Information Technology and Economic Performance: Is Measuring Productivity Still Useful?

Sorin A. Bodea

Program on Information Resources Policy

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Sorin A. Bodea is a consultant with The Monitor Company. He has consulted widely on information systems and business management, and holds a doctorate in Information Systems and Business Management from Harvard University.

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Executive Summary

In the business environment of the 1990s productivity measurements are increasingly used to evaluate business performance, yet twenty years ago Denison and Kendrick were aware that measures of the impact on business of products such as those manufactured by IBM were fraught with difficulty. They calculated that this difficulty introduced only a 5 percent error in productivity estimates at what economists call the level of the economy of the United States. Two decades ago the service sector, where the use of IBM-like products was greatest, accounted for only 20 percent of the U.S. economy. Further, the low rate of technological change in manufacturing allowed productivity measures to evaluate business performance for the manufacturing sector fairly accurately.

In the business environment of the 1990s, however, productivity measures are only marginally relevant for measuring the performance of enterprises, industries, and the economy, for three reasons:

- Twenty years after the work of Denison and Kendrick, economists still have not satisfactorily addressed the limitations on measuring output they identified. These limitations lead to significant errors in evaluating the performance, for example, of the U.S. economy, because the service sector in the early 1990s represents 60 to 70 percent of the economic output, in contrast to 20 percent when Denison and Kendrick performed their analysis and because computers are now pervasive in services (and, although to a lesser extent, also in manufacturing). Using Denison and Kendrick's argument, for this output and input measurement limitation alone a 25 to 40 percent error in the productivity estimate at the level of the economy is likely.

- The concept of productivity was designed to measure the performance of companies, industries, and economies that did not experience high rates of technological change. Today such performance is evolving rapidly owing to the high rate of technological change in information technology. As a result, the productivity concept is no longer appropriate for measuring such performance.

- Historically, when a new technology is introduced, systems using it overlap with systems using the old technology, causing a temporary increase in the cost of doing business. This is the case in the 1990s, when systems based on electronic information technology overlap with those based on paper.

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The Impact of Information Technology and Systems on Business Performance: The Productivity Paradox—Introduction

Nothing is permanent but Change.
— Heraclitus, 500 B.C.

A man may love a paradox without losing his wit or his honesty.
— Walter Savage Landor, 1841

This report examines what economists have said about the problematic assumptions of the productivity concept—what was intended by their introduction of the concept and their critiques of the difficulties involved in using it to make performance evaluations. The studies referred to were conducted at the levels of individual firms, the industry, the sector, and the economy. The report endeavors to show the complexity of using the productivity concept to evaluate the performance impact of investing in information technology. Here, information technology and systems mean the systems and technology that support the business processes in manufacturing and services.

This critique is directed toward economists and managers who do not really understand the empirical limitations of the productivity concept. It may also be useful to economists and managers who, although aware of these limitations, hope that through careful analysis the empirical difficulties can be overcome.

1.1 Multiple Facets of the Concept of Performance: Productivity as a Measure of Performance

1.1.1 Common Sense Approach

In common sense terms, the notion of good performance means doing something with less or doing more of something with the same resources. The key to this understanding of performance rests on the meaning of "something." It could refer to a product or a service. As long as the product or service is well defined, one may consider the ability of another enterprise to deliver the same product or service; in this case, the performance comparison is reliable. If the product or service varies between two companies, the evaluator has to use arbitrary means to bring the two products or services to a common denominator—that is, a standard product or service—and only then can perform a comparison. If the evaluator cannot, the definition of performance is meaningless and therefore not useful.

When an enterprise considers its ability to make a product in relation to the ability of the same or a different enterprise to make the same product at some past time, the productivity comparison is time-based. As mentioned, this kind of comparison is revealing only if the product does not change over time or if two products made at different times are reduced to a common denominator. Both approaches offer difficulties: the likelihood that the product remains the same over time is small; the ability of the evaluator to bring two products to a common denominator usually requires some subjective assumptions or judgments.

1.1.2 Economists' Concepts of Productivity

Any change in the production process that results in an increase in the ratio of output to the factors of production—e.g., land, labor, or capital input—results in an increase in productivity. Each factor of production requires its own measure of productivity. Land productivity may be conveniently measured as production per unit area, labor productivity as output per working hour.

According to economists,[1] the relationship between changes in input and output over a given period of time takes two broad forms. These forms offer a criterion for distinguishing two classes of productivity—single and multifactor productivity[2]—and of corresponding measurements.

Regardless of the class of productivity to which economists refer, productivity in a given period of time (hour, month, quarter, or year) is expressed as the ratio of output over input in the period under consideration in relation to the ratio of output over input in an earlier (base)

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[1]Because this section is based on a review of the economic literature on the productivity concept and because most of the issues are so fundamental to the study of economics, any attribution of sources is difficult.

[2]The information contained in this section is based mostly, but not exclusively, on works of the economists at the U.S. Bureau of Labor Statistics and on general reference economic materials. Because of the fundamental nature of the concepts presented here, comments are difficult to assign to particular sources. Denison is the best single source; the second best source is Kendrick.

period of the same duration. Typically, productivity is expressed as an index with an arbitrary chosen base for comparison—for instance, the year 1977.

Productivity can also be used on a cross-section basis by considering, over a given time interval, the relative change in output over input between companies, industries, or economies. Economists commonly use productivity as a possible consideration in setting strategic directions and sometimes as a tool in economic forecasting. The productivity criterion may be also used by managers, to establish supplemental retribution and reward or to allocate resources.

Single-Factor Productivity. In the case of single-factor productivity, economists relate the output—goods defined as products and services—to only one input variable, which could be labor, capital, energy, and so forth. The "labor" used in productivity estimates usually consists of statistics of hours of employment paid or worked. Labor input data consist of establishment man-hours and, whenever possible, of plant man-hours or man-hours worked. The capital input can include plant, equipment, tools, materials, and other physical aids relevant to the production process.

For example, in defining the concept of labor-hour productivity (i.e., output per unit of labor expended), labor expended by definition includes the capital equipment and labor used and the factors affecting the efficiency and effectiveness with which capital equipment and labor are used (e.g., management and worker skills, energy and materials usage, technology level).[3] All the quantities involved in the labor-hour productivity formula are averaged over the finite interval chosen arbitrarily by the economist performing the analysis.

Multiple-Factor Productivity. Multiple-factor productivity—also called total-factor productivity or total productivity—is defined as output related to a variety of input variables combined in different ways to form the input term. The input term, called aggregate input, is the result of weighing individual inputs in some manner. Economists define multifactor productivity as:

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[3]Frumkin, 1990, 209.

$$\text{Multifactor Productivity} = \frac{\text{Output}}{\text{Input}} = \frac{\text{Real GNP (or Manufacturing GNP)}}{\text{Labor Hours and Capital Services}} = \text{Output per unit of Labor and Capital Services}\;,$$ [4]

where the labor hours and capital services input is a weighted "average of the dollar value of labor hours and of capital services from plant and equipment, land, and inventories. This leaves the sum total of all multifactor elements—worker and management skills, technology, etc.—as the items affecting the efficiency of labor and capital resources,"[5] not as input factors that directly affect productivity. Therefore, by excluding the multifactor elements, multifactor productivity does not explicitly include the *direct* influence of all the factors affecting the performance of an enterprise. Because multifactor productivity comprises directly and indirectly all the casual factors affecting performance, however, further analysis is required to determine the cause of the productivity trend observed and the relative importance of the different factors affecting performance.[6]

1.1.3 Relevance Attributed by Economists to Single- and Multiple-Factor Productivity

From a conceptual point of view, most economists would generally consider that

> Productivity is important because greater efficiency increases the quality of goods and services available for civilian and defense needs. The relationship of productivity to inflation, average weekly earnings, and employment is also important. When productivity increases rapidly, more goods and services [per worker] are available at lower prices because of lower production costs. As prices fall due to the increase in productivity, the consumer economies have the tendency to increase output to further enhance productivity. Higher productivity growth permits higher wages without increasing production costs and inflation.[7]

As a consequence, if productivity increases, the welfare of nations would improve.

