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THE OIL PRICE DECLINE AND ECONOMIC GROWTH IN JAPAN AND THE UNITED SATATES*

Dale W. JORGENSON

Abstract: The purpose of this paper is to analyze the impact of the recent oil price decline on prospects for economic growth in Japan and the United States. Oil prices are linked to economic growth through their impact on rate of technical change. While changes in technology in the two countries are not identical, there are important similarities. Higher energy prices reduce the rate of technical change in both countries and dampen economic growth rates. Lower oil prices will stimulate economic growth in both countries; the stimulus will be more substantial in Japan.

The sharp decline in petroleum prices is one of the two major events of 1986 for the world economy. The other is the appreciation of the yen or, as we think of it in the United States, the depreciation of the dollar. Both of these events will have major implications for the world economy and, in particular, for Japanese and U.S. economic growth. This is a good occasion to analyze the impact of the oil price decline on prospects for growth in both countries.

The higher oil prices that accompanied the first energy crisis in 1973 and the slowdown in world economic growth that followed have precipitated an ongoing controversy.[1] To outline the terms of the debate, we can characterize the most extreme positions as follows: One view is that there is a perpetual cycle in which the economic growth eventually runs up against resource constraints, including the supply of oil. The response is, ultimately, a large increase in energy prices. This is followed by a depression in the rate of economic growth, which is followed by a reduction in energy prices. The energy price reduction stimulates a renewal of economic growth and generates renewed upward pressure on energy prices.

The theory of a perpetual cycle is that we have rising growth rates, rising energy prices, and then, declining growth rates, declining energy prices, and so on, indefinitely.[2] The idea of the perpetual cycle is, I think, a deep truth in the sense of Niels Bohr, the famous Danish physicist. Bohr defined a deep truth as a proposition the opposite of which is also a deep truth.

Opposing the theory of a perpetual cycle of energy prices and economic growth

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[1] This controversy is discussed in greater detail by Jorgenson (1986).

[2] The theory of the perpetual cycle is presented, for example, in a report by the Swedish National Energy Administration (1983).

is the idea that there is no impact of energy prices on economic growth.[3] This theory goes like this: Energy is an unimportant item in the national product accounts for any country, since most energy is consumed in the production of other goods and services. Taking both the output and the input of the energy into account, energy disappears as a final product. We conclude that energy prices cannot have an impact on economic growth.

We can think of the two opposing theories about the effects of energy prices on economic growth as two deep truths in the sense of Niels Bohr. On the one extreme, there is a perpetual oscillation of economic growth rates that is due to the rise and fall of energy prices, so that energy prices are the main determinant of economic growth. The opposing view is that energy prices have no influence on economic growth, but only affect the internal structure of the economy.

The point that I wish to make at the outset of this discussion is that the nature of the impact of oil prices, or more generally, of energy prices on economic growth in the United States and in Japan is far from settled. This is a hotly controversial matter on which there is a very wide range of views. I will advocate a position that is intermediate between the two extreme positions I have presented.

I will first analyze the sources of growth in the U.S. and Japan since 1960, which is the beginning of double digit growth in Japan. I will focus special attention on the period from the first oil crisis in 1973 until after the second oil crisis in 1979. This will provide an opportunity to review what has happened to economic growth and to oil prices in quantitative terms.

I will then discuss the sources of the growth that has taken place in the U.S. and Japan and, in particular, the role of three basic components: First, the contribution of capital; second, the contribution of labor; and third, the role of the unexplained residual. I will follow convention by calling this residual the "rate of technical change". It is an identity that the rate of economic growth is the sum of these three components.

I will contrast the sources of economic growth in the U.S. and Japan in order to provide an assessment of growth prospects in both countries. Next, I will compare the sources in economic growth in the U.S. and Japan during periods before and after the energy crisis in order to analyze the changes in economic growth in the two countries due to higher oil prices.

The most important change in both the U.S. and Japan after the oil crisis was a dramatic drop-off in the rate of technical change. The decline in economic growth is something of a mystery within the sources of growth framework. As I suggested earlier, the rate of technical change is an unexplained residual. When the residual declines it leaves the causes of the decline in economic growth unaccounted for.

My next step will be to relate the rate of technical change directly to changes in energy prices. This relationship provides an explanation for the changes in the rate of economic growth that have taken place since the energy crisis. The link between

[3] A leading proponent of the view that energy prices have no impact on economic growth is Denison (1984).

the rate of technical change and energy prices is provided by the bias of technical change. The bias of technical change gives the direction of changes in the use of various inputs, holding the input prices constant.

The strategic factor in economic growth that I wish to emphasize is the way in which changes in technology in the U.S. and in Japan affect the use of energy. As we will see, there are veıy great similarities between the two countries in this respect. We will also see that the effect of energy prices on the rate of economic growth is very substantial in both countries. Energy prices are more important in Japanese than in U.S. economic growth for reasons that will become apparent.

Finally, I will attempt to assess the impact of the current oil price situation on future economic growth in both countries. I will show that the reduction in oil prices will stimulate economic growth in both the U.S. and Japan. However, this reduction will not produce a recovery of rates of economic growth in the U.S. and Japan to the levels that characterized the period leading up to the oil crisis.

