producing unit. If 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” productivity change in productivity, after taking 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 productivity in question is related to price changes by:\(^12\)
\[
\frac{\Delta \text{ productivity}}{\Delta \text{ price}} = \frac{\Delta \text{ consumption}}{\Delta \text{ price}} - \frac{\Delta \text{ production}}{\Delta \text{ price}}.
\]

where \(P\) is the price of the imported input in question, \(\delta\) is the factor share of the imported input in domestic GNP, and \(\gamma\) is the elasticity of substitution between domestic and imported inputs. 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 1.1 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 input prices and domestic value added has been estimated.\(^15\)

In a study of the energy price increase, 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.\(^16\) (Griffin and Gregory \(^5\) [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 \(\gamma\) and 1.117 for \(\delta\), then by equation 1, this price change should have caused a “long-run” aggregate contraction in productivity of 4.74 percent. This is a large change in productivity, and it is in line with the post-1973 oil price history.\(^17\) A decline that constitutes the “productivity mystery” of Denison for 1973-76, even after taking account of the increase in taxation of capital income. More-}

The elasticity of substitution between imported oil and 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, as experienced by OPEC after 1973, probably explains most of the slowdown in U.S. productivity growth. As oil prices rose, productivity per unit of output declined 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 slowdown of the entire economy. Moreover, higher energy prices directly reduced the productivity of U.S. industry, thus caused most of or all of the “residual” slowdown not explained by the fall in capital accumulation.

11. As calculated by Griffin and Gregory \(^5\).

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, 1.352 percent, and 1.029 percent for the four years beginning 1973, respectively. This refers to gross imports: the share of net imports was slightly less.

References


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In this issue: The Productivity Slowdown: Is Oil the Culprit?

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The Productivity Slowdown: Is Oil the Culprit?

One of the most controversial topics debated in the United States today is the slowdown 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 price we have paid at the same time in all major countries in the Organization for Economic Cooperation and Development. The most critical of the slowdown, productivity decline was accompanied by a slowdown in the accumulation of new capital. For the United States, "Growth of the high employment net of capital per worker has practically halted when compared with the trend before 1972. From mid-1979, capital per worker grew at a 0.6 percent rate, leaving the level of capital per worker below what it would have been 17 percent lower than that implied by the 1950-1972 trend. 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 environmental regulations. But a considerable portion was probably due to the lagged impact that changes in capital have on productivity, and he concluded that his search for a "mystery," the entire United States and all of the developed world, explains half, but explains only 30 percent of the slowdown. It is beyond the scope of this study, but on balance, the evidence suggests that energy is the true culprit. The facts are that productivity, as calculated by Denison, is measured as the ratio of total output to labor.

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

<table>
<thead>
<tr>
<th>Sector</th>
<th>Growth rate for 1948-73 minus 1973-77, percent</th>
<th>Total input coefficient from capital and natural gas</th>
<th>Total input coefficient from labor and sanitary services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications</td>
<td>3.2</td>
<td>0.0016</td>
<td>0.010</td>
</tr>
<tr>
<td>Construction</td>
<td>0.7</td>
<td>0.0179</td>
<td>0.0152</td>
</tr>
<tr>
<td>Services</td>
<td>1.2</td>
<td>0.0002</td>
<td>0.0201</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>-19.4</td>
<td>-0.0002</td>
<td>-0.0152</td>
</tr>
<tr>
<td>Nondurable goods</td>
<td>1.2</td>
<td>0.0016</td>
<td>0.0152</td>
</tr>
<tr>
<td>Wholesale and retail trade</td>
<td>2.7</td>
<td>0.00075</td>
<td>0.0029</td>
</tr>
<tr>
<td>Electricity and gas</td>
<td>3.0</td>
<td>0.1120</td>
<td>0.1017</td>
</tr>
<tr>
<td>Agriculture, forestry and fisheries</td>
<td>3.4</td>
<td>0.0703</td>
<td>0.0273</td>
</tr>
<tr>
<td>Mining</td>
<td>1.3</td>
<td>0.0303</td>
<td>0.0345</td>
</tr>
<tr>
<td>All sectors in economy</td>
<td>2.9</td>
<td>0.0141</td>
<td>0.0494</td>
</tr>
</tbody>
</table>


The decline in productivity growth was not confined to the United States. Productivity growth slowed down at the same time in many other countries of the Organization for Economic Cooperation and Development. The first is that, after taking into account various capital-labor ratios, slowing down 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 depressed government funding of space and defense activities, produced by the economic slowdown. The slowdown and constitutes his "mystery." Nevertheless, the elasticity of the energy variable has increased, from 0.0016 in the 5 years preceding 1973 to 0.00075 in the 4 years following 1973. This is in contrast to the views of most other authors.

The Role of Energy

While slowing after 1965, productivity growth suddenly fell in 1973, and decreased by 12.6 percent from 1973-77, compared with a 4.8 percent increase in potential growth. Berndt [4] estimates that, after taking into account various capital-labor ratios, slowing down 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 depressed government funding of space and defense activities, produced by the economic slowdown. The slowdown and constitutes his "mystery." Nevertheless, the elasticity of the energy variable has increased, from 0.0016 in the 5 years preceding 1973 to 0.00075 in the 4 years following 1973. This is in contrast to the views of most other authors.

