relatively low prices and high quantities of machinery investment, are predominantly rapidly-growing nations. Of the fifteen nations in the sample that have grown the fastest over 1960–1985, ten have both lower than average machinery prices and higher than average machinery quantities.[21] Of the fifteen that have grown most slowly—or that have seen productivity fall—ten have both high relative machinery prices and low rates of machinery and equipment investment.

Innovation and Productivity

For what reasons does the supply of machinery investment have such a strong association with growth? One potentially important reason is *embodiment*. New and improved technologies are greatly assisted by and in most cases require new capital goods, and new types of capital goods. Without investing in the machinery that embodies the modern technologies of the

[21]One fast-growing economy (Italy) has higher than average machinery quantities and higher than average prices, one (Cameroon) is lower than average in both prices and quantities, and three have lower than average quantities and higher than average prices.

industrial revolution, it is impossible to utilize them in production. Jorgenson's estimates of production functions for industries find that productivity growth is strongly capital- and energy-using. Make capital goods (or energy) sufficiently expensive, and firms will not adopt more productive methods of operation.[22]

A second important reason is the key role played by *feedback* in learning how to use modern technologies. Trial-and-error and experience remain the best ways to learn how to make things work—and how things that don't work well need to be modified to be made more efficient. This importance of "learning by doing" is stressed in industrial case study after case study. Rosenberg,[23] especially, stresses that economically-valuable inventions are almost always the end of a long process of feedback and modification, for: "…most inventions are relatively crude and inefficient [at first].…They are, of necessity, badly adapted to many of the ultimate uses to which they will eventually be put…they offer only small advantages, or perhaps none at all."

One recent case study is Trajtenberg's examination of a recent medical innovation: the computerized tomography scanner.[24] The initial invention had relatively small effects. It was the explosion of incremental improvements and developments in the next decade—themselves separate from although unthinkable without the initial invention, and based on doctors' requests for new features—that contributed the lion's share of the value of the invention.[25]

In a similar vein is Preston's narrative of Nucor's construction of a steel mini-mill built around a German-made CSP [Compact Strip Production] machine.[26] Learning how to use the machine is almost as costly as building the mill, and requires that the workforce repeatedly try—

---

[22]See Jorgenson, Dale, "Productivity and Postwar U.S. Economic Growth," *Journal of Economic Perspectives* 2:4 (Fall 1988).

[21] Nathan Rosenberg, *Perspectives on Technology* (Cambridge: Cambridge University Press, 1976).

[24]See Manuel Trajtenberg, *Economic Analysis of Product Innovation: The Case of Computerized Tomography Scanners* (Cambridge, MA: Harvard University Press, 1990).

[25]Similar patterns can be found even in technologies that appear at first glance stable. Rosenberg, "The Historiography of Technical Progress," in *Inside the Black Box* (Cambridge: Cambridge University Press, 1982) makes this point for a single type of aircraft, the DC-8: "[i]n this aircraft," he writes, "operating energy costs…on a per-seat-mile basis have been reduced by 50 percent, even though the basic configuration has remained largely unchanged and the modifications have been relatively unsophisticated."

[26]Richard Preston, *American Steel: Hot Metal Men and the Resurrection of the Rust Belt* (New York: Simon and Schuster, 1991).

and repeatedly fail—to make steel. It is necessary for the German builders to teach by example, rather than through formal education or through technological literature—even though the workforce is thoroughly familiar with modern technologies, and belonged to the most machine-intensive society in the world. The ability to efficiently use modern machine technologies is largely contained in the skills and experience of the workforce, and in the operating procedures of the firm. Such knowledge is hard to teach through formal means, and hard to acquire in any way other than hands-on experience itself.

Brief summaries of industrial case studies cannot prove a general trend. Nevertheless, it is worth noting that those who have examined the process of technological development have for the most part stressed not individual acts of genius (as emphasized in histories of science) but processes of feedback, of the building of skills through hands-on education, and of incremental improvements in operation and design. Such a vision of the process of innovation at the micro level would lead one to expect a close association of machinery investment and economic growth at the macro level. The macro association of machinery investment and growth and the micro case studies from the history of technological development summarized in the earlier sections of this chapter are credibly all pieces of the same puzzle.

IV. Economic Policies and the Future

Estimates for the post-World War II period suggest that each additional percentage point of total output devoted to (gross) investment in machinery and equipment raises output per worker growth by one-third of a percentage point per year—an implied real social rate of return on equipment investment of thirty percent per year or more. Estimates for the entire past century suggest an effect at least as large: each additional one percentage point of total output devoted to (net) investment in machinery and equipment raises output per worker growth by more than half a percentage point per year.

