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Analysing Canadian Manufacturing Using the KLEMS

By

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FEATURE ARTICLE 2

Analysing Canadian Manufacturing Using the KLEMS

by Joanne Johnson[1]

1 - Introduction

Industrial restructuring has become a common place phrase in recent literature. It refers to the organization of business; their input make-up, the business size, and the range of their production processes. This paper utilizes the KLEMS database (industry data on total output, and capital, labour, energy, material and service inputs) to examine how the structure of manufacturing industries has changed over the past thirty years, as plants have adapted their input mix in response to various short run shocks and long run trends[2].

More specifically, we will attempt to illustrate the typical costs faced by establishments engaged in manufacturing. We will also discuss the real growth of output, productivity and each of the inputs, and demonstrate the inter-relation between fluctuating output growth, varying rates of technological progress, and changing relative prices, with respect to the quantitative growth of each of the inputs. In addition to discussing the use and change therein of each of the inputs, we will attempt to give the reader a picture of the nature of the inputs - fixed versus variable - used by establishments. The final element to the discussion of change and adaptation is the homogeneity of these phenomena among manufacturing industries.

2 - Input Value Shares

Material inputs dominated input costs, accounting for slightly more than half of all manufacturing costs during the 1961 to 1990 period, as Figure 1 illustrates. Labour input costs, at almost 23% were the next largest contributor. Service and capital inputs each accounted for approximately one eighth of total costs, while energy inputs made up the smallest proportion at less than two percent.

Material shares, while highest among all input shares in all but one of the 21 Canadian manufacturing industries, varied considerably among industries, ranging from a high of 77% in the refined petroleum and coal products industries to a low of 29.2% in the printing, publishing and allied industries. Similarly, labour shares stretched across a broad spectrum, reaching as

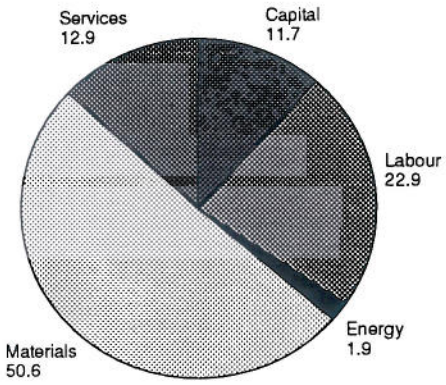
1. *I would like to thank all members of the Productivity Section who assisted in this study. I would especially like to thank Aldo Diaz and René Durand for their extensive assistance, and Jean-Pierre Maynard, Erik Poole and Jody Proctor for their helpful comments. Finally, I would like to thank Nicole Richer for her extensive time and help in the preparation of this article.*

2. *The KLEMS database is described in detail in J. Johnson, "A KLEMS Database: Describing the Input Structure of Canadian Industry" in this publication, p. 19. The article will use the quantity, price and partial productivity estimates derived using the Törnqvist index formula.*

high as 39.0% in the printing, publishing and allied industries and as low as 5.6% in the refined petroleum and coal products industries. Capital shares varied much less among industries, extending between 26.9% (beverage industries) and 4.8% (refined petroleum and coal products industries). Service shares were constrained across a narrow band of 17.9% to 10.9% in the chemical and chemical products and food industries, respectively. Finally, energy shares were the most consistent of all input shares among industries, reaching a meagre high of just 5.9% in the paper and allied products industries and a low of 0.5% in the tobacco products industries[3].

Figure 1

Average input value shares for manufacturing industries over 1961-1990



3 - Three Decades of Growth: the 60s, the 70s and the 80s

While these value shares serve as a first step towards gaining a general picture of these industries, they mask real changes in economic activity. In order to see these real changes, we must examine the quantitative growth of output, productivity and inputs. The box on next page describes a simple production function that relates output growth to productivity and input growth, and an identity relating output values to input values, which serve as the basis for analysing manufacturing industries.

3.1 - Output Growth

Manufacturing industries achieved their strongest output growth rate of the last three decades in the 1960s, an average annual compound rate of 6.0%. Growth slowed considerably in the 1970s to 3.5% and was weakest in the 1980s at 1.8%. Throughout the entire period, output growth averaged 3.7%

The strongest decade for output growth, the 1960s, was also the period of mildest inflation, where prices crawled upward at an annual rate of 1.9%. In contrast, the 1970s were marked by extremely rapid inflation, as output prices bounded ahead at an average annual rate of 9.5%. Output inflation subsided considerably in the 1980s, falling by more than half to just 4.5% annually.

To facilitate comparisons of input and output growth rates across decades, Figure 2 illustrates the quantitative growth rates of output, productivity and each of the inputs in the 1960s, 1970s and 1980s, while both the quantity and price growth rates are presented in Table 1.

3. *Energy uses refer only to energy purchased. Energy shares may be biased downward in some industries which, like the pulp and paper and aluminum industries, produce part of the electricity they use. Own account energy use is not recorded as such but rather appears distributed in the cost of inputs used for its production.*

Analytical Framework

In this simple model, firms' output (Q) is dependent upon the inputs they use (K, L, E, M, S) and the technology available to them (t), as illustrated in the following equation:

$$Q = f(K, L, E, M, S; t)$$

Output growth may be satisfied by additional use of inputs or more efficient production processes. The latter effect, productivity growth, cannot be observed directly. However, we can reasonably hypothesize that output growth that is not attributable to input growth must be a result of increased efficiency in the use of those inputs, and hence *productivity growth* may be determined residually as the growth of output not accounted for by the growth of all inputs.[1]

The value of output is equal to the value of all inputs, as expressed in the following identity:

$$PQ = r_k K + wL + p_e E + p_m M + p_s S$$

where P, r_k, w, p_e, p_m, p_s are the prices of output, capital, labour, energy, materials and services, respectively. This equality allows us to calculate the value of capital services, $r_k K$ residually as the difference between the value of output and other inputs. This is an intuitively appealing measure of capital services as it is the income generated from using that capital.[2]

This identity has strong implications for relative input and output prices. In the case in which productivity growth occurs, the same volume of output can be produced with fewer resources. Given the above identity, this implies that the same amount of revenue is distributed among fewer inputs, and hence, input prices rise relative to output prices. Thus, one can measure productivity growth as the growth of output quantities minus the growth of input quantities, or as the growth of input prices less the growth of output prices. This means that inflation in input prices is partly absorbed by productivity gains.