I will begin with a brief summary of what has happened to oil prices and to economic growth in the U.S. and Japan over the last twenty-five years, starting with the present. In 1985 oil prices reached the level of twenty-six dollars a barrel, having increased to an all time high for contract prices for crude petroleum of thirty-two dollars a barrel in 1982. By the middle of 1986, prices had declined to around fifteen dollars a barrel and for brief perids of time they have fallen below ten dollars a barrel.[4]

There is nothing mysterious about the recent decline in oil prices. This decline was a direct response of the world petroleum market to a decision by the leading exporter, Saudi Arabia, to increase production. The motives behind this increase in production are also transparent. As a consequence of aggressive price cutting the Saudi share of world petroleum exports increased dramatcially in the first six months of 1986. Of course, the price reductions required to bring about this increase in market share were very substantial.

A secondary objective of the Saudi price increase was to alter the production policies of the other members of OPEC, the Organization of Petroleum Exporting Countries. OPEC production has declined by almost fifty percent from the level of thirty-two million barels per day to around sixteen million barrels per day. This decline in production fell disproportionately on Saudi Arabia and other Arab producers on the Persian Gulf. By expanding production and lowering prices the Saudi's have succeeded,at least temporarily, in bringing about agreement among OPEC members on a new system of production quotas and a price level for petroleum exports well above the lowest levels attained during the first half of 1986.

We now have oil prices, denominated in terms of dollars, that are only 50 percent above those that prevailed before the first oil crisis in 1973, when adjusted for inflation. If we take into account the appreciation of the yen and the depreciation of the dollar since the end of 1985, we can see that prices for oil imports into

[4] Comparisons of energy price developments and energy demand patterns are given by Fujime (1983).

Japan are quite comparable today to what they were in the early 1970's. We conclude that the decision by Saudi Arabia to increase market share has led to revolutionary changes in petroleum prices.

Some observers are pessimistic about the impact of the Saudi production decision. One interpretation is that the Saudi's intend to force other producers out of the market and to achieve a higher degree of market power. There is very little evidence to support this view. The world petroleum market tody is characterized by about fifty percent excess capacity. The existence of this excess capacity suggests that world petroleum prices are likely to remain in the range of ten to fifteen dollars a barrel. There are grounds for optimism about a return to conditions in the world petroleum market not substantially different from those that prevailed before 1973.

Next, I would like to review the economic impact of the two substantial increases in petroleum prices between 1973 and today.[5] During the period from 1960 to 1973, the economic growth rate in Japan was at the rate of ten or eleven percent per year. Japan was not the only country that grew rapidly during that period. For example, Korea grew at the rate of 9.7 percent per year. France and Germany grew at 5.9 and 5.4 percent per year between 1960 and 1973 and Italy grew at 4.8 percent per year. Even the United Kingdom grew at a respectable 3.8 percent per year. The United States grew at 4.3 percent per year during this period; to fill out the roster of the seven major industrialized countries, Canada grew at 5.1 percent per year.

After the first oil crisis in 1973, and even more so after the second oil crisis in 1978 and 1979, there was a dramatic decline of economic growth among industrialized countries. Growth in the OECD countries dipped to 2.6 percent per year between 1973 and 1979. Japanese growth dropped from the double digit levels of the Sixties and the early Seventies to 4.0 percent per year from 1973 to 1979. In the United States, the growth rate dropped to slightly above the OECD average at 2.8 percent per year. The rate of economic growth in Germany dropped to 2.4 percent and in France to 3.1 percent. In every major industrialized country there was a precipitous fall in the rate of economic growth.

A great deal of attention has been paid to differences in the impact of the high energy prices on economic growth in different countries. Therefore, it is very important to focus on differences in the development of energy prices. If we take the period 1973 to 1975, the growth of crude oil prices was approximately 2.5 times for the seven major OECD countries. In Japan, oil prices grew by a factor of three. In Canada and the United States the growth of oil prices was a good deal lower.

If we focus on the prices of crude petroleum, it is easy to exaggerate the impact of the energy crisis on the prices of all forms of energy. The average increase of

[5] Comparisons of patterns of economic growth in industrialized countries are given by Chrisstensen, Cummings, and Jorgenson (1980, 1981). An excellent analysis of the slowdown in economic growth in industrialized countries is presented by Lindbeck (1983).

energy prices associated with the increase in the price of crude oil imports by a factor of 2.5 was only twenty-four percent. In other words, energy prices rose by less than one quarter, while oil prices went up by a factor of two and a half. Again, Japan was at the high end of the spectrum of higher energy prices with an inrease of approximately fifty percent, reflecting the fact that in 1973 Japan was more dependent on petroleum than almost any other country.

At the other extreme, the Canadians experienced an increase in energy prices of only 3.9 percent at a time when crude oil prices were going up all over the world. In the United States, by contrast with Japan, the increase in energy prices to final users was only twenty-three percent. Given the fact that energy prices increased in Japan by approximately fifty percent, while in the United States, oil prices increased by only twenty-three perecent, it is not surprising that the slowdown of economic growth in Japan was much more dramatic than that in the United States.