Even with the high depreciation rates of machinery, each one point of output devoted to

equipment investment each year appears to raise the level of total factor productivity by about four-tenths of a percent. A country's investments in machinery appear to have a payback period of five years, or fewer.[27]

Such rates of return are far higher than the profits captured by businesses that invest in new machinery and equipment. Such a large wedge implies a potential place for government policy to fill in the potential gap between private and social returns. Fifteen percent per year is a typical *pretax* rate of return on book value in manufacturing companies. This is less than half of the machinery investment coefficients estimated in section 2: more than half of the social gains from investment in machinery appear to be in the form of "externalities" that add to the incomes of workers, suppliers, and customers—no investors.

High government expenditures and taxes as a share of national product lead one-third of the social gains from machinery investment to flow first to the government in the form of higher tax revenues. A substantial share of the *private* benefits from high machinery investment are received by workers.[28] Machinery-intensive production processes are extraordinarily vulnerable to disruption. They require worker enthusiasm and active cooperation for their effective use.[29] Thus many potential machinery investments that are productive from a social point of view—adding up not only higher profits to the investor, but higher wages for workers and tax revenues for governments—will not appear profitable to potential investors or firms. This large wedge is at the foundation of an argument that governments should shape their policies to reward industrializers, and industrialization.

Industrial Policies

What form might such policies take? One way that a government might try to encourage

---

[27]The appropriate interpretation of the high effect of machinery investment on growth is that machinery investment is necessary for rapid economic growth. But it is not sufficient. For the poorer nations of the world, especially, investments in infrastructure, in other forms of non-residential and residential construction, and in human capital acquired through formal education are necessary complements to investments in machinery and equipment.

[28]See Lawrence Katz and Lawrence Summers, "Industry Rents: Evidence and Implications," *Brookings Papers on Economic Activity* (1989).

[29]Daniel Raff, "Looking Back at the Five-Dollar Day," *Harvard Business Review* (January-February 1989).

industrialization is through an active, interventionist “industrial policy.” Many have focused their attention on the “guidance” of the Japanese economy carried out by its Ministry of International Trade and Industry [MITI]. They say that industrial policies pursue long-run “Schumpeterian” advantage, shifting industrial structure in directions that promise rapid growth in the future. By contrast more market-oriented and less *dirigiste* systems are criticized for taking as their aim the acquisition of short-sighted short-run “Ricardian” or comparative advantage, that shifts industrial structure in directions that increase current incomes while making no provision for the future.[30]

I find such assertions far from convincing, largely because I have heard similar arguments many times before in different contexts. Many governments have sought development by using a growth-promoting “visible hand” as a replacement for the market. Almost all have justified their policies by reference to the trap of pursuing static “Ricardian” advantages in a world where “Schumpeterian” advantages are most important for long-run growth. Kishi in Japan, Perón in Argentina, Nehru in India, Kuanda in Zambia—all used the same rhetoric. Yet in most cases (outside of East Asia, and perhaps Brazil) such policies have been disasters.

Thus the argument that the industrial success of East Asian economies like Japan demonstrates a need for government management of industrialization is an odd one. It points to elements—managed trade, indicative planning, directed cartels, and so forth—of the Japanese economy similar to poor performers like Argentina, Sri Lanka, and the Philippines.[31] It would seem more fruitful to search for sources of success in aspects of the economy similar to other successes like Israel, Brazil, and Korea, and different from Argentina and Sri Lanka.

Factor Supply Fundamentals

One dimension in which Japan is like other economic winners and unlike economic losers

---

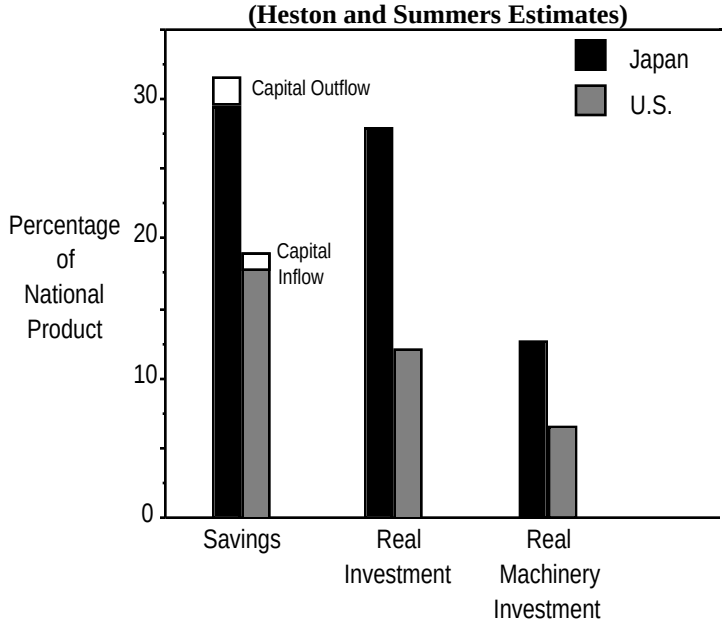
[30]See, for example, Stephen Cohen and John Zysman, *Manufacturing Matters* (New York: Basic Books, 1987).