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[4]Ibid., Frumkin, 1990, 210.

[5]Ibid.

[6]Ibid., 211.

[7]Ibid., 210.

In the economists' view, at the economy level productivity growth acts as an anti-inflationary agent. According to this view, the rate of productivity growth in the long run more or less matches the rate of increase in real average labor compensation and thus guards the economic system against inflation.

Productivity, measured in a meaningful way, can be conceived of as both an effect of economic and technological change and, through a feedback mechanism, as a cause of enhanced economic and technological change.[8] Productivity variations cannot exist without change. Change—economic, social, political, or change in labor or capital usage—is the key factor determining productivity variations. Kendrick observes:

> Changes [variations] of productivity in the course of time alter the pattern of use and cause the quantities of resources required in particular [production] uses to change. The resulting trends depend on several things. On the one hand, an increase in the productivity of, for instance, labor, since it means a decrease in labor requirements per unit of output, will tend to reduce the demand for labor. But it will also imply a cheapening of labor relative to the cost of other competing factors of production. Hence there will be a tendency to substitute labor for other factors. When labor costs represent a large fraction of total cost, a productivity increase will contribute toward a reduction in the price of the product, thereby expanding sales and with them the demand for labor. The net result will depend upon the total sum of all of these separate effects.[9]
>
> The change in a nation's overall labor productivity during any given interval represents the sum of changes in the major economic sectors and industries. Some sectors and industries move ahead more rapidly than the overall average while others may gain more slowly or even decline.[10]

The productivity level of an organization, sector, industry, or nation is determined by a series of factors that interact mutually to shape the efficiency or productivity, or both, of every organization. Such factors are adequate land, buildings, plant, and equipment, all intensively used and kept up to date by replacement; availability of suitably trained labor; adequate and steady supplies of raw material; efficient services, such as power, transport,

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[8]Basalla, 1988; Chandler, 1977; Womack et al., 1990.

[9]Kendrick, 1990, 918.

[10]Ibid., 917.

telecommunications, and so forth; the best managerial skills applied to the organization of production and the lowering of costs; markets capable of absorbing all the output; good relationships between employer and employees; an industrial climate favorable to expansion and confidence in the future; improvements in technology (more efficient machines), and the availability of advanced technology.

1.2 Empirical Limits of the Productivity Measure: What Issues Arise When an Attempt Is Made to Measure Productivity and What Do Productivity Economists Actually Achieve?

The difficulties of and limitations involved in obtaining productivity rates rest on problems encountered in evaluating the input and output variables required in any productivity estimate, regardless of the level at which the analysis is performed. Before detailing the difficulties of the productivity concept, some statements by eminent economists say on these issues are presented as well as what an eminent productivity-data-gathering agency says about the manner in which it collects its data.

According to Richard Nelson,[11] an eminent "evolutionary" economist, in reviewing the productivity approaches:

> [M]ost research by economists on productivity growth over time, and across countries, is *superficial and to some degree even misleading regarding the following matters*: the determinants of productivity at the level of the firm and of inter-firm differences; the processes that generate, screen, and spread new technologies; the influence of microeconomic conditions and institutions on productivity growth. [Emphasis added]

Economists Martin Baily and Robert Gordon examined the effect of multiple mismeasurement of productivity at industry and economy levels and concluded:

> Almost everywhere we look we find culprits, some of which imply only a misallocation of productivity growth at the industry level, but others of which contribute a partial explanation of the aggregate slowdown. Both types of mismeasurement are important. Misallocating output by industry makes it difficult to diagnose the causes of the slowdown.

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[11] 1981, 1029.

> Inferences about the importance of capital formation or education may be falsified by errors in industry input and output.[12]

Paul David, referring to the so-called productivity paradox, considers it to be a creation of productivity economists and born out of ignorance:

> Paradoxes, like other logical propositions, proceed from premises. Yet, in the case at hand, the empirical foundations for the broader of the two proposed renderings of the *productivity paradox* seem too shaky to justify treating the matter as more than superficially puzzling. In the first place it is debatable that the pace of realized technical progress actually has slowed. The pioneer discoverers of the total factor productivity residual were originally cautious about identifying it exclusively with technological change, much less with fruits of organized R&D. Abramovitz (1956) called it "a measure of our ignorance," and Jorgenson and Griliches (1967), doubting the conceptualization of sustained efficiency growth as something akin to manna falling (costlessly) from the heavens, *set out to show that the residual arose from errors in measuring inputs*. It says something about economics as a profession that the shrinkage, let alone the temporary disappearance of a quantity once thought to measure our ignorance, [the productivity residual] has now come to be viewed as a dire condition to which national leaders should attend.[13] [Emphasis added]

Responding to criticism by Denison and Mishel (1988) of the way the United States Bureau of Economic Analysis collects and analyzes its data, Baily and Gordon report:

> [The Bureau] argue[s] that *ad hoc* adjustments are essential given the weaknesses of the data on income by industry and the need to match total income with total expenditure. [Emphasis added][14]

1.2.1 Evaluating Output and Input in Physical Terms

Using physical units is a natural way of measuring output and input and, thus, of evaluating productivity. In the case of an enterprise producing one commodity, the output may be a count of units of the commodity produced per unit of labor input expressed as time (hour, week, month, year) or per unit of a material input expressed in physical terms.

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[12] 1988, 349.

[13] 1989, 3.

[14] 1988, 366.

Although very attractive and potentially relevant to measuring performance, this measure cannot be used very often and, if used, may have the disadvantage of not accounting for quality differences between two inputs or outputs of the same kind—say, labor hours and cars. Such unaccounted-for quality differences limit the usefulness of the cross-section (point-in-time) and the time-series productivity measures using physical units. The problem is more that of a time-series than of point-in-time productivity, because quality differences are more likely to be larger in the case of a time-series.

Compare the productivity of the Ford automobile division in 1991 to its productivity in 1916, using as a measure the number of cars produced per unit of time. The comparison is meaningless, because output has evolved tremendously. The nature of the materials used in construction in 1916 and the technical characteristics of a Ford Model T automobile produced then are very different from those of Ford models produced in 1991. Both are cars; in productivity assessments using physical units of measurement, they are treated the same way. But there is a world of difference between the nature of the materials in the Model T and those in the 1991 models. Further, the products, although both are cars, have very different characteristics.

