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MEASUREMENT & ANALYSIS OF PRODUCTIVITY GROWTH: A Synthesis of Thought

U.S. DEPARTMENT OF COMMERCE
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Measurement and Analysis of Productivity Growth: A Synthesis of Thought

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Productivity is one of the most important factors influencing our economic well-being. Productivity growth is essential to a higher standard of living and is vital to a sound economic and political environment. However, there has been a slowdown in the growth of productivity in the United States since the mid-1960s. This slowdown has caused concern among policy makers and researchers. Accordingly, several questions persist both in policy and academic circles. Why has productivity been slowing? and What can be done to reverse this trend?

The purpose of this report is to address broadly the first of these two questions by surveying and synthesizing the vast literature on the measurement and determinants of productivity. This review is intended to be a source document for those interested in the measurement and analysis of productivity growth.

The report is divided into five sections. In the first section, the importance of productivity growth on economic activity is discussed. In the second section, the so-called "facts" about patterns of measured productivity growth in the United States are presented. In the third section, the methods currently used for calculating productivity indices are summarized. In the fourth section, the literature related to the determinants of the productivity growth slowdown are reviewed. Finally, in the last section, some suggestions are made for future work in this area.

Key words: determinants of productivity; literature review; measurement of productivity; productivity; research and development; technological change.

1. INTRODUCTION

"Efficient production of goods and services is a primary goal of economic effort, and statistical measurement of productivity is an important tool for monitoring and promoting its advance" [Moss, 1979, p. 276]. Few economists, researchers, or policy makers would disagree with this evaluation of the concept of productivity; however, some may suggest that this statement underplays the economic and social importance of productivity. Productivity is not only a useful barometer of economic conditions, but it is also a fundamental contributor toward our overall well-being. According to Fabricant [1978, p. 502], "[h]igher productivity is essential to our economic growth and a key to a higher standard of living for all our people."

Productivity growth enhances standards of living in several ways. First, our Nation's competitive financial and military position within the international community surely improves with increased production efficiency (that is, as more goods and services are produced while scarce resources are being conserved). Second, the income generated from productivity improvements can potentially be reallocated toward more leisure time or toward improving such conditions of social concern as environmental pollution. And third, productivity growth may exert a positive influence in ameliorating inflationary pressures. Rees [1980], among others, argues that when productivity growth slows, economic and political bargaining for income shares exert upward pressures on prices. These pressures are then intensified as monetary and fiscal policy become tools of the participants in the political arena for sustaining the growth of their own real incomes.[1]

[1] See Harriss [1981] for a related viewpoint regarding productivity and the realities of politics.

Because of the social importance of productivity growth, the persistent slowdown in productivity (for example, output per unit of labor hours) since the mid-1960s has caused considerable concern among policy makers. Between 1948 and 1966 the average annual rate of growth in labor productivity in the economy was 3.2 percent; it was 2.3 percent from 1966 to 1973 and 0.7 percent from 1973 to 1981.

Why has the growth in productivity been slowing? Has the structure of the economy changed so that traditionally measured indices are biased? Has the work ethic of the American labor force been deteriorating since World War II? Is this measured slowdown nothing more than a statistical artifact? As evidenced from a glance at the many references cited in this report, it is clear that researchers have given the causes and consequences of the slowdown a great deal of attention.

The purpose of this report is to synthesize this vast body of literature and to summarize the major issues on contemporary researchers' agendas. It is hoped that this summary will prove to be a valuable resource for both policy makers and industrial planners. In addition, several new and important topics within the field of productivity analysis will be examined quantitatively. Finally, an alternative conceptual model is suggested for thinking about the causes of productivity growth.

In section 2, the so-called "facts" about the productivity slowdown are examined. Patterns of measured productivity growth are documented for various time periods and for various sectors of the U.S. economy.[2] Then in section 3, methods for calculating these indices are reviewed and discussed. As important as the issue of productivity is, there is considerable disagreement regarding the meaning of these widely cited measures. Section 4 reviews the large literature, mostly empirical, related to the question, Why has productivity growth slowed? The theoretical arguments associated with many commonly mentioned determinants are summarized and the associated empirical literature is referenced. Some original research regarding several of these issues is presented in appendices to the paper, and is referenced throughout section 4. Finally, section 5 concludes the paper with some ideas regarding future analysis of productivity growth.

2. PATTERNS OF MEASURED PRODUCTIVITY GROWTH

There are many methods for measuring or indexing productivity. Both partial and total factor, or multi-factor, productivity measures are commonly used. The methods used to calculate these measures will be examined in section 3 of this report. First, some generally accepted and frequently published productivity statistics are presented to establish the existence and strength of the much talked about slowdown in productivity growth that occurred over the past decade.

Labor productivity (Q/L) and capital productivity (Q/K) measures are calculated by dividing a measure of real output by either total labor hours and the value of capital inputs, respectively. Total factor productivity (TFP) is similarly derived: the denominator is a weighted sum of labor and capital input quantities.

First consider the long-term behavior of these indices for the U.S. private business economy. In table 1, average annual productivity growth rates are reported for selected periods from 1800 to 1973 (the last year available using Kendrick's time-compatible data). With the exception of a slight slowdown in the growth of capital productivity between 1948 and 1973, there is no evidence that the economy's overall rate of productivity growth slackened in the most recent periods.

However, when the post-World War II period is considered in more detail, a slowdown in the mid-1960s and 1970s becomes noticeable. Table 2 reports average annual productivity growth rates for five sectors of the economy for three separate time periods. For each sector of the economy, except farming, the average growth in productivity (measured by any of the three indices) declined sometime after 1966. In the farming sector there was a significant rise in capital productivity after 1966, but this was offset by the decline in labor productivity.

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[2] The primary focus of this chapter is the productivity slowdown in the U.S. economy. Several interesting studies have been done on the productivity issue as it relates to either (1) other countries per se or (2) a comparison of other countries' experiences. They will not be discussed herein. See, for example, Bartik [1981]; Bernhardt [1981]; Christensen, Cummings, and Jorgenson [1980]; Daly [1980]; Evans [1978]; Hulten [1981]; Hulten and Nishimizu [1980]; National Research Council [1979]; Norsworthy [1982]; Ostry and Rao [1980]; Prais [1981]; Sharpe [1981]; and Yamada and Ruttan [1980], among others.

Also, some important work has been done on measuring productivity within the organization [Adam and Dogramaci, 1981]. The focus of this report is on the more aggregate measures of productivity and productivity growth.

A decline in productivity growth dating from the mid-1960s' trend is consistent with the data summarized in tables 3 and 4. For each sector reported in table 3, the growth rate in labor productivity increased between 1948 and 1957 and between 1957 and 1968; however, the average annual rate of growth slowed in each of the two subsequent time periods covering the years 1968–79. A similar pattern is also observed in the TFP series reported in table 4. Therein, growth in the last time period (1973–76) was even reported to be negative. These patterns of declining growth have suggested to some that there may have been two productivity slowdowns; one from the mid-1960s to about 1973 and a second thereafter.

Table 1. Average annual productivity growth rates: U.S. private business sector (in percents)

	Alternative productivity indices		
Time periods	Output/labor	Output/capital	Total factor productivity
1800–1855	0.5	–0.1	0.3
1855–1890	1.1	–0.6	0.3
1899–1919	2.0	0.7	1.7
1919–1948	2.4	1.6	2.2
1948–1973	3.1	1.3	2.4

Source: Kendrick (1980c, p. 2)

Table 2. Average annual productivity growth rates: Selected sectors (in percents)

	Output/labor			Output/capital			Total factor productivity		
Sectors	1948–1976	1948–1966	1966–1976	1948–1976	1948–1966	1966–1976	1948–1976	1948–1966	1966–1976
U.S. private business sector	3.0	3.5	1.9	1.1	1.5	0.3	2.3	2.9	1.4
Nonfinancial corporate business sector	2.6	3.1	1.8	0.9	1.4	0.0	2.2	2.7	1.3
Farm sector	5.0	5.3	4.5	–0.2	–0.6	0.6	3.0	3.5	2.2
Nonfarm/non-manufacturing sector	2.4	3.0	1.4	1.1	1.5	0.5	2.0	2.5	1.1
Manufacturing sector	2.7	2.9	2.2	0.3	1.0	–0.9	2.1	2.5	1.4

Source: Kendrick and Grossman (1980, p. 34)

Table 3. Average annual labor productivity growth rates: Selected sectors (in percents)

	Total	Disaggregated periods			
	1948–79	1948–57	1957–68	1968–73	1973–79
Total private economy	2.56	3.16	3.11	2.19	0.97
Private business sector	2.49	3.02	3.14	2.15	0.75
Nonfarm business sector	2.08	2.31	2.77	1.89	0.64
Nonfinancial corporate business sector	2.29	2.61	2.80	2.18	0.98

Source: Baily (1981a, p. 3)

Table 4. Average annual total factor productivity growth rates (in percents)

	Total	Disaggregated periods			
	1948–76	1948–57	1957–68	1968–73	1973–76
Total private economy	1.64	1.80	2.38	1.21	-0.87
Private business sector	1.14	1.57	1.51	0.68	-0.70

Source: Baily (1981a, p. 3)

Table 5. Average annual labor productivity growth rates: Industrial sector (in percents)

	1947–66	1966–77
Private business sector	3.1	1.6
Farm sector	5.6	4.6
Nonfarm sector		
Manufacturing	3.1	2.2
Mining	4.3	-1.0
Construction	3.0	-1.5
Transportation	3.1	2.0
Communications	5.2	5.6
Utilities	6.3	2.2
Wholesale and retail trade	2.6	1.9
Finance, insurance and real estate	0.9	0.4
Services	1.5	1.1
Government enterprises	-0.7	-0.1

