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Robert J. GORDON

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Abstract

The point of departure for this paper is the justified concern of central bankers that the information technology (IT) revolution may have fundamentally changed the environment in which monetary policy is conducted. We find that IT in general and computers in particular have acted, at least in the United States, as a beneficial supply shock that has improved the inflation-unemployment tradeoff, particularly in the mid-1990s. More profound issues are raised for monetary policy by the apparent failure of IT to boost the rate of multi-factor productivity (MFP) growth or of average labor productivity (ALP) growth in the United States in the past decade. The framework for our study of computers and productivity growth is the famous Solow computer paradox, that computers are everywhere except in the productivity statistics.

This paper discusses general problems raised by information technology for monetary policy and then takes a closer look at the productivity statistics themselves. We find little evidence that productivity growth has slowed down more than average in sectors of the economy that are hard to measure and that indeed the most impressive productivity statistics have been achieved by the manufacturing industries which make the computers, not by the computers themselves in those industries which use computers most intensively.

Key words: Information Technology, Multifactor Productivity, NAIRU, Solow Paradox

JEL classification: C50, E50, O47

* Northwestern University and National Bureau of Economic Research

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"The invention of the seminconductor transistor set in motion a technological revolution that is arguably even more impressive and pervasive than that of the Great Industrial Revolution of the last century." -- Flamm (1997, p. 1)

I. Introduction

Much of the contribution of information technology (hereafter IT) and its implications for monetary policy involve controversial issues, but there can be no controversy about the growing importance of IT as a share of total economic activity and as a source of lower inflation. If there were a single indicator of inflation, and if the effect of IT on that inflation indicator could be measured unambiguously, then the implications of IT for monetary policy would be relatively straightforward. IT would improve the inflation-unemployment tradeoff and would lower the NAIRU, the famous "Non-Accelerating Inflation Rate of Unemployment."

Since the companion paper at this conference by James Stock (1998) has as its main focus the recent decline in the NAIRU for the United States, only a short preliminary section in this paper is devoted to that topic. We ask in that section how much IT could have contributed to the decline in the NAIRU. And we relate the effect of IT on the NAIRU to two earlier strands of analysis of monetary policy, namely the optimal reaction of policymakers to supply shocks and the case for a monetary policy which targets nominal GDP growth.

Monetary Policy and Productivity Growth

Instead of focussing on the reduction in the NAIRU, the first major channel by which IT alters the environment in which monetary policy operates, instead the main topic of this paper will be a second major channel, the effects of IT on productivity growth. If the inflation-unemployment tradeoff and its reactions to IT are well understood, one might argue that the monetary policymakers could close their eyes to the pace of productivity growth. In this view, "only the NAIRU matters."

In what context would it make sense for monetary policymakers to be interested in productivity growth? First, as Stock's work shows, estimation of the NAIRU is subject to substantial uncertainty. Central bankers may react by preferring a two-pronged approach, in which they try to estimate not just the NAIRU but also the growth rate of "natural" or "potential" output, that is, the growth rate of the economy that is consistent with steady inflation. Clearly, an understanding of productivity growth is directly relevant for the estimation of potential output growth, which often proceeds by adding together an estimate of future productivity growth with that of the growth rate of future potential hours of work.

Second, monetary policymakers may attempt to cope with the uncertainty surrounding estimates of the NAIRU by examining the behavior of alternative price and wage indexes and the NAIRU estimates that are the byproducts of several types of price and wage measures.[1] For instance, in late 1997 and 1998 the major U. S. inflation rate indexes (GDP deflator, consumption deflator, and the CPI) have exhibited substantial

1. By definition, the NAIRU is the rate of unemployment that is consistent with steady, non-accelerating inflation for some price index. There is a different NAIRU for each price index, e.g., the GDP deflator, personal consumption deflator, and CPI. There is also a different NAIRU for each concept of unit labor cost growth, e.g., the growth rate of a wage index minus the growth rate in actual or potential productivity. NAIRU estimates for several U. S. wage indexes are provided in Gordon (1997b).

decelerations despite record low levels of the actual unemployment rate. However, several wage indexes have exhibited accelerations, and the NAIRU estimates corresponding to these wage indexes are considerably higher than for the price indexes.[2] Clearly monetary policymakers have a strong motivation to understand why price and wage indexes are diverging. One interpretation is that different forces are influencing prices and wages, at least temporarily, and that the growing wedge between price and wage growth will be resolved by a squeeze on profits. Another interpretation is that a marked acceleration in real wage growth is consistent with the acceleration of productivity growth that has occurred in the U. S. data in 1996-98.

Thus it seems that productivity is important after all. The 1996-98 acceleration of productivity growth to an annual average of 2.0 percent, after 25 years of growth averaging only 1.0 percent, might be the harbinger of a revival of productivity growth.[3] Set against this optimistic view is a pessimistic interpretation in which the 1996-98 experience simply made up for the period 1992-95 in which productivity growth was virtually zero. The pessimists view 1996-98 as a temporary "blip" in a dismal story in which U. S. business productivity has grown at a meager rate of just 1.2 percent whether one looks over the past 10 years or the past 25 years. Despite this lack of progress, productivity growth should have revived on account of measurement improvements in the Consumer Price Index which have had the effect of reducing measured inflation relative

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2. Gordon (1997b) estimates that the wage-NAIRU was as high as 6.0 percent in mid-1997.