1.2.2 Evaluating Output and Input in Commonly Accepted Units Other Than Physical Units

In most cases, firms, industries, and economies produce a heterogeneous mix of tens, hundreds, even thousands of goods and use a similar number of heterogeneous inputs. These goods may be products or services and, in many cases, the border between the product and the service may not be clearly defined. Using physical measures of productivity in this context is difficult. In the case in which physical data are not available, productivity economists quantify output and input terms in some commonly accepted units, such as money.[15]

In their attempt to ensure comparability among the year-to-year output and input evaluations, economists construct a price index, an index of "real output" or "real input," based on which they adjust for inflation and for other market forces that may be mistakenly regarded as output and input changes. Through such an index, productivity economists express the dollar value of input and output in money of a year arbitrarily chosen as a base for comparison (i.e., 1973 U.S. dollars).

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[15]Mark, 1983.

The "meaningful" construction of a price index requires significant amounts of marketing and sales information and involves approximations that may affect the final productivity evaluation. To assure that economists measure only the change in output and input and do not interpret fluctuations in price as changes in productivity, they attempt to keep the value-unit weights (i.e., price or cost per unit) fixed for the periods of productivity comparison.

A time-series comparison of productivity requires caution for many reasons. First, in calculating the dollar value of the output and input, a base year must be chosen and all output and input evaluations reported must reflect the currency of that particular base year. Second, a "proper" price index must be used, that is, that a large shift in the price of the output is not mistakenly identified as a productivity change.

Labor is the most common input variable for evaluating productivity, because input measurements are readily available, because labor is the most important value-adding factor in the production process, and because human beings have an understandable special interest in evaluating their contribution to transforming input into output. Whenever labor is relevant, the productivity measurement uses physical measurements of the labor input. According to Mark:

> To analyze the productive capacity of labor and the effects of changes in working hours, or in use for projections of manpower needs, an output per man-hour measure is most relevant. The most suitable unit of measure is man-hours worked. There are some ambiguities or differences of opinion on what to include, for example, standby time, coffee breaks, etc. In general, "hours worked" refers to the time spent at the place of employment, and therefore excludes hours paid for but used on leave for vacation, holiday, illness, accident, etc. In some cases total hours paid are utilized in the productivity measures because data on hours worked are not available.[16]

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[16]1983, 4.

1.2.3 Measurement Problems in Evaluating Productivity at the Levels of Industry and Economy

> [M]any factors influence productivity and complicate its measurement. At best, productivity measures incorporate an element of art as well as of science.[17]

The economic literature provides measures of labor productivity at the firm, industry, and national economy levels. Firm-level measures depend on the particulars of the organization under consideration. Industry measures combine data on products and services produced by a given industry. At the national level, every quarter the Bureau of Labor Statistics measures output per man hour for the private economy and for farm, nonfarm, and manufacturing sectors and publishes it in *Productivity, Wages, and Prices*. Regardless of the level of analysis, these data must be derived from input and output measures.

After the units for measuring output and input are chosen, two significant problems arise for measuring output and input and, therefore, for evaluating productivity. First, in many cases direct quantification of input and output is not possible and approximations and substitute measures must be used.[18] Second, little information has been collected specifically for past productivity measurements, and a time-series productivity comparison will necessarily rely on input and output data that may not be consistent with productivity data previously collected. The type of data collected in the past as well as the approximations and errors made in analyzing the data most probably differ from what are now used. Both problems stem from the impossibility of choosing output and input units that anyone can evaluate consistently and accurately (an impossibility pointed out in section 1.2.2).

It is an understatement to say that pointing out conceptual and empirical problems in measuring productivity is not original. Over the past four decades, much has been written on this subject, raising concern about the validity of the productivity measure at both the aggregate and industry levels. These problems are reiterated here, because the so-called productivity paradox may, in fact, reveal the questionable fundamentals of the concept and the sloppiness with which productivity evaluations are made. Input can be categorized as *labor input* and *capital input*.

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[17]Meyer and Scott Morton, 1975, 497.

[18]Mark, 1983, 4.

Labor Input: Quality issues.[19] Standard labor-productivity evaluations assume that the difference between the value of an hour of labor of a college-educated worker and that of a worker who is a high-school graduate, intensity of work during the labor hour, and time at work relative to time working average out as small random effects. In mid-1989, for example, the Bureau of Labor Statistics changed the way to report labor hours from hours paid to hours at work. This change improves productivity estimates, because it excludes labor input overestimates caused by accounting for paid vacation and sick leave as hours at work. However, the measurement still includes the strong assumption that the worker actually works while present at work. This assumption leads to an overestimate of labor input and, thus, an underestimate of productivity. Omitting paid vacation and sick leave is good if the measure is intended to reflect production efficiency, but bad if the measure is assessing effectiveness.

The productivity measure may or may not try to take into consideration the quality of man-hour work. Hours worked by workers more highly paid may, thus, be given more weight than those worked by lower paid workers. Further, as pointed out by Meyer and Scott Morton, the quality of "man-hours worked is not so unambiguous a term as it may at first seem,"[20] because the quality of man hours has improved over time. How meaningful is the average labor-hours figure if the quality of hours worked is not differentiated, and, therefore, how meaningful is the productivity evaluation resulting from it? Once such a gross figure is set, is it possible to make inferences about the firm's efficiency and effectiveness beyond a precise but inaccurate statement?

Data coverage.[21] Data gathered to date do not cover all categories of labor. When data are not available, surveys are conducted and the results extrapolated to the entire labor category. The data consider only average number of hours at work in a particular week of the month; the result is extrapolated to the entire month. These factors result in incorrect data in every case in which something unusual happens within the period over which extrapolation was applied.

Regarding the problems in acquiring (labor) input data:

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[19]Mark, 1983.

[20]1975, 498.

[21]Mark, 1983.

> [T]here are several data gaps in the available measures. They relate to changes in the composition of labor (the quality), groups of the work force for which data are lacking or is incomplete, the relationship of output to the time of research development and other workers whose activities are not directed to current production, and finally, the absence of adequate hours worked data on a comprehensive basis.[22]

Capital input. Capital input refers to the real value of the stock of capital facilities and equipment.

> Capital stock estimates include the constant dollar value of structures, plants, and equipment currently available for production. These estimates may also take into account the value of land, inventories, and working capital.... There are different ways of measuring the stock of capital; for example they may be gross or net. Net stock estimates are derived by depreciating assets (and there are various methods of depreciation). Gross stock estimates are derived by retaining assets at their full value until they are retired from use.[23]

The main drawback in using capital-stock productivity is that it does not account for fluctuations in the intensity of use of capital capacity, while using the net-stock method, the use of depreciation methods adds significant subjectivity to the productivity evaluations:

> The cost of capital is itself made up of the price of investment goods, the cost of financing the investment (debt and equity), the rate of depreciation and the rate of tax.[24]

Inaccuracies in these factors have an impact on the productivity and relevance of capital evaluations. The price of capital goods decreases, in some cases significantly, over time. It is difficult to measure changes in the quantity of investment in industries with rapidly changing technologies. Some studies argue that the "price of a PC [personal computer] has fallen by an average of 25% a year since 1982."[25]

The capital-productivity measure preferred by economists is the flow of capital services. This measure, they claim, reflects the fluctuations in usage and efficiency of capital and evaluates their effects on output and, thus, on productivity. This measure is difficult to derive, because it weights the aggregate hours of capital use by the rental value of each capital item,

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[22]Mark, 1983, 6.

