# Changes in Energy and Other Factor Productivity

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## ABSTRACT

Manufacturing productivity has improved by 24 percent over the 25-year period from 1973 to 1998. Data from the Department of Labor's Bureau of Labor Statistics (BLS 2000) show that only labor and energy productivity had a net increase over that period, with labor productivity more than doubling, and energy productivity improving by more than 60 percent. The productivities of capital, materials, and business services have actually declined, by 15 percent for capital, almost 19 percent for materials, and 7 percent for business services.

The role of each of these components in manufacturing productivity takes into account these component-specific productivity changes as well as weights that reflect changes in quantities and prices of inputs. Multifactor and component productivities in several industries included in the Department of Energy's Industries of the Future program have had similar patterns.

## Introduction

A few years ago, the Office of Policy in the Department of Energy undertook a study comparing methods of estimating the employment impacts of an energy price increase. The expected economic impact was some mixture of decreases in GDP and employment, maybe some energy price-induced technological change, maybe some increased speed of replacing less energy-efficient capital stock. In most of the models examined, that was what happened. But the structure of one model required that when energy prices increased, labor was always substituted, so any energy price increase had to result in increased employment. In this perfect substitution scenario, when less energy was used per unit of output (energy productivity increased), more labor was used (labor productivity had to decrease). This seemed intuitively incorrect, leading to a basic question: how did labor and energy productivities change between 1973 and 1998?

It is not unreasonable to hypothesize that improvements in energy and labor productivity could occur together. This paper will look at capital, labor, energy, materials, business services, and multifactor productivity measures for manufacturing from 1973 to 1998 to see what in fact happened to the productivity of other factors of production as energy efficiency has increased. In addition to general industrial averages, the paper will focus on some of the energy-intensive industries included in the Department of Energy's Industries of the Future Program.

[1] The views expressed here are not necessarily those of the Department of Energy.

## Background

While labor productivity, output per hour worked, is still the most frequently cited productivity measure, the Department of Labor's Bureau of Labor Statistics (BLS) first introduced a set of multifactor productivity measures in 1983 (BLS 1983). The intention was to attempt to measure productivity change not accounted for by changes in labor and capital inputs, such as technological change, changes in efficiency, managerial expertise, and economies of scale. Converting recent BLS data (BLS 2000) to compound annual rates of change:

| | | | | |
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| 3.2 percent increase in private nonfarm business output (real gross domestic product in that sector) from 1973 to 1998 | = | 2.7 percent increase in the combined units of labor and capital | + | 0.5 percent increase in multifactor productivity |

The 2.7 percent increase in the combined units of labor and capital is the weighted sum of a 2.1 percent increase in labor inputs with a weighting factor of 0.68 reflecting labor's share of the cost of combined inputs and a 4 percent increase in capital services weighted by the remaining 0.32, capital's share of the combined costs.

Multifactor productivity measures were expanded in 1987 (Gullickson & Harper 1987). To avoid double counting, the productivity measures of the larger portions of the economy, private business and the private nonfarm business sector featured above, had excluded intermediate inputs. In the development of measures that would be used for industry level analysis, BLS adopted an output measure that included intermediate products shipped to or from other sectors (Dean & Harper 1998). Succinctly put, then, the multifactor productivity index for manufacturing "compares what is produced in the manufacturing sector for use outside of manufacturing with the inputs used in the manufacturing process obtained from outside of manufacturing" (BLS 2000, 6).

Two types of manufacturing productivity measures will be examined here:

- two multifactor measures:
  - the combined inputs measure, necessary only to calculate the residual which is
  - multifactor productivity
- the single factor measures - output per unit of a single input. The single inputs considered include capital, labor, energy, materials, and professional business services, the set of inputs with the acronym KLEMS.

Capital is measured as the rental price of services derived from physical assets and software. The measure of labor input is an aggregate of hours at work of all persons. Energy, materials, and business service indexes are constructed from cost and quantity data (BLS 2000).

## Calculating Sector Shares of Multifactor Productivity

In 1973 multifactor productivity in manufacturing was 91.4 on an indexed scale where 1992=100, and increased to 113.2 by 1998, a 24 percent increase over the period, or a 0.9 percent compound annual rate (BLS 2000). A BLS analysis (Gullickson 1995) divided the period of analysis being considered here into pre- and post-1979 sections to isolate some of the effects of energy price shocks and double-digit inflation in the 1973-1979 period. The compound annual growth rate of manufacturing productivity in the earlier period was a decrease of 0.6 percent, while productivity grew at a compound annual growth rate of 1.3 percent in the later period.