[31]In many sectors of the Japanese economy, intervention has not enhanced productivity. Okimoto (1989) gives a short list: “agriculture, livestock, sugar refining, confectionaries, food processing, coal, lumber processing, silkworm cultivation, tobacco, aluminum refining, space and aeronautics, defense production, health services, retail distribution, and segments of the financial services” are all industries in which productivity is relatively low, in large part because of government policies.

has been detailed above: Japan has low producer goods prices, and high machinery investment rates. These are powerful fundamental factors making for rapid economic growth: a high rate of machinery investment means that workers' productivities are multiplied by the assistance given by a high capital-labor ratio, and that workers and firms have the opportunity to quickly acquire the skills and experience necessary to use modern technology efficiently, and to innovate to make it more efficient; a well-educated population can easily teach itself to be more productive. In addition, Japan has a very well educated and slowly-growing population that does not require that any substantial share of national savings be drained off to widen the capital stock. The cross-country patterns of growth tell us that we would expect a country with factor supply fundamentals like Japan to grow rapidly: about as rapidly as Japan has in fact grown.

From a perspective that sees machinery investment as a key factor, Japanese economic policies have been a tremendous success because they have created an environment in which investment—especially in machinery—is easy and lucrative. As a result, machinery investment is high, the workforce rapidly learns the skills needed to handle modern industrial technologies, and firms rapidly develop the expertise needed to turn new technologies from curiosities into efficient production methods. The cross-nation pattern suggests that Japanese development would have proceeded about as fast and about as successfully whether or not its MITI was attempting to guide industrial evolution.

Figure 13
Japan and U.S. Saving and Investment, 1981–1990
(Heston and Summers Estimates)



Conversely, the cross-section pattern suggests that nations that do not achieve high rates of machinery investment and accumulation are unlikely to grow rapidly. For the United States this is bad news. Figure 13 compares the relative success of the American and Japanese economies in the 1980's at channeling shares of national product into (gross) machinery investment. The first group of bars shows relative national (gross) savings rates: Japan's savings rate has far exceeded that of the United States. The gap in savings rates has been partly offset by international capital flows. Japan has been a capital exporter in the 1980's: thus the pool available for domestic investment has been smaller than total national savings. The U.S. has been a capital importer: thus the pool available for domestic investment has been larger than national savings.

The second group of bars shows relative real national (gross) investment rates in the 1980's. The Japanese edge in investment was larger than the edge in savings, largely because investment goods are relatively cheap—consumption goods relatively expensive—in Japan.

The third group of bars shows relative real (gross) rates of investment in machinery and equipment. Both the U.S. and Japan have devoted similar proportions of total investment to machinery and equipment in the 1980's. Differences in the determinants of machinery

investment between the U.S. and Japan in the 1980's lie in national savings rates and in relative capital goods prices, and not so much in the relative allocation of investment to machinery or non-machinery uses. If these differences in national savings rates persist—and if machinery investment truly is key to productivity growth—then it is hard to be optimistic that the U.S. will match Japan's economic growth in the future.

American Policies

The low savings and investment rates of the U.S. in the 1980's were to a degree caused by and were certainly severely aggravated by government policies. U.S. private savings rates have been very low in recent decades. The government deficits of the 1980's have been a substantial drain on the pool of savings available for investment—at what appears to be a heavy long-run cost.

It is puzzling that the 1980's, which saw a rhetorical retreat from Keynesian demand-side doctrines and renewed debate about how to manage the supply side also saw the emergence of large deficits. In the 1970's and before, "supply side" translated as "no deficit." Economic advisers in the Eisenhower years, and in the Kennedy and Johnson administrations, who were concerned with the supply side ranked a federal government budget *surplus* first on their list of steps the government could take to accelerate long-run economic growth. Kennedy and Johnson-era advisers looked forward in the early 1960's to establishing a structural government *surplus* on average over the business cycle, seeing:

> [the] Federal tax system…[as] an important asset in achieving the levels of investment needed for rapid advance in productive capacity.…When the Federal Government retires debt it, in effect, exchanges cash for an asset which had been a store of wealth for the owners of the debt.…[T]he debt retirement process channels savings into uses which facilitate investment for economic growth.[32]

---

[32]*The American Economy in 1961: Problems and Policies. Statement of the Council of Economic Advisers before the Joint Economic Committee*, in James Tobin and Murray Weidenbaum, eds., *Two Revolutions in Economic Policy* (Cambridge, MA: M.I.T. Press, 1988).