Substitution effects are also of major importance in this analytical framework. These effects refer to the substitution of one input for another, in response to a relative price change. Given that other factors which have an impact on the use of inputs are continually changing, we cannot exactly measure this effect. However, we can infer it by measuring the changes in prices and quantities relative to the average for all inputs. This does not imply that a rise in the relative price of an input is the sole cause of a reduction in its use; these may both be the result of a third factor: technological progress. This is particularly likely to be true in the case of labour. Labour saving technological progress may reduce the need for additional labour units while increasing the marginal product of labour and consequently its wage rate. Hence, these numbers suggest only correlation, not causation.

Finally, the present model enables us to generate a measure of *upstream vertical integration.* Upstream vertical integration refers to the span of production processes that a given firm is involved in,

1. *Note that inaccurate measures of either output or input growth lead to biased productivity estimates. This problem is quite serious for the natural resource industries where it is unlikely that all inputs are accurately measured. Measuring real growth in certain service industries may also be problematic, as it is difficult to distinguish between price and quantity increases in their output values. Conversely, these problems are relatively minor in industries such as manufacturing, as the natural resources they use are typically purchased from other establishments, and thus have a market value, while deflation is less problematic given that their outputs are quantifiable goods.*
2. *Once again, as in the case of productivity estimates, incorrect measures of inputs or outputs will lead to biased estimates of capital services.*

Analytical Framework

with respect to its output. The more processes it covers, the more upstream vertically integrated it is. Alternatively, the more intermediate inputs it purchases from other firms, the less upstream vertically integrated it is. Thus, it reflects a decision on the part of the company to purchase an input rather than produce it itself. We can measure upstream vertical integration as the amount spent on production within the establishment (the amount spent on capital and labour), as a share of total input costs[3].

Output growth, productivity growth, upstream vertical integration, and substitution effects; these are the measures that we use to analyze absolute and relative input growth. These phenomena, while affected by other independent factors, are inter-related. For example, output growth may affect productivity growth by increasing the intensity of economic activity, and subsequently stimulate establishments to strive for greater productivity gains.

While productivity growth reduces the growth of all inputs necessary for attaining a certain output growth rate, it may affect these differentially if substitution effects are brought about. To see this, recall that productivity growth, the excess of output growth over input growth, must be matched by a rise in input prices relative to output prices. Recognizing that intermediate inputs are outputs of other establishments, and are thus subject to these productivity gains and downward pressure on prices, relative input to output price increases must generally, and over the long run, accrue to primary inputs. As a result of this rise in primary input prices, firms are likely to conserve on them and use more intermediate inputs. Hence, productivity gains should lead to increasing use of intermediate inputs and rising returns to primary inputs, although some substitution also occurs among intermediate or primary inputs. As a result of these effects, productivity growth may or may not change input shares. It is said to be neutral when input shares remain constant.

If substitution effects are strong enough, they may encourage establishments to spend relatively more on purchasing outputs of other establishments; hence, they may change the level of upstream vertical integration. Clearly, in this case productivity growth would not be neutral.

In summary then, output growth has positive impacts, *ceteris paribus*, on the use of all inputs. Productivity growth, on the other hand, reduces the need for any given input. However, productivity growth raises the relative price of primary inputs and thus, through substitution effects typically increases the quantitative growth of intermediate inputs. To the extent that these substitution effects are neutral or not, they may also affect the integration of industries.

Finally, it must be acknowledged that while output growth, productivity growth, changing relative prices and upstream vertical integration are inter-related, they are also affected by other factors. Output growth is affected by the degree of international trade, productivity growth is affected by expenditures on research and development, relative prices are affected by supply and demand conditions, and the degree of vertical integration is affected by factors such as the desire on the part of firms to monopolize inputs. Consequently, there are elements of endogeneity and exogeneity in each of these phenomena.

3. Upstream vertical integration refers only to the production process supplying that industry. Downstream vertical integration refers to the activities that bring an establishment's product closer to final demand. It can be measured as the ratio of final sales to total sales. Composite vertical integration refers to the combination of the terms. As estimates of downstream vertical integration, and hence, composite vertical integration, require final demand estimates, they are beyond the scope of the KLEMS database, and thus are not presented here.

Figure 2

Average annual percentage growth of manufacturing output, inputs and productivity over the last three decades