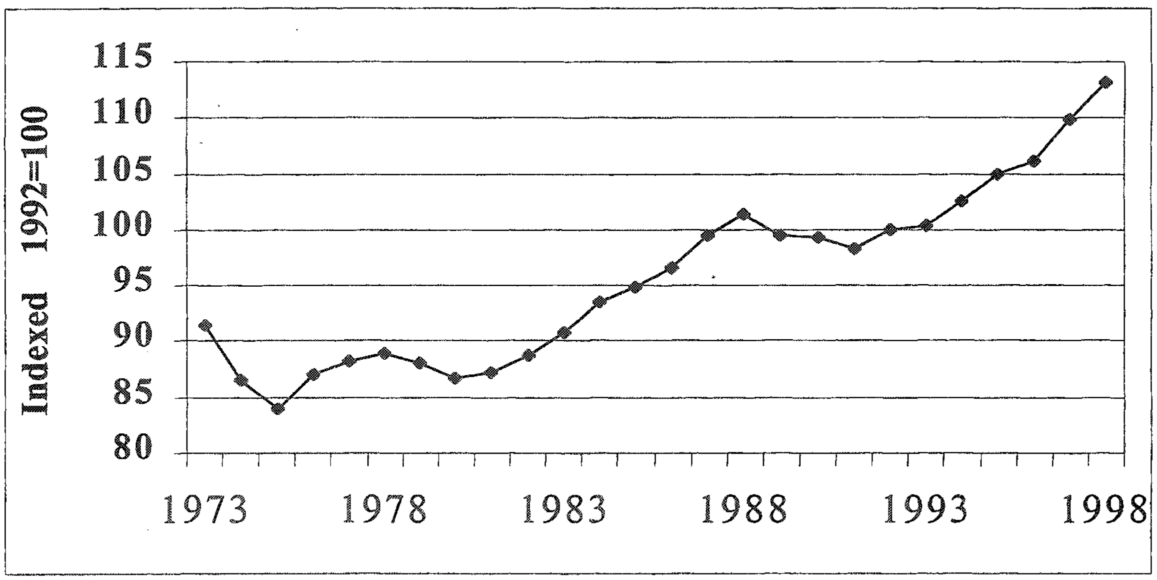


**Figure 1. Multifactor Productivity**

The path of the increase is shown in Figure 1. What has been driving this? In the following sections, we will be looking at the role of inputs, sectoral productivities, and factor weights in determining multifactor productivity.

### First Take Out the Input Effects

To examine the roles of energy and labor productivity in manufacturing productivity changes, one must first net out the changes in output attributable to changes in the magnitude of inputs. As shown in Figure 2, from 1973 to 1998, manufacturing output grew at a compound annual rate of 2.7 percent. Inputs of capital, energy, materials and services grew at compound annual rates ranging from 0.7 percent for energy to 3.5 percent for materials. Labor inputs actually decreased by 0.2 percent. When these input changes are weighted by their relative importance in the cost structure of all inputs, their combined compound annual rate of increase