[23]Ibid., 4.

[24]"Capital Punishment," *The Economist*, May 18, 1991, 90.

[25]Ibid.

measures not readily available. Depreciation is a commonly used measure of flow of capital services and, as mentioned above, produces significant uncertainties in productivity evaluations.

Measuring the productivity of capital requires a more sophisticated choice of input variables than measuring the productivity of labor. Capital is a variable hard to estimate because of the devaluation of the invested capital with time. Capital devaluation strongly depends on the level of technology of the original investment and on the frequency with which technology is introduced, the type of capital employed (i.e., plant, machinery, tools, other equipment), and on the organization's management. Capital input evaluation strongly depends on the depreciation rate used. The choice of this rate may significantly influence the productivity of capital and multifactor productivity evaluations.

The depreciation method chosen has a critical influence on evaluation of input and thus on productivity. In practice, differences of depreciation methods may lead to fundamental differences in productivity evaluations. For example, in a productivity evaluation in which the capital input is assumed to be depreciated by 10 percent more than by some other depreciation method, and on the assumption that everything else remains fixed, an overestimate would be registered of productivity change relative to the base year and relative to the other measure, of 11 percent. The use of different depreciation rates is a plausible hypothesis in explaining the large differences between U.S. and Japanese organizational efficiency estimates.

Since 1986 all U.S. labor and multifactor productivity evaluations have used a price index in evaluating capital costs, which decreases the price of computing power (not the list price of hardware or software) by 14 percent per year for the period 1969 to 1987. The introduction of such an index may, in practice, change a significant decrease in productivity during 1969 to 1987 into a significant increase. There is no doubt that the price of computer power decreased significantly over the period, but the 14 percent mark could easily be called into question. The relevance of using computer power in productivity evaluations could also be inquired into. Both the computing power and the price of the computer (PC, workstation, mainframe) and of software associated with it should be used in productivity evaluations. The use of one figure or the other provides a distorted picture of the computer's contribution to productivity. Consider the example of desktop and laptop computers, both delivering similar computer power and having similar characteristics except for price. The prices of laptops are two or three times that of desktop models. Were productivity-paradox economists to include both computer power and the market value of the computer in their price index, they would have to weight the computing power and the computer value. Without that weighting, value cannot be dealt with acceptably.

Denison[26] expresses disapproval of the computer-related price index and argues that it treats capital—the result of savings and investment—and innovation—the result of progress in knowledge—bundled together. Denison also opposes this index, because it leads to inconsistencies in the way other measurements that enter the industry and national accounts are made. In other words, if the computer-price index is used to account for quality changes, then the same should be done with many other inputs that undergo significant quality changes. Baily and Gordon explain:

> The [national income and product accounts] measure real output, investment, and capital in units of 1982 dollars. The autos or loaves of bread or computers produced in 1987 are valued in real GNP based upon the price paid for these items in 1982. *Even if we accept that the price indexes that are used do a good job at adjusting for changes in the nature of autos or bread or computers over time, this procedure is still flawed because in fact relative prices have changed.* The marginal utility of consumer goods was not the same in 1987 as in 1982. Nor was the marginal product of investment goods. The effect of changing relative prices is not random. Goods where the technological progress has been rapid have falling relative prices and increasing sales volumes. The use of base-period prices overweighs the growth of these dynamic commodities in years following the base year and underweights them in years preceding the base year. ... In the case of the computer, the distortion of real output created by the declining relative price is likely to be important because of the rapidity of the decline. [Emphasis added][27]

To address these and other evaluation problems, productivity economists have come up with other indexes, which, however, do not satisfactorily solve the problem of rapid decay in the price-to-performance ratio over time.[28] This statement is easily sustained by the variations in the obtained results. David Romer, referring to price indexes, comments:

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[26]1989, 10.

[27]1988, 386.

[28]*Yellow Pages in the 1990s*, Figure 4.3.

> In the good old days, productivity data were like most other standard economic time series: they were quite useful *as long as you did not make the mistake of thinking hard about where they come from*. In the case of price indexes, for example, if one were to set out to construct an economically appropriate price index, *one would soon find that there were deep problems* involving the absence of any representative consumer in the economy, the treatment of new commodities, the treatment of quality changes, and so on, that probably made the construction of a *valid* price index impossible.[29]

Some economists still use such indexes to adjust for all kinds of real economic phenomena, thereby affecting the data collection process and influencing the results of the productivity analysis. Ultimately, the certainty with which the economists draw conclusions from these data appears at times too strong.

The GNP or the total labor hours worked at the economy level are figures that hide this complexity and may potentially include an accumulated error significant enough to lead to a meaningless result. Baily and Gordon (1988), in their treatment of the relationship between the investment in computer power and productivity, give a broad sense of this complexity with supporting examples.

To account for variations in certain economic phenomena, such as inflation, economists use price-deflation techniques. When output is not physically quantifiable it is expressed in "constant dollars" of the base year chosen for comparison, using price indexes. This output measure is dependent on the price criteria used.

Capital stock measures are

> the most difficult and complex measures to derive. They contain highly differentiated elements, and to express this differentiated stock in physical terms requires adjusting dollar values of assets for price change.[30]

When constructing price indexes, adjusting for quality improvements in products is difficult because of the introduction of new equipment. It is also difficult to account for savings in inputs utilization:

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[29]Comments to Baily and Gordon, 1988, 425.

[30]Mark, 1983, 7.

> There is some question as to whether improvements in the quality of new capital should be incorporated in the capital stock measures or treated as a productivity increase. ... [T]otal factor measures as currently presented are not consistent with their treatment of capital and labor. In general, labor refers to actual man-hours whereas capital refers to available stock not taking into account varying levels of utilization.[31]

Consider, for example, the problems arising from the changing nature of investment—the evaluation of information technology capital. The rapid decline in the unit cost of information technology hardware might distort some of the factors that enter into the productivity evaluation. How is information technology capital amortized? If information technology capital-replacement cost is used, then the value of information technology capital drops dramatically from year to year. With the drop in hardware costs, less capital is needed to replace information technology equipment. Because the value of the hardware drops so dramatically, the enterprise whose productivity is evaluated has to include in production expenses an increment of equal magnitude with the relative price drop of the unit of hardware. Economists amortize information technology capital using the computer-price index. That index alone may or may not produce large enough errors to compensate for the productivity increase caused by the introduction of information technology and, thus, alone may or may not account for the productivity paradox.

Capturing the capital devaluation over time through price indexes is subject to significant errors. Consider the method productivity economists use to evaluate changes in computer capital over time. Roughly speaking, the cost of computing power decreased from $50,000 per million instructions per second (MIPS) in 1981 to $5,000 per MIPS in 1985 to $50 per MIPS in 1991.[32] If a company invested in computer technology in 1985 and later wanted to evaluate the resulting changes in productivity from 1985 to 1991, on the assumption (not insignificant) that the labor input remains constant, multifactor productivity would depend significantly on the way the capital stock is calculated.

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[31]Ibid.

