September 8, 1980

ECONOMIC COMMENTARY

In this issue:

The Productivity Slowdown: Is Oil the Culprit?

Federal Reserve Bank of Cleveland
Research Department
P.O. Box 6387
Cleveland, OH 44101

Address correction requested

BULK RATE
U.S. Postage Paid
Cleveland, OH
Permit No. 385

The Productivity Slowdown: Is Oil the Culprit?

by Steven E. Plaut

One of the most controversial topics debated in the United States today is the dramatic fall in productivity growth in recent years. This slowdown has been held accountable for falling personal incomes, higher inflation and unemployment rates, and a falling dollar. Slower productivity growth seems to be the disease for which advocates of the "reindustrialization" panacea have been searching. Hardly a single major news publication has failed to give cover space to the issue. Increasing attention is being devoted to the importance of correcting the productivity problem, yet no consensus has been reached as to the reason for the slowdown in productivity.

It will be the contention here that most of the productivity slowdown in the mid-1970s was due to the quintupling of oil prices in 1973-75. As such, this *Commentary* is in basic agreement with the work done by researchers at the Federal Reserve Bank of St. Louis.[1] This is in contrast to the views of most other authors.

The Productivity Mystery

On the surface, energy seems to be the most obvious explanation for the productivity slowdown. The stylized facts about productivity trends all provide circumstantial evidence in support of the hypothesis that energy is the true culprit. The facts are that productivity, as calculated by Denison [4] and measured by real National Income Per Person Employed (NIPPE), grew at an average but declining rate of 2.4 percent per year from 1948 to 1973. While slowing after 1965, productivity suddenly fell in 1973, and decreased by an average 0.5 percent per year from 1973-76. After 1976, productivity rose somewhat, but the growth rate of NIPPE for the entire period of 1973-78 was zero. That was equivalent to a 12.6 percent decrease in productivity when compared with the pre-1973 trend.[2]

1. See Rasche and Tatom [14], [15], and [16], and Tatom [17] and [18].
2. See Denison [4].

Steven E. Plaut is a research associate, Federal Reserve Bank of Cleveland, and assistant professor of economics, Oberlin College.

The decline in productivity growth was not confined to the United States. Productivity growth declined at the same time in all major countries in the Organization for Economic Cooperation and Development (OECD). In all these countries, the productivity decline was accompanied by a slowdown in the accumulation of new capital.[3] For the United States, "Growth of the high employment net capital stock per worker has practically halted when compared with the trend rate of growth of 2.9 percent per year from 1950 to mid-1972. From mid-1972 to mid-1979, capital per worker grew at a 0.6 percent rate, leaving the level of capital per worker by mid-1979 about 17 percent lower than that implied along the 1950-72 trend."[4] This implies a $200 billion (1972 prices) decrease in the capital stock, compared with the earlier trend.

The fall in productivity growth varied considerably across industries for the United States. The slowdown for a number of sectors is shown in table 1. Of these, the largest decline occurred in mining. Part of the decline in mining was due to new environmental regulations. But a considerable portion was probably due to the increased cost of energy-intensive processing of ore, especially smelting. The factor shares of energy are shown in the table by sector, and a weak correlation seems evident. The share of energy for the sectors where productivity fell the most (mining, agriculture, electricity and gas, and wholesale and retail trade) is considerably larger than for the sectors where productivity did not fall greatly. Communications, where productivity rose, is the least energy-intensive sector shown. A deeper analysis of the cross-sectoral productivity patterns is beyond the scope of this study, but on the surface energy intensity would appear to explain a great deal of the pattern.

By 1977, productivity growth began a modest recovery. Yet, beginning with the first quarter of 1979, U.S. productivity fell for six straight quarters. Once again, the

3. See Tatom [18], p. 15.
4. See Tatom [18], pp. 6-7.

Table 1 Decline in Growth Rates of National Product per Hour Worked and Shares of Energy, by Sector

	Growth rate for 1948-73 minus rate for 1973-76, percent	Total input coefficient from crude petroleum and natural gas	Total input coefficient from electricty, gas, and sanitary services
Communications	-3.2	0.0016	0.0010
Construction	0.7	0.0179	0.0152
Services	1.2	0.0092	0.0021
Manufacturing			
Durable goods	1.3	na	na
Nondurable goods	1.5	na	na
Wholesale and retail trade	2.7	0.0075	0.0209
Electricity, gas, and sanitary services	3.0	0.1120	0.1017
Agriculture, forestry, and fisheries	3.4	0.0703	0.0273
Mining	10.2	0.0303	0.0345
All sectors in economy	2.9	0.0141	0.0494