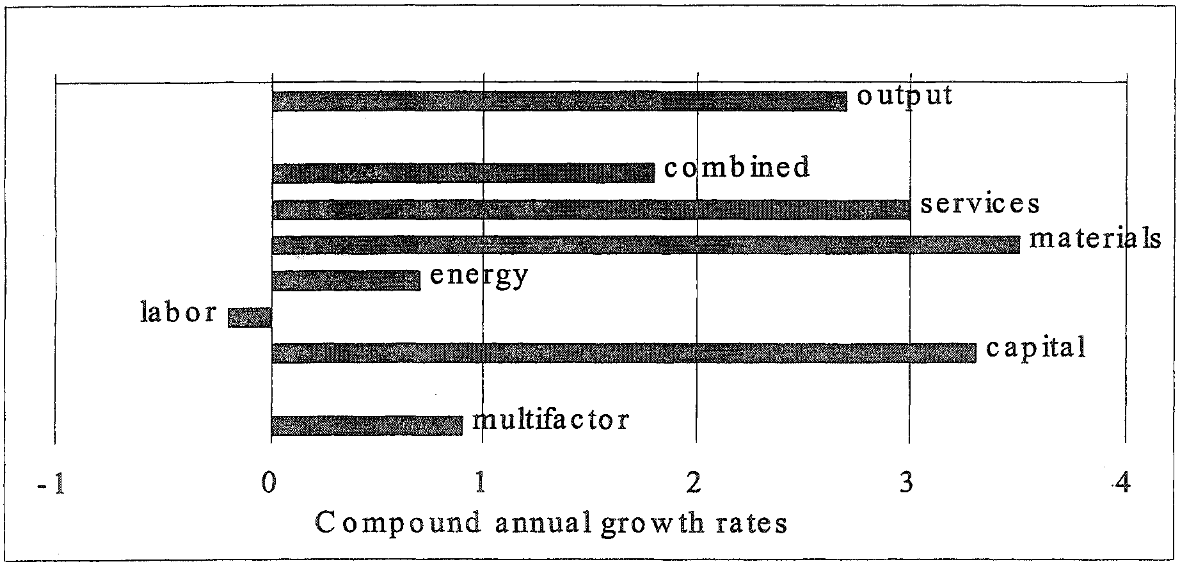


**Figure 2. Components of Output Change, 1973-1998**

was 1.8 percent. The residual, the 2.7 for output less the 1.8 for the role of inputs, is the compound annual rate of 0.9 percent mentioned above for the effect of productivity of all of these factors.

**Next, Examine Individual Sector Productivities**

Multifactor productivity can be disaggregated to show the effects of the productivity gains in the various sectors. Looking at the KLEMS components, not only were labor and energy productivities not operating in opposite directions, they were the only sectors that had higher productivity at the end of the period than at the beginning. The 'perfect substitution' assumption underlying the model mentioned earlier is not supported by the data.

As shown in Figure 3, average productivity gains were highest over the whole 1973 to 1998 period for labor at 2.9 percent, followed closely by energy at 2.0 percent, and lowest for materials, dropping by 0.8 percent. The BLS multifactor productivity change is a weighted average of the productivities of these sectors, so the composition of the weights also bears examining.

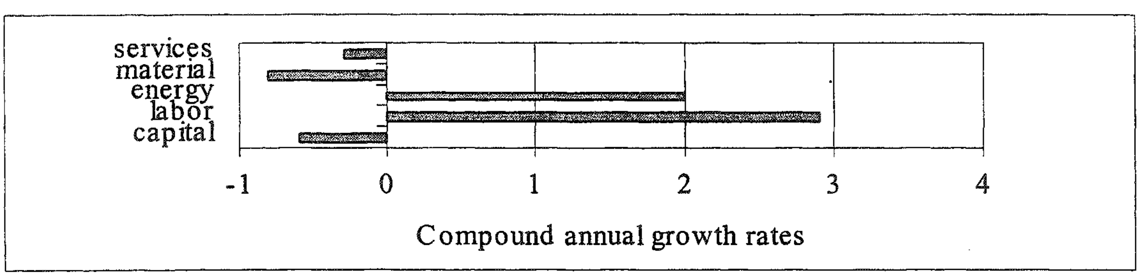


**Figure 3. Component Productivity Change**

**Finally, the Weights**

The last piece of the puzzle is the composition of the weights used to aggregate the individual input productivities into multifactor productivity. BLS calculates the weight for each of the KLEMS inputs as the average percentage of its cost in total costs for the current year and