Source: National Research Council (1979, p. 156)

Table 6. Average annual total factor productivity growth rates: Industrial sector (in percents)

	Aggregated Periods: 1889–1976			Disaggregated periods: 1948–1976						
	1889–1919	1919–1948	1948–1976	1948–1953	1953–1957	1957–1960	1960–1966	1966–1969	1969–1973	1973–1976
Private business economy	1.7	2.2	2.3	3.4	2.0	2.1	3.4	1.5	1.8	0.7
Farm sector	0.2	1.7	3.0	5.4	2.7	3.8	2.3	3.2	3.3	1.1
Nonfarm sector										
Manufacturing	0.7	2.9	2.1	2.9	1.0	1.1	3.9	0.9	2.7	0.1
Mining	1.6	2.3	1.7	4.1	2.2	0.6	4.6	1.7	-0.7	-4.6
Construction	—	—	1.0	2.6	1.8	4.2	2.0	-0.3	-5.0	1.8
Rail Trans.	2.4	4.0	2.5	2.5	2.6	4.2	7.0	1.3	0.2	-3.6
Non-rail trans.	—	—	1.6	0.4	2.1	1.2	2.6	1.9	2.8	1.2
Communications	2.2	1.7	4.2	5.7	4.5	5.9	3.5	3.4	2.5	4.3
Utilities	3.8	4.6	3.0	6.8	4.7	4.6	3.7	2.7	0.2	-3.8
Wholesale and retail trade	0.8	1.5	2.1	2.1	1.6	1.8	3.6	1.0	2.9	-
Real estate	—	—	2.8	4.4	2.9	3.8	2.6	1.3	1.3	3.1

Source: Kendrick (1980a, pp. 12, 15, 20)

In table 5, the nonfarm sector of the economy is disaggregated into 10 major industry groupings and labor productivity growth rates are reported on a pre- and post-1966 basis. All industry groupings, except for the communications and government enterprises, slowed after 1966. The more dramatic declines were seen in the mining, construction, and utilities groups.

More time-disaggregated data, by major industry grouping, are available for estimates of TFP. As shown in table 6, there are few exceptions to the statement that the growth in TFP during the 1970s, especially from 1973 to 1976, was slower than in any previous period since 1889.

This fact is particularly true for the manufacturing sector, by far the largest single sector in the U.S. economy. There, the average annual rate of growth in TFP was 2.5 percent from 1948 to 1966 and 1.4 percent from 1966 to 1976, with a dramatic decline after 1976: the rate of growth from 1973 to 1976 was only 0.1 percent per year. At this time we cannot tell if the 1973–76 period is simply a cyclical factor or an indication of a long-run trend.

Tables 7 through 11 contain average annual TFP growth rates for each two-digit SIC industry within the manufacturing sector. The data in tables 7, 8, and 9 are from three separate

Table 7. Average annual total factor productivity growth rates: Manufacturing industry (in percents)

	1948–78	1948–65	1965–73	1973–78
Manufacturing	2.0	2.5	1.8	1.0
Food	2.8	2.7	2.6	3.2
Tobacco	2.3	2.4	3.2	0.7
Textiles	3.2	3.7	2.3	3.1
Apparel	2.6	2.0	3.2	3.5
Lumber	2.9	4.8	0.8	–0.1
Furniture	1.8	2.2	1.3	1.1
Paper	2.1	2.1	3.9	-1.0
Printing, publishing	1.6	2.5	0.6	0.2
Chemicals	2.9	3.5	3.6	–0.2
Petroleum	2.3	3.0	1.3	1.5
Rubber	1.7	2.2	1.8	–0.1
Leather	1.2	0.9	1.8	1.0
Stone, clay, glass	1.4	1.9	0.6	1.2
Primary metals	–0.1	0.7	0.4	-3.4
Fabricated metals	1.1	1.5	0.9	0.1
Machinery, ex. electrical	1.0	1.3	1.1	–0.4
Electrical machinery	3.5	4.3	3.1	1.8
Transportation equipment	2.7	3.3	1.4	2.8
Instruments	2.4	3.4	2.0	–0.1
Miscellaneous	2.6	2.1	3.0	3.6

Source: Grayson (1980, p. 40)

Table 8. Average annual total factor productivity growth rates: Manufacturing industry (in percents)

	1948–76	1948–66	1966–76
Manufacturing	2.1	2.5	1.4
Food	2.9	3.0	2.6
Tobacco	2.6	2.5	2.6
Textiles	3.1	4.0	1.3
Apparel	2.5	2.1	3.2
Lumber	2.9	4.0	0.9
Furniture	1.8	2.1	1.3
Paper	2.0	2.2	1.8
Printing, publishing	1.5	2.4	0.0
Chemicals	3.2	3.5	2.5
Petroleum	2.1	2.9	0.6
Rubber	1.8	2.2	1.1
Leather	1.1	1.1	1.1
Stone, clay, glass	1.3	1.7	0.6
Primary metals	0.1	1.0	—1.4
Fabricated metals	1.3	1.7	0.5
Machinery, ex. electrical	1.1	1.3	0.7
Electrical machinery	3.7	4.2	2.8
Transportation equipment	2.7	3.2	1.8
Instruments	2.2	3.1	0.8
Miscellaneous	2.7	2.8	2.5

Sources: Kendrick (1980a, p. 22) and Kendrick Grossman (1980, p. 46) sources. The methods used by Grayson (table 7) and by Kendrick (table 8) are similar, as one would expect when comparing the numerical values for the TFP series. The Gollop-Jorgenson (table 9) estimates are measured using a different statistical technique (as will be discussed in sec. 3), hence direct numerical comparisons between table 9 and tables 7 and 8 are potentially misleading. What can be discerned from the statistics in all three tables are the marked inter-industry differences in growth rates over time. With regard to table 7, for example, 14 industries exhibited a slowdown in their average annual rate of growth in TFP between the 1948–65 period and the 1965–73 period, and of that group, 9 industries continued to have declines to at least 1978. A total of 13 industries exhibited declining average growth rates between the two periods 1965–73 and 1973–78. The apparel and miscellaneous products industries are the only ones to show increases in their average annual growth rates through the post-war period.

The Gollop-Jorgenson data in table 9 indicate that average growth rates were lower in the 1966–73 period compared to the 1948–66 period in only eight industries. Therefore, the reported trends in table 9 are found to differ significantly from those in the other two tables; for example, the figures in table 9 differ markedly from those in table 7 for eight industries: food, lumber, furniture, chemicals, petroleum, fabricated metals, instruments, and miscellaneous products.

An analysis of TFP growth rates for smaller time periods, as shown in tables 10 and 11, reveals at least two interesting facts. The first is that TFP has not changed smoothly during the post-war years: there is a significant amount of inter-time period, intra-industry variation in these growth rates. The Kendrick-Grossman data in table 10 suggest that the post-1966 slowdown was greater over the years 1966–69 compared to 1969–73, and that the period from 1973 to 1976 was, in general, more severe than from 1966 to 1969. There are reasons to believe there is a cyclical component to TFP growth. The second fact is that different time trends across manufacturing industries are indicated from the two sources reported in these tables. This raises the question as to whether the slowdown in TFP growth is, to some extent, a statistical artifact or whether the slowdown appears in the data because the methods used for related calculations are inaccurate. This question will be taken up below.

Table 9. Average annual total factor productivity growth rates: Manufacturing industry (in percents)

	1947–73	1948–66	1966–73
Manufacturing	–	–	–
Food	0.01	–0.97	1.23
Tobacco	0.28	0.79	0.85
Textiles	1.54	3.74	2.25
Apparel	0.67	0.77	1.83
Lumber	–0.61	–0.63	1.02
Furniture	1.21	0.49	1.48
Paper	0.01	0.46	0.94
Printing, publishing	0.57	1.43	0.61
Chemicals	2.33	4.68	2.67
Petroleum	0.69	–2.08	0.94
Rubber	0.99	2.69	1.87
Leather	–0.68	–3.79	1.79
Stone, clay, glass	0.23	1.32	0.70
Primary metals	–0.49	–0.79	–0.46
Fabricated metals	0.19	0.45	0.90
Machinery, ex. electrical	0.55	1.02	1.05
Electrical machinery	1.48	3.67	1.60
Transportation equipment	0.64[a]	1.89[a]	0.81[a]
Instruments	0.66	1.54	2.43
Miscellaneous	0.85	2.21	1.66

Source: Gollop and Jorgenson (1980, pp. 118–119)

[a] Simple average of growth rates for motor vehicles and other transportation equipment.