3. Private business output per hour grew at an average annual rate of 2.04 percent for the twelve-quarter period between 1995:Q4 and 1998:Q4.

to true inflation and raising measured productivity growth relative to true productivity growth.

The current contradiction between the deceleration of price indexes and acceleration of wage indexes, and the ambiguous behavior of productivity growth, suggests that central bankers should welcome an investigation of the interconnections between IT and aggregate productivity growth. No one has better stated the puzzling nature of these interconnections than Nobel-prize winner Robert M. Solow.

The "Solow Paradox"

It has been more than a decade since Robert M. Solow (1987) came up with his lovely quip, "You can see the computer age everywhere but in the productivity statistics." The prevailing reaction to Solow's paradox has been "well, the computers are indeed everywhere, so there must be something wrong with the productivity statistics."

The idea that the contribution of computers to output is inherently difficult to measure and has been systematically understated can be classified as the first solution to the Solow paradox.[4]

A second possible solution to the Solow paradox has been suggested by the important work of Stephen Oliner and Dan Sichel (1994, Sichel 1997), who criticize Solow's basic premise by arguing that "the computers are *not* everywhere." Specifically,

4. The first three proposed explanations of the Solow paradox correspond to those in Allen (1997), while the fourth is contributed here for the first time. Allen's review of the first (mismeasurement) hypothesis largely consists of a summary of Baily-Gordon (1988). Triplett (1998) parses the explanations of the Solow paradox into seven and briefly explores the main theme of this paper, that the contribution of computers to productivity growth is inherently limited and subject to diminishing returns.

computers and related peripherals represent only about 2 percent of the nation's capital stock. Further, this tiny share is not likely to increase appreciably, as so much of investment in computers is chewed up by depreciation and obsolescence of relatively young hardware and software. Only if the return from computers were to increase dramatically in the future would their contribution to productivity growth accelerate.

The third explanation has been proposed by Paul David (1990) and others. David argues by analogy with the invention of the electric motor around 1880; the payoff of the electric motor in creating an acceleration of productivity growth in U. S. manufacturing did not become apparent in the statistics until the interval 1913-29. This analogy would seem to imply that it may take a full generation before systems of production are changed to take full advantage of IT.

There is a fourth possible solution to the Solow paradox. Computers may be pervasive, but they have not created a revival of productivity growth because something is unique about computers. According to this interpretation, the Paul David analogy with electric motors fails because there is no comparison between the rate of decline in computer prices over the history of the computer age since the early 1950s, and the rate of decline in the prices of electric motors in the early twentieth century. As a result of this drastic decline in prices, computers have been subject to diminishing marginal returns and diminishing marginal utility much sooner and to a much greater extent than electric motors.

This paper takes a closer look at the first interpretation, that the contribution of computers is understated through a systematic tendency of the official data to understate the contribution of computers to output and productivity growth. An important new source of data, released within the past year, allows us to pinpoint exactly where the productivity slowdown has occurred, how much is in industries where productivity is hard to measure, and how much shifts in the composition of the nation's output can explain the slowdown.

Plan of the Paper

The paper begins in Part II with a brief review of IT's impact on inflation in the context of the literature on supply shocks and nominal GDP targeting. Then Part III examines the facts that lie behind the Solow paradox, including the path of multi-factor productivity (MFP) growth over the past 125 years for the entire U. S. economy and the path of labor productivity growth over the past 50 years. Next, we examine the industrial composition of productivity growth and the productivity slowdown at the level of individual two-digit industries, using newly released data.[5] Our point of departure is Griliches' Presidential Address, which demonstrates that the composition of output has shifted toward those industries where output is relatively hard to measure, and so measurement errors may have contributed to the slowdown even if measurement has become no worse at the level of individual industries. We find that the industries suffering the most severe productivity growth slowdowns include not just those where output is hard to measure, but also a number where output is relatively easy to measure, and we find no tendency for computer-intensive industries to exhibit larger productivity

5. The new source of data is the long-awaited updating of data on Gross Product Originating by two-digit industry contained in the article by Lum and Yuskavage (1997).

growth slowdowns.

II. *Monetary Policy, IT, and the NAIRU*

In the U. S. national income accounts, the price deflator of computers has been declining at a rate of 35 to 40 percent per annum over the past two years. Expenditure on narrowly-defined computer hardware in recent years has increased rapidly as a share of GDP and of business investment, not just in real terms but also in nominal terms, and computer hardware is the tip of an iceberg of IT that also includes software, peripheral equipment, and telecommunications equipment.

Putting together the rapid decline of computer prices and the increasing share of IT, there can be no doubt that IT is holding down the rate of inflation in both an arithmetic and substantive sense. Narrowly defined computer hardware is currently contributing to a reduction of U. S. inflation at an annual rate of almost 0.5 percent per year, and this number would climb toward one percent per year if a broader definition of IT, including telecommunication equipment, were used.[6] Thus the first implication of IT for monetary policy is obvious: the growing importance of IT operates as a beneficial supply shock, similar to the impact of a sharp drop in the price of oil and with the opposite impact of a sharp increase in the price of oil such as those which occurred in 1973-75 and 1979-81. The economy's tradeoff schedule between inflation and

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6. The current nominal share of producer and consumer computer hardware spending in U. S. nominal GDP is about 1.4 percent, which multiplied by a rate of price decline of about 35 percent per year contributes to reducing the rate of change of the GDP deflator by 0.49 percentage points per annum.