SOURCE: Based on Edward F. Denison, *Accounting for Slower Economic Growth: The United States in the 1970s* (The Brookings Institution, 1979), table 9-1, p. 146; and U.S. Department of Commerce, Bureau of Economic Analysis, *The Detailed Input-Output Structure of the U.S. Economy:1972* (Washington, D.C., 1979).

fall in productivity followed sharp increases in oil prices. While oil prices had remained fairly constant in real terms from 1976 to 1978, they shot up rapidly following disruptions of Iranian exports in the fall and winter of 1978-79. In the second quarter of 1980, nonfarm business productivity fell at an adjusted annual rate of 4.1 percent, the largest fall in six years.

There have been a number of recent analyses of the productivity slowdown.[5] Of these, perhaps the most familiar is that by Denison [4]. His study attempted to explain the causes of the shift in productivity, and he concluded that his search was largely unsuccessful. Denison summarized his findings by saying, "What happened, is, to be blunt, a mystery"(p.4). Since then, a number of other studies have attempted to resolve the "productivity mystery," many of which have debated the importance of the OPEC-induced energy-price change.

One could divide the factors contributing to the productivity growth slowdown into two sets. First, there seems to have occurred a sharp decline in the U.S. capital-labor ratio or the rate of accumulation of capital. There is disagreement, however, as to the magnitude, significance, and cause of the decline.

The Role of Capital

Tatom [18] estimates that 38 percent of the decline in productivity in the mid-1970s may be attributed to this fall in capital accumulation, although some have argued this may be too large, given the lagged impact that changes in capital have on productivity. Kopcke [9] believes that one-half of the slowdown is due to this factor, and for manufacturing perhaps the entire slowdown is due to it. Norsworthy, Harper, and Kunze [11] also claim that it explains half, but explains only 30 percent for manufacturing. Denison [4], however, estimates that the change in capital accumulation can explain only 4.0 percent of the observed decline in actual non-residential NIPPE growth, and explains about the same (4.8 percent) for potential growth. Berndt [1] is even dubious that growth of the capital-labor ratio slowed very much, at least in manufacturing, where it grew at a

5. For a concise yet comprehensive survey, see Nordhaus [10].

rate of 2.5 percent from 1973-77, compared with 2.9 percent for the preceding eight years.[6]

There seem to be two candidates for the factor causing this slowdown in capital accumulation. The first is inflation and its distorting effects on taxation of capital, especially because of obsolete mandated depreciation standards. Yet, it seems unlikely that the inflation-caused tax distortion could entirely explain a worldwide pattern, since other countries have very different tax systems and inflation histories. The second candidate is the change in energy prices. Hudson and Jorgenson [7], among others, have argued that energy and capital tend to be complements, and therefore the capital-labor ratio would fall when energy prices rise.

The decrease in capital accumulation, whatever its causes, explains only part of the fall in productivity growth. In addition, another set of factors must be included. Again, there is debate about what these factors are or how important they are. It is striking that almost all studies find that a significant part of the slowdown is "unexplained." Denison takes into account various demographic, sociological, and economic factors, together with changes in capital, yet is still left with an unexplained fall of 2.1 percent in productivity growth for the 1973-76 period. This is 72 percent of the slowdown and constitutes his "mystery." Norsworthy, Harper, and Kunze [11] find that, after taking into account various capital and labor changes, 13 percent of the productivity slowdown in private business remains unexplained, compared with 78 percent in manufacturing. Other studies also are forced to allow for large "residuals."[7]

Some have argued that these large residuals are really manifestations of a slowdown in technological development. It is true that the percentage of U.S. GNP devoted to research and development fell somewhat in the 1970s. But this reflected decreased government funding of space and defense research; private funding of research rose during most of the period. Moreover, any fall in research funding should affect productivity growth only after a long lag. It could well be the case that the 1948-73 "residual" in Denison's study (1.4 percent) represents technological advance. But the technological advance probably was not much different during 1973-76, meaning that a 2.1 percent decrease in productivity growth after accounting for technology remains "unexplained." In any case, it is very hard to believe that this slowdown in research could explain a worldwide pattern, or the slowdown-recovery-slowdown pattern that has been observed for the United States.