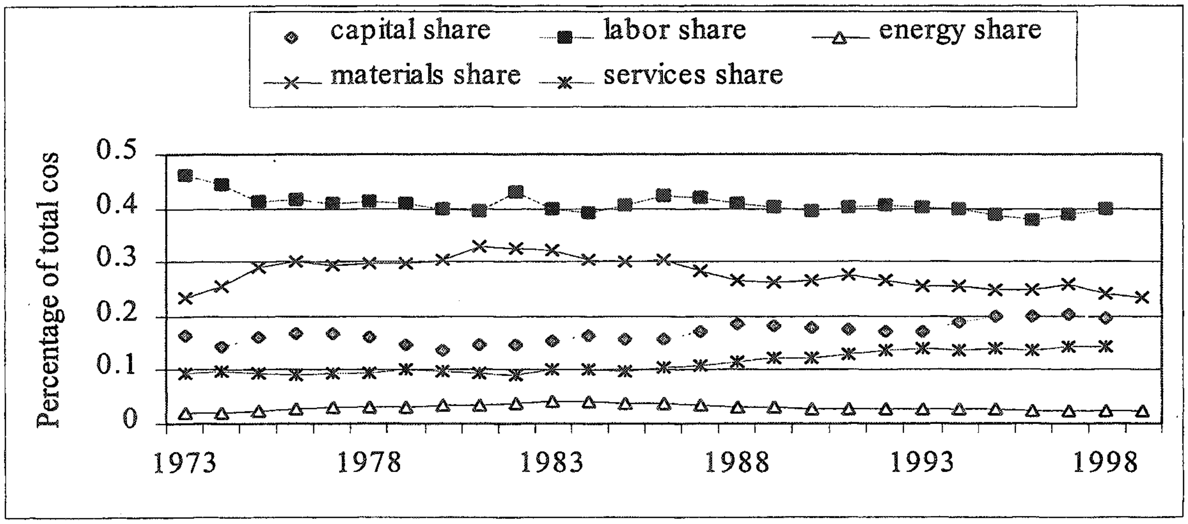


**Figure 4. Weights**

for the one before that. The weights, reflecting relative compensation shares of the components, vary by time period, and total costs are the current dollar value of shipments adjusted for inventory change. As shown in Figure 4, the weights have been fairly level over the period, with the labor share hovering around 40 percent, materials averaging in the high twenties, capital in the high teens, services increasing from about 10 to 14, and energy averaging only about 3 percent.

**The Contributions of the Components**

The contributions to multifactor productivity of each input share, the component productivities times the weights, are shown in Figure 5. Since only labor and energy had

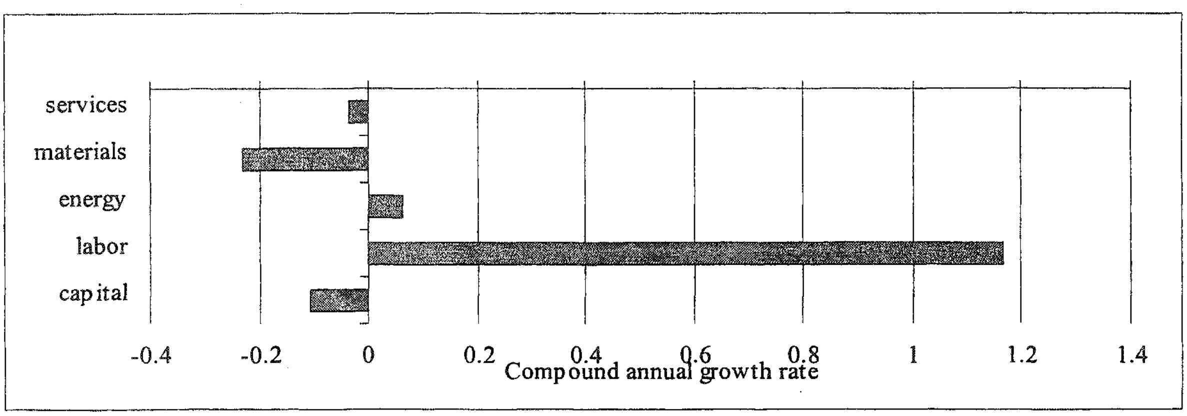


**Figure 5. Contributions to Multifactor Productivity**

improvements in sectoral productivity, only labor and energy made a positive contribution to manufacturing productivity over the 1973 to 1998 period. The heavy weighting of labor's productivity growth as a result of its large share of total costs gave labor the lion's share of the contributions.

## Some Influences on Single Factor Measures

### Sector Definitions

Some light is shed on the underlying influences on the movement of the single factor measures when the BLS definitions are examined. For manufacturing, the labor inputs to the BLS index of output per unit of labor are a simple sum of hours at work for all persons as collected by the BLS Current Employment Statistics program and the Current Population Survey. This measure does not capture the effects of changing labor composition (BLSb).

For its private business sector, BLS does construct a labor composition index, with a 1 percent change in the index having the same effect as a 1 percent change in hours worked. This index measures changes in the age, education, and gender of the work force. Labor composition index growth rates tend to be high at the beginning of an economic recession, as employees with less education and less seniority are laid off (BLS 1997). As an example of the magnitude of the labor composition effect, in 1997 the growth rate of the labor composition index was almost one-third of the growth rate of hours worked.

The compositional effect in manufacturing is also important in the BLS capital productivity measure. BLS estimates that over the 1995 to 1998 period, all of the contribution of capital intensity to manufacturing output was attributable to the contribution of information processing equipment and software (BLS 2000).