The U.S. government has been very far from achieving a structural budget surplus in the 1980's.[33] The "structural" deficit the federal government has today does not spring from reductions in taxes over the 1980's: during the Carter era the federal government took in around 19 percent of national product in taxes; in 1991 the federal government took in 18.7 percent. The structural budget deficit for the most part springs from relative expansions in spending: increases in the proportion of national income spent on the non-investment items defense, social security, and (most important) interest—the result of the combination of rapid spending increases and temporary tax cuts in the early 1980's—account for a 4.7 percentage point drag on today's national savings rate. The widening of the deficit during the early Reagan administration years came as an unpleasant shock in the early 1980's to Republican policy advisers, who believed they had an administration committed to cutting the federal budget share of national product by about four percentage points—not increasing it by that amount.[34]

The harm growing out of the Reagan-era budget deficits was partially offset as far as investment in the U.S. (although not saving) was concerned by borrowing from abroad. Borrowing, however, was not costless. The capital inflow is another name for the trade deficit. U.S. companies lost substantial amounts of market share during the period of the high dollar in the 1980's. To the extent that the lost market shares and goodwill of U.S. companies should be viewed as national assets, these assets were sacrificed to gain access to the capital inflow to keep investment in the U.S. from collapsing.

Moreover, trade deficits—borrowing from abroad—are only a short-run cure for low national savings. In the longer run, investors' desires to keep most of their portfolios in their

---

[33]Some economists in the early 1980's hoped that the emergence of a structural budget deficit would see an offsetting rise in private savings. It is too bad that it did not happen.

[34]See Murray Weidenbaum, "America's New Beginning: A Program for Economic Recovery," in James Tobin and Murray Weidenbaum, eds., *Two Revolutions in Economic Policy* (Cambridge, MA: M.I.T. Press, 1988). It is depressing to compare the view of Kennedy administration economists toward their work, which they "look back at… with affection, respect, and indeed defiant pride… [as] contain[ing] much that is still valid and useful," with that of Reagan administration economists toward their work: they note that "political constraints…color much of the language…and warp the forecasts," urge readers to "reflect on the points that were made that are relatively free of politics," and hope that someday "a future administration [will]…be guided by…principles" like those they tried to persuade the Reagan administration to adopt. See Robert Solow and James Tobin, "Introduction," and William Niskanen, William Poole, and Murray Weidenbaum, "Introduction," in James Tobin and Murray Weidenbaum, eds., *Two Revolutions in Economic Policy* (Cambridge, MA: M.I.T. Press, 1988).

home countries limit the ability of America to borrow. Recent reductions in the U.S. trade deficit have not been matched by any rise in national savings: without substantial increases in private savings and reductions in government deficits, the 1990's will be another poor decade for investment and productivity growth in America.[35]

The mid-1980's were also marked by the abandonment of long-standing preferences that provided incentives to direct savings into machinery investment, and away from other forms of investment thought to have fewer external benefits, and to play a smaller role in creating the skilled labor force and experienced firms needed to make modern technologies productive. Administration support for the 1986 tax reform has been a great puzzle for those who try toascribe a coherent world view to the administrations of the 1980's: the 1986 tax reform was in many ways in a direction opposite the administration's initial, 1981 change in the tax law.[36]

Democratic congressional support for rate reductions on high incomes financed by reducing corporate investment incentives is equally puzzling: the investment tax credit, after all, was a *Democratic* program, originally proposed by a Kennedy administration worried that "the fraction of our GNP devoted to investment in plant and equipment has been declining since 1948." It believed—as argued here—that:

> investment in new equipment…is perhaps the most important way in which laboratory discoveries become incorporated in the production process. Without their embodiment in new equipment…new ideas…lie fallow.…[The] interaction between investment and technological change permits each worker to have not only more tools, but better tools as well.[37]

Such changes in the tax laws cannot help increase investment in machinery and equipment.

---

[35]See Martin Feldstein, "The Budget and Trade Deficits Aren't Really Twins" (Cambridge, MA: NBER Working Paper 3966, 1992).

[36]In fact, Niskanen, Poole, and Weidenbaum count "the investment incentives in [the 1981] ERTA"—more than reversed in 1986—as a great accomplishment, and lament that "…the rest of the supply-side dream remains unfulfilled."

[37]*Economic Report of the President 1962,* in James Tobin and Murray Weidenbaum, eds., *Two Revolutions in Economic Policy* (Cambridge, MA: M.I.T. Press, 1988).

The Future

In the past, those countries that have grown most rapidly are those that have invested heavily in machinery, and in doing so acquired mastery of the technologies of the industrial revolution. This is a vision of the process of economic growth familiar to historians, and to the first generations of post-World War II development economists—as well as those shaping economic policy under the Kennedy administration.