The Role of Energy

Among the factors we are left with is the direct impact of energy prices, that is, the impact after taking into account their effect on capital investment. Denison is skeptical about the ability of energy to explain the "mystery." He estimates that the factor share of energy in GNP is only 4.6 percent.[8] Perry [12] and de Leeuw [3] also reject the energy explanation on grounds that sharp productivity changes due to energy prices could only result if a great deal of energy conservation occurred, that is, if energy demand elasticity were high. Perry estimates that energy used per unit of output declined 10.2 percent from 1973 to 1976, but that most of this reflected a time trend.[9] Tatom [18], however, estimates the elasticity of the energy/real GNP ratio to energy prices as -1.207, indicating considerable responsiveness to price.[10]

Consider a factory that used only capital and electricity to produce some product. When the price of electricity rose, less output would be produced in the factory. The output or "capacity" of the factory would really be a direct function of the cost of obtaining electricity. At a higher cost, the factory and its capital stock would be less productive in both an average and marginal sense. By analogy, the entire United States and all of its domestic resources (including labor) may be thought of as constituting a large

---

6. Berndt, however, does not conclude that energy is the solution to the mystery. Part of the confusion has to do with definitions of capital. Compare Norsworthy, Harper, and Kunze [11].
7. See Nordhaus [10], table 1.
8. It is not clear from the book whether this number refers to direct or total shares.
9. Tatom [18] disagrees that there was any trend at all.
10. Tatom [18] notes that there may be problems with the data.

producing unit; when the price of imported energy rises, productivity falls—exactly as in the case of the simple factory.

Extending this example, it can be argued that increases in prices of imported intermediate goods lead to contractions in the entire set of production choices for economies importing the good. This is equivalent to saying that the price increase leads to a contraction in output capacity and a decline in productivity for domestic capital and labor. A formula may be used to illustrate the relation between the long-run fall in productivity and the price change of any imported input.[11] This decline in productivity would be observed after full adjustment of the economy. The formula treats capital and labor as one aggregate factor, but that is equivalent to investigating the "residual" change in productivity, after taking into account changes in the capital-labor ratio. In effect, capital and labor are "altered" when the price of imported energy rises, and they become less productive in both an average and a marginal sense.

The contraction in productivity is related to price changes by:[12]

(1) % change in productivity =

$$-\frac{\theta_m}{1-\theta_m} \cdot \sigma_{LM} \cdot \text{(\% change in } P\text{)},$$

where P is the relative price of the imported input in question, θ_m is the factor share of the imported input in domestic GNP, and σ_{LM} is the elasticity of substitution between the imported input and domestic value added (capital, labor, and other resources).

Rough estimates of the relevant variables can be substituted into equation 1. The percent increase in the price of imported oil for 1973-75 was about 400 percent.[13] The share of imported fuels in U.S. GNP averaged 1.117 percent between 1973 and 1976.[14] The elasticity of substitution between imported oil and domestic value added is unknown. However, the elasticity of substitution between *all* energy inputs and domestic factors *has* been estimated.

Hudson and Jorgenson [6] estimated the elasticity of substitution between energy and labor for the United States to be 2.16, and that between energy and capital to be -1.39, for an "aggregate" elasticity of substitution of about 1.27.[15] (Griffin and Gregory [5] and Berndt and Wood [2] produce lower estimates.) This elasticity refers to *all* energy consumption. The elasticity for imported energy should be larger. Even if we use 1.27 for σ_{LM} and 1.117 percent for θ_m, then by equation 1, the post-1973 oil price hike should have caused a "long-run" aggregate contraction in productivity of 4.74 percent.[16] This alone is three-quarters of the 6.4 percent decline that constitutes the "productivity mystery" of Denison for 1973-76, even though it ignores substitution between domestic and imported energy. If, after taking that into account, the elasticity of substitution between imported oil and domestic value added were 1.35, then the entire "mystery" of Denison would be accounted for fully.