### Energy and Materials Prices

As shown in Figure 6, energy prices were rising rapidly during the beginning of the period. Looking at the BLS energy price index (1992=100), energy prices had varied very little from 1949 to 1972, growing from 15.1 to 20.6 (BLSd). By 1978, energy prices had tripled, to an index of 60.5, and doubled again to 119.4 in 1984, their peak in the pre-1999 period. Energy

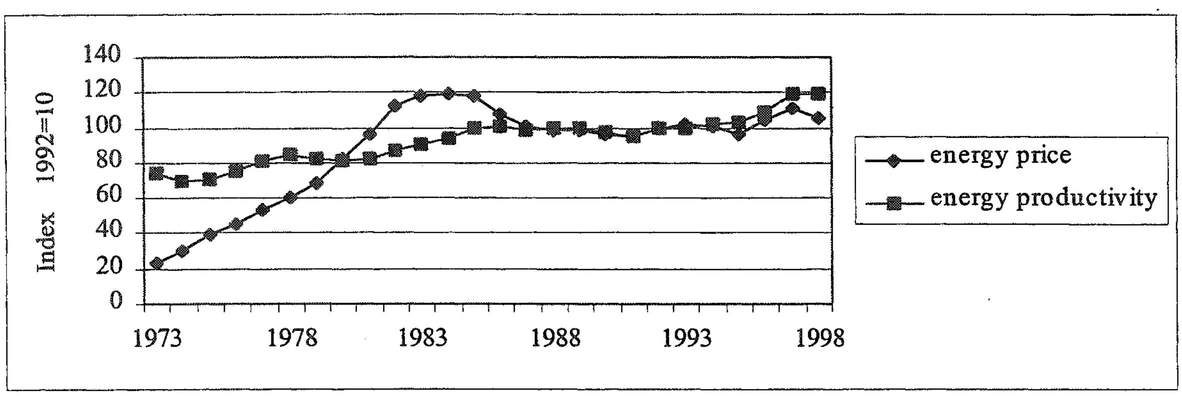


**Figure 6. Energy Price and Productivity Indexes**

productivity during the two periods of fastest energy price growth, 1973 to 1978 and 1980 to 1984, grew at compound annual rates of 2.6 and 2.8 percent for the two periods, considerably faster than the average of 2 percent for the whole 1973 to 1998 period.

Non-energy materials prices were approaching the volatility of energy prices, no doubt as a result of the effects of the energy embedded in some of the materials. During the 1973 to 1978 period, materials prices increased at a compound annual rate of 7.3 percent.

### Outsourcing

Purchased business services, as a group, hold the largest potential for input substitution. Increasingly we see outsourcing replacing in-house manufacture, and decreases in the indexes for inputs of other factors of production can show up as increases in the services indexes.

## Energy-Intensive Industries

This last section of the analysis provides the opportunity to compare these all-manufacturing averages with three BLS industries, petroleum, chemicals and primary metals. The main portions of each are included in the Department of Energy's Industries of the Future Program coordinated by the Office of Industrial Technologies.

The Industries of the Future Program creates partnerships among industry, government, and supporting laboratories and institutions to accelerate technology research, development, and deployment, with the goal of improving the efficiency and competitiveness of materials and process industries. The nine Industries of the Future currently included in the program include steel, aluminum, chemicals, glass, metal casting, petroleum, agriculture, mining, and forest products.

BLS defines its industry-specific multifactor productivity data by 2-digit Standard Industrial Classification (SIC) codes which do not usually match the definitions of the Industries of the Future. The BLS industrial categories chosen for this comparison with the all-manufacturing average are chemicals and petroleum where 2-digit BLS codes do fit the definitions of Industries of the Future, and the BLS primary metals industry since the steel, aluminum, and metal casting Industries of the Future together are over 70 percent of the output of primary metals (Annual Survey of Manufactures 1998).

Figure 7 shows the decline in output in primary metals over the 1973 to 1998 period, with the compound annual rate of change of combined inputs also negative. In chemicals, output was going up over the period, as were all inputs. Petroleum output increased, with decreased inputs of labor and energy. The compound rates of change of the index of multifactor productivity were negative in both chemicals and primary metals over the period, and there was no change for petroleum.