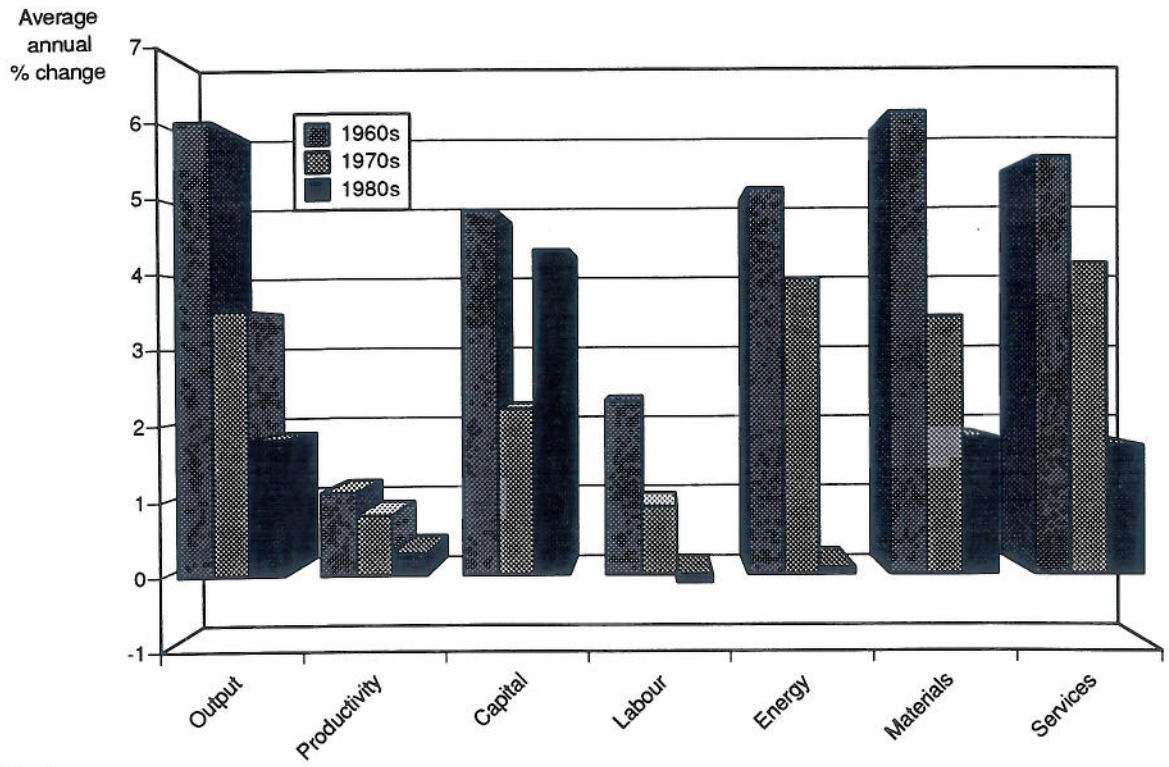


Table 1

Average Annual % Change of Quantities and Prices in Manufacturing

	1960s		1970s		1980s	
	Quantities	Prices	Quantities	Prices	Quantities	Prices
Output	6.0	1.9	3.6	9.5	1.8	4.5
Productivity	1.1	1.1	0.8	0.8	0.3	0.3
All Inputs	4.9	2.9	2.8	10.3	1.6	4.8
Input Categories	Growth in quantities relative to all inputs	Growth in prices relative to all inputs	Growth in quantities relative to all inputs	Growth in prices relative to all inputs	Growth in quantities relative to all inputs	Growth in prices relative to all inputs
Capital	-0.1	0.4	-0.6	-0.2	2.7	-1.0
Labour	-2.6	2.7	-1.9	0.0	-1.7	2.0
Energy	0.2	-2.2	1.1	2.6	-1.4	1.3
Materials	1.2	-1.0	0.6	0.5	0.2	-1.1
Services	0.6	-0.3	1.3	-2.4	0.1	1.2

3.2 - Productivity Growth

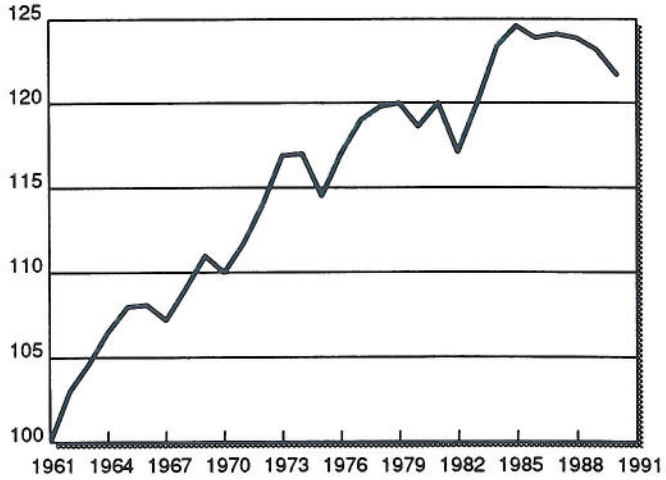
One important determinant of output growth is productivity growth[4]. It followed a pattern similar to that of output, peaking in the 1960s at a rate of 1.1%, falling to 0.8% in the 1970s, reaching a low of 0.3% in the 1980s, and averaging 0.7% for the whole period under study.

This tendency for productivity growth to mimic output growth was also found at a more disaggregated industry level. The four industries with the highest growth rates of output had among the five highest productivity growth rates. Similarly, of the ten highest output growth industries, 70% had above average productivity growth.

Figure 3 demonstrates that productivity growth follows a pro-cyclical path. This is due to the quasi-fixed nature of some inputs. For instance, capital input growth lags output growth, leading to pro-cyclical capacity utilization. Hence, when output declines, capital growth is still just peaking, causing productivity to temporarily fall back. The productivity measure does partially correct for changes in capacity utilization. Productivity growth is calculated by measuring the growth in the quantities of all outputs and inputs, weighting these growth rates by their value shares, and summing them. The value of capital services - income generated by capital services - falls in recessionary periods, thus reducing the estimated contribution of capital. However, this weighting does not remove all the effects of changing capacity utilization.

Figure 3

Multifactor productivity in manufacturing industrie



Some of the cyclicality of productivity is also due to the stickiness of labour input. Labour is somewhat fixed over the short run because of costs associated with temporarily reducing labour input such as training and hiring. Thus, rather than lay off workers during recessionary periods, employers often keep them on.

We can also see that while the general trend for productivity growth was upward, the 1973-1981 period was characterized by particularly poor productivity growth. The causes of this productivity growth decline have been heavily debated, and are probably the result of a combination of factors, a reduction in net capital accumulation and the energy crises being at the forefront of these.

3.3 - Input Growth

Turning to input growth, we can see that average input quantities grew in a fashion similar to output growth; fastest in the 1960s, at 4.9% annually, less in the 1970s at 2.8% and slowest in

4. *Multifactor productivity growth estimates on gross output used in this article are available for total manufacturing and the 21 major groups in the tables of Part 1 of this publication. Quantity and price indices for total manufacturing output and the major KLEMS input categories are provided in the Appendix to this article.*

the 1980s at 1.6%. While the growth of inputs slowed through time, declining productivity growth prevented it from falling as much as output growth.

We will now turn to the make-up of input growth and explain some of the relative changes. The relative growth rates of each input, calculated simply as the growth in its quantity minus the average input growth rate, along with the relative inflation rates, are presented in Table 1 above. These relative growth rates indicate which inputs industries favour by using more of, as well as which are becoming relatively more expensive.

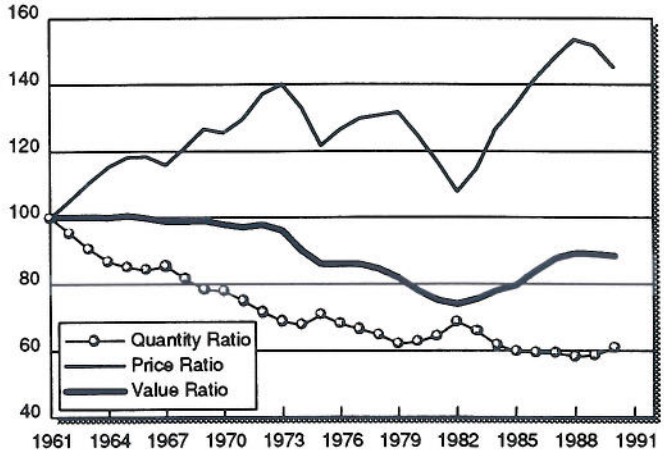
Growth of Primary and Intermediate Inputs

Before examining the individual KLEMS input categories, it is interesting to note the increased reliance on intermediate inputs relative to primary inputs over the past three decades. Establishments increased the quantities of intermediate inputs (energy, materials and services) at more than double the rate of primary inputs (capital and labour), and reduced the value share of primary inputs from 37.1% in the 1960s to 32.5% in the 1980s[5].