In conclusion, the analysis here indicates that the energy price increase caused by OPEC after 1973 probably explains most of the slowdown in U.S. productivity growth. As oil prices rose, productivity and output capacity contracted for the United States and other OECD countries. The increase in energy prices directly caused capital accumulation to slow down, and indirectly caused higher inflation, resulting in the effective increase in taxation of capital income. Moreover, higher energy prices directly reduced the productivity of U.S. resources, and thus caused most or all of the "residual" slowdown not explained by the fall in capital accumulation.

11. See Plaut [13].
12. See Plaut [13].
13. This, of course, varied by types of crude. But the number is conservative, since one could argue that further price increases were anticipated. By mid-1980, oil prices rose more than tenfold in real terms.
14. The actual numbers were 0.367 percent, 1.168 percent, 1.302 percent, and 1.629 percent for the four years beginning 1973, respectively. This refers to gross imports; the share of net imports was slightly less.
15. As calculated by Griffin and Gregory [5].
16. The estimate of 1.27 for σ_{LM} is somewhat arbitrary. If $\sigma_{LM} = 1.5$, the estimated productivity decline because of the energy price change would be 5.6 percent; if $\sigma_{LM} = 0.8$, the decline would be 3.0 percent; if $\sigma_{LM} = 0.6$, the decline would be 2.2 percent.

References

1. Berndt, Ernst R. "Energy Price Increases and the Productivity Slowdown in United States Manufacturing." Manuscript, 1980.
2. ______ , and David O. Wood. "Technology, Prices and the Derived Demand for Energy," *Review of Economics and Statistics*, vol. 57 (August 1975), pp. 259-68.
3. de Leeuw, Frank. "Comments on Rasche and Tatom," in *U.S. Productive Capacity: Estimating the Utilization Gap*. St. Louis: Washington University, Center for the Study of American Business, Working Paper 23, December 1977, pp. 137-45.
4. Denison, Edward F. *Accounting for Slower Economic Growth: The United States in the 1970s.* Washington, D.C.: The Brookings Institution, 1979.
5. Griffin, James M., and Paul R. Gregory. "An Intercountry Translog Model of Energy Substitution Responses," *American Economic Review*, vol. 66 (December 1976), pp. 845-57.
6. Hudson, Edward A., and Dale W. Jorgenson. "U.S. Energy Policy and Economic Growth, 1975-2000," *Bell Journal of Economics*, vol. 5 (Autumn 1974), pp. 461-514.
7. ______ . "Energy Prices and the U.S. Economy: 1972-76," *Data Resources U.S. Review*, September 1978, pp. I.24-I.37.
8. Kendrick, John W. "Survey of the Factors Contributing to the Decline in U. S. Productivity Growth." Manuscript, 1980.
9. Kopcke, Richard W. "Capital Accumulation and Potential Growth." Manuscript, 1980.
10. Nordhaus, William D. "Policy Responses to the Productivity Slowdown." Manuscript, 1980.
11. Norsworthy, J.R., Michael J. Harper, and Kent Kunze. "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," *Brookings Papers on Economic Activity*, vol. 2 (1979), pp. 387-431.
12. Perry, George L. "Potential Output: Recent Issues and Present Trends," in *U.S. Productive Capacity: Estimating the Utilization Gap.* St. Louis: Washington University, Center for the Study of American Business, Working Paper 23, December 1977, pp. 1-20.
13. Plaut, Steven E. "The Pure Theory of International Trade in Intermediate Goods." Manuscript, 1979.
14. Rasche, Robert H., and John A. Tatom. "Energy Resources and Potential GNP," *Federal Reserve Bank of St. Louis Review*, vol. 59 (June 1977), pp. 10-24.
15. ______ . "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," *Federal Reserve Bank of St. Louis Review*, vol. 59 (May 1977), pp. 2-12.
16. ______ . "Potential Output and Its Growth Rate—The Dominance of Higher Energy Costs in the 1970s," in *U.S. Productive Capacity: Estimating the Utilization Gap*. St. Louis: Washington University, Center for the Study of American Business, Working Paper 23, December 1977, pp. 67-106.
17. Tatom, John A. "Energy Prices and Capital Formation: 1972-1977," *Federal Reserve Bank of St. Louis Review*, vol. 61 (May 1979), pp. 2-11.
18. ______ . "The Productivity Problem," *Federal Reserve Bank of St. Louis Review*, vol. 61 (September 1979), pp. 3-16.