The first oil crisis was hardly assimilated before there was a second oil crisis in 1978 associated with the Iranian revolution. Between 1978 and 1980, crude oil import prices doubled for the seven major OEDC countries. The increase from 1973 to 1980 was a factor of two. Oil prices increased by a factor of five in these two steps.

Between 1978 and 1980 real energy prices increased by about a third for the major OECD countries. Again, Japan was very hard hit with an increase that totaled eight percent. In the United States, the increase was about thirty-four percent, and in Canada, only 8.7 percent. There were large differences in energy price increases among industrialized countries. Japan was by far the most heavily impacted in terms of the impact of the crude oil price increase on the prices actually faced by energy consumers.

In the United States, economic growth declined substantially from the rates that had prevailed before the energy crisis, but the final decrease was of the order of magnitude of one half to one percent, whereas the Japanese growth rate dropped by almost two-thirds from the level of eleven percent into the range of three to four percent. There was a tremendous increase in energy prices and there was a big decline in economic growth. These two things were very closely associated in time.

Next, I will analyze the sources of economic growth in the U.S. and Japan and attempt to relate changes in these sources to the change in energy prices. The sources of economic growth in Japan and the U.S. over the whole period from 1960 to 1979 are given in Table 1. This table is the product of joint work between myself, members of the faculty at Keio University, specifically, Professors Masahiro Kuroda, Hikaru Sakuramoto, and Kanji Yoshioka, and Dr. Mieko Nishimizu of the World Bank. We have been collaborating over an extended period of time on an analysis comparing sources of economic growth in Japan and the U.S. The analysis in this table is the result of our joint work.[6]

[6] Results of this work are reported in Jorgenson and Nishimizu (1978), Kuroda, Yoshioka, and Jorgenson (1984), Jorgenson, Kuroda, and Nishimizu (1986a), and Jorgenson, Sakuramoto, Yoshioka, and Kuroda (1986).

If we compare Japan and the United States during the period 1960–1979, we see that the growth of output over the whole period was 8.3 percent in Japan and only 3.5 percent in the United States. We allocate this growth in output in the two countries among its three sources, namely, the contribution of capital input, the contribution of labor input and the rate of technical change. By far the most important contributor to economic growth in both countries is the growth of capital input. This growth source accounts for about five percentage points of the Japanese economic growth rate and about 1.5 percentage points of the U.S. economic growth rate. This amounts to sixty percent of Japanese growth and forty percent of U.S. growth.

Labor input in the two countries is a major contributor to economic growth, accounting for 1.5 percent of the Japanese growth rate and 1.2 percent of U.S. growth rate. The rate of technical change is an important contributor as well, at nearly two percent in Japan and 0.7 percent in the United States. We conclude that by far the most important contributor to economic growth in the two countries is the growth of capital input. The relative importance of capital input is much greater in Japan than in the United States.

Focusing attention on the period from 1973 to 1979 after the energy crisis, we can see that there was a steep decline in the rate of economic growth in Japan to about 3.8 percent. There was a much less substantial decline in the United States to about 2.8 percent. I have already emphasized that both crude petroleum prices and the price of energy increased much more in Japan than in the U.S.

Considering the sources of economic growth from 1973 to 1979 in Table 1, we can seen that capital input retained its lead as a source of economic growth in both countries. However, the decline in the growth of capital input in Japan was much greater than in the United States. The contribution of capital dropped from 5.0 percent in Japan to 2.8 percent in the period 1973–1979. Labor input declined as well, from 1.5 percent to 0.8 percent, and the rate of technical change dropped from approximately two percent to a mere one-tenth of one percent, 0.13 percent to be more precies, during the period from 1973 to 1979.

If we consider the corresponding figures for the United States, we see that there was an almost negligible decline in the contribution of capital input from 1.5 to 1.4 percent per year. The same is true of the decline in labor input.

Therefore, the impact of the oil crisis on U.S. economic growth has to be traced to the decline in the rate of technical change, the so-called "unexplained residual", which declined from 0.7 percent to 0.3 percent per year.

Turning attention to the causes of the group in economic growth, we first recall that a sustainable process of ecmicono growth is one in which capital input increases at the same rate as output. Both growth rates are determined by the rate of growth of labor input and the rate of technical change. In a sustainable path of economic growth, the basic mechanism is the increase in capital input per unit of labor input.