[32]*Yellow Pages in the 1990s*, Figure 4.3. The absolute numbers may not mean much, but the order of magnitude decreases are probably valid reflections of reality.

Further, because the capital stock does not take into account fluctuations in the intensity of use of information technology stock, the productivity measure is irrelevant in determining the impact of the information technology investment on business performance. The information technology equipment may well be idle 40 percent of the time and that the organization overinvested. As the cost of computing power drops from $1,000 per MIPS to one cent per MIPS, i.e., when computer power becomes a commodity, idle time, as well as the capital-stock method chosen to evaluate productivity, will be relatively unimportant, because changes in the price of computing will have a significantly smaller effect on the productivity measure. Information technology capital stock will be so cheap that even relatively large fluctuations in its price around that low value will have little impact on productivity evaluations.

Evaluating output. Lack of appropriate measurement units, important in manufacturing, is even more acute in services. At the firm level, service companies such as McDonald's, Super Cuts, and Mrs. Fields' Cookies can find physical measures of productivity, e.g., number of hamburgers sold per day, number of haircuts per hour, number of cookies sold per day, respectively. At the industry level, however, few physical variables exist on which data are or can be gathered. Economists appeal to money as the most convenient means of evaluating output and input.

At the industry level, some economists argue, the errors are greater than at the national level, because they are less likely to be cancelled out:

> Three major problems are encountered in developing measures of output from available data for industry productivity indexes. First, for many industries the appropriate detailed product data are not available. Second, there is the well known quality change problem which results from the development of new products and the changing specifications of the existing products. Third, appropriate weights are often not available for deriving the desired industry measure.[33]

These weights surface in the derivation of industry-output measures from the economy-level measures. The separation techniques involve using separation weights. Denison (1989) considers the errors in allocating the real business gross domestic product (GDP) by industry when he makes the point that the industry-level analysis cannot be relied on.

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[33]Mark, 1983, 6.

Quality and data coverage. The impossibility of distinguishing quality differences among the same productivity variable adds to uncertainties in the productivity evaluations. If the measure is cars produced per unit time or passenger mile in a given time interval, productivity evaluations need to make adjustments for differences in the quality of the cars or length of trip.

It seems difficult, if not impossible, to evaluate the extent to which economists' correction techniques affect the data. Regarding the national figures:

> Separate estimates are developed for the business sector, the non farm business sector, and the total of all manufacturing industries. They are based on real gross national product data *adjusted* to eliminate those components of the GNP that would cause an inappropriate measure of productivity because (a) the output indicator used is also an input measure or (b) the output and input data are inconsistent.[34] [Emphasis added]

Cronin et al. (1991), for example, found a 3.3 percent average increase in productivity in the telecommunications industry over the period 1963 to 1982, while the overall economic productivity of the U.S. economy increased on average only by 0.4 percent per year. This finding might not be so robust as it seems. The authors recognize that productivity "improvements occur when the same output can be produced using fewer inputs."[35] The 1982 output, however, is qualitatively significantly different from that of 1963.

In the case of the productivity of a firm, industry, or economy, year-to-year changes in price are somehow removed from the time-series productivity comparisons by using a price index that, some economists claim, removes price fluctuations from output and input so the changes in aggregate output reflect changes in physical volumes of goods produced. The problem with these indexes is that in productivity evaluations price fluctuations may be interpreted as fluctuations in the efficiency and effectiveness of an enterprise, industry, or economy.

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[34] Frumkin, 1990, 208.

[35] Cronin et al., 1991, 4.

It has long been recognized in the economic literature that indexes do not sufficiently take into account changes in the quality of the variable to which they are related.[36] For instance, the medical-service index does not account for changes in the quality of the medical services measured.

At the aggregate level the output used is real GDP, defined as the gross national product (GNP) minus net foreign income and minus government net pay to its employees. The resulting GDP figure is adjusted by about eight hundred different commodity deflators, which customarily do not account appropriately for product quality improvements, product price immediately after introduction to the market, or for inflation.[37]

Most productivity evaluations are performed by using only one method of calculation, and when two different bureaus perform these evaluations it is not unusual to find statistical discrepancies of a few tenths of a percent. "That discrepancy, however, is what remains after BEA [the Bureau of Economic Analysis] has done its best to bring about consistency."[38] On the basis of comparisons of results of data set analysis with other agencies, BEA adjusts its initial analysis assumptions so that the discrepancy in the results of analysis exists but will not be truly significant.

Discrepancies between the degree of convergence of output and input add to the uncertainties in the data. There are cases when the input and output measures are not compatible. For example, in the real estate industry, the national income output includes a term called rent for home ownership for which there is no corresponding labor input term.

Some output terms of services cannot be estimated directly and at times are estimated by approximations using changes in input. Such measurements are not particularly suitable for productivity measurements. They produce an underestimate or overestimate of both the productivity of the service sector and the economic sectors it affects and results in a downward or upward bias of productivity at the economy level.

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[36]Meyer and Gomez-Ibanez, 1980.

[37]Baily and Gordon, 1988.

[38]Baily and Gordon, 1988, 359.

In the service industries the measures derived from national accounts are particularly subject to error:

> Measuring output in the service activities is difficult because of the absence of a directly quantifiable entity which describes a unit of service. Consequently, various substitute indicators are utilized in the national accounts. These usually involve the use of some "price" index for deflating the value of the service activities or the use of an employment index to develop trends in producers of services.[39]

Both the labor and the multifactor productivity measures use exaggerated deflators. Baily and Gordon capture this gracefully:

> The potential for error is much greater for *real* GDP by industry, however, than for the current-dollar values. Deflating value added requires estimates of both prices and quantities of intermediate goods and services. The [national income and product accounts] were set up to measure final goods and services production, rather than intermediate production, and the data base reflects this. In practice the survey coverage of prices of intermediate goods is quite limited, and the quantities of purchases and of intermediate goods are not known from year to year, so *extrapolations* are made from census years.[40] [Emphasis added]

In addition, since the early 1980s, investments in information technology and systems allowed the price of intermediate goods and services to fluctuate at high rates, which make suspect the price extrapolations and, as a consequence, the productivity evaluations using price deflators. The productivity economist thus is forced to make hundreds of approximations based on measurements whose own error margins are not really known, that is, approximations that yield productivity error variations of a few fractions of a percent.

Misallocation issues. To obtain the real GNP by sector or by industry, economists use arbitrary separation techniques, in which the main issue is the separation weights. Cronin et al. first compute the "actual improvement in the economy's overall efficiency over time."[41] From this they estimate the proportion "attributable to improvements in telecommunications efficiency." Two possible sources of problems can be foreseen in following this approach.

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[39]Mark, 1983, 5.

[40]Baily and Gordon, 1988, 360.

[41]Cronin et al., 1991, 7.

First, the authors use the GNP figure as a measure of output and do not consider the quality issues in the nature of output that underlie a certain GNP figure. To ask what the cost of generating the GNP of the comparison year would be with the technology available during the base year might not be sensible because making the products that determine the GNP in the comparison year would be technologically impossible during the base year. If the comparison is made between two consecutive years, the error introduced by this approach would be insignificant. But making the comparison between, say, 1982 and 1963, however, would be less appropriate. Second, the separation techniques used allow the authors to label output from other industries as telecommunications output, which may lead to mismeasurement of telecommunications productivity.