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One of the most controversial topics debated in the United States today is the productivity slowdown in recent years. This slowdown has been held accountable for falling personal incomes, rising inflation and unemployment rates, and a falling dollar. Slower productivity growth seems to be the primary reason why so much of the "reindustrialization" phenomenon has failed to give over space to the issue. Increasing attention is being devoted to the importance of correcting the productivity slowdown. No consensus has been reached as to the reason for the slowdown in productivity. While the concern here is not the actual slowdown in productivity but the mid-1970s was due to the quieting of oil prices in 1975-76. As such, thisCommentary is in basic agreement with the work done by researchers at the Federal Reserve Bank of St. Louis. 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 thesis that energy is the true culprit. The facts are that productivity, as calculated by Denison 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 grew at an average 0.5 percent per year from 1973-76. This slowdown was most pronounced in mining. Other studies also found a number of recent analyses of the productivity slowdown.6

Of these, perhaps the most familiar is that by Tatom [18]. His study attempted to explain the causes of the shift in productivity, and he concluded that his explanations were largely unsuccessful. Denison summarized his findings by saying: "What happened, is, to be blunt, a mystery."(p.4)

Consider, for instance, a factory that used only electricity, gasoline, and retail trade. 2.7 0.0057 0.0209

Electricity, gas, and sanitary services 3.0 0.0120 0.0107

Manufacturing (not durable goods) 2.7 0.0703 0.0273

Manufacturing (durable goods) 1.3 na na

Nondurable goods 1.5 na na

Agriculture, forestry, and fisheries 3.4 0.0075 0.0209

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

Growth rate for 1948-73 minus growth rate for 1973-76, percent

Total input coefficient from capital and energy

Total input coefficient from capital, energy, and sanitary services


The fall in productivity growth varied considerably across industries for the United States. The slowdown for a number of sectors is seen in Table 1. Of these, the largest decline occurred in mining. Part of the decline in mining was due to new environmental regulations. It is conceivable that portion was probably due to the increased cost of energy-intensive processing in the mining industry. Of the factor shares of energy are shown in the table by sector, and a weak correlation seems evident. The share of energy in the mining sector where productivity fell the most (mining, agriculture, electricity and gas, and petroleum) was an average 2.4 percent per year from 1948 to 1973. While slowing after 1965, productivity grew at an average 0.5 percent per year from 1973-76. After 1976, productivity rose somewhat, but the rate of NIPPE (the average rate of output per hour worked) of 1973-78 was zero. That was equivalent to a 12.6 percent decrease in productivity when compared with the pre-1976 period. By 1977, productivity growth began a modest recovery. Yet, beginning with the spring of 1975, U.S. productivity rose for six straight quarters. Once again, the

6. Berndt, however, does not conclude that energy is the solution to the mystery. Perry [12] also notes that there are problems.

7. It is not clear from the book whether this rate refers to direct or total shares.

8. It is left to the reader to decide whether these also have productivity implications.

9. Tatom (18) notes that there may be problems with the data.
The Productivity Slowdown: Is Oil the Culprit?

One of the most controversial topics debated in the United States today is the slowdown in productivity growth in recent years. This slowdown has been held responsible for falling personal incomes, rising inequality and unemployment rates, and a falling dollar. Slower productivity growth seems to be the key ingredient in the so-called "reindustrialization" or the "productivity wedge". Recently, the question of why productivity growth has been slow has been the subject of considerable debate. One of the longstanding explanations is that energy prices are too high. In this paper, we will examine the evidence for this hypothesis and other explanations.

**The Productivity Mystery**

On the surface, energy seems to be at the root of the productivity slowdown. The increase in energy prices has led to a slowdown in the accumulation of capital and a decrease in productivity. This is in contrast to the view of many other authors who have argued that energy and capital complement each other. However, there is evidence that energy prices have not been the only factor affecting productivity. In fact, there are many other factors that have been identified as contributing to the productivity slowdown.

**The Role of Energy**

The decrease in capital accumulation, as shown in table 1, has been due to the fall in productivity growth. In addition, another factor that has been identified is the decrease in capital used per unit of product. This is a direct result of the decrease in productivity growth. In addition, there is evidence that the capital-output ratio has increased. This is consistent with the idea that energy has become a substitute for capital.

**The Role of Capital**

The productivity slowdown has been due to a decrease in the capital-output ratio. This is consistent with the idea that energy has become a substitute for capital. In addition, there is evidence that the capital-output ratio has increased. This is consistent with the idea that energy has become a substitute for capital.

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**The Role of Other Factors**

There are many other factors that have been identified as contributing to the productivity slowdown. These include changes in the tax system, changes in the labor market, changes in the technology, changes in the demand for goods, and changes in the supply of labor.

**Concluding Remarks**

In conclusion, the productivity slowdown is due to a decrease in the capital-output ratio. This is consistent with the idea that energy has become a substitute for capital. In addition, there is evidence that the capital-output ratio has increased. This is consistent with the idea that energy has become a substitute for capital.

---

1. See Rasche and Tatom (14), (15), and (16), and Tatom (17) and (18).
2. Steven E. Plaut is a research associate, Federal Reserve Bank of Cleveland, and assistant pro-
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5. For a concise yet comprehensive survey, see Nordhaus (10).
6. Benford, however, does not conclude that energy is the solution to the mystery. Perry (12) also 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. 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 accounting for 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 productivity in construction is related to price changes by $$\frac{\Delta P}{P} \cdot \frac{c_{LM}}{c_{LM}^{\text{change}}}$$. The elasticity of substitution between imported oil and domestic value added was 0.8, 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-per-capita output capacity contracted for the United States and other OECD countries. The increase in energy prices caused a decline in capital accumulation to slow down, and indirectly caused higher inflation, resulting in the slowdown in the rate of increase in taxation of capital income. Moreover, higher energy prices reduced the incentive for the production of oil and other energy-saving goods. The increase in capital accumulation, therefore, caused most of or the “residual” slowdown not explained by the fall in capital accumulation.

11. See Flath (13).
12. See Flath (13).
13. This, of course, varied by types of crude. The number is conservative, since one could argue that further price increases were anticipated. By mid-1980, oil prices were more than twice as high as in 1973.
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