unemployment is shifted downward, as is its NAIRU. This allows monetary policymakers to choose lower inflation with the same unemployment rate, lower unemployment with the same inflation rate, or lower rates of both unemployment and inflation.[7]

The central bank cannot make the actual unemployment rate differ from the NAIRU in the long run, but it can maintain a stable rate of inflation if it succeeds in setting the actual unemployment rate equal to the NAIRU. If instead of maintaining a stable rate of inflation, the central bank desires to reduce the inflation rate toward zero or some other target, then it needs to keep the actual unemployment rate above the NAIRU. Either way, whether the goal is steady inflation or lower inflation, the Fed needs to know the value of the NAIRU and little else. By this interpretation all that the central bank cares about is the econometric estimation of the time-varying NAIRU, as pioneered by James Stock in his work with Mark Watson and Douglas Staiger (1997a, 1997b), and extended in my own work (1997a, 1997b) and by Stock and Watson (1998) and Stock (1998).

Computer Prices as a Beneficial Supply Shock

The oil shocks of 1973-75 and 1979-81 appeared at the time to be permanent, lasting more than a few years, but ultimately proved to be temporary, since the real price of oil declined in several stages after 1981 until today it is no higher than at the time of the first

7. The theory of monetary policy reactions in the presence of supply shocks was introduced by Gordon (1975) and Phelps (1978), and these two contributions were subsequently synthesized by Gordon (1984).

1973 shock. The beneficial supply shock created by computer prices in the 1990s would appear to be permanent, since there is no reason for computer prices to reverse their historical decline and to begin to rise in real terms.

If the real price of computers declined forever at a steady rate and if the share of computers in nominal GDP were fixed at some level, then the effect of computers on inflation in the GDP deflator would be easy to calculate. In the example provided above, computers subtract 0.5 percent at an annual rate from aggregate inflation. However, with a fixed rate of computer deflation and a fixed share of computers in total expenditures, the 0.5 percent downward impact on inflation would remain fixed. If the economy were operating below the NAIRU and as a result inflation in the non-computer part of the economy were accelerating, the mere existence of computer price deflation would not prevent aggregate inflation from accelerating if the downward impact of computers on inflation were fixed at 0.5 percent or some other number, as hypothesized above. Under these conditions, with a fixed share and fixed deflation rate, computers would not reduce the NAIRU. For computers to matter for monetary policy their downward impact must increase from year to year, either because their share in nominal spending increases and/or because the rate of deflation in computer prices increases.

An increase in the downward impact of computer prices on the U. S. rate of inflation is exactly what happened in 1996 and 1997, and this contributed to an improvement in the policy environment faced by the Federal Reserve Board. Figure 1 displays the 1995-97 increase in the share of nominal computer hardware expenditure, both in GDP and in personal consumption expenditures.[8] Figure 2 shows the 1995-97 acceleration in the rate of deflation for computers in GDP and in personal consumption expenditures, respectively. Taken together, the impact of computers in reducing the rate of change of the GDP deflator is shown in Figure 3.[9] My explanation of the coexistence of low inflation and low unemployment in the 1996-98 period relies not just on the beneficial supply shock supplied by computers, but also the beneficial effects of a deceleration in the rate of medical care inflation as well as measurement improvements that have reduced the measured rate of inflation relative to the true rate of inflation. Figure 4 contrasts the official GDP deflator with an alternative GDP deflator that is "stripped" of computer and medical care expenditures as well as the impact of the measurement improvements.

Finally, Figure 5 contrasts the time-varying NAIRU, estimated by the same technique as in Staiger, Stock, and Watson (1997a, 1997b) and Gordon (1997a, 1997b), for both the official and "stripped" GDP deflator. It appears that the three elements that are stripped out of the official GDP deflator, computer spending, medical care spending, and measurement improvements, explain all of the decline in the NAIRU in the 1990s. Of this difference between the two NAIRUs corresponding to the official and stripped

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8. The upper line is the nominal share of computers purchased both as producers' durable equipment and as personal consumption expenditures as a share of nominal GDP; the lower line is the share of consumption computers as a share of nominal personal consumption expenditures.

9. The contribution of computers to reducing inflation is computed on a chain-weighted basis by subtracting the chain-weighted nominal share of computers in GDP times the rate of computer price deflation in the GDP deflator. This yields a chain-weighted price deflator for non-computer GDP. An alternative method, to subtract both nominal and real computer spending from nominal and real GDP, introduces base-year bias and greatly exaggerates the difference made by excluding computers.

GDP deflators, computers contribute roughly one third.

Beneficial Supply Shocks and Nominal GDP Targeting

Nominal GDP targeting is a particular type of monetary rule that implicitly applies equal weights to deviations of inflation and real GDP growth from target rates.[10] As I showed in my paper at the first Bank of Japan monetary conference (Gordon, 1985), a nominal GDP targeting rule leads to instability unless the targeting regime commences when the economy is operating with its unemployment rate at the NAIRU (i.e., the unemployment gap is zero) and when the target growth rate of nominal GDP is set at the inherited rate of inertial inflation (corrected for any temporary supply shocks) plus the growth rate of potential real GDP.[11]

The impact of computers on a central bank that has implemented a nominal GDP targeting regime is likely to be minor. If the nominal share of computer spending increases slowly by a tenth of a percentage point per year or less, as seems to be suggested by Figure 1, and if the rate of computer deflation is relatively steady at 25 to 40 percent per year, then in a given year computers have the effect of reducing the inflation rate by 3 to 4 one-hundredths of a percentage point as compared to the year before.[12]

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10. In the United States, where the unemployment gap (the actual unemployment rate minus the NAIRU) fluctuates by about half as much as the output gap (the percentage log ratio of actual to potential GDP), a nominal GDP target implicitly places a weight of 2/3 on deviations of the inflation rate from target and 1/3 on the unemployment gap.