The growth in relative intermediate input quantities appear to be primarily driven by productivity growth. The effects of rapid productivity growth in the 1961-1973 period are clear: as the price of primary inputs raced ahead of intermediate inputs, firms continually substituted less costly intermediate inputs for primary inputs. Technical progress was neutral during that period, given that value shares declined only very slightly beginning in the late 1960s. Productivity declines induced increasing relative use of primary inputs, coincident with a fall in their real returns in the 1974/1975 and the 1979/1982 periods, leading to a slackening of intermediate input growth over the 1974 to 1990 time frame. The fall in real returns to primary inputs and slight but continual substitution of intermediate inputs for primary inputs led to upstream vertical de-integration. Hence, technical progress was not neutral during the latter period.

Figure 4

Primary/intermediate inputs, quantity, price and value ratios



The continuing productivity growth and upstream vertical integration support our hypothesis that these phenomena are related. However, it is interesting to note that the most rapid upstream vertical de-integration occurred in a period of extremely weak productivity growth, from 1973 to 1981. Thus, it is obvious that other factors were impacting on the degree of integration. The oil crises likely was one of these factors, as it increased transportation and hence intermediate input costs, resulting in a change in the integration measure.

5. *Intermediate inputs are those goods and services which are produced and consumed in a given year by the business sector of the economy. In an open economy such as Canada, imports may be viewed as primary inputs. However, in the context of the KLEMS database, this would be inappropriate and hence imports have been allocated to their appropriate intermediate input classification.*

We will now turn to an analysis of how output growth affected the use of all inputs, as well as how productivity growth, changing levels of integration and changing relative prices affected the demand for specific types of inputs.

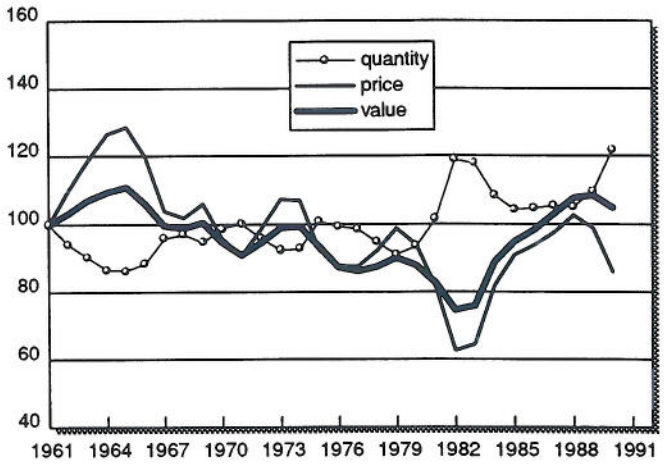
Growth of Capital Inputs

The average annual growth rate of capital matched that of output growth, at 3.7% over the entire 1961-1990 time frame, almost one quarter more than the average of all inputs. Capital input growth peaked in the 1960s, at 4.8%, declined in the 1970s to 2.2% and made a strong recovery in the 1980s, clipping along at a healthy pace of 4.3% annually. It was the only input whose pattern of growth diverged from output growth and was greater in the 1980s than in the 1970s.

As Figure 5 illustrates, capital input growth relative to average input growth appeared to be quite sensitive to its relative price. Table 1 and the accompanying graph relating capital input growth to the growth of all inputs illustrate that capital growth was strongest in relative terms in the 1980s, when its relative inflation rate was most favorable.

Figure 5

Capital/all inputs, quantity, price and value ratios



Falling relative returns, unaccompanied by sufficiently rapid capital formation, depressed capital's share of revenues during the 1965 to 1982 period. Rising capital prices in the mid 1980s and rapid real investment in the latter part of the decade reversed this trend and pushed capital shares up to levels not seen since the 1960s.

The fluctuating relative capital input quantity, price and value ratios were due to a combination of productivity growth and substitution between capital and other inputs. As discussed previously, strong productivity gains in the 1961 to 1973 period permitted primary, and subsequently capital inputs, to realize higher relative returns and encouraged intermediate input substitution for them. Declining productivity growth thereafter reduced the relative return to capital and negated the many of the benefits of substitution.

The long term effect of productivity growth is quite different than the short term effect previously discussed. Capital goods are in fact produced outputs of establishments. Hence, they are subject to the same productivity gains and reduced prices over the long run as intermediate inputs over the short run. The difference in effect arises because capital goods are used up over a much longer time frame and hence it takes longer for productivity growth to affect the quantity and price of capital goods. Consequently, capital growth while varying with respect to output growth over the short run, approximated output growth over the entire 30 year period.

Substitutions between capital and materials and capital and services were also observed during the short run, although each of the inputs quantities and prices grew at about the same rate over the long run. In contrast, capital goods persistently replaced labour, as establishments

continually automated their production processes. These substitution effects will be discussed in greater detail in the sections of the respective substitutes.

Growth in Labour Input

Labour input experienced the lowest average annual growth rate out of the five types of inputs, only 1.0%, over the entire period under study. Growth in labour input was strongest in the 1960s, at 2.3%, marginal in the 1970s at 0.9% and negative in the 1980s at -0.1%.

Figure 6

Labour/all inputs, quantity, price and value ratios

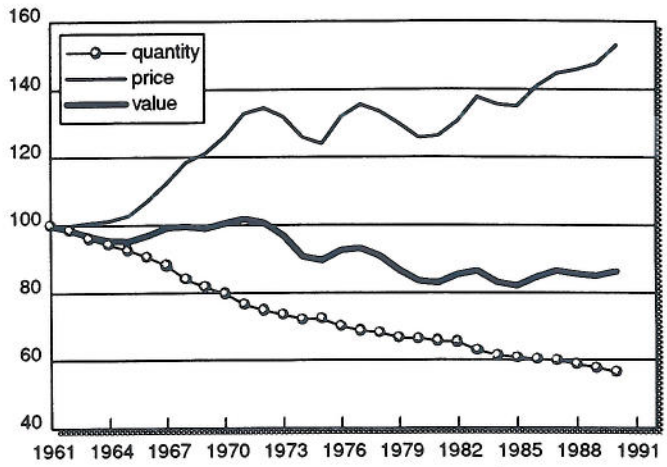
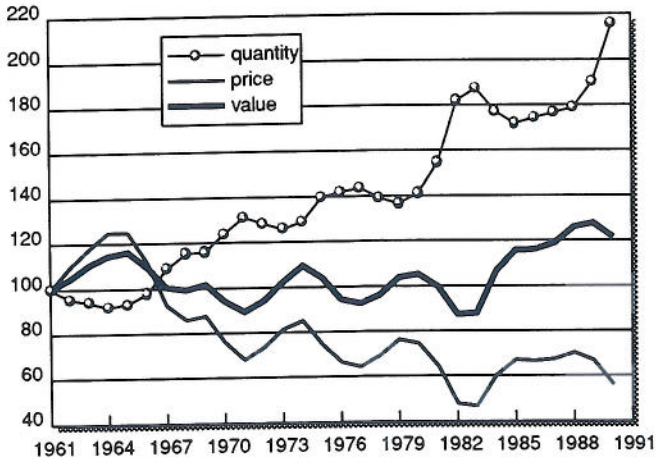


Figure 6 demonstrates that a strong negative correlation existed between the growth in the quantity and the price of labour, relative to those of average inputs. This was more of a long-run phenomena than was the case with other inputs, as the growth of labour input consistently fell short of that of all inputs while wage increases surpassed average increases in a cyclical manner. The difference in relative growth rates was most marked in the 1960s, where the growth of labour fell short of average input growth by 2.6%, and wages grew by 2.7% more. Due to these extremely low relative growth rates, that were not compensated for by wage increases, labour shares dropped over the 1961 to 1990 period, falling from 24.4% in the 1960s to 23.6% in the 1970s to 21.1% in the 1980s.