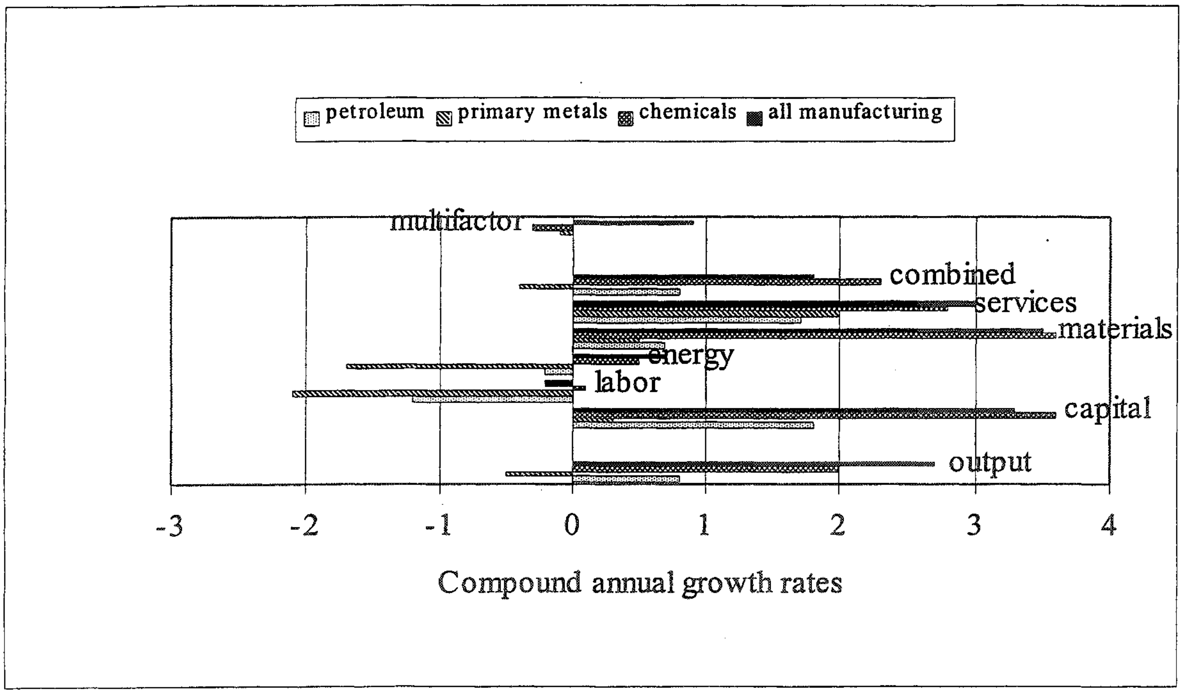


**Figure 7. Components of Output Change, 1973-1998**

Component productivities in these industries followed much the same path as did component productivities throughout manufacturing. As seen in Figure 8, only labor and energy