11. For a more recent treatment of nominal GDP targeting and references both to my paper and the more recent literature, see Hall and Mankiw (1994).

12. If in 1996 the share of computers in GDP is .01 and the rate of computer deflation is -0.35, the impact on the GDP deflator is -0.0035. If the next year the computer share increases to 0.11, and the rate of computer deflation stays the same, the impact on the GDP deflator rises to -0.00385, a difference of 0.00035 or 3.5 one-hundredths of a percentage point.

This impact is trivial compared to the effect of oil prices, import prices, and even measurement changes which in some recent years have reduced the inflation rate by as much as one or two tenths of a percentage point.

If the central bank sets a nominal GDP target and successfully maintains the actual rate of nominal GDP growth at that target, and if the economy starts out the nominal GDP targeting regime with a zero unemployment gap, then any beneficial supply shock will reduce the inflation rate and increase the rate of real GDP growth. Whether this creates a positive GDP gap depends on whether the rate of potential GDP growth increases *pari passu* with actual real GDP growth. If the beneficial supply shock takes the form of measurement improvements in price indexes, then real GDP and potential real GDP will accelerate by the same amount. But there is no assurance that an increased share of computers in total GDP will generate a corresponding increase in productivity. Thus the key issue for monetary policy in formulating the proper response to an increasing share of computer prices in GDP comes back to the basic topic of this paper. Has the computer revolution, or more generally the IT revolution, created an acceleration of productivity growth? If not, why not?

III. Basic Facts Regarding Computers and Productivity Growth

The unhappy facts supporting Solow's paradox are presented first in Table 1, which displays the growth rates of output, labor input, capital input, and MFP for selected intervals dating back to 1870. The years chosen for the intervals are those when the economy was operating in a neutral cyclical position, i.e., at its NAIRU, and the final year of 1996 is the most recent year for which official data on MFP are currently available. The upper half of the table displays intervals spanning one to three business cycles, while the bottom half displays averages over longer intervals of 43, 51, and 32 years, respectively.

It is important to observe that the growth rates of input and of MFP in Table 1 are based on a homogenous concept, that is, of straight quantities of aggregate labor and capital input with no adjustment for the shifting composition of labor (among age, sex, and education categories) and of capital (between structures and equipment and among types of equipment with different service lives, e.g., furniture vs. computers). Thus the MFP growth rate in Table 1 for 1988-96 is more optimistic than the official MFP statistics published by the Bureau of Labor Statistics (hereafter BLS). For instance, in place of the 1988-96 MFP growth rate of 0.79 percent which does not take account of changes in labor and capital composition, the equivalent BLS figure for MFP growth is a mere 0.12 percent.

This historical record shows the phenomenon I have previously (Gordon, 1999) called "one big wave," an acceleration of MFP growth that peaks in 1928-50 followed by a deceleration to 1964. In my own research I have questioned a particular aspect of these data, namely the extremely slow growth in capital input recorded for the 1928-50 interval, and my results reduce MFP growth during that interval and slightly increase MFP growth in the following two intervals spanning 1950-72. But my results do not change the record of slow MFP growth after 1964 that, according to the BLS version, can be almost entirely accounted for by shifts in the composition of labor and capital with virtually nothing left over for "true" MFP growth.

The basic data on U. S. aggregate productivity performance are published quarterly by the U. S. Bureau of Labor Statistics (hereafter BLS) and refer to output per hour or average labor productivity (ALP), not to MFP. The record for selected postwar intervals is provided in Table 2, which extends through 1997. Business sector ALP has grown over the past 4 years and past decade at the slowest rates of the postwar, with no sign of a revival. The BLS provides further information for three subaggregates, durable and nondurable manufacturing and the nonfinancial corporate sector. Productivity growth in the past four years has been much faster in these subaggregates than for the total economy, which means that it must have been much worse in the omitted residual.

While the residual sectors are not published by the BLS, on the grounds that methodologies are inconsistent, they can be trivially calculated. As we shall see, the caution by the BLS is unnecessary, because exactly the same conclusions emerge when the consistent data set compiled by the U. S. Bureau of Economic Analayis (hereafter BEA) is used, and this allows the calculation of ALP growth for almost 50 additional two-digit industries. As shown in Table 2, productivity growth outside of manufacturing has slowed significantly in the 1990s (line 2), further deepening the computer paradox, since that is where most of the computers are located. As ALP growth has accelerated in the nonfinancial corporate sector (line 3), it has decelerated commensurately in the financial and noncorporate sectors (line 4).

Productivity by Two-digit Industry

The BEA has published Gross Product Originating (i.e., real value added) by Industry through 1996. The GPO data can be converted into labor's average product (ALP) by dividing through by hours worked in each industry.[13] At present real GPO data using the current improved methodology are published only back to 1977, but Table 3 treads where the BEA will not, by comparing the post-1977 data with the most recently published pre-1977 data.[14]

Table 3 arranges the data in the same order as the BEA original tables, except to convert the private economy into the private business sector (for comparability with the standard BLS aggregate series). To save space, the two-digit manufacturing industries are not shown separately, except for the two crucially important industries where the production of computers and related machinery is concentrated, "Industrial machinery" and "Electronic and other electric equipment." The table exhibits annual growth rates of ALP on each line for the intervals 1948-67, 1967-77, and 1977-96 and calculates a slowdown rate between the last period and the first. Shown in the final column is the share of each sector in nominal 1992 GDP.