Figure 7

Capital/labour quantity, price and value ratios



Declining labour input growth, while in part a result of falling output growth, was due largely to increasing substitution of capital, materials and services for labour. Had it not been for these substitutions of other inputs for labour input, falling productivity growth would have necessitated relatively higher labour growth.

Figure 7 illustrates that the capital/labour ratio increased considerably from 1961 to 1970 (23.9%), was much flatter in the 1970s, increasing only 13.8%, and exploded by 53.2% in the 1980 to 1990 period. Conversely, increases in the price of labour exceeded those of capital by 78.0% during this entire time frame, almost offsetting the increase in the quantity ratio and maintaining an almost constant share of payments to labour out of primary inputs. The burgeoning capital/labour ratio was likely to have been an effect of both labour saving technological progress, and relative increases in the price of labour. These effects reinforce each other: as the capital/labour ratio increases, the productivity of labour, and thus the wage rate increases and, as the price of labour relative to capital rises, further increases in the substitution of capital for labour are brought about.

Growth in Material Inputs

Material inputs in the manufacturing sector grew at a strong pace of 3.7% throughout the 1961 to 1990 period. As Figure 2 illustrates, this growth was highest in the 1960s and declined sharply through time. In addition, material inputs achieved their highest growth relative to average inputs in the 1960s, concurrent with their lowest relative inflation rate, as Figure 8 shows. Materials also achieved higher relative growth rates and lower relative inflation rates than the average in the latter two decades.

Given the rapid relative quantitative growth of material inputs, material shares generally increased over the 1961 to 1990 period. The average material input share climbed from 48.4% in the 1960s to 50.6% in the 1970s and finally to 52.2% in the 1980s.

The declining growth in material input, while partially due to depressed output growth, was also due to declining productivity growth and subsequently diminishing returns to substitution. Negative productivity growth from 1973 to 1975 and again from 1979 to 1982 caused material prices to surge ahead of average input prices and suffer falling relative growth rates.

Figure 8

Materials/all inputs, quantity, price and value ratios

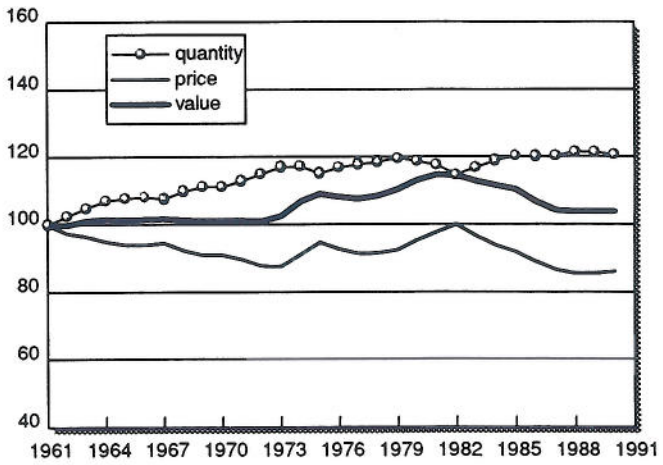
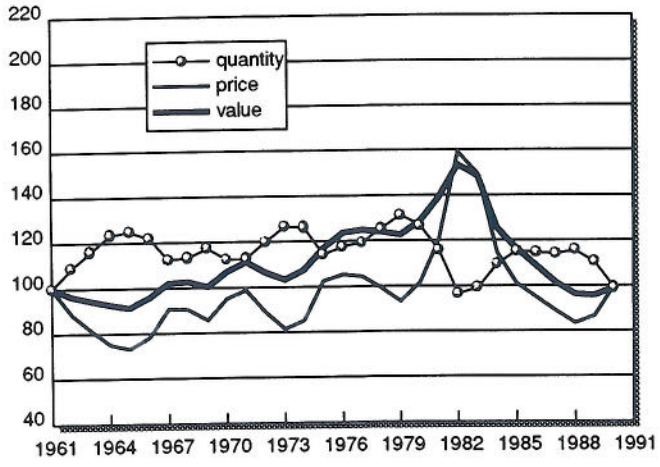


Figure 9

Materials/capital quantity, price and value ratios



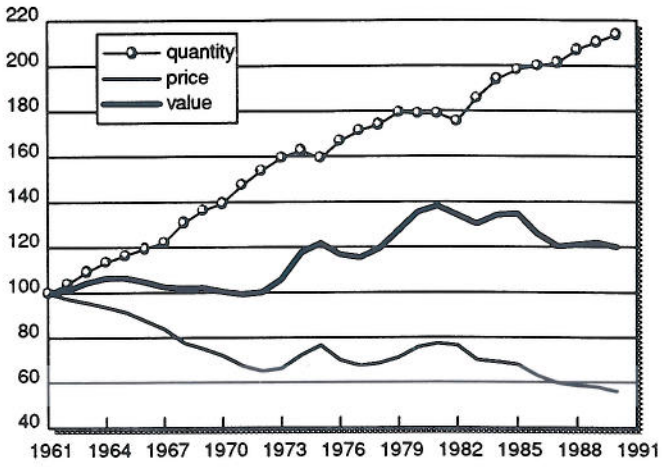
Substitution effects between material and labour inputs, and material and capital inputs also appeared clear throughout the entire period. Figure 9 illustrates that the relative growth of material and capital inputs varied inversely with their relative prices up until 1973, maintaining a relatively constant value ratio between them. The exception to this was the late 1970s and early 1980s, in which rising material prices were not fully offset by declines in their use.

Substitution effects between materials and labour input were more visible than those for capital and materials as changes in relative growth rates and prices were more pronounced. They were also uni-directional, that is, materials were increasingly substituted for labour, rather than trading off as was the case with materials and capital. The increasing use of materials dominated relative wage gains and hence, the value of materials relative to labour rose.