During short periods of time, it is possible for output growth to exceed the

TABLE 1. SOURCES OF ECONOMIC GROWTH, JAPAN AND THE U.S., 1960–1979

	1960–1979		1960–1965		1965–1970		1970–1973		1973–1979	
	Japan	USA	Japan	USA	Japan	USA	Japan	USA	Japan	USA
Average Annual Growth Rate										
Net Output	0.0825	0.0346	0.0993	0.0430	0.1276	0.0292	0.0860	0.0421	0.0379	0.0283
Capital Input	0.0956	0.0399	0.1130	0.0334	0.1121	0.0489	0.1118	0.0397	0.0595	0.0378
Labor Input	0.0313	0.0203	0.0530	0.0194	0.0331	0.0208	0.0240	0.0219	0.0154	0.0172
Annual Rate of Contribution to Growth										
Capital Input	0.0503	0.0154	0.0591	0.0131	0.0617	0.0190	0.0595	0.0150	0.0286	0.0144
Labor Input	0.0149	0.0119	0.0253	0.0118	0.0149	0.0126	0.0117	0.0136	0.0082	0.0105
Technical Change	0.0201	0.0073	0.0148	0.0181	0.0510	−0.0024	0.0154	0.0135	0.0013	0.0033
Quality Change of Capital Input	0.0181	0.0035	0.0317	0.0027	0.0219	0.0050	0.0154	0.0031	0.0048	0.0032
Quantity Change of Capital Input	0.0321	0.0119	0.0275	0.0105	0.0398	0.0141	0.0440	0.0119	0.0239	0.0113
Quality Change of Labor Input	0.0103	0.0022	0.0193	0.0032	0.0085	0.0045	0.0067	−0.0002	0.0046	0.0006
Hour Worked Change	0.0046	0.0097	0.0059	0.0085	0.0064	0.0080	0.0051	0.0138	0.0037	0.0099
Weighted Average of Sector Technical Change	0.0071	0.0040	0.0102	0.0188	0.0264	−0.0018	0.0081	0.0113	−0.0121	−0.0072
Contribution of Allocational Changes										
Net Output	0.0037	0.0020	−0.0105	−0.0023	0.0003	−0.0015	0.1240	0.0018	0.0141	0.0087
Capital Input	0.0085	0.0009	0.0099	0.0018	0.0158	0.0014	0.0016	0.0007	0.0046	−0.0001
Labor Input	0.0009	0.0004	0.0052	−0.0002	0.0085	−0.0005	−0.0068	−0.0003	−0.0053	0.0021

Source: D.W. Jorgenson, M. Kuroda, and M. Nishimizu (1986b).

sustainable level by increasing the proportion of the national product devoted to capital formation. That is the mechanism at work in the very rapid growth in the Japanese economy during the 1960's and the early 1970's. Referring again to Table 1, capital input grew 1.3 percent more rapidly than output in Japan during the period 1960–1979. This was the consequence of the increase in the proportion of the national product that was devoted to capital formation.

During the period 1960–1965, capital input in Japan grew a good deal more rapidly than in the period 1960–1979 as a whole. The rapid growth of capital continued through 1973 in Japan and finally dropped off during the period from 1973 to 1979. We now arrive at a difficult problem. Was it possible to sustain the very high rates of growth that occurred in Japan during the period from 1960 to 1973? If the rate of growth of capital and the rate of growth of output in Japan had been equal during the period 1960 to 1973, the rate of growth of both capital and output would have had to be considerably reduced. Therefore, a sustainable rate of growth in Japan, even before the energy crisis, would have been a considerably below the double digit levels that prevailed before 1973.

Next, we can address the following question: Was the decline in the growth of output that took place in the period from 1973 to 1974 due to the fall in the growth of capital? Since capital is so imporatnt to Japanese economic growth, this is a potential explanation of the slowdown. In Table 1 we see that the decline in output was 4.5 percent. But capital declined only 3.6 percent. Therefore, after the energy crisis as well as before, the growth rate of capital input was higher than that of output. Rather than causing the slowdown, the growth of capital after the energy crisis contributed to the continued growth of output at unsustainable levels. Our first conclusion is that the decline in the growth rate of capital is not the cause of the slowdown in Japanese economic growth.

Turning to the United States, we see that the output growth rate declined by about six-tenths of a percent while the capital growth rate declined by only two-tenths of a percent. Despite the fact that capital is the most important source of U.S. growth, the decline in the growth rate of capital was not the cause of the slowdown in the growth of output. In the U.S. as in Japan the growth of output was maintained at unsustainably high levels during the period after the energy crisis. The growth of capital did not account for the slowdown that took place in the U.S..

There was a decline in the growth rate of labor input in Japan from an average of 3.1 percent for the period 1960–1979 to 1.5 percent for the period 1973 to 1979. We can examine the mechanism underlying the decline in labor input growth in Table 1. The contribution of labor input can be decomposed into the contributions of quality change of labor input and change in the number of hours worked. Quality change corresponds to the upgrading of the labor force and accounts for about two-thirds of the growth in labor input that took place in Japan for the period 1960–1979.

If we consider the period 1973–1979, we see that hours worked have continued to grow in Japan, but that the upgrading of the labor force has declined by about fifty percent. Labor quality change is a very important growth source and is part of the story of the slowdown in economic growth in Japan. We have now identified one factor that is clearly responsible for part of the decline in the growth in Japan—the decline in the change of quality of labor input.

The contribution of labor quality in the United States dropped from 0.22 percent to 0.06 percent between the period 1960–1979 and the period 1973–1979. Decline in this growth source is also a significant factor in the slowdown in U.S. economic growth. During the early 1960's, the U.S. labor force was upgraded at very rapid rates. Since than this source of growth has disappeared as a contributor of economic growth in the United States.

Hours worked in the United States have grown at rates almost double those in Japan throughout the period 1960 to 1979. This remains the case during the period 1973–1979. The growth of the hours worked in the United States is a much more important source of growth than in Japan. Hours worked grew even more rapidly during the period after the energy crisis than before. Our second conclusion is that the slowdown in the upgrading of the labor force was an imporatant factor in the decline of economic growth in both countries.