Allowing for differences in time intervals, Table 3 echoes the BLS conclusion in Table 2 that manufacturing has exhibited no productivity slowdown and that durables has

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13. As described in the notes to Table 3, the BEA publishes hours data only at the one-digit level. The exercise carried out here requires the assumption that hours per employee in each two-digit industry within a one-digit industry are identical to the one-digit industry average.

14. The BEA no longer publishes pre-1977 data because of numerous changes in methodology that were introduced with its current data for the year 1977 and later.

performed better than nondurables. However, the sterling achievement of durables is almost entirely attributable to the one-third of durable output located in the machinery and electronic sectors. Omitting these, as shown on the next line, what we will call "net durables" exhibits a sharp productivity slowdown that is worse than that in many of the service industries. Table 3 contains numerous other interesting contrasts. Of all industries shown, the productivity champion for 1977-96 was the railroad industry, beating out even machinery and electronics. There was a productivity explosion in nondepository institutions and Security and commodity brokers, suggesting that BEA has dropped its previous practice of extrapolating output in these industries on the basis of labor input.

The Slowdown Culprits

Table 4 provides a rearrangement of the Table 3 data with 36 industry groups ranked by the size of the slowdown, from the largest slowdown to the the largest acceleration. The table lists both the magnitude of the slowdown and the absolute magnitude of ALP growth during 1977-96; the ALP growth rates for 1948-67 and 1967-77 are not repeated. The groups listed are mutually exclusive, i.e., manufacturing is divided into three groups (machinery and electronics, "net" durables, and nondurables) but the total for manufacturing is not listed separately. Similarly, the totals for such categories as transportation, finance/insurance, and services are not listed separately.

Two other pieces of information are listed in Table 4. Each of the 36 industry groups is "rated" on the criterion of accuracy of measurement, from category "A" which represents the most accurate to category "D" which represents the least accurate.

Definitions of the four categories are provided in the notes to Table 6 below. This measurement classification goes well beyond the cruder distinction introduced by Griliches (1994), who grouped all of agriculture, mining, manufacturing, transportation, communication, and public utilities into an easier-to-measure category and the remaining industries (construction, trade, FIRE, and services) into a harder-to-measure category. Our finer-grained categories reflect the fact that within the finance, insurance, and service sectors various industries may differ in their intrinsic difficulty of measurement. For instance, personal services (e.g., barber shops and beauty parlors) is rated in the "A" category; the product changes little over the decades, there are few if any unmeasured product attributes, and there has never been a suggestion that the underlying Consumer Price Indexes for haircuts or beauty treatments contain a bias. Further, the rapid productivity growth in BEA measures of productivity for nondepository institutions and securities brokers since 1977, contrasted with negative productivity growth for depository institutions, suggests that the BEA may be capturing the growth in transactions per employee in the former groups with less error than in the latter group.

The second additional piece of information shown is the growth in ALP as measured by the BLS industry productivity program. The BLS measures are based on a gross output concept rather than the BEA's value-added concept and thus might be expected to differ. Published BLS employment weights are used to aggregate the individual BLS indexes for particular industries, e.g., beauty shops, bakeries, coal mining, brick and structural clay tile, etc., into categories corresponding to the BEA measures.

The overall productivity growth slowdown for the private business sector in the

BEA data for 1977-96 vs. 1948-67 is 1.32 percent per year, as shown on the second line of Table 3. Thus all industries ranked 1-15 in Table 4 have greater than average slowdowns, while the remaining industries ranked 16-36 experienced a smaller slowdown than average or a productivity growth acceleration (hence there is a dividing line drawn after the industry ranked 15th). This ranking contains some familiar culprits, including construction, health services, and mining. But there are some unfamiliar culprits as well, including telephone/telegraph and, perhaps most surprisingly, "net" durable goods, that is, the two-thirds of durable goods production excluding industrial machinery and electronic/electric goods.

Clearly, the ranking of industries by the extent of the slowdown cuts across the categories of measurement accuracy, whether Griliches' original dichotomy or our more finely tuned categorization. Some of the largest slowdowns occurred in industries where output is particularly easy to measure, e.g., pipelines, air transportation, utilities, and mining. But some of the largest accelerations also occurred in industries where output is relatively easy to measure, including railroads.

Conflicts in the Official Data

The BEA and BLS productivity data are not directly comparable; the concepts are different (value-added vs. gross output), the time periods are slightly different, and in some cases the industry definitions do not match exactly.[15] Nevertheless, it is

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15. Both the BEA and BLS data are available annually. However, to save space recent BLS releases have presented growth rates over relatively long intervals rather than annual levels for each industry. In preparing Table 4, we have taken the short cut of using the published BLS growth rates for the interval shown (1979-95) rather than locating the underlying annual data and calculating growth rates

intriguing to note a tendency for the BLS productivity growth rates for 1979-95 to exceed those of the corresponding BEA growth rates for 1977-96, sometimes by substantial amounts. As shown in Table 5, the difference between the weighted average growth rates of output per hour for the BLS and BEA data depends heavily on whether the industrial and electronic machinery industries are included. The BLS and BEA data for these industries are clearly not comparable, as the BLS does not cover the computer industry which, through the BEA's use of a hedonic price deflator for computers, contributes much of the outstanding performance of this pair of industries in the BEA data.