It should be noted that this rise in the value of materials relative to labour inputs, given an overall constant ratio of material and service values to capital values, was a manifestation of decreasing upstream vertical integration. Given that other value shares remained constant and that the share of primary inputs as a whole fell, the decline was accounted for solely by a decline in labour's share.

Figure 10

Materials/labour, quantity, price and value ratios

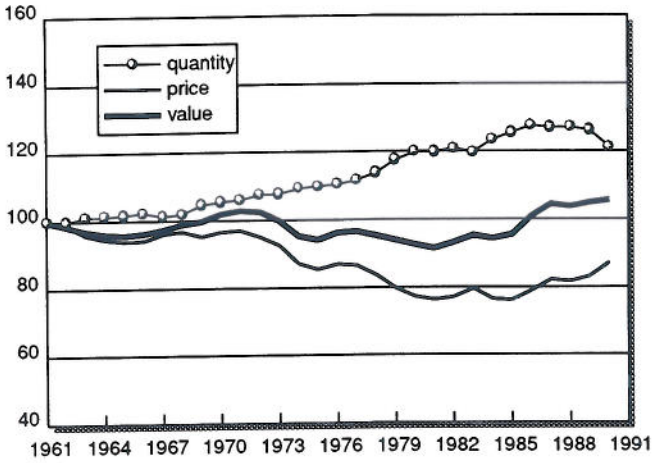


Growth in Service Inputs

The average growth in real service inputs across all manufacturing industries was 3.7%, the same rate as that of output and capital and material inputs. As was the case with most other inputs, the growth in demand for service inputs declined from each decade to the next. Figure 11 illustrates that, in contrast to its absolute growth rate, services grew strongest relative to average inputs in the 1970s, the decade in which its relative inflation rate was lowest. The service input share for all manufacturing industries was remarkably stable throughout the period under study, at 12.8% in the first two decades and rising slightly to 12.9% in the 1980s.

Figure 11

Services/all inputs, quantity, price and value ratios



As was the case with material and capital inputs, ongoing substitution between capital and services occurred during the 1961 to 1990 period. With the exception of the drastic fall in the relative return to capital in the early 1980s, the relative quantity and price changes were basically offsetting, thus rendering constant value shares. These substitution effects were short run phenomena only, as the quantity, price and value ratios in 1990 were exactly those observed in 1961.

While material inputs supplanted labour in somewhat of a cyclical fashion, service inputs did so continually. As in the case of material substitution for labour, this was also a manifestation of decreasing upstream vertical integration.

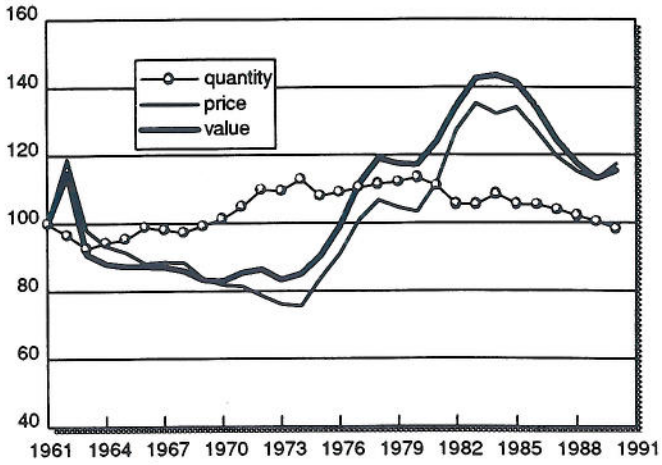
Growth in Energy Inputs

Energy inputs were similar to other inputs in the sense that they achieved their maximum average decade growth rate in the 1960s (5.5%) and their minimum average decade growth rate in the 1980s (0.2%). Energy prices were much more volatile than other inputs, creeping up by less than

three quarters of a percent annually in the 1960s, and exploding to 12.9% annually in the 1970s - more than doubling between 1973 and 1977 alone. The early part of the 1980s were also marked by massive increases in the price of energy, but deflation in the latter part of the 1980s depressed the average during the 1980 to 1990 period to 6.1%.

Figure 12

Energy/all inputs, quantity, price and value ratios



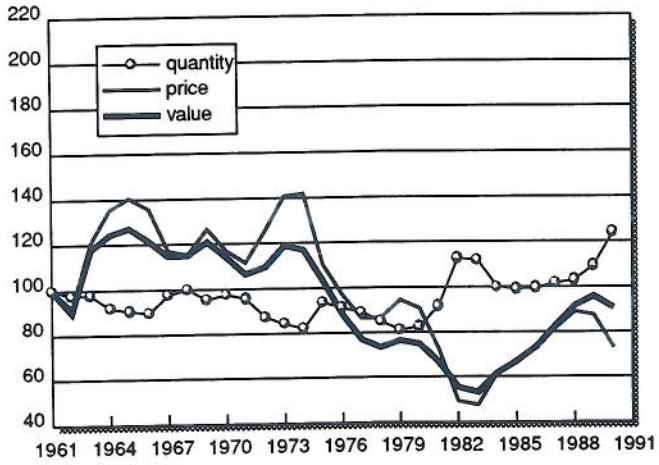
The growth in quantities of energy relative to all inputs appeared to be considerably less responsive to relative changes in its price than other inputs. In fact, similar movements in these rates were frequently observed (1962/63, 1967/68, 1972/73, 1976/78 and 1985/90) throughout the period. Furthermore, the highest growth of energy inputs relative to other inputs occurred in conjunction with its highest relative inflation rate, in the 1970s.

The 1973 oil crisis did lead to a drop in the relative quantities of energy used. However, the decline was only temporary. This weak response of energy use to the energy crisis was likely to have been a result of the fact that while international prices rose, Canadian oil prices were held down by the National Energy Program. Furthermore, energy input shares of total costs, at less than two percent, may also have been too insignificant to incite strong substitution effects in response to relative price changes. Consequently, the relative quantity of energy use increased in 1975 and continued to grow until 1980.

The effects of the oil price shock of 1979 were also muted in Canada by the National Energy Program until 1981. This latter energy shock sustained lasting effects in manufacturing, leading to continuing absolute declines in the quantities until 1984, and an almost uninterrupted decline in the growth of energy inputs relative to total inputs up to 1990.

Figure 13

Capital/energy, quantity, price and value ratios



Due to the drastic rise in the relative price of energy, energy shares experienced the greatest increase of all inputs, rising from 1.6% in the 1960s to 1.7% in the 1970s and finally to 2.3% in the 1980s.