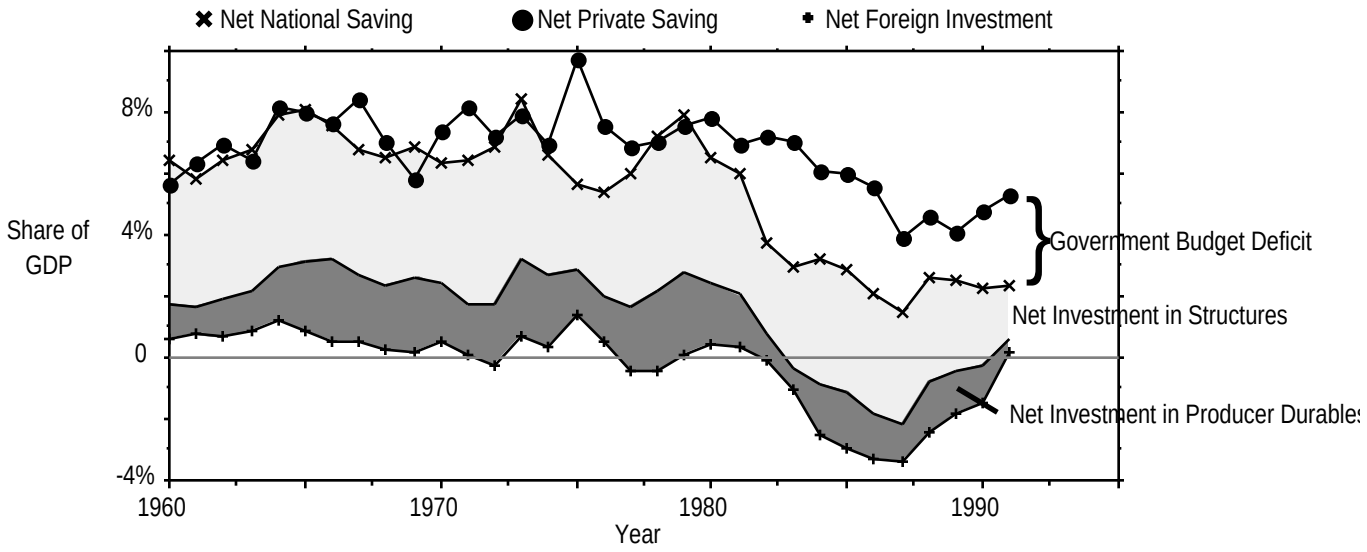
The 1980's have been a time of economic turmoil. Economic policies adopted in the United States—the decisions to run large budget deficits, to increasingly manage trade, to shift more of the tax burden to the corporate sector, and so forth—have not moved the country closer to the economic policy stance of a Japan or a Korea. They appear, instead, to shift the U.S. economic policy stance in the direction of an Argentina or a Uruguay. Over a year or even a decade such shifts do little visible harm to an economy as large and as productive as America's. As Adam Smith wrote, "there is much ruin in a nation."

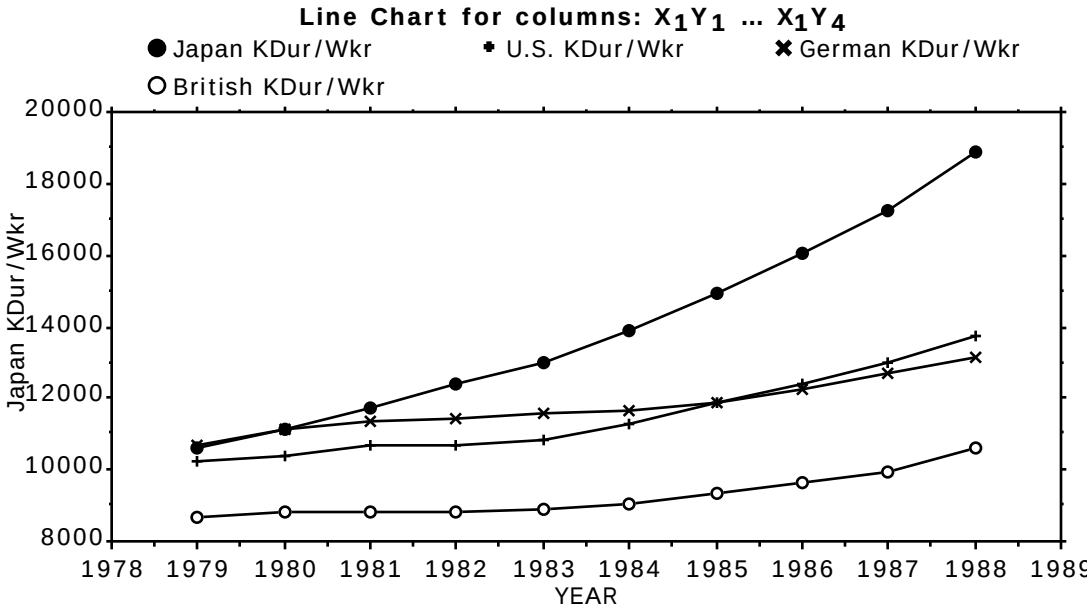
Decades, however, turn into generations. Today the five Pacific Rim economies of Japan, South Korea, Taiwan, Singapore, and Hong Kong are expanding their real machinery capital stocks as fast as the entire non-Japanese OECD, a group of economies with three times the population of the Pacific Rim five. Japan, with half America's workers, today invests more in total in machinery and equipment than does the United States. Extrapolating present trends—always dangerous to do—raises the possibility that by 2030 Japan and its neighbors will have as much of an edge in productivity over the U.S. as the U.S. had over western Europe in 1950.