Finally, we can turn our attention to the rate of technical change. The decline from 1960–1979 to the sub-period 1973–1979 was 1.9 percent in Japan and 0.4 percent in the United States. It is clear that that is a very important factor—in fact the predominant factor—in the slowdown in economic growth in both countries. We now have a candidate for the explanation of the slowdown in economic growth at the time of the energy crisis. There is an important element in the slowdown related to the drop in upgrading of the labor force in both countries. However, it is clearly the decline in the rate of technical change that must play the predominant role in explaining the slowdown.

The next question is: How is it possible to link the rate of technical change to energy prices? There is an element of truth in the idea that the growth of output at the aggregate level cannot be traced directly to the change in energy prices, since energy itself is a small proportion of aggregate output. This is true in both Japan and the United States. However, this point of view ignores the fact that the economy is composed of individual industrial sectors.

I will now focus on the connection between the consumption of energy in individual industrial sectors and the increase in energy prices. For that purpose, I will decompose the rate of technical change into its component at the level of individual sectors. We first divide both the U.S. and Japan into approximately 30 industrial sectors. We find that an important contributor to the rate of technical change is the rates of technical change at the level of individual industries.

At this point we introduce a very important distinction. At the aggregate level output is produced form capital and labor inputs. At the level of individual sectors, we find a role for capital and labor inputs, but also for inputs of energy and other intermediate goods. In the average industry in the United States, approximately fifty-five percent of the value of output is attributable to inputs of intermediate goods including energy, while capital and labor inputs account for about forty-five percent. At the aggregate level only capital and labor inputs play a role, since intermediate goods link energy cancel out when we construct aggregate accounts.

Rather than carrying over measures of output appropriate for economic aggregates to the sectoral level, we can define the value of output for each industrial-sector to include the value of capital, labor, energy and other intermediate inputs. In Table 1 we have weighted the sectoral rates of technical change at the individual sectors by the total output of the sector, divided by the deliveries of output to final demand. This system of weights reflects the fact that technical change at the sectoral level affects the technical change at the aggregate level in two ways: First, technical change in a given industrial sector enhances the productivity of the capital and labor input employed in the sector itself; second, it enhances the productivity of other sectors that use the output of the given sector as inputs.

The other components that link technical change at the sectoral level to technical change at the aggregate level include the redistributions of output, capital input and labor input among sectors. It we consider the period from 1960–1979, we see that the decomposition of the rate of technical change in Japan of 2.0 percent allocates 0.7 percent to rates of technical change at the sectoral level, 0.4 percent to the redistribution of outputs among sectors, 0.9 percent to the redistribution of capital input, and 0.1 percent to the redistribution of labor input.

At this point we can recall how reallocations of output, capital input, and labor input affect the rate of economic growth. The aggregate rate of technical change is a weighted sum of rates of technical change at the sectoral level, plus gains or losses in efficiency due to movements of economic resources from one sector into another. If these movements result in higher rates of remuneration for capital or labor inputs, the reallocations produce a gain in aggregate efficiency and appear as a positive contribution to the rate of technical change. If the movements result in lower rates of remuneration the reallocations appear as a negative contribution to the rate of technical change.

In Table 1 we see that sectoral technical change accounts for only about a third of the aggregate technical change. The remaining two-thirds correspond to gains in efficiency which are not sustainable. These gains in efficiency result from the redistribution of the basic factors of production and the output of the different sectors. Redistributional gains are not sustainable since there is an upper limit to the amount of reallocation that can take place.

For example, a factor like labor input can be completely reallocated from a low productivity sector to a high productivity sector by eliminating one kind of economic activity and concentrating the whole of a country's activity in the more productive sector. Once the reallocation has taken place, the possibilities for productivity gains from that source are exhausted. Therefore, the only sustainable productivity gains are those that are associated with rates of technical change at the sectoral level. In quantitative terms only one-third of the aggregate rate of technical change in Japan is sustainable.

If we now consider the period from 1973 to 1979 we find that the weighted sum of sectoral rates of technical change in Japan went from a positive 0.7 percent to a negative 1.2 percent. In other words, the rate of technical change from 1973 to 1979 was negative in the average Japanese industry. In the U.S., rates of technical change at the sectoral level declined from 0.4 percent to a negative 0.7 percent. This is a paradox, and it deserves an explanation.

Technologies come into existence and do not disappear. How is it possible for the rate of technical change to be positive through the exploitation of new technologies and to then become negative? Why cannot these new technologies continue to be exploited? The answer to this question lies in a distinction between technologies that are available and technologies in use. The technologies available before the energy crisis are also available afterward. However, the drastic changes in the prices of energy inputs led to a substitution away from energy toward other inputs. This required the use of technologies that were attractive from the economic point of view at higher energy prices, but represented a lower state of technological development.

In both Japan and the United States production methods reverted to vintages of technological development that existed before the energy crisis—perhaps in the middle 1960's in Japan and the early 1960's in the United States. These earlier technological strata were appropriate to the new energy price situation. We conclude that it is perfectly consistent with a theory of economic growth to have negative rates of technical change, like the ones we see in Table 1 for the period 1973 to 1979.