Energy inputs, in contrast to other inputs, have generally been thought to be complements in production to capital. This does appear to be the case, particularly in the 1961-1973 period, in which the relative use of capital/energy was only weakly responsive to the relative price ratios. However, taking a longer term perspective, we can see that the price of capital relative to energy fluctuated randomly between 1961 and 1973 and declined thereafter. On the other hand, the quantity ratio fluctuated until

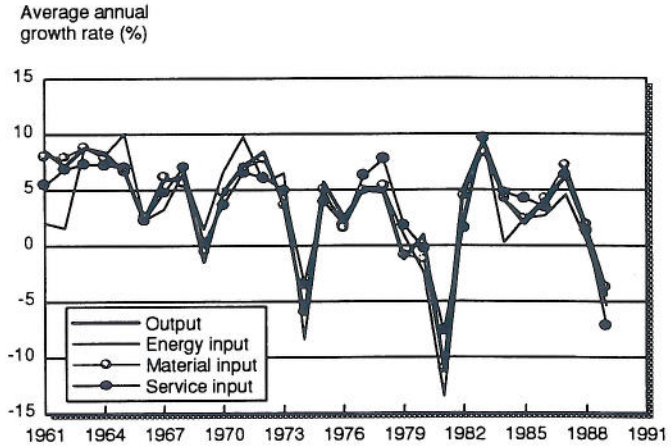
1979 and increased in subsequent years. Therefore, there does appear to be a long term substitution effect. In addition to this substitution, the unusually rapid capital accumulation that began after the second oil crisis may have been an attempt to adopt energy saving capital.

4 - Fixed Versus Variable Inputs

In addition to looking at average growth rates through time, it is also useful to examine the relative fixity or variability of inputs. Figures 14 and 15 illustrate that all inputs, except for capital, generally followed a common pattern: they all declined in recessionary periods and increased in times of strong economic growth. Capital input growth lagged output growth and rarely fell as much as other inputs in times of weakening output growth.

Figure 14

Growth in output, energy, material and services



The variance of the ratio between output and input growth for each input category illustrates the degree to which firms harmonized their input growth with their output growth. The higher the variance, the more sticky the input.

The variance of the output/input growth rate was highest for capital inputs, at 44.3/100, and lowest for materials and services at 0.5/100 and 3.5/100 respectively. This illustrates the strong relative fixity of capital inputs. Material inputs were almost perfectly harmonized with output growth. This is to be expected as input measures correspond to inputs used, rather than purchased. Any input not used in the reference year accumulates in the inventories, and inventory stocks are not included in the input estimates used for productivity measures. Material inputs can be stored; hence their use, after purchase, can be adjusted relative to demand for the establishment's output[6].

While the variance of the output/energy input ratio, at 6.1/100, was higher than that for labour at 5.7/100, throughout the 1961 to 1990 period, labour input growth was more volatile in the 1970s and the 1980s. Thus, the moderately high variance of the labour partial productivity growth rate does suggest some fixity of labour input as well. This could be due to labour hoarding or a high degree of administrative labour. Clearly, however, labour input growth was much more synchronized with output growth than capital inputs.

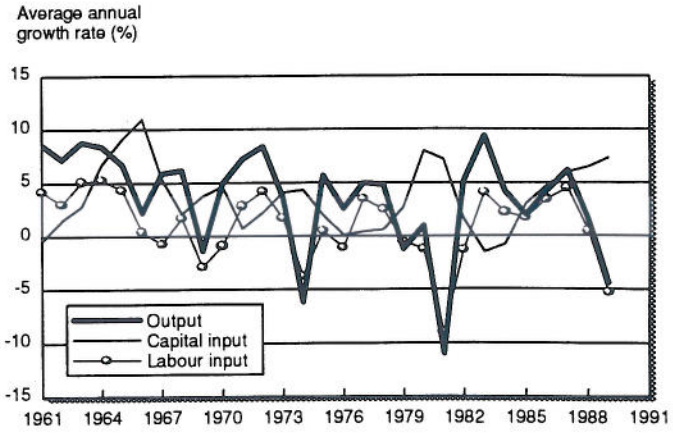
Firms appeared to adjust their use of materials and services more rapidly than they adjusted their use of labour or capital. This flexibility of intermediate input use suggests that capital intensive or value-added industries are likely to have higher variability in their multifactor productivity (MFP)

6. *Note that in comparing the variance of partial productivity growth rates for each input category, it is implicitly assumed that technology affects all inputs in the same degree. It could be argued that the entire thirty year period is a sufficiently long time to afford the opportunity for technology to affect the levels of the partial productivity growth rates disproportionately. For example, if technological progress is primarily labour saving, then the partial productivity growth rate would increase through time, and other things equal, would lead to a higher variance in the partial productivity growth rate. However, even on a decade basis, the above assertions, regarding the relative fixity of inputs, hold.*

growth rates, than industries that use more intermediate inputs. This hypothesis is supported by the high variance of MFP growth rates of industries which are highly capital or capital and labour intensive. Of the industries with the ten highest variances in MFP growth (weighted by the average MFP growth rate for that industry), seven also placed in the top ten of industries ranked according to capital input share and six placed in the top ten industries ranked according to primary input shares.

Figure 15

Growth in output, capital and labour



This quasi-fixed nature of capital and labour input may also be an additional factor in explaining the increasing specialization of industries through time: a higher intermediate input shares allows firms to adjust their inputs more quickly in response to market conditions.

5 - Industry Breakdown

Turning to a summary of the industry breakdown, there were five strong growth industries throughout the 1961 to 1990 period: plastic products, transportation equipment, electrical and electronic products, machinery and chemical and chemical products industries. Transportation equipment and electrical and electronic products industries generally broke with the trend in manufacturing and increased their inputs most in the first and last decade, rather than having growth rates that steadily declined through time.

There were two declining industries - tobacco products and leather and allied products industries, and a third consistently low growth industry, primary textile and textile products industries. Input growth was also low in the refined petroleum and coal products industries in the 1960s and the 1980s, but was second highest of all industries in the 1970s.

There appeared to be a set pattern of growth among industries. They typically behaved in a consistent fashion across their use of inputs; that is, if a particular industry's annual average growth rate for one category of inputs was above the manufacturing average, then the average growth rate for the rest of its inputs was also likely to have been above the average. While the rankings of these growth rates were very similar, the values varied significantly across industries.

Price indices are available for each industry - given that industries use different types and combinations of inputs within each category of inputs, and thus, face different aggregate prices. However, the growth of most prices, excluding those of capital, varied little among individual industries. Furthermore, the direction of the changes in the average growth rates from one decade to the next were almost unanimous among industries for labour, energy, materials and services. Indeed, there was not a single industry in which the growth in the price of any of these inputs was higher in the 1960s than in the 1970s. With respect to the 1970s and the 1980s, the services category was the only input which had higher growth rates of prices in the 1980s than in the1970s, although this only occurred in four of the 21 industries.