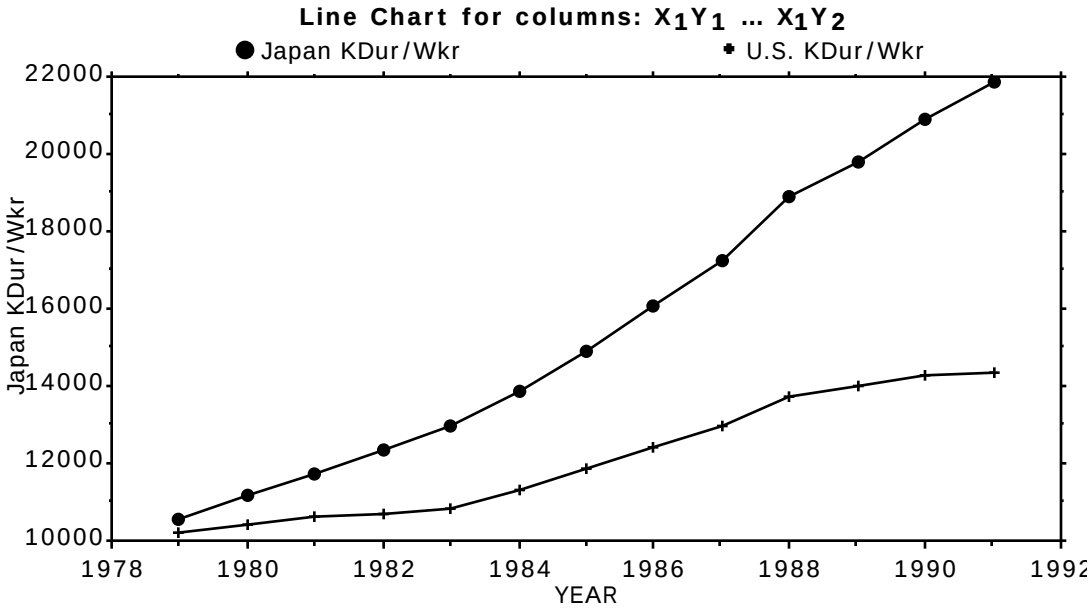
For most of the twentieth century the world has looked to the United States as, in Leon Trotsky's words, "the furnace where the future is being forged." All over the world nations have striven to imitate the United States in economics and in politics. By and large this process has been beneficial: it has led to a world more wealthy and much more free than one imagines would otherwise have come to pass. But today's trends suggest that in half a century things will be very different.

Charles Steindel, “Industry Productivity and High-Tech Investment,” Federal Reserve Bank of NY Working Paper 9202 (January 1992).

“*Within* the manufacturing sector different levels of investment in high-tech capital were associated with different productivity performance in the 1980’s…which might be justified by the very rapid changes in the nature of high-tech capital in the 1980’s. The relationship between productivity and high-tech investment appears sufficiently large to account for a large fraction of the acceleration in manufacturing productivity in the 1980’s.


Net National Saving
Net Private Saving
Net Foreign Investment
8%
4%
0
-4%
Share of GDP
1960
1970
1980
1990
Year
Government Budget Deficit
Net Investment in Structures
Net Investment in Producer Durables


Line Chart for columns: X1Y1 ... X1Y4
Japan KDur/Wkr
U.S. KDur/Wkr
German KDur/Wkr
British KDur/Wkr
20000
18000
16000
14000
12000
10000
8000
Japan KDur/Wkr
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
YEAR



Caveats

My claim that a high rate of machinery investment is akey cause of rapid growth would be sharply disputed by many economists. Some would argue that all kinds of investment are more-or-less equally productive—whether investment in machines, investment in buildings, investment in infrastructure, or investment (through education) in human beings—and that machinery investment appears most strongly associated with growth because we have better measurements of machinery than of the other components of "investment" in the broadest sense.[38] Others argue that there is a key component to investment, but that the key component is investment in human beings through education—which, unfortunately, is measured with considerable error.[39] Still others might argue that the key is to be found in the political régime—low inflation, stable government, low taxes, unobtrusive regulation, and trust in market

[38]See N. Gregory Mankiw, David Romer, and David Weil, "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 51:2 (May 1992). They argue that the bulk of differences in livings standards and productivity levels across nations are accounted for by differences in the ratio of population growth to "investment" broadly construed.