Table 10. Average annual total factor productivity growth rates: Manufacturing industry (in percents)

	1948–53	1953–57	1957–60	1960–66	1966–69	1969–73	1973–76
Manufacturing	2.9	1.0	1.1	3.9	0.9	2.7	0.1
Food	3.3	2.5	1.1	4.0	1.1	2.8	3.7
Tobacco	1.1	3.5	4.8	2.0	3.6	3.0	1.1
Textiles	0.8	3.6	1.9	8.2	0.1	2.7	0.7
Apparel	2.8	1.4	1.9	2.0	0.8	5.5	2.5
Lumber	0.4	5.8	1.5	7.2	1.6	4.9	-4.7
Furniture	2.2	2.7	0.1	2.7	2.0	1.0	0.8
Paper	3.7	-0.4	1.7	2.8	2.7	5.3	-3.5
Printing, publishing	2.2	2.8	0.6	3.1	0.2	0.7	-1.0
Chemicals	1.8	4.3	2.5	5.0	2.9	4.7	-0.9
Petroleum	1.8	0.6	5.4	4.1	0.8	2.3	-1.7
Rubber	2.1	-2.4	5.7	3.6	3.2	1.4	-1.5
Leather	-2.0	0.7	3.0	3.1	-0.3	2.1	1.2
Stone, clay, glass	2.4	0.1	1.1	2.4	0.8	1.7	-0.9
Primary metals	3.2	-1.5	-4.1	3.3	-3.1	1.8	-3.9
Fabricated metals	1.4	0.3	2.0	2.6	1.5	0.9	-0.9
Machinery, ex. electrical	2.5	-1.9	1.1	2.6	-0.2	2.3	-0.5
Electrical machinery	4.4	2.0	2.6	6.2	2.9	3.7	1.6
Transportation equipment	3.2	1.5	3.3	4.2	-0.5	2.7	3.0
Instruments	4.6	0.6	3.0	3.5	3.1	-0.4	0.1
Miscellaneous	4.0	3.3	2.6	1.6	3.1	2.8	1.6

Source: Kendrick and Grossman (1980, p. 46)

Table 11. Average annual total factor productivity growth rates: Manufacturing industry (in percents)

	1947–53	1953–57	1957–60	1960–66	1966–73
Manufacturing	–	–	–	–	–
Food	0.05	0.90	-4.66	0.30	1.23
Tobacco	-0.48	2.38	-3.35	0.80	0.85
Textiles	0.62	1.73	1.90	1.31	2.25
Apparel	1.10	0.27	-1.44	0.20	1.83
Lumber	-2.85	1.07	-6.91	1.77	1.02
Furniture	4.01	0.86	-3.52	0.68	1.48
Paper	-0.64	-0.77	-2.24	1.24	0.94
Printing, publishing	-0.00	2.11	-3.06	1.87	0.61
Chemicals	2.06	2.08	2.69	2.18	2.67
Petroleum	0.95	0.02	-1.34	1.62	0.94
Rubber	0.25	-1.74	4.33	0.84	1.87
Leather	-1.32	-0.38	-8.71	0.88	1.79
Stone, clay, glass	0.04	0.10	-2.69	1.43	0.70
Primary metals	0.94	-1.74	-5.94	1.60	-0.46
Fabricated metals	0.39	0.12	-3.29	0.96	0.90
Machinery, ex. electrical	0.80	-0.64	-2.72	2.18	1.05
Electrical machinery	0.81	-0.13	0.06	3.80	1.60
Transportation equipment	1.86[a]	-0.08[a]	-2.03[a]	1.26[a]	0.81[a]
Instruments	-1.53	-1.01	2.19	1.15	2.43
Miscellaneous	0.14	0.97	-0.20	1.07	1.66

Source: Gollop and Jorgenson (1980, pp. 118–119)

[a] Simple average of growth rates for motor vehicles and other transportation equipment.

To address an earlier question, Has productivity growth slowed?, the data presented above for the major sectors of the economy, and for industries within the manufacturing sector, would lead one to conclude that it probably has since the mid-1960s, and surely has since 1973. Of course, there remains the issue of the validity of such a conclusion based on short-run data. Nordhaus [1980] points out that if one examines aggregate labor productivity data from 1912 to 1979 the type of post-1973 slowdown we are now experiencing did occur twice within the last 60 years: he concludes that such slowdowns are simply not uncommon phenomena (and perhaps not worthy of extraordinary policy debate).

The next section of the report considers the issue of statistical biases in productivity measures. Methods for measuring productivity are reviewed and discussed to illustrate the breadth of debate surrounding this important issue.

3. ANALYSIS OF PRODUCTIVITY MEASURES

It is well known that a production function is a stylized representation of reality.[3] Functionally it is the association of a volume of inputs to some physical quantity of outputs. Productivity, then, is the degree of efficiency exhibited in this input to output process. Total factor productivity refers to the ratio of output to the combination of all inputs; partial factor productivity refers to the ratio of output to the amount of a single input.

3.1 Total Factor Productivity

The concept of total factor productivity (TFP) can be understood by writing output, Q, as a function of inputs, X, as

$$Q = A\ f(X) \tag{1}$$

where A is a time-related technology factor. This form of the production function results from a more general version through certain simplifying assumptions (a homothetic additively weakly separable production function whose output vector can be approximated by a "composite output" scalar, and in which time-related technology is neutrally embodied).[4]

Given eq (1) as representative of the relevant (that is, economy, sector, or industry) production process, then total factor productivity can be written as

$$\text{TFP} = A = Q/\Sigma\ w_i\ x_i \tag{2}$$

where the w_i's are input weights, $(0<w<1)$.

The validity of the assumptions required to derive eq (2) have been discussed in great detail within the literature. As a result, some have called into question the meaningfulness of empirical approximations of TFP from an equation like (2). For example, Gold [1981] objects to the production function concept in general, arguing that it is inherently impossible to measure the

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[3] Some may take issue with the initial assumption that a production function does exist and can be written in terms of input aggregates. This aggregation issue has been debated for more than 2 decades, and even a review of this literature is beyond the scope of this report.

[4] To derive eq (1), begin with a general multi-input and multi-output production function:

$$H(Q_1t, \ldots, Q_mt; X_1t, \ldots, X_nt; t) = H(\tilde{Q};\tilde{X};t) = 0$$

where t represents time and the symbol $\tilde{}$ denotes the vector of m-numbered outputs (Q) and n-numbered inputs (X) [Berndt, 1980a; Sudit and Finger, 1981]. If the function H is homothetic weakly separable, then

$$H(\tilde{Q};\tilde{X};t) = H^*(G^*(\tilde{Q});F^*(\tilde{X});t) = 0$$

and if the separability of the function is additive, then

$$G(\tilde{Q}) = F(\tilde{X};t).$$

Finally, if the multi-output vector can be replaced by a single "composite output" vector, **Q**, and if time-related technology is neutrally embodied, then the previous equation becomes

$$\mathbf{Q} = A\ f(\mathbf{X})$$

where **Q** represents the level of physical output and where **X** is a vector of input quantities. For a further discussion of the assumptions necessary to represent output by this composite index, **Q**, see for example Diewert [1978].

physical efficiency of any production process. He states that there is no accurate way to formulate a meaningful composite index of physical inputs (the denominator in eq (2)) to compare with physical output.

More fundamentally, Sudit and Finger [1981] criticize the assumptions necessary to arrive at eq (1). They contend that at the aggregate level (where most calculations of TFP are made) the assumption of separability (see footnote 4) is "economically restrictive since most production processes . . . probably do not in general exhibit independence of input and output substitution rates along the efficiency frontiers" (p. 8). Afriat [1972], among others, expresses a very similar view.

Also, some argue that the implicit assumption of production efficiency, which underlies eq (1), is unrealistic. The parameter A is a shift factor on the function: it does not measure movements along the function. Therefore, empirical evaluations of eq (2) between any two points in time are assuming either that all inputs are efficiently utilized, including management, in the formation of a frontier production surface [Aigner and Chu, 1968], or that the extent of inefficiency is constant over time. For example, organizational innovations to overcome management and production inefficiencies are not captured in A, although they certainly have an impact on productivity.

These criticisms are not without merit. Still, apart from basic data problems, the production function approach for estimating has some construct validity. For example, Nadiri [1970, p. 1146] writes "the use of an aggregate production function gives reasonably good estimates of total factor productivity . . . due mainly to the narrow range of movement of aggregate data rather than the solid foundation of the function." This may be true for particular time periods, but it probably is not of valid concern over extended periods of time, especially in high-technology industries where both the product mix and the state-of-the-art process technologies change rapidly.

The so-called first generation (using the terminology of Sudit and Finger [1981]) of TFP indices was developed by Abramowitz [1956], Denison [1962], Fabricant [1942], and Kendrick [1961]. For example, Kendrick's arithmetic index of total factor productivity is

$$d\text{TFP}/\text{TFP} = dA/A = [(Q_1/Q_0)/((wL_1+rK_1)/(wL_0+rK_0))] - 1 \qquad (3)$$

where labor (L) and capital (K) are the relevant inputs and where w and r are their respective unit factor costs.[5] Subscripts 1 and 0 refer to alternate time periods; 1 being the current period and 0 being the base period.

The so-called second generation production function indices were developed by Solow [1957], Jorgenson and Griliches [1967], Christensen and Jorgenson [1970], and Star [1974], among others. Solow's geometric index of TFP is based on a Cobb-Douglas production function assuming neutral technological change and constant returns to scale as

$$d\text{TFP}/\text{TFP} = dA/A = dQ/Q - [a(dK/K) + (1-a)(dL/L)] \qquad (4)$$

where the weights a and $(1-a)$ are the relevant shares of K and L, respectively. As Levahri, Kleinman, and Halevi [1966] point out, Solow's index is equivalent to Kendrick's [1961] index for small changes in Q, L, and K given the conditions of competitive equilibrium.