Excluding this pair, the BLS growth rates exceed those of the BEA by a weighted average of 0.93 percent, and 1.06 percent for nonmanufacturing. Stated another way, the BLS growth rates are double those of the BEA growth rates for comparable industries. The discrepancy between the BLS and BEA growth rates applies not just to the industries that are ranked as harder-to-measure, but also those that are ranked as easier-to-measure. This finding questions the utility of the Griliches distinction, since the BLS-BEA discrepancies suggest that measurement difficulties may plague the easier-to-measure sectors as much as the harder-to-measure sectors.

The BLS-BEA differences may usefully indicate the potential range of measurement errors but there is no presumption that one index is more accurate than the other. For instance, my study of the transportation sector (Gordon, 1992, pp. 374-382)

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for the same period as shown in Table 4 for the BEA data (1977-96).

concluded that the BLS measure was superior for air transportation but the BEA measure was preferable for trucking and warehousing. Thus, until detailed industry-by-industry comparisons are made and explained, and until these comparisons are extended further back into the early years of the postwar period, we cannot conclude that these measurement differences help to explain the productivity slowdown, but the possibility exists.

The Shifting Composition of Economic Activity

Since the early and pioneering study of the productivity slowdown by Nordhaus (1972), a familiar hypothesis has been that the slowdown could have been partly or largely caused by the shifting composition of economic activity. Thus far our ALP growth rate for the private business aggregate in the BEA data has been based on the published total output measured in constant 1982 dollars (1948-77) or constant 1992 dollars (1977-96). However, these aggregates differ from the conceptually preferable chain-weighted or Tornqvist indexes with weights based on shifting nominal output shares.

The first two lines of Table 6 contrast the productivity growth rates published by the BEA with a "quasi-Tornqvist" which, rather than shifting weights each year, bases the aggregation within a time interval on the average of the nominal output shares for the first and last year of each interval. Thus the growth rate of ALP for 1948-67 is aggregated from the 36 component subindustries (those listed in Table 4) using an average of 1948 and 1967 nominal shares, and similarly for 1967-77 and 1977-96. The use of the quasi-Tornqvist weights boosts productivity growth in all periods without appreciably changing the magnitude of the slowdown. Some of the reasons for the higher growth rates are obvious. For instance, prior to 1977 the weights on manufacturing are uniformly higher than in recession-racked 1982. Further, Tornqvist weights are higher in the earlier years for other sectors with relatively high productivity growth, e.g., agriculture. In recent years the use of the average of 1977 and 1996 weights, rather than the BEA's 1992 weights, reduces the importance of industries having negative productivity growth, such as medical care.

How much of the slowdown was caused by a shift in composition toward industries that have had relatively slow ALP growth rates throughout the postwar period? We can answer this question by using weights fixed at the beginning of the period or at the end of the period. With fixed 1948-67 weights the slowdown drops from -1.24 percent to -0.77 percent, and with fixed 1977-96 weights to -0.92 percent. Averaging these two alternative measures of the fixed-weight slowdown, we conclude that exactly one-third of the slowdown in the quasi-Tornqvist indexes can be accounted for by a shift to slower-growing sectors, e.g., from agriculture and manufacturing to the services. The remaining two-thirds of the slowdown is caused by a deceleration of ALP growth within individual industries, which as we saw in Table 4 affects 25 of the 36 industries listed.

The bottom section of Table 5 aggregates the ALP growth rates and slowdown measures by measurement category. Somewhat surprisingly, the largest slowdown occurred in the category where productivity is easiest to measure. However, if categories A and B are aggregated, as on the last line of the table, we conclude that the slowdown has been uniform across categories. Productivity growth has always been fastest in the categories that are the easiest to measure, and slowest in those categories that are hardest to measure.

I emerge from this exercise with a different slant than emerged from Griliches' (1994) address, at least as I understand it. I took him to be saying that "things are OK with reasonably robust productivity growth and negligible slowdowns in the easier-to-measure sectors and are not OK in the harder-to-measure sectors where most of the slowdown has occurred, hence mismeasurement may have become more important." My conclusion is that things are not OK in the easier-to-measure sectors, which have experienced the same order-of-magnitude slowdown as the harder-to-measure sectors. There is no correlation of the slowdown with difficulty of measurement, just a shift in the composition of output to sectors that have always had poor productivity growth performance, back in the golden age and today as well.

Price Measurement and the Productivity Paradox

There remains the possibility that inflation is overstated more in the hard-to-measure categories "C" and "D" than in the easier-to-measure categories "A" and "B". Assuming that current-dollar spending is correctly measured, then any overstatement of inflation would correspond to an understatement of output and productivity growth. Let us assume that in the 1990s the hard-to-measure sectors have inflation that is understated by 1.5 percent per year while the easier-to-measure sectors have inflation that is understated by 0.5 percent per year. In the context of the Boskin commission report (1996), this amounts to assuming that quality change and new product bias is zero in the easier-to-measure categories and proceeds at a rate of 1.0 percent per year in the harder-to-measure categories.[16] Since categories "C" and "D" comprised 38 percent of private business GDP in 1948 and 59 percent in 1992, these assumptions imply that inflation is overstated by 0.9 percent in 1948 and 1.1 percent in 1992, while productivity growth is understated by the same amount.[17] Thus this particular form of the mismeasurement hypothesis would explain 0.2 percent of the productivity growth slowdown, somewhat less than the 0.3 percent explained by the shifting shares hypothesis in Table 6.