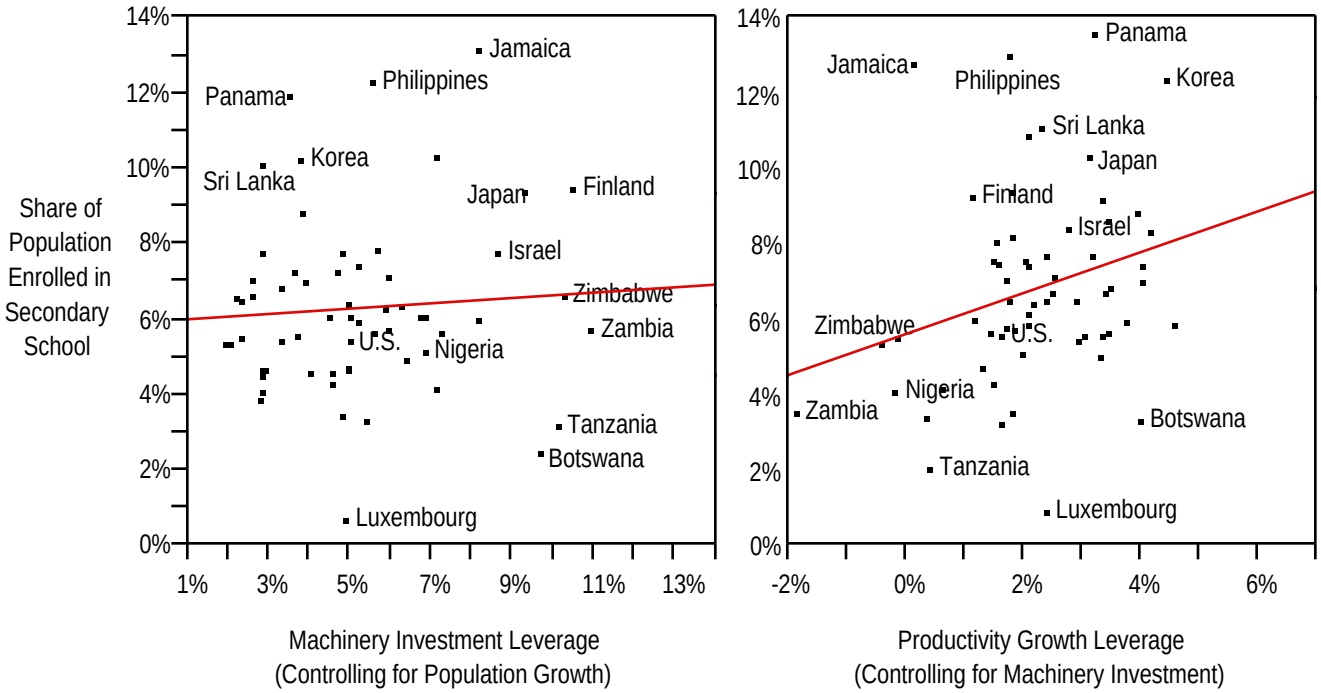
[39]For example, Alwyn Young, "A Tale of Two Cities," *NBER Macroeconomic Annual* 1992 (Cambridge, MA: M.I.T. Press, forthcoming) contrasts Hong Kong and Singapore, and argues that the conjunction of Singapore's higher physical investment rate with Hong Kong's higher productivity growth rate supports views that see education and not capital accumulation as the key to productivity growth. See also Paul Romer, "Endogenous Technological Change," Journal of Political Economy 98 (October 1990), pp. S-71–S102.

capitalism will generate rapid growth, and will also raise the rate of profit and so generate a high rate of machinery investment.

From my perspective these alternative visions of growth might be true, but are best seen as secondary complements rather than primary replacements for a vision that sees machinery investment as key. Certainly a stable government and trust in market institutions are important: countries like Zambia and Tanzania appear to have had high rates of machinery investment, yet their semi-socialist economies have seen absolute declines in productivity and livings standards; the Soviet Union was another case in which enormous resources were committed to capital accumulation with disappointing results.

But I would strongly dissent from points of view that hold that the association between growth and machinery investment arises primarily because machinery investment is a signal that other factors are favorable for rapid growth.

Reverse Regressions: Schooling as a Function of Machinery Investment, and of Productivity Growth



The hypothesis that machinery investment has a much stronger association with growth

than other factors because other factors are measured with considerable error, and so (measured) machinery investment is a better proxy for, say, (true) formal education than is (measured) schooling itself, can be tested. If such is the case, then that component of (measured) schooling not itself correlated with machinery investment should be largely noise: there should be little or no partial relationship (controlling for machinery investment) when (measured) schooling is regressed on growth. By contrast, there should be a substantial association between (measured) schooling and machinery investment, controlling for growth. If this is not the case—if, controlling for growth, measured schooling is not a function of machinery investment—then it is not the case that machinery investment is proxying for the underlying "signal" that is masked by the noise contained in (measured) schooling.