Most of the empirical literature related to the measurement of TFP and its growth rate has restricted itself to looking at simplified versions of eq (4):

$$d\text{TFP}/\text{TFP} = dA/A = dQ/Q - dX/X \qquad (5)$$

where X is a composite input index. Some of the earlier works using this type of formulation were by Dhrymes [1963], Hogan [1958], Massell [1960], and Pasenetti [1959]; but even more recently, Gollop and Jorgenson [1980] and Hulten [1979] have been working within the same broad general type of framework. The major advances within the literature have not been so much in the

[5] Equation (3) is based on the assumption of a linearly homogeneous production function and on the applicability of Euler's Theorem. Kendrick and Sato [1963] have shown that this Kendrick index is consistent with a constant elasticity of substitution $(1/(1/(1+p)))$ production function of the form

$$Q = A\ K\ L/(cL^p + dK^p)^{1/p}$$

for A a constant of disembodied technical change and c and d efficiency parameters.

indexing procedures (with the exception of duality analysis) as in the refinement of input measures—intermediate inputs and quality adjustment measures of labor and capital—and in production function specifications.[6]

The Solow index was formulated on the assumption of a Cobb-Douglas production function. Analytical models have progressed beyond this point. Researchers are now examining alternative forms such as the transcendental logarithmic (translog) production function and its dual [Berndt and Khaled, 1979; Gollop and Jorgenson, 1980; Gollop and Roberts, 1981]. However, Maddala [1979] demonstrates that measures of TFP are not overly sensitive to the form of the underlying production function. The reason is that alternative functional forms differ with respect to their elasticity of substitution, which basically depends on second derivatives, whereas productivity measures are related to first derivatives.

A reader should not develop the impression that all TFP measures are formulated within the context of an equation like (5). Other very novel and imaginative approaches have been suggested [Dogramaci, 1981]. For example, Leontief-type [1966] measures are formulated from sectoral input-output models. These models begin with the assumption of a linear production function, as

$$x_{ij} = a_{ij} X_i / A_i A_j \tag{6}$$

where x_{ij} is the output of sector j consumed by sector i, the a's are input coefficients, and X_i is the net output of sector i. Productivity is measured in terms of A_i and A_j. For example, if A_i increases, the less inputs (that is, outputs from sector j consumed by sector i) are needed in sector i to produce a unit of output, X_i. Erdilek [1977] and Moon [1981] have applied this kind of model in several case studies. Other interesting approaches to productivity measurement are used by Afriat [1972], Farrell [1957], and Gold [1955, 1976, 1981].

3.2 Partial Factor Productivity

A partial factor, or single factor, productivity measure is a ratio whose numerator is some measure of output and whose denominator is a measure of a single input as Q/X. The more common indices refer to average labor and average capital productivity. Labor productivity measures have been "popular" for decades and are more commonly noted in the literature. Thus, the following discussion will specifically focus on Q/L, where L is total labor hours.

The appeal of an average labor productivity measure is its ease of calculation. No statistical or parametric adjustments are needed because all necessary data are available. Also, aggregate data are readily available in Government publications, and microeconomic data can be found in business-related data banks like Compustat. However, there is a tradeoff for this ease of calculation. The use of Q/L, or the average product of labor, to measure productivity has "numerous serious, if not quite fatal conceptual flaws" [Perloff and Wachter, 1980, p. 116]. Four of these are discussed below. Even with knowledge of these problems, partial factor productivity measures remain widely used. According to Christainsen and Haveman [1980, p. 3], "[a]lthough [these] productivity measures . . . have serious weaknesses, the picture of productivity change which they yield is not greatly different from that of more complete measures."

First, to ensure reliability in any productivity index, output and input measures must be consistent and thus must refer to the same production activity. Since there are many production activities underlying any aggregate measure of output, a meaningful composite measure can be formed simply by denominating each separate physical output measure by a price index. However, when labor is denominated by a measure of hours some conceptual problems arise because the use of hours in the denominator of the index only corrects for one of the many heterogeneous aspects of workers. Additional adjustments are needed. Labor is not homogeneous with respect to demographic characteristics or skill levels. The age/sex/skill composition of the labor force varies from industry to industry and from sector to sector. Since average labor productivity measures are primarily used for intertemporal comparisons, then changes in the composition of the work force will affect measured output but will not be captured in Q/L unless these changes are perfectly correlated with an hours factor. This conceptual flaw can be overcome (but is often not) by adjusting the calculation of L for the heterogeneous composition of the labor force [Kunze, 1979;

[6] Hebert and Link [1982] and I. Siegel [1973], among others, point out the surprising omission of entrepreneurial talent as a factor of production.

McIntire, 1980]. Perloff and Wachter [1980] refer to such an improved index written in terms of efficiency labor units as a "demographically adjusted measure of [average labor] productivity."

Second, the average product of labor is very sensitive (in a quantitative sense) to cyclical movements in business activities (demand), and hence, it may indicate trends that are totally unrelated to productivity or efficiency improvements. Gordon [1979], for example, contends that firms hire more workers in the last stage of a business cycle than is justified by the level of output. As a result, average labor productivity, as measured by Q/L, will show a decline until firms adjust their hiring to their expectations about demand. Unless this fact is accounted for, conceptually and quantitatively, intertemporal comparisons of Q/L indices at any level of aggregation that do not adjust for the business cycle will be in error.

Third, the average product of labor is a poor proxy for productivity when policy makers are interested in making inferences about movements in real wages. The reason is simple: the average product of labor is an imperfect estimate of the marginal product of labor. In a Cobb-Douglas world the two measures are related by a constant of proportionality. In a non-Cobb-Douglas world, the proportionality factor is related to relative factor proportions [Perloff and Wachter, 1980]. Therefore, the policy-related usefulness of an average labor productivity series is questionable.

Finally, the fourth, and perhaps the most serious, conceptual flaw associated with using Q/L as a productivity index is that labor is not the sole source of productivity improvements. Such improvements resulting from other factors are not directly seen in Q/L calculations, and are only indirectly captured to the extent that such innovations result in labor-saving adjustments (but the quantitative impact of this is likewise not assessable from a Q/L series). Gold [1981], for example, has been very critical of Q/L measures for precisely this reason. A useful and meaningful productivity framework must identify, he contends, the sources of the productivity improvement and its interaction with other factors in the overall production process. Changes in the average product of labor reflect the passive results of changes initiated elsewhere. Gold [1981, p. 95] strongly emphasizes that output per man-hour is unacceptable "as a measure of labor productivity in view of its lacking any consistent relationship to the magnitude or effectiveness of labor's contribution to the output representing the sum of all contributions."

Craig and Harris [1973] illustrate that because any partial factor productivity measure does not quantify the impact of technology substitution, Q/L is conceptually wanting as a management decision-making tool. Q/L can rise due to the purchase and implementation of a new technology (product or process) which is largely embodied in the capital stock. Because this new technology saves labor, then Q/L rises, other things held constant. But, if the cost of the new technology equals the cost savings from less labor, then the total costs of production remain unchanged. In this latter case, if labor bargains for an increased wage (see point three above) on the basis of higher measured labor productivity, then output's price must also rise. Stockholders, in noting the rise in measured labor productivity, are, in contrast, expecting prices to fall and the value of their stock to rise. From management's perspective the dilemma's source is the use (or misuse) of a partial productivity measure.

3.3 Data Issues

The most frequently referenced productivity index is the Bureau of Labor Statistics' (BLS) measure of labor productivity.[7] The numerator in this index is gross domestic private product (gross national product less output from (a) household employment of domestic workers, (b) employees hired directly by the Government, and (c) nonprofit organizations) less the imputed real value of the benefits from owner-occupied homes. The denominator is the weighted sum of the hours of all workers used in the production of output. These series are published annually for the U.S. private business sector and quarterly for manufacturing industries. McIntire [1980] carefully analyzes several issues related to the calculation of these series (although his points apply equally well to any productivity series). The following data issues are valid for both partial factor and total factor indices.

The BLS measures output gross, rather than net, of depreciation. The argument for this is that there is no reason to exclude capital consumption expenditures since other services are not excluded that contribute directly to economic well-being. There is a problem, however, when, due

[7] This section draws heavily on McIntire [1980].

to technological change, net output and real depreciation grow over time at different rates. Under such a circumstance the use of net rather than gross output measures would yield different measured productivity trends. Also, output is usually adjusted by a price index which introduces related problems. The price index used to deflate sales is referenced at the time of shipment of the basket of goods. Clearly, during periods of rapid inflation, as in the 1970s, changes in real output would be understated [Fabricant, 1981].

Clark [1981] has also considered this issue of measurement problems in the price index related to productivity statistics. For example, he notes that between 1965 and 1980 the nonresidential, nonfarm deflator increased 132 percent: only 20 percent of that increase had to be overstated in order to explain the post-1965 decline in labor productivity. There are at least two reasons to expect that there was in fact overdeflation since 1965: first, the ratio of list prices to transaction prices has been rising; and, second, energy price increases have led to newly-installed capital equipment whose higher quality is at best poorly captured in traditional price indices [Griliches, 1979]. These facts led Clark [1981, p. 10], among others, to conclude that "there is a reasonable chance that much of the apparent slowdown observed in the United States since the mid-1960s is a product of the method used for measuring aggregate productivity, rather than a significant slowing of the engine of progress."

Still, gross output is the appropriate numerator for aggregate analyses and it is generally used by researchers in calculating TFP and Q/X series.[8] However, when such calculations are made at the sectoral, industry, or even firm level, another issue arises regarding the correct measure of the numerator. At the microeconomic level, the value of goods and services from outside (intermediate goods purchased as inputs) should be subtracted from gross output, thereby leaving some measure of (real) value added as the proper proxy for Q. Bruno [1978], Diewert [1978], and Sudit and Finger [1981] point out that this implicitly assumes that the underlying production function is additively separable in the form $Q=(VA+M)$ where VA represents value-added and M represents intermediate inputs. Also, biases result in the calculation of TFP when intermediate inputs are omitted from the input mix in the denominator, but as Bruno [1978] proves, the direction of this bias is not known unless some restrictions are initially imposed. Star [1974] has attempted to quantify the bias associated with the use of value-added in a Solow-like model. Gollop and Jorgenson's [1980] estimates of TFP are corrected for these problems; they explicitly included intermediate inputs in their industry production functions.[9]

Most data problems are related to the manner in which factor inputs are measured, especially labor services. Labor is denominated by hours paid rather than hours worked. The difference between these is paid leave, sick leave, and paid vacations and holidays. This difference has been especially important during the last several years when hours paid has grown faster than hours worked. Also, as noted above, labor's hours are not adjusted for either demographic or skill levels. In addition, data are not directly available for nonproduction workers' hours in the manufacturing or mining sectors; these hours are assumed to have been constant since 1962.