Systemic issues. Productivity measures lack relevance in the 1990s business context, mostly because of systemic effects. Problems in productivity measures occur because the benefits of innovations in businesses are, in most cases, distributed among other firms in the business system of which the firm making the innovation is a part. As an example, consider the relationship between the increase in effectiveness of fertilizers produced by the chemical industry and the productivity of the farming industry.[42]

Those performing the analysis must pay particular attention to the characteristics of the systems and to the choice of quantifiable variables.

According to the Bureau of Labor Statistics:

> industry output per employee hour input measures...often do not reflect adequately changes in the degree of plant integration and specialization.[43]

This statement implies that the productivity measure does not take into account two of the most important elements of business life in the 1990s: quality improvements and plant integration. Instead, the measure focuses on quantity, which is no longer the most important feature given that increasingly successful businesses use lean (i.e., quality-oriented) production methods.[44]

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[42]Martin L. Ernst, Program on Information Resources Policy, Harvard University, personal communication, January 1992.

[43]1977, 9. I am indebted to Ernst for this reference.

[44]Womack, 1990.

In addition, since the 1960s the world has experienced major disruptions in business caused by the emergence of a new way of making things—that lean production system that replaces obsolete mass production and relies heavily on both systemic improvements and information technology. It also experienced an extensive diffusion of those lean production methods and their corresponding flat organizational structures. When interconnected systems are evaluated on the basis of productivity, measured increases may not properly be attributed properly to the element of the system that contributed to the increase.

Time averaging. By definition, the concept of productivity represents an average over an arbitrary finite period of time. Choosing a different time interval for averaging may result in different productivity measures. In a volatile business environment, such as the 1980s, this generic problem is accentuated, because changes take place rapidly owing to significant alterations in the nature of products and the means of production, mostly related to investments in information technology. The influence of time averaging on productivity evaluations and the subjectivity with which the finite time interval is chosen by economists was captured by Kendrick (1990):

> Because quarterly movements of productivity are heavily influenced by cyclical changes in output, short term changes in productivity mainly reflect cyclical changes in economic activity rather than basic changes in efficiency. Such basic changes are discerned by examining trends over at least several quarters that have relatively *steady rates* of economic growth.

1.3 Conclusion

The foregoing analysis underscores a host of important and puzzling questions long recognized by economists engaged in productivity studies. Which method of capital-stock evaluation is used by firms or industries that claim no increase or even claim a decline of productivity from information technology? If they use the gross-stock method, information technology stock valuation may be one of the reasons productivity measures obtain a decrease in productivity. The stock-valuation problem, combined with overinvestment in information technology, may be significant enough to explain the apparently discouraging results of early 1990s productivity estimates attributed to information technology. How is inventory stock treated in productivity measurements? Can changes in input and output be attributed to the correct source in an economy highly integrated and in which the interorganizational boundaries are continually more blurred?[45]

As the natures of input, output, and production process evolved over time, so did the relevance of the productivity concept. With the exception of a few technological discontinuities, such as those brought about by the steam engine, electricity, and the computer, it is unclear whether the evolution in input, output, and production process was continuous or not.[46] Once steam-powered machines were introduced into the production process, the price and technical characteristics of the machines changed relatively smoothly over the following decades. Similar smooth changes occurred in the labor requirements for using these machines and in the characteristics of their output. In this environment of relatively stable characteristics, the classical definition of productivity was appropriate, i.e., capital-stock devaluated smoothly.

It is not unreasonable to consider, as many of the authors on the issue do, that the major shift in the performance-to-cost ratio of information technology was not properly accounted for in the productivity estimates. Also, that shift, in combination with an emphasis on product quality and complexity and with being at the beginning of the information-technology-diffusion S-curve, may account for economists' inability to see significant changes in productivity at industry and national levels. The computer, like the steam engine, fundamentally altered the production process. In the decades that followed its industrial debut, however, the computer increased sharply in power, and its price dropped by orders of magnitude since the 1980s. During this period, the nature of the input, the output, and the production process changed dramatically, making the conventional concept of productivity difficult if not impossible to use to gain insight into business performance.

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[45]Consider the example of the systemic issues in the financial services industry. Do automatic teller machines (ATMs) make banks more productive or do they make the banks' customers more productive, or both?

[46]Basalla, 1988; Kendrick, 1990.

Two

Why the Benefits of Investments in Information Systems and Technology Are Not Apparent as an Impact on Business Performance?

Many authors[1] have contributed to an understanding of the broad changes information technology has brought to society at large and to economic enterprises, although there is no agreement on what these changes actually are. On the basis of some rather limited case studies, authors such as Zuboff (1988) and Strassmann (1985) have generalized about the impact of information technology on work and power. Although these authors gained useful insights from a few case studies, they extrapolate they extrapolate from them too easily. Zuboff promotes the inferences she draws about workers' resistance to changes owing to the introduction of information technology in pulp mills as general, revolutionary issues, yet many of them are case-specific adaptation issues. These issues are also related to the characteristics of the human-machine interface in the paper mills Zuboff studied. Many of Strassmann's statements can probably be contradicted by investigation.

The trend in the 1990s of the impact of information technology and systems was captured by Walter Wriston, the former chairman of Citibank:

> The massive amounts of information that move over the network, combined with the speed of transmission...[are] changing the relationship between the government and the citizen; between one sovereign government and another; between corporations and regulators. ... Intellectual capital is becoming relatively more important than physical capital. Indeed the new source of wealth is not material, it is information, knowledge applied to work to create value. The pursuit of wealth is now largely the pursuit for information, and the application of information to the means of production.[2]

The problems in applying the concept of productivity to manufacturing are magnified significantly when it is applied to the service sector. The fundamental problem with productivity in services is defining output and input in terms of physical quantities. In many

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[1]See part **One**, note 2, and the selected bibliography at the end of the paper.

[2]1992, xi.

cases the ultimate measure for evaluating output and input is money, an evaluation fraught with difficulties.

Investments in information technology contribute to the quality of business life and to the quality of time spent at the work place. There are many specific success stories, including the old favorites: Benetton, SABRE, McKesson, APOLLO; retailing (books, drugs, supermarket POS), banks and automatic teller machines (ATMs), and, not least, Wal-Mart. Stories of specific failures can also be found, although naturally firms do not like to talk about them. It is hard to imagine that once accustomed to information technology and systems, one could do without them. Think of the use of information technology by airlines, hotels, brokerage houses, car rentals, E-mail, banks, and manufacturing. A trip to an Eastern European country—in most of which the use of information systems is limited to a few organizations—reveals the difference information technology makes to life in the U.S.

Experience in the U.S. shows that the power to employ technology effectively and efficiently lies in the hands of those using it. A company may decide to replace dumb terminals on each employee's desk with desktop computers. The decision may be justified by the computing needs of the employees, and the investment can pay off handsomely. If the employee's needs are limited to a dumb terminal, however, then the desktop computer is likely to be used only as a dumb terminal. The effect shown in productivity evaluations will be a decrease in multifactor productivity when, in fact, the performance of the employees does not change.

There are a number of uncontested benefits derived from investing in information technology and systems.