The figure above presents the partial scatters, controlling for productivity growth and for machinery investment, respectively, of schooling regressed on machinery investment and on productivity growth. Controlling for growth, schooling is not associated with machinery investment; on the other hand, controlling for machinery investment schooling remains associated with growth.

It is very difficult to fit this pattern into a framework in which machinery investment is a good proxy for poorly-measured schooling. It is much more suggestive of a framework in which machinery investment and schooling are independent, relatively unrelated factors—and in which both are determinants of growth.

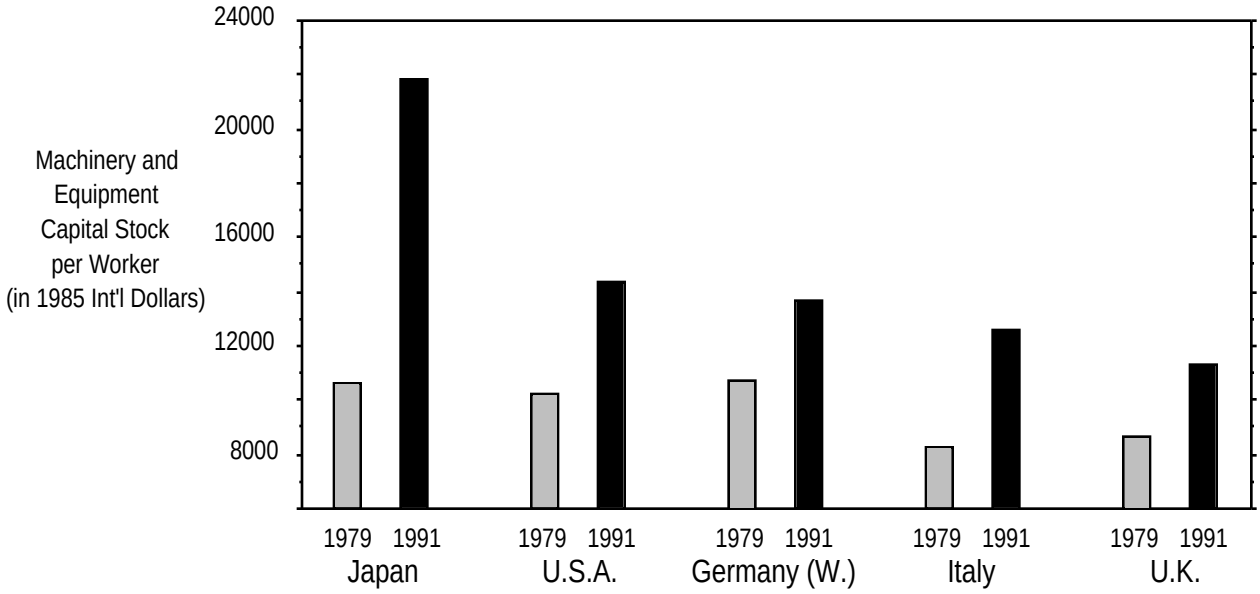
A fourth possibility gives me more pause. There is no law of nature that states that the future must be like the past.

26

27

As far as America is concerned, the case against moving toward more government micromanagement of industrialization is strengthened by the observation that the "activist" industrial policies the U.S. government does undertake are so often incompetent, and counterproductive. Consider recent attempts to manage trade: pressuring Japan to purchase more American automobiles appears counterproductive given that U.S. domestic manufacturers have been unsuccessful at the limited task of gaining a significant share of the (small) market for imported cars in Japan. Alternatively, consider recent attempts by the Commerce Department and the ITC to protect the American liquid-crystal computer display industry by imposing high anti-dumping tariffs on imports of such computer displays. Since the tariff applies only to displays, and not to computers with displays attached, the policy provides a very powerful incentive for manufactueres to move the most valuable portion of the domestic portable computer manufacturing industry offshore. These are only two of the examples that lead many economists to think that a full-blown American "industrial policy" would be more likely to turn the American economy into that of Argentina than that of Japan.

For most of the twentieth century the world have has looked to the United States as, in Leon Trotsky's words, "the furnace where the future is being forged." All over the world nations have strived striven to imitate the United States in economics and in politics. By and large this process has been beneficial: it has led to a world more wealthy and much more free than one imagines would otherwise one can easily imagine having have come to pass. But today it looks like today's trends suggest that in half a century things will be very different. Looking at the U.S. economy and at economic policies in the 1980's, there is no reason to expect people in the twenty-first century to look to the U.S. as a model.


Machinery and Equipment Capital Stock per Worker (in 1985 Int'l Dollars)
24000
20000
16000
12000
8000
1979 1991
Japan
1979 1991
U.S.A.
1979 1991
Germany (W.)
1979 1991
Italy
1979 1991
U.K.