According to McIntire [1980], the net effect of these data issues is to bias the BLS labor productivity series downward, especially in the more rapidly growing sectors of the economy. The magnitude of this bias is unclear.[10] Again, Gollop and Jorgenson's [1980] analysis gives meticulous attention to each of these points.

3.4 Concluding Observations

Productivity indices, partial or total factor, are most reliable for the primary (agricultural, forestry, fishery, mining, and extraction) and secondary (construction and manufacturing) sectors of the economy with the exception of the construction industry. However, the percent of GNP originating in these sectors has fallen since World War II. In fact, the percent of GNP originating in the tertiary sector (communications, distributive trades, finance, service trades, transportation, and utilities) rose 20.3 percent between 1947 and 1976 [Perlman, 1979]. "What is going on in the tertiary sector is probably quite dismal, but the service sector seems always to have been absolutely low in productivity" [Perlman, 1979, p. 82].

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[8] Terborgh [1979] examined the possibility of measuring output in physical units. See also, Popkin [1979].

[9] See Gollop [1979] for a conceptual discussion of aggregating sectoral value-added functions. See also Scott [1979] for a discussion of data problems related to output measures in service industries.

[10] Holland and King [1979] have imaginatively used computer simulation to assess relative errors in productivity indices.

It is generally agreed by researchers that TFP measures are conceptually more meaningful, but the ease of calculation has led many to simply examine labor productivity series. However, it has been recommended by the Joint Economic Committee and by others, that the BLS begin to publish TFP measures. Surely, the research community will analyze any such new data with boundless energy.

4. A REVIEW OF THE LITERATURE

The information presented in section 2 suggests that productivity (TFP or Q/X) growth has slowed in the United States since the mid-1960s, and especially after 1973. Volumes of papers have appeared within the literature attempting to identify the causes or correlates associated with this experience. Many of the more recent works summarize the relevant thought that has led to this research. Thus, there already exist several partial reviews on this topic [Christainsen and Haveman, 1980; Mansfield, 1980b; Nadiri, 1970; Nelson, 1981]. Each of these reviews categorizes in a unique manner existing knowledge related to the determinants of productivity growth. The framework for summarization employed here differs from that of others. The "divisional categories" used represent the hypothesized determinants themselves. The theoretical arguments purporting to explain why each determinant should affect productivity growth are reviewed (a question often overlooked in empirical research) and a summary of the relevant conclusions is presented. It must be remembered in reading this section that researchers' methodologies vary; therefore, disparate findings may simply reflect different techniques in measurement or estimation.

From this section the reader will understand that there are many possible explanations for the causes of the productivity slowdown and that the relative importance of any one correlate is disputable. It will then be suggested that the current methods for conceptualizing the productivity dilemma may themselves be the culprits that lead to these varied findings. If this is so, then fruitful research might lie either in an analysis of the interrelationships between these presumed-to-be independent determinants, or in a radically new approach which stresses a microeconomic analysis of attitudes and behavioral incentives within the firm.

In section 3, it was noted that the observed, or measured, slowdown(s) is perhaps partially a statistical artifact. Biases surely exist in aggregate data used for productivity calculations. As Henrici [1981, p. 123] queried, "Are we dealing with a sick patient or a sick stethoscope?" Most researchers do acknowledge this possibility to some degree. But, as Rees [1980] observed, for such data problems to be the sole contributor to the slowdown implies that downward biasing pressures must have been growing substantially over the last decade. In fact, he argues, there is some belief that measurement problems have been occurring less frequently in recent years. Nevertheless, the studies considered below are based on the maintained hypothesis that there are random independent exogenous factors associated with the U.S. productivity decline.

The remainder of this section is presented in two parts. First, the analytical frameworks most frequently used by empirical researchers are presented. These are generally either regression models or applications of growth accounting. Then, the theoretical and empirical arguments regarding the analyses are summarized.

4.1 Analytical Frameworks

4.1.1 Regression Models

One method for examining the impact of a menu of possible productivity determinants is to formulate a linear regression model wherein the dependent variable is a productivity index and the independent variables are the hypothesized determinants. Such models have often been estimated using time-series data at the aggregated level; less frequently the units of analysis are cross-firm or cross-industry. As discussed below, the time-series studies have focused on structural changes in the productivity growth trend relationship; the key variables in these studies are, among others, the growth rate of prices (inflation) and changes in the regulatory climate of the economy [Christainsen and Haveman, 1981; Filer, 1980]. The more microeconomic-oriented cross-sectional studies focus on many variables, R&D expenditures being one.

These studies vary with respect to the functional form used to formulate the regression model. Most models are based on a Cobb-Douglas production function; however, the more generalized forms are frequently being used. Also, as the National Science Foundation's data bank on R&D estimates expands, time-series analyses are beginning to be conducted to examine the lag structure between R&D and productivity growth [Terleckyj, 1982a].

A fundamental characteristic of all regression models is the hypothesized one-directional causal flow. Measures of productivity or of productivity growth are assumed to be related to a vector of time, industry, and firm characteristics. It is also likely that changes in productivity growth alter aspects of firms' behavior. Simultaneous models will certainly begin to appear within the literature as more and better data series are developed.

4.1.2 Growth Accounting

Growth accounting is a technique to quantify the impacts of any specific factor on productivity growth. Basically, the underlying assumption of this approach is that there exists in the aggregate some well-behaved production function and that the contribution of any one input to production is approximately equal to its market return [Nordhaus, 1980]. More specifically, following Denison [1962, 1979] and others, the following type of model is examined [Nadiri, 1970]:

$$dQ = u\,[\Sigma\, a_i\, d\mathbf{X}_i + \Sigma\, \mathbf{y}_i + J] \qquad (7)$$

where,

dQ = growth of real national income
u = an economies of scale parameter
a_i = an index of the shares of factor i
$\mathbf{X}$ = a vector of factors of production such as changes in employment; the composition and quality of employment; levels of inventories; nonresidential land, structures, and equipment; and changes in the quality of assets
$\mathbf{y}$ = a vector of disequilibrium factors such as changes in sectoral allocations of resources; institutional restrictions and regulations; aggregate demand, technology adoption rates, and economies of scale
J = a residual.

4.2 The Theoretical and Empirical Arguments

The following hypothesized determinants have attracted much attention in the empirical literature. The order of presentation of these factors is arbitrary and is not intended to reflect any judgment as to their relative theoretical or quantitative importance.[11]

Cyclical losses: As a starting point it may be useful to address whether the sources associated with the productivity slowdown are cyclical (that is, short run due to changes in the composition of demand or in the utilization of inputs, say) or secular in nature (that is, long run due to sectoral or demographic shifts in labor or changes in capital or technological investment behavior, say). Following others [Nordhaus, 1972; Perry, 1971, 1977], Gordon [1979] and Mohr [1980] contend that short-run cyclical movements in labor productivity are to be expected. The hypothesis is that firms consistently hire more workers in the last stage of a business expansion than is justified by the level of output; thus Q/L falls. As the cycle turns down, labor hiring adjustments are made. Employers can usually make output adjustments at the end of an expansion faster than labor adjustments because of "sticky" contractual agreements. Gordon's [1979] empirical analysis seems to confirm that at least a portion of the post-1965 slowdown in labor productivity is simply due to the cyclical "end-of-expansion" phenomenon brought about by managerial misperceptions regarding the hiring of labor.[12]

[11] Inter-sectoral shifts have been an important determinant of productivity growth, but their impact on productivity diminished after 1966, and especially after 1973 [Kutscher, Mark, and Norsworthy, 1977]. This factor is not discussed in the text below.

[12] See also Dickens [1982], Kendrick [1977], and Neftci [1981].

Most of the empirical research conducted, and reviewed below, is based on an implicitly-maintained hypothesis that the productivity (labor and total factor) slowdown is due to secular changes brought about either by shocks to the economy or by "imposed constraints" on economic activity.

Inflation and energy prices: There is a high negative correlation between inflation and labor productivity in the economy which can be documented using data as far back as the mid-1940s [Clark, 1981, 1982]. According to some, this relationship is more than an empirical coincidence. Inflation is not a newly singled-out culprit for the slowdown: the Council on Wage and Price Stability's 1979 Report to the President, for example, cited inflation as a primary contributor to the post-1973 productivity slowdown. But even more important than this contention is the fact that there are sound theoretical reasons to expect inflationary tendencies to have a dampening impact on productivity growth.

First, the certainty about price signals is lower during periods of unanticipated, or even prolonged, inflation than in periods of stable prices. Therefore, managerial decisions are made in an above "normal" climate of uncertainty [Jarrett and Selody, 1982]. This will result in a real efficiency loss because planning horizons are shortened [Hayes and Abernathy, 1980]. More specifically, the forecasting or actual decisionmaking that takes place in this shortened time frame may be in error. For example, as input prices rise during inflationary periods, it becomes increasingly difficult to determine the portion of the increase in wages, say, that is inflationary or that is actually due to a change in relative factor costs [Clark, 1981].

Second, as a result of this increased uncertainty in factor-related decisions, managerial talents may be diverted from long-run cost-reducing activities to more short-run production-oriented decisions [Clark, 1981]. The ramifications of this type of internal organizational shift may show up in an altered attitude on the part of managers regarding their proclivity for risk-taking. This factor will not be realized in short-run productivity trends but will surely influence long-run behavior.