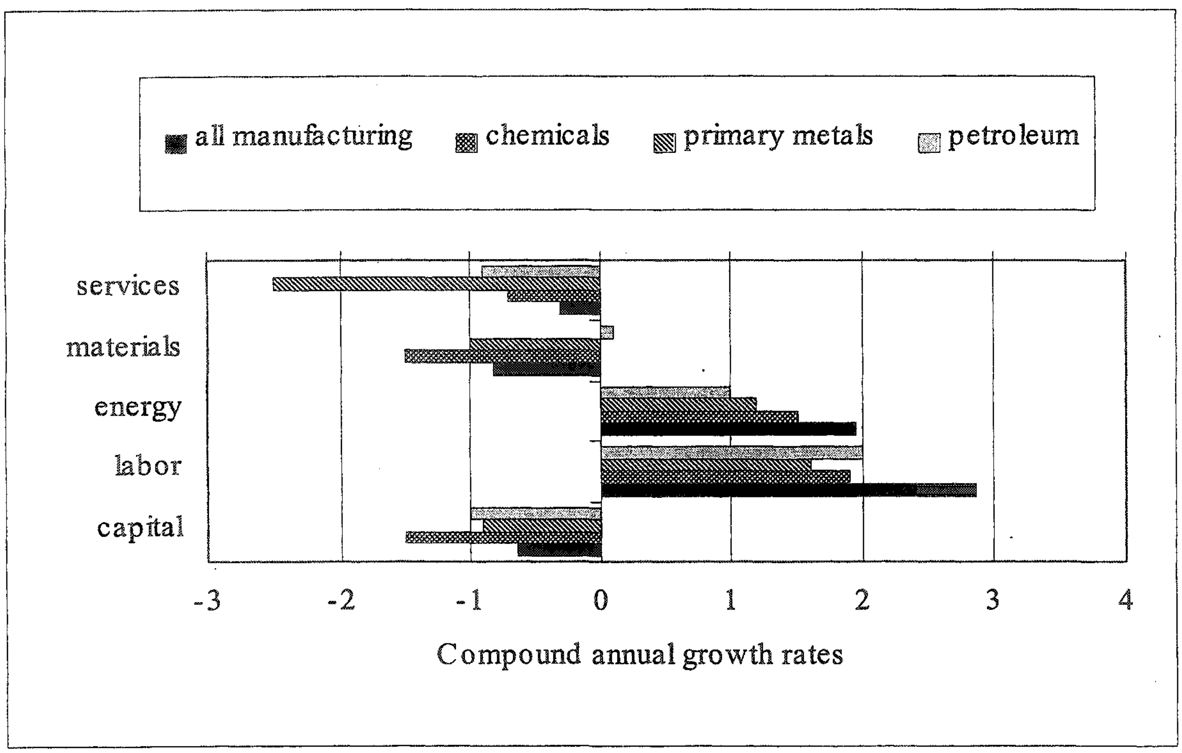


**Figure 8. Component Productivity Growth**

had positive growth rates over the period for all manufacturing as well as for the energy-intensive industries, with materials productivity increasing for the petroleum industry.

As would be expected (Figure 9), the average factor shares over the period for the energy-intensive industries are different from the all-manufacturing averages. Energy shares are usually higher, materials shares are higher, labor shares are lower, and services and capital shares are mixed.

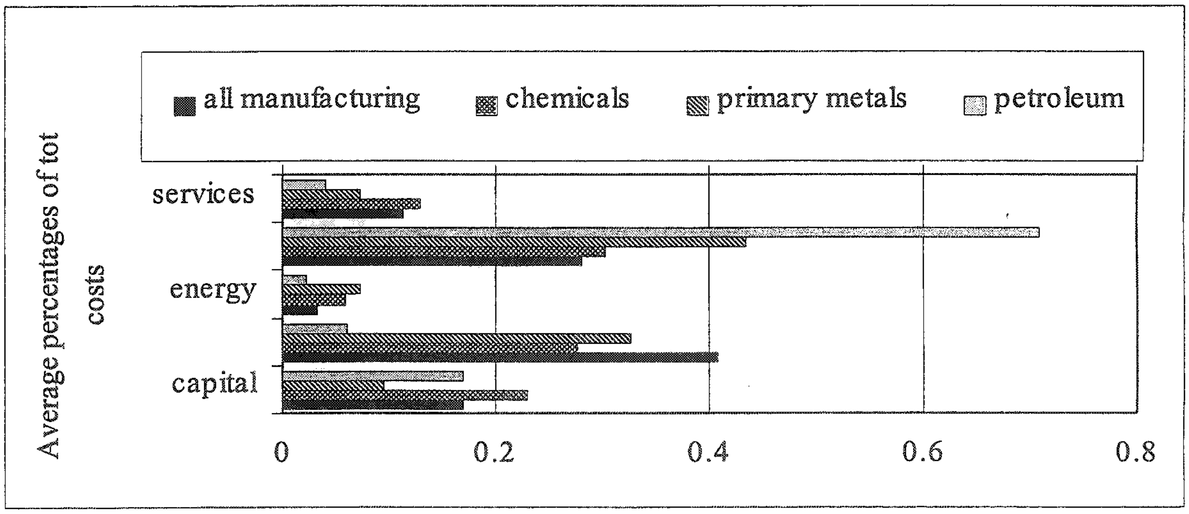


**Figure 9. Average Shares of Total Costs, 1973-1998**

Again, Figure 10 shows that only labor and energy made positive contributions to productivity in all of the industries, with energy's share about 40 percent larger in chemicals