We now have an even deeper mystery than before. The rate of technical change in Japan and the United States at the aggregate level is an unexplained residual and the same is true at the sectoral level. We find that dramatic changes in the rate of technical change at the sectoral level are behind the growth slowdown that we have observed. These changes are in the nature of unexplained residuals at the level of individual industries.

Before developing an explanation of the changes observed in Table 1, I would like to recapitulate the basic findings of our analysis of the sources of economic growth. The first and most important finding is that the slowdown in economic growth that took place in both Japan and the United States after 1973 was much more dramatic in Japan. In terms of the growth rate of output the slowdown was approximately two-thirds in Japan, while in the United States, the slowdown was of the order of magnitude of twenty percent.

Second, if we look at the sources of economic growth at the aggregate level, capital is clearly not a contributor to the slowdown in either country. Even though the growth rate of capital delcined, capital growth rates were maintained at levels above those of the growth of output in both counteries. Therefore, the continued growth of capital input was an offset to the slowdown, not a contributing factor.

Third, there was a significant contribution, especially in Japan, of the decline in the rate of upgrading of the labor force. In the United States, there was a similar decline, although it started earlier—in the middle 1960's. Although this is a factor in the slowdown in both countries, the impact was modest in magnitude.

The most important single factor in the slowdown in economic growth in the United States and Japan is a decline in the rate of technical change at the level of individual industrial sectors. This raises the question: How is it possible to relate this decline to the energy crisis that begain in 1973 and extended through 1979? Earlier, we have observed that the character of technical change is the key to understanding the impact of energy prices on economic growth. By the character of technical change I mean the direction of changes in input use associated with changes in technology.

At this point, I will use the concept of biased technical change to analyze the changes in economic growth that we have seen both in Japan and in the United States. In Table 2 I have classified industries in Japan by the pattern of biases of technical change. Four basic types of biases are related to capital, labor, energy and materials inputs. We now require a more precise definition of the notion of a bias.[7]

The bias of technical change is the change in the relative share in the value of the output of a particular input as technology evolves If we take capital as an example, we can say that if the share of capital in the value of the output of an industry is constant, then technical change is unbiased or neutral with respect to capital. If the share of capital declines we say that technical change is capital saving. Therefore, we have a three-fold classification of technical change with respect to each input—capital, labor, energy and materials—input-using, input-saving, and neutral. The sum of all four biases must be equal to zero.

One aspect, then, of biased technical change relates to the direction of changes in the use of various inputs as technology evolves. If we use more capital, labor, and energy and save materials, we have the pattern that is described in the first panel of Table 2. And as you can see, this pattern characterizes a substantial number of industries in Japan. However, there is a completely different implication of biased technical change. If technical change is capital using, then the rate of technical change declines when the price of capital increases. This provides the link between changes in input prices, including energy prices, and changes in the rate of technical change at the sectoral level.

In Japan the character of technical change involves using energy and saving other inputs. In particular, the first panel of Table 2 gives the industries for which technical change uses energy along with labor and capital inputs and saves materials inputs. The second panel, which contains only three industries—machinery, finance, and insurance—gives the industries with energy saving, material saving, and labor using technical change, along with capital saving technical change. In the third panel, we find energy using technical change combined with labor using, material

[7] Biases of technical change are discussed by Jorgenson (1983), Jorgenson (1984), and Kuroda, Yoshioka, and Jorgenson (1984).

TABLE 2. Classification of Japanese Industries° by Biases of Productivity Growth

Pattern of biases	Industries
Capital using, Labor using, Energy using, Material saving	Agriculture, mining, construction, textiles, fabricated metal, transportation equipment, services
Capital saving, Labor using, Energy saving, Material saving	Machinery, finance and insurance
Capital saving, Labor using, Energy using, Material using	Food, petroleum
Capital saving, Labor using, Energy using, Material saving	Apparel, lumber, furniture, paper, printing, chemicals, rubber, leather, stone, clay, and glass, iron and steel, nonferrous metal, motor vehicles, instruments, miscellaneous manufacturing, transportation and communication, utilities, trade, real estate

Source: M. Kuroda, K. Yoshioka, and D. W. Jorgenson (1984).

using, and capital saving change. Finally, in the last panel, we find the most common pattern, which is energy using, labor using, capital saving and material saving technical change.

Among all Japanese industries, only three out of the thirty listed in Table 2 are characterized by energy saving technical change. In the other twenty-seven industries technical change is energy using. If we have unchanged input prices the evolution of technology results in the use of more and more energy and a reduction in the use of the other inputs. The other implication of energy using technical change is that if we have an increase in energy prices, there must be a corresponding reduction in the rate of technical change. In twenty-seven out of the thirty Japanese industries, we have a direct link between energy prices and the rate of technical change through the energy using bias.

To make the link between sectoral rates of technical change more explicit, the typical Japanese industry described in Table 2 is characterized by energy using technical change. At unchanged input prices, the typical industry uses more energy as the level of technology changes. This implies that when energy prices increase, as they did in 1973 and again in 1978, there will be a reduction in the rate of technical change in the average industry. We have already seen a decline in the weighted sum of sectoral rates of technical change for Japanese industries in the period 1973–1979 in Table 1. We have identified this decline as the major explanatory factor in the slowdown of Japanese economic growth.