Third, not only can inflation indirectly affect the optimal choice of an input mix, it can impact directly on capital investments. Because the depreciation and replacement of plant and equipment is based on historical costs, prolonged inflationary periods will significantly increase the deviation between these historic costs and effective replacement costs. As a result, current profits, and thus current profit taxes, will be "too high" vis-a-vis that level necessary to finance required investments [Lee, 1980]. The net result is a slowing of the growth of newer vintages of capital to complement labor, and thus, a slowing of the growth of output.

One obvious factor associated with the record of inflation in the 1970s was the 1973 energy crisis. Not by coincidence did some writers quickly contend that the 1973 crisis was the primary factor to bring about the post-1973 productivity slowdown. R. Siegel [1979, p. 60], in fact, is bold enough to state that "[e]nergy prices stand out as the single most important contributor to the 1973 [productivity] break."

Why might unexpected or rapid energy price increases alter productivity? The thesis under question seems to be that the so-called energy shock represented a structural change in production activity which rendered much existing capital obsolete.[13] On the one hand, the works of Baily [1981a], Coen and Hickman [1980], Hudson and Jorgenson [1978a, 1978b], Rasche and Tatom [1977a, 1977b], and R. Siegel [1979], using alternative methods, conclude that increased energy prices have significantly reduced measured productivity. Denison [1979]; Norsworthy, Harper, and Kunze [1979]; and Perry [1977] find only mild negative effects. On the other hand, Berndt [1980b], Clark [1982], and Stein [1981] totally dismiss this energy shock hypothesis. Clark [1982], for example, argues that over time, organizational structures have been improving as management learns-by-doing in an atmosphere of low energy prices. The energy price may have simply stopped this particular learning process cold, and as a result, productivity fell.

Capital investments: Quite frequently, changes in the growth of capital are viewed as a potentially independent causal factor in explaining the productivity slowdown. When such a hypothesis is tested empirically, most researchers find that the post-1973 slowdown in the capital-to-labor ratio is significantly correlated with both partial and total factor productivity growth [Baily, 1981a, 1981b; Clark, 1982; Kendrick, 1980c; Klotz, 1980; Kopcke, 1980; Norsworthy and Harper, 1981; Norsworthy, Harper and Kunze, 1979; Stokes, 1981]. Mark's [1978] analysis does not support the findings of these other studies. Economic theory clearly predicts that the marginal product of labor will fall as the absolute stock of capital declines, holding the quality of labor,

[13] Baily [1981a] carefully points out that this corresponds to a decline in the flow of capital services rather than in the stock.

among other things, constant. Why did the capital-to-labor ratio fall after 1973? If it were a profit-motivated factor-usage response to the recently increased price of energy, then modeling "energy" and "capital formation" as independent phenomena is incorrect. The interaction of the two effects appears to be a relevant causal factor to consider. If unexpected inflation did create an atmosphere of uncertainty (accompanied by rising interest rates which led businessmen to slow down their long-run financial commitments) then again it would be the interaction of these effects that should be considered. To my knowledge this type of modeling has not occurred. Nevertheless, Fraumeni and Jorgenson [1981, p. 49] argue that the "revival of capital formation is clearly the key to reestablishment of postwar trends in economic growth in the United States."[14]

Regulations: One might hypothesize that Federal regulations, such as environmental and worker-safety programs, will reduce measured productivity growth in a regulated industry because the compliance costs are born by diverting real resources (financial, technical, and human) from productive (in a measurable or market sense) activities [Abramowitz, 1981; Myers and Nakamura, 1980]. It is important to emphasize the adjective "measured" when speaking about the impacts from Federal regulations on productivity. Improvements in the value and quality of life resulting from environmental and worker-safety programs are simply not quantified in the output numerator of conventional productivity indices. Moreover, the stimulus to supplier industries to provide capital goods and services needed by the regulated industry may increase productivity in the supplier industries. If this occurs, it will show up in a calculated productivity index for the supplier industries as an "unexplained" residual rather than a consequence of regulation.

If the shifted funds come at the expense of newer vintages of plant and equipment, then the effective capital-to-labor ratio will be falling over time and measured productivity growth will likewise fall. If the reallocation comes from other resources, say from total R&D expenditures, then several things could happen to reduce productivity growth. One, the overall level of a firm's in-house innovative activity will fall (the link between R&D expenditures and total factor productivity is well documented and will be discussed below). Two, the composition of the firm's R&D portfolio will change, probably more toward defensive R&D (on an offensive/defensive spectrum) [Rothwell, 1981] or more toward development (on a basic/applied/development spectrum) [Link, 1982c]. In either case, one would not expect the newly undertaken R&D to significantly add to the firm's stock of innovative-related knowledge.

Available data seem to support these propositions. At the aggregate level, the results from Christainsen and Haveman [1981] suggest that between 12 and 21 percent of the slowdown in the growth of measured labor productivity within the manufacturing sector between the periods 1958–65 and 1973–77 is due to Federal regulations per se. The study by Evans [1978] supports this view, too. Other specific industry studies also find that regulations, specifically environmental and health and safety policies, have resulted in lower measured labor and total factor productivity growth during the 1970s vis-a-vis earlier periods [Boden, Zimmerman, and Spiegelman, 1981; Crandall, 1981; Gollop and Roberts, 1982; Priest, 1981]. In fact, Crandall [1981, p. 368] concludes that there "can be little doubt that [labor] productivity has declined more sharply in pollution-control-affected industries than in others."[15] The only semi-direct empirical test of the diversion of resources hypothesis is by Link [1982c]. Therein, he shows that in selected manufacturing industries R&D expenditures directed toward meeting environmental regulations have had a negative impact on total factor productivity compared with the positive impact of R&D expenditures directed toward "traditional" types of innovative ventures.

An alternative to this regulation-induced diversion of resources hypothesis is that the impact of regulations on a firm simply renders certain production methods, and hence certain stocks of capital, cost inefficient. In those instances, no resource reallocation would take place because the compliance costs are prohibitively high. As a result, regulations themselves could lead to a reduced capital-in-use to labor ratio: the end result would of course be lowered measured productivity (although perhaps an increase in environmental quality).[16] Here again, it is difficult to separate the impacts from regulation and those from a declining capital-to-labor ratio during the time period of the 1970s. These two presumed to be causal factors may themselves be related.

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[14] See Terborgh [1981].

[15] See Crandall [1980].

[16] See, for example, Collins and Thomas [1978].

Technological advances: Technology is considered by many to be one of the most important factors influencing economic activity and economic growth. In the 1950s, the importance of technological change attracted professional attention as a result of the research by Schmookler [1952], Fabricant [1954], Abramowitz [1956], and Solow [1957]. Their findings supported the belief that the historical growth in output per man-hour in the economy was predominantly due to the application of new production technologies. Perhaps the most influential of these was Solow's study which reported that nearly 87 percent of the growth in productivity in the United States between 1909 and 1949 was due to technological change, rather than to growth in capital and labor inputs. There is little doubt as to why technology often became cited as one of the determinants of the post-1965 productivity slowdown. In fact, the motivation for analyzing changes in technology perhaps is justified better within the economic literature than are any of the hypothesized factors discussed above.

For nearly 2 decades economists have been documenting the productivity-to-technology relationship in studies focusing exclusively on R&D spending (primarily using cross-sectional industry and firm data from the manufacturing sector). Beginning with Terleckyj [1960], a number of studies were conducted relating productivity growth to, among other things, R&D investments in the stock of technical capital [Griliches, 1973; Mansfield, 1965; Minasian, 1962; Terleckyj, 1974].[17] Although the intended purpose of these early papers was not policy oriented in the sense of identifying a culprit for the productivity slowdown begun in 1965, the framework used in these studies has become the "state-of-the-art" for many ongoing investigations.[18] It is not so surprising then that R&D has come into focus as one primary candidate for explaining the post-1965 and post-1973 slowdowns. A simple analysis of aggregate data reveals that the curtailment in R&D spending is closely associated with the decline in productivity growth: total R&D as a percentage of GNP peaked at 3.0 percent by 1964, then fell to 2.3 percent by 1975 and even to a slightly lower level by 1977, where it has approximately remained with only a slight increase in the most recent years.[19]

The available empirical evidence is fairly consistent in its implication that there is a positive direct relationship between R&D (in total and also by categories of usage) expenditures and measured (usually TFP) productivity growth at both the industry and firm level [Clark and Griliches, 1981; Griliches 1980a, 1980b; Griliches and Lichtenberg, 1981; Griliches and Mairesse, 1981; Link, 1980, 1981a, 1981b, 1982a, 1982b, 1982c; Mansfield, 1980a; Terleckyj, 1980, 1982b; Sveikauskas and Sveikauskas, 1982].[20] From these cross-sectional studies, it is generally concluded that a similar relationship would exist over time if such data were available. Hence, the slowing of R&D remains a candidate for explaining a portion of the observed productivity slowdown. One of the only time-related studies to verify this belief is by Terleckyj [1982a].

An underlying assumption in all of these studies is that the productivity-related technological basis of the firm (and hence the industry) is its own R&D program. This is simply a convenient assumption predicated on the basis of data availability, but it is overly restrictive. Technologies can enter the firm not only as the result of its own R&D—call these induced innovations—but also through such channels as the licensing of other's technologies or the purchasing of new capital equipment that embody new technologies—call these purchased innovations. Few efforts have been made within the R&D literature to account for this inter-firm flow of technology. The quantitative evidence that is available comes from Terleckyj [1974, 1980, 1982b] and Scherer [1981, 1982] and is based on aggregate industry data. Both of these researchers conclude that R&D technologies embodied in capital or in intermediate goods purchases have a greater impact on an industry's productivity than R&D conducted within the industry. Unfortunately, time-series data are not available to document the importance of technology flows in relationship to the post-1965 slowdowns. The analysis presented in Appendix A to this report is a reconsideration of the

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[17] See also, Rothwell and Robertson [1973].