- A reduction in the length of the product cycle, which means that the enterprise can make the same product in a shorter period of time. The change is not clearly reflected in sequential comparisons (year to year) in productivity.

- Information technology improves accuracy, which translates into reducing delays and expenses, upgrading the use of resources, and increasing their productivity.

- Information technology allows dispersed firms to operate and benefit from economies of scale, because information can flow efficiently and almost as quickly in a multisite organization as in an organization at one site, as is the case of "Mrs. Fields' Cookies."[3]

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[3]*Mrs. Fields' Cookies*, 1989.

• Information technology can help increase the information accessibility within an organization and between the organization and its customers and suppliers. The accessibility of information contributes to a reduced number of intermediaries between the organization and its customers and suppliers. Fewer intermediaries may involve some labor reductions, and although workers may be replaced with fewer but more highly qualified workers, in the end, this does not really amount to saving labor costs. It does, however, improve business performance because of improved relations with customers and suppliers. Banks, for example, introduced ATMs, significantly reducing the number of tellers who interact with customers, but then had to create new divisions to serve the ATMs. If the benefit of introducing ATMs accrues to the customer, it is not reflected in the productivity of the bank or the banking industry and may be buried in national productivity figures.

The dramatic product and process innovations that occurred in information technology since the early 1960s are not reflected in conventional productivity evaluations, because their impact was on quality improvements in the product and on an increase in the efficiency of the system of which the firm is part, effects not readily reflected in the simple ratios used in many productivity analyses. As for the impact of computer investments on manufacturing productivity, managers report significant improvements. Reporting on why computer investments do not seem not to appear in white-collar worker productivity evaluations, Baily and Gordon make the following point:

> dramatic changes in technology can make productivity worse before it gets better. People have to be retrained, and companies have to learn to use the new technology efficiently.[4]

Their hypothesis, which has its origin in historical lessons learned from the introduction of the steam engine, the telegraph, and electricity, may have been proved in the years since it was asserted. In the six years since Baily and Gordon wrote the paper, managers seem to have realized that investments in computers did not pay off to the extent they could, so that managers are very receptive to organizational reengineering.[5] The popularity, if not the validity, of the need to reengineer to achieve the benefits of information technology investments is attested to by the present large market growth for information technology consulting firms.

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[4]Baily and Gordon, 1988, 427.

[5]Champy and Hammer, 1993.

The need for reengineering is not surprising, because whenever a new technology such as information technology has developed it had to coexist for a while with the old technology, thus significantly increasing the cost of doing business during the period of transition. Only through reengineering could new systems be created to make effective and efficient use of the new technology while eliminating the outdated one from the business environment.

Martin L. Ernst, wondering what happened to that expected gain in productivity, synthesized his conclusions more than a decade ago.[6] Ernst identified a series of possible options classified here into three main categories: (*i*) real gains in the productivity of the firm making the investment in the information system and technology; (*ii*) gains not realized by the firm making the investment but by its customers or by other parts of the firm; and (*iii*) real losses in productivity. The productivity increase may have been passed to the bottom line in the form of a larger return on investments, as in some successful cases, among them accounting systems, marketing systems, and design and engineering systems. The productivity increase may have been passed on to the customer in the form of faster, cheaper, and better service or to other parts of the business system of which the organization is a part. Examples, among others, are ATMs, airline reservation systems, brokerage-house systems, electronic-data interchange systems between wholesalers and retailers. In other cases, the investment in information systems and technology of one firm benefited its suppliers, which can plan their production just-in-time and thus significantly reduce their inventory.[7] In this category are ocean freight containerization and meat-packing houses that started to package smaller cuts instead of shipping full or partial carcasses.

Finally, gains in productivity may be losses to internal and external bureaucracy. Many examples show that gains in productivity can easily be wasted within an organization by adding unnecessary external reporting requirements, by superimposing internal information systems on older ones, or by creating the monumental systems projects such as those that came into vogue in the mid-1980s in many management information systems functions. The external bureaucracy—most commonly, government bureaucrats who increased the complexity of the Internal Revenue Service and of the data required from businesses—may act as a sink for productivity gains.

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[6]1980. Personal communication, January 1992.

[7]Ernst, 1980; Womack, 1990.

In some organizations management may acquire an information technology overcapacity. It is also common in U.S. organizations for each manager to own a laptop, although many seldom use theirs. Many organizations have significantly more laser printers than they need. This overcapacity adds to the cost of doing business and does not necessarily compensate in terms of improved efficiency and effectiveness of the employee, although, with diminishing price and experience, they may.

Recently, some have claimed there is no longer a productivity paradox, that information technology and systems have begun to pay off. If that is true, we may see positive results, because there is a gap in time between investments in information systems and their effects. This gap may be explained by the diffusion of technology theory, that is, we are still at the early stages in the diffusion of information technology and systems and information technology will continue to spread.

Hardware and software costs are decreasing rapidly and therefore make up a smaller portion of the total costs of introducing information systems into an organization. As a result, technology-cost details matter less than organizational costs related to the integration of information technology and systems within the firm.[8]

If Scott Morton's statement—that "evidence at the aggregate level does not indicate any improvements in productivity or profitability"[9] due to the introduction of information technology—is accepted, and *if* productivity measurements are assumed to be meaningful, then the following paraphrase of his synthesis of the questions and arguments of those who take productivity evaluations seriously may clarify why an increase in productivity may be associated with investments in information technology.

First, might it be that productivity increased but that the increase is not readily seen, because it is not measurable, or because there are not sufficient (or accurate) data available, or because a significant time shift exists between implementation of an information technology project and its harvest?

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[8]Ernst, personal communication, January 1992.

[9]1991, 19.

Second, is this increase in productivity allocated (mostly) to the customer (disguised as price a decrease, product variety, quality improvement, time savings) or to the institution making the investment in information technology? In the case of the banking industry, for example, the investment of billions of dollars in information technology did not result in higher profits for banks—thus, it is unlikely that bank productivity increased; the productivity gain was attributed to the banks' customers. In other cases, the productivity increase is distributed between the organization and its customers (e.g., American Airlines' SABRE reservation systems, a distributor placing order-entry terminals in small pharmacies).

Third, might the rewards of information technology be harvested in intangibles, such as quality of life, easier ways of performing tasks, or availability of information and the power that may be derived from information technology?

Fourth, although information technology may increase performance, might the benefits of the increase be reallocated into expanding product features, enhancing the quantity of information transmitted among organizational levels or reported to the government, or into increasing the frequency with which certain tasks are performed? The expansion of product features, flux of information, and frequency of performing tasks may not increase the organization's output-input ratio but decrease it.

Fifth, might use of additional information provided by information technology not be to the firm's advantage and thus not contribute to its relevant output? For instance, with the help of computers, many firms close books at the end of the day, rather than at the end of the month, as they used to. No real gains may accrue from doing so, however, and closing the books at the end of the day involves more work. Although information technology may save time, might that time simply be left for activities that do not result in a better financial performance of the organization?