The weighted sum of sectoral rates at technical change dropped from 0.7 percent per year in Japan for the period 1960–1979 to a negative 1.2 percent during the period 1973–1979. That decline of 1.9 percentage points more than accounts for the decline in the aggregate rate of technical change in Japan. This rate is the most important source of the slowdown in economic growth that occurred after 1973.

We have now completed our analysis of the slowdown in economic growth in

Japan after 1973. The most important source of economic growth during the period from 1960 to 1973 is the unsustainably high rate of growth of capital input. The most important source of the slowdown after 1973 was the decline in the rate of technical change at the aggregate level. This decline can be traced to the drop in rates at technical change at the sectroal level. This drop can be linked in turn to the character of technical change in Japanese industries—predominantly energy using—as described in Table 2.

In Table 3 we consider the implications of biased technical change for the slowdown in U.S. economic growth. In the first panel of this table we observe that the character of technical change in the United States is predominantly capital using, labor using, energy using and material saving. By contrast, the character of technical change in Japan is predominantly capital saving, labor using, energy using, and material saving. In both countries, technical change is characterized by using more energy But in the United States, technical change also uses more capital as well as more labor, whereas in Japan, technical change uses less capital, less materials, and more labor along with more energy.

The common element, then, in technical change in the United States and Japan

TABLE 3. CLASSIFICATION OF U.S. INDUSTRIES BY BIASES OF PRODUCTIVITY GROWTH

Pattern of biases	Industries
Capital using, Labor using, Energy using, Material saving	Agriculture, metal mining, crude petroleum and natural gas, nonmetallic mining, textiles, apparel, lumber, furniture, printing, leather, fabricated metals, electrical machinery, motor vehicles, instruments, miscellaneous manufacturing, transportation, trade, finance, insurance and real estate, services.
Capital using, Labor using, Energy saving, Material saving	Coal mining, tobacco manufactures, communications, government entreprises.
Capital using, Labor saving, Energy using, Material saving	Petroleum refining
Capital using, Labor saving, Energy saving, Material using	Construction
Capital saving, Labor saving, Energy using, Material saving	Electric utilities
Capital saving, Labor using, Energy saving, Material saving	Primary metals
Capital saving, Labor using, Energy using, Material saving	Paper, chemicals, rubber, stone, clay and glass, machinery except electrical, transportation equipment and ordnance, gas utilities
Capital saving, Labor saving, Energy using, Material using	Food

Source: D.W. Jorgenson (1983).

is the role of energy using technical change along with labor using technical change. The role of capital is completely different in the two countries. In the United States, technical change uses capital; in Japan, technical change saves capital. In both countries, technical change economizes on materials. Our conclusion is that the common element that links the slowdown in Japan to the slowdown in the United States is the character of technical change, which is energy using in both countries.

Turning back to Table 1, we can see that the weighted sum of sectoral rates of technical change rates declined from 0.4 percent in the United States to a negative 0.7 percent, more than one percent in total. That is only half as much as the decline in Japan; on the other hand, the slowdown economic growth was very much less in the United States than in Japan. Other factors that contributed to U.S. economic growth include unsustainable sources of growth that cannot be expected to revive in the future.

We have now arrived at the final explanation of the slowdown in U.S. and Japanese economic growth. I have emphasized that there are important sources of the slowdown in Japan associated with the fall-off in upgrading of the labor force. However, the most important single factor in the Japanese slowdown in the sharp decline in the rate of technical change. We have now succeeded in linking that decline directly to energy prices through the character of technical change in Japan.

In the United States, the character of technical change is similar to that in Japan in the use of energy. The effect of higher energy prices in the United States was to slow economic growth. Of course, there are two additional facts that should be kept in mind. First, economic growth in the United States was a good deal less rapid than in Japan before the energy crisis. Second, energy prices increased much less substantially in the United States than in Japan. This is why the weighted sum of rates of technical change at the sectoral level decreased in the United States by only one percent, whereas in Japan, the decrease was nearly two percent.

Our overall conclusion is that there was a dramatic impact of energy prices on economic growth during the energy crisis. The economic impact was very strongly negative in both the U.S. and Japan. The impact of higher energy prices was pervasive in the sense that it affected almost every industry in both economies. Almost every industry experienced a slowdown in the rate of technical change. This can be traced to the relationship between higher energy prices and the rate of technical change at the sectoral level in both countries.

The higher energy prices that resulted from the energy crisis produced substitution away from energy toward the use of other inputs—especially toward labor, but to some extent toward capital—that led to a reduction in the technological level. This reduction was a consequence of bringing back technologies that had been used during earlier periods and discarding advanced technologies that required the use of more energy. From the economic point of view those advanced technologies were available only at the lower energy prices that prevailed before 1973.