[18] Somewhat in response to these findings and to the slowdown in productivity growth beginning in the mid-1960s, the National Science Foundation documented its interest in a better understanding of technology and in R&D. See, National Science Foundation [1972, 1977]. See also, Griliches [1979] and Nelson [1981] for a critique of these models.

[19] Kendrick [1978] refers to R&D as "the fountainhead of productivity advance" and was an early proponent for industry tax-related incentives for reversing this trend. See also, Committee for Economic Development [1980] and Avard, Catto, and Davidson [1982]. For a more complete discussion of R&D tax laws and related policy alternatives, see Bozeman and Link [forthcoming].

[20] Nadiri and Bitros [1980] demonstrate that R&D affects labor productivity in a dynamic model.

empirical importance of technology flows using cross-sectional firm data. There, it is shown that both induced and purchased technologies significantly influence productivity growth.

In the discussion related to the above-mentioned determinants of productivity growth, the point was stressed that there are sequential interaction effects between many of the hypothesized variables and productivity. Similarly, inter-industry (-firm) differences in R&D spending reflect not only inter-industry (-firm) differences in technological investments, but also inter-industry adjustments to certain macroeconomic events which themselves exert an impact on productivity. For example, inter-industry (-firm) differences in levels of R&D at a given point in time reflect, to some degree, inter-industry differences in past responses to changing interest rates and inflation (such as in the interest rate elasticity of R&D). Also, inter-industry (-firm) differences in current levels of R&D partially reflect inter-industry (-firm) differences in their post-1973 adjustment to regulations per se and to the energy crisis in particular. Certain industries are affected more severely than others by these externally-generated events. So, to the extent that a firm's R&D investments are allocated in response to these events, observed R&D expenditures reflect more than simply productivity-enhancing technological investments. Again, there appears to be an interrelationship among causal factors in terms of their productivity consequences.

Unions: The traditional monopoly view of unionism predicts that unions per se will decrease labor productivity. Not only will union wage gains in excess of labor productivity increases lead to an inefficient factor mix, but also unions will lower productivity by reducing management flexibility, introducing inefficient work rules, and limiting compensation based on individual productivity. Following this line of reasoning, many of the R&D studies referenced above include a union variable as an independent regressor. Consistently, researchers have reported a negative relationship between levels of industrial unionization and growth in the associated industry's (or individual firm's) growth in total factor productivity.

In contrast to this monopoly concept of unions, a body of literature by Harvard economists has recently emerged which emphasizes a "collective voice/institutional response" (CV/IR) view.[21] This view suggests that unionism may increase labor productivity in those work environments characterized by worker complementarities, imperfect monitoring, and attendant public good and externality problems. In this view, unions act as agents for workers by providing a collective bargaining voice. Productivity is enhanced through decreased turnover and the establishment of grievance procedures, work rules, seniority systems, and the like. In addition, unionization "shocks" management so that existing inefficiency is also reduced. Thus, the CV/IR view of unionism predicts that unions may increase productivity, even after accounting for the microeconomic adjustments made by firms in response to union wage gains (in particular, an increase in the capital-to-labor ratio and the selection of higher quality workers).

One would be hard pressed to argue that unions have had a significant influence in encouraging the post-1965 slowdowns. It is true that union membership declined throughout that period, but no data exist on the rate of change in the overall effectiveness of unions on firms' production processes.[22]

However, cross-industry differences in unionization may be an important determinant of cross-industry or cross-firm differences in productivity growth. The R&D studies noted above conclude that the level of unionization does impact on TFP growth, but the CV/IR thesis has yet to to be tested empirically within that context. This type of analysis is presented in Appendix B. The results cast reasonable doubt on the strong conclusions reached in the Harvard studies.

Entrepreneurship: Although there have been many conceptualizations of who the entrepreneur is and what he does [Hebert and Link, 1982], one important, and generally accepted, characteristic of entrepreneurship is an ability to deal with disequilibrium situations (or in a more narrow vein, competitive forces). In a dynamic economy environments change, modes of competition change, and constraints on all activities are constantly in a state of flux. "[D]isequilibria are inevitable in [a] dynamic economy. These disequilibria cannot be eliminated by law, by public policy, and surely not by rhetoric. A modern dynamic economy would fall apart if not for the entrepreneurial actions of a wide array of human agents who reallocate their resources and thereby bring their part of the economy back into equilibrium" [Schultz, 1980, p. 443]. It is this

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[21] See in particular, Freeman and Medoff [1979b, 1982].

[22] Some may argue that relative wage gains to unions have increased slightly during the past decade, but this evidence is not conclusive.

constant readjustment to equilibrium, often as a result of innovative insights and actions, that stimulates productivity and ultimately leads to growth. According to some [Klein, 1979], the recent slowdown in U.S. productivity growth can be viewed in terms of a decline in businessmen's ability or desire to deal with disequilibria.

Does today's businessman lack the perception and ability to exercise entrepreneurial talent? Have these abilities been declining over the past decade? Hayes and Abernathy [1980] suggest that the "rules of the game" may have changed. What could be called "managerial myopia" may simply be the rational response by businessmen to short-run profit incentives. "[W]e believe that during the past two decades American managers have increasingly relied on principles which prize analytical detachment and methodological elegance over insight, based on experience, into the subtleties and complexities of strategic decisions. As a result, maximum short-term financial returns have become the overriding criteria for many companies" [Hayes and Abernathy, 1980, p. 70].

There is some quantifiable evidence that management's focus has become more short run during the recent years. Not only have investments in total R&D slowed since the mid-1960s, but also the composition of R&D has been moving away from the basic/long-term/exploratory ends of the spectrums toward the development/short-term/routine ends [Bozeman and Link, forthcoming]. There is an increasing tendency to purchase (directly through mergers) technologies rather than to innovate. The reason appears to be straightforward: management's reward system is based today on short-run performance criteria guided by short-run quantifiable profits.

As with most of the above-mentioned determinants of productivity growth, the direction of entrepreneurial activities is partially related to other factors. The atmosphere created by the unanticipated inflation and the volatile movements of interest rates during the past several years has not been conducive for long-term and risky kinds of investments. Quite naturally, those investments characterized by high payoff ratios have been undertaken faster than others. Unfortunately, those investments that were postponed are likely to be those kinds of investments that are technology embodying, and hence are related to future productivity growth. The post-1965 change in R&D spending is only one example.

4.3 Summary

Several factors were reviewed here that have been suggested as determinants of the U.S. productivity slowdown. Although the theoretical arguments associated with each are straightforward, one important issue generally has been overlooked. Those determinants associated with the productivity slowdown are treated within the literature as independent and exogenous events to the firm. More likely, it is the combined impact of these many events that is the culprit for the decline in productivity growth. Although it is convenient to model determinants as independent phenomena (as often dictated by the ease of use of regression analysis), the issue at hand should warrant a more complete and integrated treatment. A suggestion as to how such an approach might be designed is the topic of the next section.

5. WHERE DO WE GO FROM HERE? SOME CONCLUDING THOUGHTS

Many important insights about the general topic of productivity, and about the specific issue of the productivity decline, have been gained by the researchers whose works are summarized in this report. Our understanding of productivity over the last decade or so has been improving, perhaps at an exponential rate. We are more knowledgeable about methods for measuring productivity and have a better conceptualization about the causes and consequences of a changing rate of productivity growth. Perhaps more important, there is a growing realization in both academic and policy circles that productivity is an extremely complex topic for analysis. The more we learn about productivity, the more we discover that it is a complex phenomenon. Clearly, we need to learn more about this important concept.

Nelson [1981] has recently written that the theoretical models (generally neoclassical) underlying the productivity literature are "superficial" and generally wanting in at least three respects: (1) the microeconomic determinants of productivity growth; (2) the processes that generate, screen, and spread new technologies; and (3) the influence of macroeconomic conditions on productivity growth.

Related to Nelson's first criticism, not only is more thought (and imagination) needed in formulating a microeconomic model of the determinants of productivity growth, but care must be taken in quantifying these factors. It was argued in the earlier sections that the methodology surrounding the measurement of productivity indices was itself an ill-defined science. In addition, data used in these calculations are aggregated and subject to many biases. The same criticisms apply to whatever vector of determinants is considered. For example, one cannot accurately index innovative activity, nor can one isolate the impact of, say, inflation, from other macroeconomic events, on productivity. Efforts to do these important tasks will require some refinement in data and technique.

Each of Nelson's specific points has been tangentially referred to in the earlier review of the literature. Most models are concerned with explaining cross-firm (-industry) differences in measured productivity or changes in aggregate productivity growth over time. The independent variables in these studies were discussed in the previous section: increasing inflation and energy prices, slowing capital investments, more stringent environmental regulations, slackening R&D spending, and an overall decline in entrepreneurial activities. Some of these variables are exogenous to the firm (such as inflation), while others are internal (such as capital and R&D spending). It appears that few efforts have been made to conceptualize the interrelationships between the macroeconomic events and the microeconomic responses of firms on productivity growth.

In the 1970s, the unanticipated rise in inflation and the increase in effective environmental regulations altered the constraints on corporate decisionmaking. The impact of unanticipated inflation was universal across all firms in all sectors of the economy while the decisionmaking-related consequences of environmental regulations were more industry specific. Nevertheless, both events were exogenous to firms and affected the investment attitudes of managers.