Finally, returning to the common sense management view of performance, information technology may not increase productivity as managers and economists understand the concept. Many organizations cannot identify the contribution of information technology to their bottom line. Investments in areas of low payoff, automation of old practices, and implementation of information technology without real changes in the organizational way of getting things done may be some reasons why information technology may not seem to pay off (at least, not immediately).[10] Many past investments concentrated on generating information, not on how to use the acquired information to improve performance:

> One root cause for the lack of information technology impact on the economic performance of organizations is an organization's unwillingness to invest heavily and early enough in human resources. Changing the way people work can be extremely threatening and therefore takes a great deal of investment. There must be investment in new skills, in psychological ownership of the change process, and in a safety net under the employee so that there is no fear of taking prudent risks.[11]

Quality changes in the product and its complexity should be considered in evaluating the output appropriately, because producing higher quality or increasing product complexity involves development and engineering costs that add to the input side. If quality and complexity are not taken into account, output will be underestimated and productivity will be lower.

The quality of jobs involving information technology has changed and may impact productivity evaluations. In some cases jobs now require better skills and education than they did a before 1990, and workers' activities have become information intensive, in the sense that workers are required to know more about the process and the product. This requirement may be due simply to the diffusion of lean production methods, which are based on team work, and to the investments in information technology, which, particularly in the early phases of technology diffusion, require mastering significantly new skills.

In the world of information technology and systems there are two kinds of believers. On one side are those who believe that information technology is the best thing ever for business and for humankind and who point to Mrs. Fields' Cookies, the American Airlines reservation system, and other information technology applications that on the surface seem successful. On the other side are those who cite examples that show information technology as a "competitive

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[10]Scott Morton, 1991.

[11]Ibid., 21.

burden"[12] with a "puny payoff."[13] A candid, impartial researcher might have a hard time deciding one way or the other.

Some authors already recognize problems with the productivity concept and are making attempts, unsuccessful as of early 1993, to determine the business value of investing in information technology. Inquiring into the contribution of computers to organizational performance, Strassmann, for example, critiques the "traditional measures of bottom line impact, such as direct labor cost substitution and return-on-investment."[14] He considers that "understanding management productivity and measuring it are prerequisites for analyzing the effect of information technologies."[15] He analyzes management performance by calculating a return-on-management and a total value added to the firm. and separates this value into contribution from labor and contribution from capital. His point of view is that management "is the only contributor to all labor surplus value."[16] Dividing labor-surplus value by the cost of management, Strassmann obtains return-on-management as an indicator of management's overall performance. The main problem with this approach is the uncertainty in evaluating the value added and the arbitrariness of separating the contribution to the value added by labor from the contribution added by capital.

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[12]Warner, 1989.

[13]Bowen, 1989.

[14]Strassmann, 1988, 16.

[15]Ibid., 40.

[16]Ibid., 41.

Three

Conclusions, Suggestions

Using the classical productivity concept is a highly unpromising approach to settling the dispute about the business value of investing in information technology and systems. In the 1990s the ability to understand and quantify business performance according to that concept makes it impossible to resolve the performance-enhancement dispute. Improved understanding of the role of information technology and systems in business performance will most likely come from a better understanding of the complex relationship between information technology and the organization. Organizational learning should be done across all relevant elements of the business system, particularly during the stages of choice and implementation of information-technology-and-systems transfer.

To understand the tasks performed by information technology and to make its use more efficient and effective, managers should concentrate on analyzing and optimizing the information architecture of the organization before embarking on the technical and the implementation architecture.[1] Michael Zack and James McKenney (1988, 1989) consider the first and most important task of managers is to define the *Information Domain* of their organizations and then to address the issues of concern in managing it. Many failures in obtaining the desired impact of information technology and systems since the mid-1980s stem from ignoring this very important step when bringing information technology into firms. David, using a number of historical cases, points out that during historical transitions from one technological paradigm to the next, overlaying one technical system upon a pre-existing technical and organizational one is not unusual.[2]

Information technology affects the entire business system of an organization in fundamental ways.[3] This fact, surprising to some contemporary managers still unable to cope with its reality, was predicted in the early 1960s. Oettinger clearly expressed the thinking of those with the vision to foresee this impact on the banking industry:

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[1]Kaplan, 1992; Tinsley and Power, 1990.

[2]1990, 9.

[3]McFarlan, 1991; Walton, 1989.

> There is a growing realization of the paradox inherent in the following widely observed phenomenon: automating and extending the scope of routine work tends to jeopardize the growth of demand deposits; and, conversely, scrambling for greater volume of demand deposits disproportionately increases routine work. In this paradox lie the seeds of revolution. ... The revolution's victims will be those to whom automation is yet another tool with which to do conventional banking as usual, only faster. Its beneficiaries will be those who see in automation a major technical upheaval without parallel for modern banking since its birth about 500 years ago.[4]

Peter Drucker (1991) analyzed the main difference between the meaning of productivity in manufacturing in comparison with its meaning in services. He points out that the essence of improving performance in manufacturing products has always been working smarter, and with better machines and equipment, and not taking the task to be performed for granted. Referring to the productivity challenge in the service sector, Drucker says that in improving business performance, working smarter is the only key. In the service industries the key is understanding the task and redefining it.[5] These points are very similar to those made by Zack and McKenney (1988, 1989).

Unfortunately, *under contemporary conditions* there is no way for economists, however well trained and candid, to address the fundamental problems in estimating productivity *in the context of the information technology and systems revolution.* As the testimony of the economists used here suggests, lack of empirical content of the productivity measures when evaluating the performance of companies operating in rapidly changing environments is a reality economists cannot escape. Claims that "the massive investments in [information] technology simply have not improved productivity,"[6] although true and justified, do not provide insight into the impact of information technology investments on business performance, because in the 1980s and 1990s the productivity concept lacks empirical content. new material, revised Once the revolution in information technology has ended and the business environment is more stable, the productivity concept might once again be used to gain some insight into the business impact of investing in information technology.

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[4]1964, 36.

[5]Hammer, 1990.

[6]Roach, 1991, 85.

In conclusion, this report has addressed the so-called productivity paradox—the apparent lack of productivity enhancements from information technology and systems. The analysis showed that the productivity-paradox may be largely attributable to an inability to identify the benefits to companies investing in information technology, for the following three reasons:

- **Measurement problems**. Measurement problems are caused by the inability to quantify productivity—that is, output and input—satisfactorily.

- **Systems duality**. Systems duality problems become apparent when new technology emerges and coexists with antiquated technology, thus temporarily producing a higher cost of doing business.

- **Inappropriate tools**. The development of information technology takes place rapidly. Evaluating information technology investment performance cannot be done in terms of productivity because productivity is a measure for evaluating performance in environments that are relatively stable, as the economists who pioneered the concept recognize.

The analysis[7] here showed that at this time the business value of investing in information technology and systems cannot be evaluated using productivity measures and that the best way to improve performance is by concentrating on managerial issues. It also showed that productivity measures must be used and interpreted with care and that their ability to explain the performance of the business/economic system varies from case to case.

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[7]A study sponsored by the National Research Council of the National Academy of Sciences of the United States of the impact of investing in information technology on performance confirmed some of the conclusions of this report; see *Impact of Information Technology on Performance Not Evident from Productivity Measures*, National Research Council, National Academy of Sciences, Washington D.C., Dec. 21, 1993.

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Acronyms

ATM	automatic teller machine
BEA	Bureau of Economic Analysis
GDP	gross domestic product
GNP	gross national product
MIPS	million instructions per second
PC	personal computer

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