We are now prepared for the last part of our discussion, which is to describe the prospects for future economic growth in the United States and Japan. The key developments that have occurred since the beginning of 1986 in Japan and in the United States are two. First, in both countries, there has been a sharp decline in energy prices. Crude oil prices have declined from twenty-six dollars per barrel to something like fifteen dollars per barrel. If you add to that the appreciation of the yen in terms of the dollar that has taken place, crude oil prices in Japan have now fallen to levels that are only slightly above those that prevailed before 1973.

The energy price decline will set in motion a series of changes in technology throughout the Japanese economy that will involve reversing many of the changes that resulted from the first oil criisis. To be sure, there have been many important developments in the Japanese economy since 1973 other than higher energy prices. As a consequence of the energy price situation, there are opportunities for deployment of energy intensive technologies that have not existed for almost fifteen years.

The same opportunities exist in the United States as in Japan, but on a less far-reaching scale The U.S. is a substantial producer of petroleum products and supplies a sizable part of its own consumption. The U.S. domestic price level for crude petroleum is less responsive to world prices than the crude oil price level in Japan. Furthermore, non-oil sources of energy are much more important in the United States, so that the effect of crude oil prices on energy prices is attenuated. Still, there will be a stimulus to U.S. economic growth that I would estimate to be of the order of magnitude of half or three quarters of a percentage point.

My conclusion is that in both the United States and Japan will enjoy renewed prospects for economic growth. We can attempt to estimate more precisely the impact on the growth rate in the United States and in Japan of lower energy prices. For that purpose, I will use the analysis of economic growth that I described at the outset. The key idea is that a sustainable growth rate is one in which the growth of capital and the growth of output are precisely the same.

If we consider the sources of economic growth in the U.S. and in Japan, we can see that the growth of labor input in Japan during the most recent period from 1973 to 1979 was only 1.5 percent. If we take the rate of technical change of 0.1 percent that has prevailed during this period, multiplied by a factor of two to reflect the fact that this can be treated as an augmentation to labor, we estimate the sustainable rate of economic growth of Japan, based on the experience of 1973 to 1979, of only 1.8 percent—a very low growth rate. If, on the other hand, we take the average rate of technical change of 0.7 percent that prevailed from 1960 to 1979, again multiplying by a factor of two, we would raise our estimate of the sustainable growth rate in Japan to around three percent.

Although there will be a revival in the rate of economic growth in Japan due to more rapid technical change at the aggregate level, this revival will not produce anything like the double digit growth rates that prevailed during the 1960's and the early 1970's. I would estimate that the sustainable rate of growth in Japan is of the order of magnitude of three to four percent even with much easier terms for buying energy.

In the United States the most recent period we have analyzed involves a growth of labor input, including labor quality, of about 1.7 percent, higher than in Japan. Productivity growth, on the other hand, is a good deal lower. If we take the 1960–1979 average, it is only 0.4 percent. That would correspond to a sustainable rate of growth in the United States of 2.5 percent. Our overall conclusion is, then, that growth prospects in both countries have improved.

I would like to sum up by recapitulating the basic argument. This argument involves examining the sources of economic growth in both countries and asking what portion of the growth source could be regarded as sustainable in the long-run. In Japan and in the United States the growth of labor input is a very important sustainable growth source. The difference between rates of growth in the two countries is due mainly to the difference between rates of technical change at the aggregate level. Immediately after the energy crisis, the rate of technical change at the aggregate level dropped precipitously in both countries, but the decline was much greater in Japan than in the United States.

The key to the link between energy prices and economic growth is the character of technical change. The results we have reviewed do not suggest that changes in technology in Japan and in the United States are identical. While there are some similarities, there are equally important differences. The similarites have to do with the role of energy in technical change and, therefore, with the impact of energy prices on the rate of technical change. The differences have to do with the role of capital, which turns out to be the critical element in Japanese economic growth.

As a consequence of the decisions by the Saudi Arabian Government to increase output of petroleum products to gain market share in the world petroleum market, there has been a rapid decline in the price of crude petroleum facing all importing countries. The major industrialized countries, except for the United Kingdom, are major importers of petroleum products. A reduction in energy prices throughout the industrialized world will result in a stimulus to economic growth. That stimulus will be more substantial in Japan than in the United States, because of the greater change in energy prices that will occur.

At the same time, the character of economic growth in Japan has changed permanently because of the unsustainable nature of two critical sources of economic growth in Japan that characterized the period of very rapid growth. The first of these is continuing increases in capital formation as a proportion of the national product, leading to rates of growth of capital that far exceed rates of growth of output. This is not sustainable in the long run, and therefore, the era of very rapid growth in Japan now seems to be at an end.

A second important growth source in Japan that has now disappeared is the upgrading of the labor force. This took place during the period of rapid growth as a consequence of increased education and increased efficiency of the allocation of labor. These forces are now counter-balanced by the aging of the population and the increasing role for less productive components of the labor force. There are also decreased possibilities for reallocation of labor to increase the efficiency with which labor is used. These reallocations have been a very important source of growth in Japan, but possibilities for growth from this source have been substantially diminished.

The basic driving force of economic growth in Japan, as in the United States, is the development of technology. Although the rate of technical change is relatively unimportant as a proportion of economic growth, technical change is a critical source of fluctuations in the rate of economic growth, like those that took place after the energy crisis. The new oil price situation gives us grounds for optimism about future economic growth in both countries.

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