In a related exercise Steindel (1997) takes a narrower definition of the hard-to-measure sectors, including financial and business services, medical care, and educational and charitable expenses. He makes two alternative assumptions about price mismeasurement in these sectors, (A) that their prices rise at the same rate as other products (instead of faster) and (B) that their prices rise 2 percent more slowly than as published. He calculates that assumption (A) boosts productivity growth by 0.2 percent for 1960-73 and 0.4 percent for 1974-96, explaining 0.2 percent of the slowdown, the same as our alternative calculation above. Assumption (B) boosts productivity growth by 0.3 percent for 1960-73 and 0.4 percent for 1974-96, explaining only 0.1 percent of the slowdown. Despite the differing approaches and assumptions of these exercises, they all arrive at the same conclusion. The hypothesis that inflation is mismeasured more in a

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16. These numbers reflect the assumption that the upward bias of inflation in the easier-to-measure categories is limited to upper-level, lower-level, and outlet substitution bias, determined to be 0.5 percent per year in 1995-96 by Boskin *et. al.* (1996). Quality and new product bias was determined to be 0.6 percent by the Boskin commission report, and this is allocated as 1.0 percent per year in the harder-to-measure sectors and 0.0 percent per year in the easier-to-measure sectors.

17. The share of categories "C" and "D" in GDP are shown in Table 6. Corresponding data for 1948 are obtained from the sources underlying Tables 3 and 4.

subset of hard-to-measure sectors cannot plausibly explain more than a small fraction of the overall post-1973 productivity growth slowdown.

All of this investigation of the productivity data is motivated by the first proposed resolution of the Solow paradox, that the computers are not in the productivity statistics because the benefits of computers have been mismeasured. We have concluded that the productivity slowdown is pervasive across industries that are both intensive and non-intensive in computer use. It is also pervasive across industries where output is relatively easy and relatively hard to measure. Thus it is hard to make a case that the output of computers is being systematically missed in the output and productivity statistics.

IV. Waiting for Godot

As the years go by without a productivity payoff from computers commensurate with their cost, journalists have become more frenetic in proclaiming that we are in the midst of a true revolution: "Computers may be the most profound technology since steam power ignited the Industrial Revolution."[18] There is a "waiting for Godot" quality to the anticipation generated as productivity growth continues to languish while computer investment continues to surge. Those who wait for Godot appeal to Paul David's (1990) electricity analogy, arguing that since 25 years elapsed between the invention of electricity and the beginning of its transformation of farm, home, and factory, so it is

18. Mandel (1994, p. 23), quoted by Sichel (1997, p. 1).

reasonable to expect such a delayed impact of the computer. Yet if anything is clear, it is that however unimportant the computer is today in generating productivity growth, we can be sure that at the margin it was *more* important a decade ago and will be *less* important a decade hence, simply because continuing exponential declines in the cost of computer power reduce the marginal product of computer power, i.e., push incremental increases in computer power into lower and lower productivity uses.

Since Gary Becker's seminal article (1965) on the economics of time, household production has been viewed as an activity which combines market goods and time. The fixed supply of time to any individual creates the fundamental limitation on the ability of exponential growth in computer speed and memory to create commensurate increases in output and productivity. In performing the two activities that were revolutionized by the personal computer, namely word processing and spreadsheets, I cannot type or think any faster than I did with my first 1983 personal computer that contained one-fiftieth of the memory and operated at one-thirtieth of the speed of my present model. The capital stock with which I work has increased by a factor of at least fifteen, according to the hedonic price methodology used by the BEA in the U. S. national accounts, yet my productivity has hardly budged, occasionally benefitting for a few seconds when I can jump from the beginning to the end of a 50-page paper much faster than in 1983.[19] As a result, there has been an exponential rate of decline in my output-to-capital ratio, and an

19. A price index that declines at 25 percent per year for 15 years reaches a level of 2.4 in 1998 on a base of 1983 equals 100. This implies that my present $1000 1998 model computer represents $42,300 in 1983 prices, or 17 times the $2,500 that I spent in 1983 on my computer net of peripherals.

equally sharp decline in the marginal productivity of computer capital.

The Pervasiveness of Diminishing Returns

There is nothing unique about the applicability of diminishing returns to the computer hardware and software industries. Numerous industries have run into barriers to steady growth in productivity, most notably the airline industry when jet aircraft reached natural barriers of size and speed, and the electric utility industry when turbogenerator/boiler sets reached natural barriers of temperature and pressure. The apparent dearth of productivity growth in the construction and home maintenance industry reflects that electric portable power tools could only be invented once and have been subject to only marginal improvements in recent decades. The retailing industry has been subject to diminishing returns for years. In the decade to 1996 retailing square feet per capita increased by 31 percent, leading to reduced real sales per square foot and per employee.