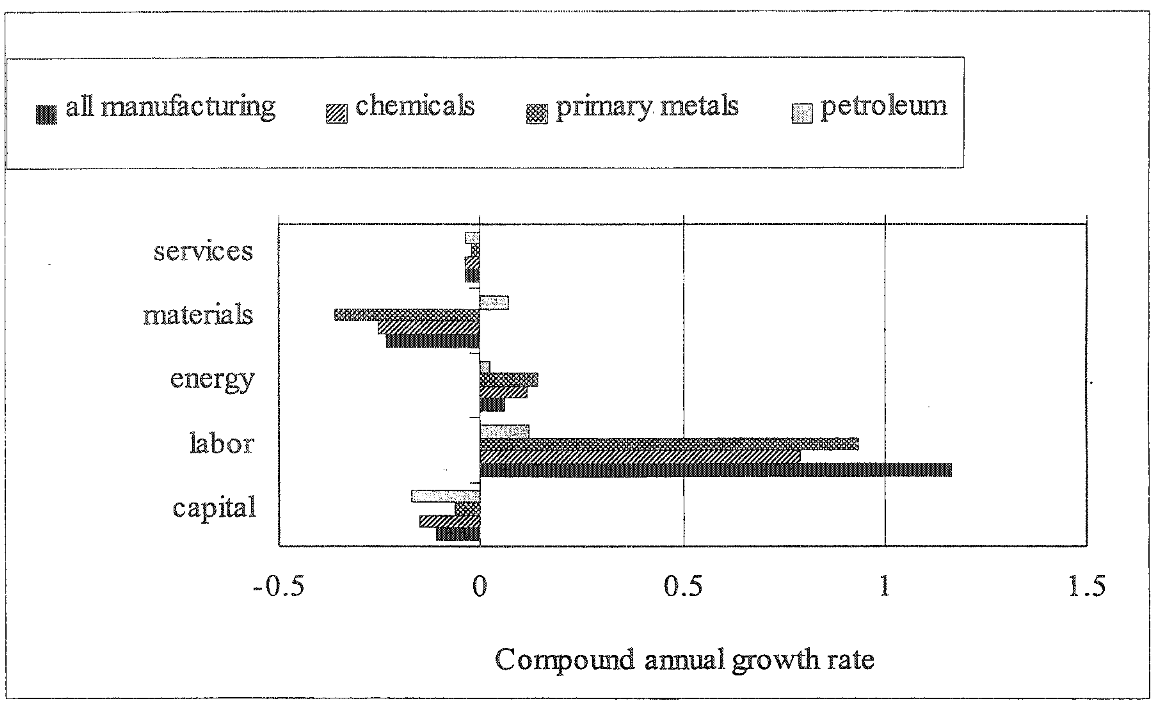


**Figure 10. Contributions to Multifactor Productivity**

and primary metals and labor's share generally smaller in those two industries, and much smaller in the petroleum industry.

## Conclusion

Considering all industries, with minor productivity losses in 1974 and 1979, labor has consistently made a positive contribution to manufacturing productivity. As seen in Figure 11, energy was the only other sector to make a positive net contribution.

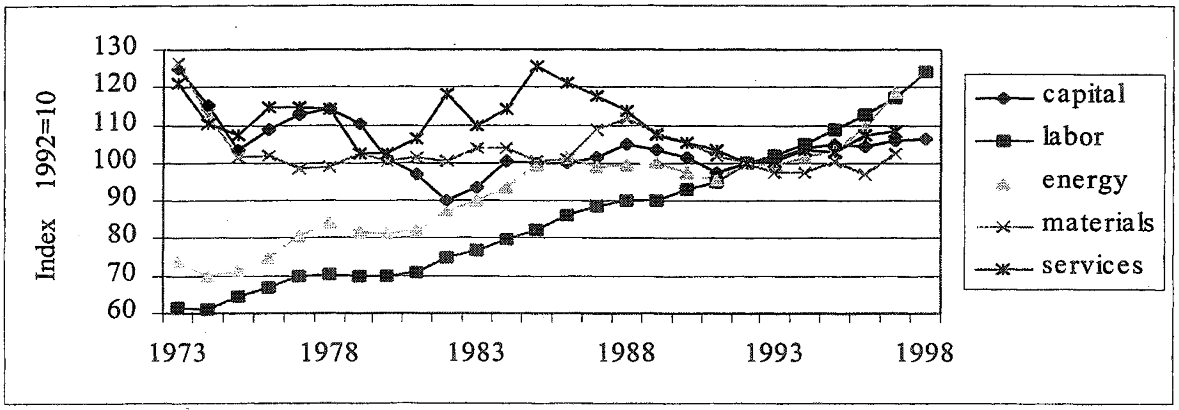


**Figure 11. Productivities of Components**

In the three energy-intensive industry groups examined, again both labor and energy continued to play a positive role in multifactor productivity change. Labor's strong productivity growth was muted by its smaller share of total factor costs in these industry sectors, with energy picking up larger shares in chemicals and primary metals. While materials are larger components of factor costs in these industries, materials productivity was declining in chemicals and primary metals and materials made a positive productivity contribution in petroleum.

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