The growth of the price of capital did display some variation across industries, ranging from a high of 8.9% in the plastic products industries to a low of zero percent in the refined petroleum and coal products industries. Similarly, there was some variation in the direction of the changes in these growth rates; there were five industries that had higher growth rates of capital input prices in the 1960s than in the 1970s, and there were five industries again in the 1980s that had higher growth rates of capital input prices in the 1980s than in the 1970s.

6 - Summary

This article reviews the structure, growth and adaptation in Canadian manufacturing from 1961 to 1990, using the KLEMS database. Output and productivity growth in the manufacturing sector were most rapid in the 1960s, concurrent with the lowest inflation rate observed among the three decades. The 1970s, with ballooning energy prices and other business costs commenced the decline of output growth and productivity growth that only worsened in the 1980s.

Manufacturing industries became increasingly upstream vertically de-integrated throughout the 1961 to 1990 period. This may have been, in part, a result of the benefits of specialization and economies of scale, coupled with increasingly complex production processes and globalized trade.

Manufacturing industries were sensitive to relative price changes, substituting capital, material and service inputs for each other over the short run and for labour inputs over the short and long run. Energy input growth was only mildly dented by the 1973 oil crisis, likely because energy input shares accounted for less than two percent of total costs. However, the second oil shock seems to have brought about relative declines in the use of energy. The fear of impending massive increases in energy costs instigated by these crises may have been partially responsible for rapid capital formation in the 1980s, as firms may have sought to adopt energy saving capital.

The strong productivity growth of the 1961 to 1973 period raised efficiency and hence the relative return to primary inputs, thereby stimulating substitution of intermediate inputs for them. Declining productivity growth in subsequent years continually mitigated differences in relative returns, and consequently reduced the growth differentials. Productivity growth over the entire period, however, resulted in falling capital prices and capital formation matching output growth. Thus, the long run effect of productivity growth was to raise real wages and encourage substitution of other inputs for labour.

Capital, and to a lesser extent labour inputs, were relatively fixed factors in production. Energy input growth was more volatile relative to output growth in the 1960s but was closely synchronized with output growth in the 1970s and the 1980s. Material inputs were almost perfectly harmonized with output growth. This relative fixity of primary inputs, in particular capital, may be an additional contributing factor to the de-integration of industries, as they attempted to achieve an input mix that could be more responsive to fluctuations in the demand for their output.

This article has illustrated changes in Canadian manufacturing industries, and provided some insight on why these developments occurred. Further work in this area, with the use of econometric techniques, would enable more concrete conclusions about price elasticities, sensitivities of factor input to technological progress as well as factor contribution to productivity growth, and the relation between productivity growth and upstream vertical integration.

Table 2

The KLEMS data for Canadian manufacturing industry 1961-1990, index levels, 1961=100

Year	Output		Capital		Labour		Energy		Materials		Services	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price
1961	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1962	109.0	101.2	99.6	117.7	104.3	103.0	102.1	100.6	108.4	102.4	105.6	101.6
1963	117.1	102.3	101.1	127.6	107.5	106.9	103.7	102.5	117.4	103.6	113.2	102.2
1964	127.9	103.6	104.0	141.4	113.1	111.2	113.3	102.2	128.4	104.7	121.8	103.7
1965	139.2	105.0	111.2	145.6	119.3	117.0	122.9	103.7	139.0	106.4	131.1	106.7
1966	148.7	107.5	121.8	133.6	124.5	126.2	136.0	102.7	148.7	109.6	140.6	109.7
1967	152.1	109.9	136.0	120.1	125.0	133.7	139.2	104.2	152.7	111.1	143.8	114.3
1968	161.3	112.1	143.5	125.8	124.2	144.2	143.9	106.9	162.5	112.7	150.8	118.8
1969	171.6	115.7	146.5	137.2	126.3	155.5	153.6	105.3	171.9	116.4	161.9	123.1
1970	169.2	118.9	152.0	116.5	122.7	167.6	155.9	108.8	171.1	119.4	162.4	128.1
1971	177.7	122.1	159.3	127.4	121.6	180.8	166.6	112.3	179.4	121.9	168.6	131.7
1972	190.9	127.5	160.4	145.3	125.1	194.8	183.8	114.6	192.4	127.7	180.1	138.4
1973	207.6	140.3	164.1	181.0	130.4	210.6	194.5	121.0	207.9	145.4	191.4	148.6
1974	215.2	169.4	170.9	207.7	132.6	241.7	207.5	155.4	215.8	184.5	201.2	168.9
1975	202.4	191.9	178.5	195.0	127.7	277.1	190.7	187.3	203.5	208.1	194.4	189.4
1976	214.4	202.0	182.1	203.2	128.4	316.5	199.7	228.8	214.1	217.4	202.4	208.2
1977	220.0	216.9	182.3	227.5	127.0	347.8	204.2	274.2	217.6	236.0	206.4	221.6
1978	231.3	237.9	183.0	264.5	131.5	373.9	215.3	308.0	228.9	262.6	219.8	237.4
1979	242.6	272.0	184.1	329.3	134.8	413.0	226.8	335.0	241.7	304.5	237.8	258.2
1980	239.8	308.4	189.2	330.1	134.2	456.0	229.2	384.6	239.8	352.5	242.4	281.9
1981	242.2	345.9	204.9	330.6	132.5	525.4	223.7	480.8	237.0	407.1	241.8	313.8
1982	216.9	368.7	220.3	247.1	121.1	580.1	195.4	574.2	212.4	429.5	224.1	342.7
1983	228.3	379.8	224.1	322.3	119.6	618.5	200.4	625.6	222.2	435.8	227.7	360.3
1984	250.7	395.9	220.6	421.3	124.6	647.1	220.5	640.9	241.7	457.4	250.8	372.2
1985	261.6	402.5	218.9	461.0	127.4	683.1	221.2	668.3	252.3	456.8	263.3	386.5
1986	266.9	399.5	225.6	475.9	129.6	714.1	226.7	600.4	258.6	430.0	275.0	407.1
1987	278.4	412.5	236.6	509.7	134.0	738.3	232.9	596.3	269.9	442.5	284.9	419.8
1988	296.0	429.0	251.1	558.1	140.3	770.7	243.9	596.4	290.3	453.2	303.8	432.5
1989	300.6	440.8	268.0	528.5	140.8	800.4	245.1	603.7	296.1	464.8	308.2	457.1
1990	287.7	446.4	288.3	457.5	133.5	844.6	232.4	658.2	285.4	465.9	286.9	470.5

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