Important issues in establishing a microeconomic framework for understanding productivity are what changes internal to the firm were made in response to these exogenous events, and how did these changes alter output per unit of inputs? The answer to this may be a first step toward understanding the microeconomic determinants of the productivity slowdown.

An interrelated model may include the following microeconomic and macroeconomic relationships. The possible reactions by managers to the volatile interest rates in the 1970s were varied. As uncertainty regarding opportunity costs grew within the financial sector of the economy, long-term investment decisions were altered. As a result, capital (net of depreciation) to labor ratios fell. Total R&D spending was reduced, and that spending still undertaken was redirected toward the short-term payoff end of the spectrum. The result of the altered investment patterns was, among other things, a decline in measured productivity.

A richer understanding of the causes, and thus the remedies, of productivity growth may come from a more microeconomic-oriented approach to the managerial decisionmaking process, especially within an atmosphere of cyclical demand management by the Government. As our understanding of the process improves, the macroeconomic to microeconomic linkages noted above may become more evident. Therefore, to answer the question, Where do we go from here?, the evidence appears to suggest that we go deeper into the microeconomic foundations of choice theory to better model and predict corporate productivity-related responses to our changing macroeconomic environment.

APPENDIX A
INTER-FIRM TECHNOLOGY FLOWS AND PRODUCTIVITY GROWTH

As part of an earlier study for the National Bureau of Standards by Link, data were gathered and analyzed on the percentage of a firm's technological advances that are induced through its own self-financed R&D activities, INDUCE. These data, for a sample of 302 R&D active firms within the manufacturing sector, reflect the 1976 subjective evaluation of the R&D vice-president of the role of R&D within the firm's overall strategy for acquiring new technologies.

These data are used here to calculate a measure of the total expenditures on technological advances, TECHADV, for each of these 302 sample firms. The assumption underlying this calculation is that the percentage of a firm's technological advances generated through its own R&D program can be approximated by the ratio of its R&D expenditures (as reported by Compustat), RD, to its total expenditures for technological advances: INDUCE= RD/TECHADV, or TECHADV=RD/INDUCE.

Also, given each of these sample firm's estimates of its total expenditures on technological advance (as calculated from the above equation), the dollar value of purchased innovations, PURCH, for each firm was calculated as (TECHADV–RD).

The relationship between induced and purchased innovations and measured TFP can be seen from a Cobb-Douglas approximation of eq (1) in the text with the stock of technical capital, T, included as a third factor input:

$$Q = A\, e^{lt}\, K^{a}\, L^{(1-a)}\, T^{b}$$

where l is a disembodied rate of growth parameter, t represents time, A is a constant of proportionality, and the parameters a and b are output elasticities. Constant returns to scale are assumed only with respect to the inputs K and L. Defining total factor productivity growth as in eq (4) in the text leads to

$$d\text{TFP}/\text{TFP} = l + p(I/Q)$$

where the parameter p is interpreted as the marginal product of technical capital, T, and I represents the net investments of the firm into that stock.

For estimation purposes, TFP is measured annually over the period 1975–79 as (ln Q–(a)ln L–(1–a)ln K). Then dTFP/TFP is calculated as the slope coefficient from a regression of TFP on trend for each firm. Data on Q, L, and K come from Compustat. The average share of labor, a, over the period 1975–79 is estimated as the total labor expenditures of the firm in 1977 per unit of 1977 sales. For those firms not reporting labor-related expenditures to Compustat, labor's share was computed using the firm's associated 1977 industry average annual wage, as reported by the Bureau of the Census, and the Compustat estimate of the firm's total 1977 employees.

Three versions of the productivity growth equation are estimated using ordinary least-squares analysis. In each version, an index of industry unionization, U, is also included (see Appendix B). Those data came from Freeman and Medoff [1979a].

In the first equation, the firm's investment into the stock of technical capital, I, is measured conventionally as the firm's total, self-financed, R&D expenditures, RD. The estimated results, with t-statistics in parentheses, are

$$\underset{}{d\text{TFP}/\text{TFP}} = \underset{(3.92)}{0.06} + \underset{(1.49)}{0.07}\ \text{RD}/Q - \underset{(-1.81)}{0.008}\ U; \qquad \text{R-square} = 0.34.$$

These results compare favorably with those of other researchers [Griliches, 1979]. The estimated coefficient on the R&D term is positive, but not significantly different from zero.

Alternatively, when I is measured as TECHADV, the estimated results are

$$d\text{TFP}/\text{TFP} = \underset{(-2.36)}{-0.27} + \underset{(2.32)}{0.12}\ \text{TECHADV}/Q - \underset{(-1.64)}{0.007}\ U; \qquad \text{R-square} = 0.41.$$

Here, the technology coefficient is significantly positive and noticeably larger than in the first estimated equation.

Finally, when induced and purchased investments are considered separately, the estimated results are

$$d\text{TFP}/\text{TFP} = \underset{(-2.75)}{-0.38} + \underset{(2.13)}{0.45}\ \text{RD}/Q + \underset{(3.02)}{0.25}\ \text{PURCH}/Q - \underset{(-1.68)}{0.007}\ \text{U}; \qquad \text{R-square} = 0.49.$$

These findings indicate that both sources of a firm's technological advances are important determinants of its measured productivity growth and that purchased technologies have the relatively greater and more significant impact. This conclusion complements the aggregate findings of Terleckyj [1974, 1980, 1982b] and Scherer [1982], and is the first microeconomic analysis on this topic.

APPENDIX B
UNIONS AND PRODUCTIVITY GROWTH

The Harvard studies testing the collective voice/institutional response view of unions utilize a Cobb-Douglas production function which allows for differences in union labor and nonunion labor. Following Brown and Medoff [1978], this function is written as

$$Q = A\,K^{a}\,(Ln + cLu)^{(1-a)}$$

where Q is output, K is the stock of physical capital, Lu and Ln are union and nonunion labor, the parameter a is the output elasticity of capital, and A is a constant of proportionality. The parameter c reflects differences in productivity between union and nonunion labor, (if $c>1$ then union labor is more productive than nonunion labor). For purposes of estimation, this relationship is approximated by

$$\ln(Q/L) = \ln A + (a)\ln(K/L) + (1-a)(c-1)\,P$$

where $L=(Ln+Lu)$ and $P=Lu/L$. Since $a<1$, if the estimated coefficient on P is positive, then $c>1$. Brown and Medoff [1978], and similar studies, report estimates of $c>1$.

The R&D studies discussed in the text all find the growth rate in total factor productivity to be negatively related to unionism; however, none of the studies cited in the Harvard school literature acknowledge these latter findings. The R&D studies assume a three factor Cobb-Douglas production function like the one estimated in Appendix A. Empirically, their model is

$$d\mathrm{TFP}/\mathrm{TFP} = l + p(I/Q) + hU$$

where p is interpreted as the marginal product of technical capital, T ($T=dI/dt$), and U is an appended variable measuring unionization.

If one rewrites the underlying production function for both the Harvard and the R&D studies to include both union and nonunion labor as well as the stock of technical capital, then the following equation results:

$$d\mathrm{TFP}/dt = l + (1-a)(c-1)\,dP/dt + p(I/Q).$$

This latter equation is estimated using data for 19 two-digit SIC manufacturing industries. The average annual rate of growth in total factor productivity between 1957 and 1973 comes from Gollop and Jorgenson [1980]. Unionization data on the proportion of production workers covered by collective bargaining agreements in each industry come from Freeman and Medoff [1979a] for 1958 and 1968–72. The variable dP/dt is the difference between the proportions covered in 1958 and 1968–72. R&D data to measure I/Q for 1958 are taken from Terleckjy [1974]. Also held constant in the estimating equation are three other variables: the industry four-firm concentration ratio for 1958 [Shepherd, 1979], the proportion of sales by each industry to nongovernmental buyers in 1958 [Terleckyj, 1974], and an index of cyclical instability in industry output [Terleckyj, 1974].

The least-squares regression results, with t-statistics in parentheses, corresponding to the R&D and union variables are in the following table:

Independent variables	Coefficients
dP/dt	–0.049 (–1.85)
I/Q	0.05 (0.66)
R-square	0.32

The coefficient on the unionization variable is negative and marginally significant. This finding is opposite from that predicted from the CV/IR argument. The coefficient on the R&D intensity variable is positive: its insignificance is not a surprise given the period over which the data relate [Link, 1981b]. Similar results to these were found when the Kendrick and Grossman [1982] data on TFP were used. While these empirical results are hardly conclusive, they do cast reasonable doubt on the strong conclusions reached in the Harvard studies.

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Productivity is one of the most important factors influencing our economic well-being. Productivity growth is essential to a higher standard of living and is vital to a sound economic and political environment. However, there has been a slowdown in the growth of productivity in the United States since the mid-1960s. This slowdown has caused concern among policy makers and researchers. Accordingly, several questions persist both in policy and academic circles. Why has productivity been slowing? and What can be done to reverse this trend?

The purpose of this report is to address broadly the first of these two questions by surveying and synthesizing the vast literature on the measurement and determinants of productivity. This review is intended to be a source document for those interested in the measurement and analysis of productivity growth.

The report is divided into five sections. In the first section, the importance of productivity growth on economic activity is discussed. In the second section, the so-called "facts" about patterns of measured productivity growth in the United States are presented. In the third section, the methods currently used for calculating productivity indices are summarized. In the fourth section, the literature related to the determinants of the productivity growth are reviewed. Finally, in the last section, some suggestions are made for future work in this area.

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