Diminishing returns has significant implications for measurement. Unless weights are changed continuously to reflect the ever-falling marginal value of computer speed and memory, it is likely that the official accounts will overstate the growth rate of computer investment and capital input relative to final noncomputer output. If so, then measures of MFP that subtract the overstated capital input series will provide an even more dismal view of the payoff from computers than the labor productivity series examined in Tables 2-6 above. While the BEA's new chain-weighted output indexes avoid previous conceptual errors, some analysts compute the contribution of computers to output growth and inflation in a way which greatly exaggerates the role of computers.[20]

Continuity from Mainframes to Personal Computers

The diminishing returns argument provides the definitive answer to the Paul David (1990) "delay" hypothesis. The reason that electric motors and consumer appliances took time to diffuse is that initially they were very expensive and didn't work very well. But the personal computer worked reliably from the beginning, provided its main benefits early on, and encountered relatively soon not just diminishing returns but the pervasiveness of face-to-face technology in the service sector that limits the ability of super-fast computers to replace labor input in a significant way.

The David (1990) "delay" hypothesis encounters another obstacle. Personal computers are only a secondary step in the evolution of computer technology that began with the first commercial mainframe computer (the UNIVAC I in 1951). Price indexes compiled by Chow (1967), Gordon (1990, Chapter 6), Berndt and Griliches (1993), and Flamm (1997), show that steady price declines at geometric rates of 25 to 35 percent have characterized both the mainframe and personal computer industries since the beginning.[21] Many of the industries that are the heaviest users of computer technology, e.g., airlines, banks, and insurance companies, began in the 1960s and 1970s with mainframe

20. In particular, in years after the 1992 base year, the computer contribution will be greatly overstated if nominal and real expenditures on computers are subtracted from nominal and real GDP (or any lesser aggregate). See footnote 10 above.

21. The transition from mainframes to personal computers for many activities created a sharp decline in price along the transition path which has not apparently been measured by any of the numerous hedonic regression studies of computer prices, which have focussed exclusively on mainframes or PCs but not both together.

technology and still perform the most computation-intensive activities on mainframes, often using PCs just as smart terminals to access the mainframe data base. In this sense computers have been around for more than 40 years, not just a decade or so, and the "waiting for Godot" hypothesis of David and others loses further credibility.

V. Conclusion

The point of departure for this paper is the justified concern of central bankers that the information technology (IT) revolution may have fundamentally changed the environment in which monetary policy is conducted. We find that IT in general and computers in particular have acted, at least in the United States, as a beneficial supply shock that has improved the inflation-unemployment tradeoff, particularly in the mid-1990s. If the share of computers in nominal spending and the rate of decline of computer prices is constant, then the existence of computers will reduce inflation by a fixed amount but will not change the unemployment rate below which the inflation rate in the non-computer part of the economy will accelerate, i.e., under these conditions the existence of computers does not reduce the NAIRU. Instead the NAIRU is reduced when there is an increase in the nominal share of computer spending and when the rate of decline of computer prices accelerates; both of these two events occurred in the mid-1990s and contributed to the decline of the U. S. NAIRU during that period.

More profound issues are raised for monetary policy by the apparent failure of IT to boost the rate of multi-factor productivity (MFP) growth or of average labor productivity (ALP) growth in the United States in the past decade. The framework for that computers are everywhere except in the productivity statistics. We organize our investigation by four different approaches to resolving the Solow paradox, that official measures of productivity miss the contribution of computers, that computers are too small a part of the capital stock to have a major impact, that the benefits of computers for productivity have been delayed and are awaiting us in the future, and finally the hypothesis that diminishing returns contradicts the delay hypothesis and makes the greatest benefit from computers almost surely in the past rather than in the future.

Our review of the productivity data shows that MFP growth has been much lower since 1964 than previously, and that there was no acceleration of ALP growth in 1988-98 when compared with 1973-88. Our analysis of industry data shows that there is a huge variation in the extent of the post-1972 productivity growth slowdown across industries, suggesting the futility of any attempt to explain the slowdown by a single over-arching explanation. Perhaps the greatest surprise of the investigation is that productivity growth in durable manufacturing, far from being the star sector of the economy, has actually been very poor once the industries producing the computers are excluded, and that the greatest achievement of computers seems to have been in reproducing more computers..

The productivity slowdown has occurred in roughly the same magnitude across industries with widely differing degrees of difficulty in output measurement. The statistical investigation concludes that roughly one-third of the slowdown has been caused by a shift in the composition of industrial output toward those sectors where productivity grew relatively slowly, both before and after the advent of the slowdown, regardless of whether output in those sectors is relatively easy or relatively hard to measure.

The negative view of computers and the IT revolution taken in this paper does not deny that computers have produced benefits for firms and consumer surplus for households. Some industries, particularly in manufacturing, have not experienced a productivity slowdown at all, and the IT revolution may be partly or largely responsible for these success stories. Computers have produced many useful new services or attributes of services, from ATM machines to cash-management accounts to frequent-flyer programs, although most of these innovations were made possible by mainframe computers, not personal computers, and the benefits from mainframes reach back more than 40 years, not just the last 15 years in which the information technology revolution is claimed to have occurred. In the end our conclusion is that the productivity slowdown is real, and that diminishing returns places the most productive contribution of the computer behind us in the past. Our conclusion stands in sharp contrast to the widespread view that we have a "new economy" dominated by the revolutionary implications of the information age.

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Table 1

Annual Percentage Growth Rates of Output, Inputs, and MFP for Non-farm Non-housing Business GDP, 1870-1996

Medium-term Trend				
Years	**Output**	**Labor**	**Capital**	**MFP**
1870-1891	4.41	3.56	4.48	0.39
1891-1913	4.43	2.92	3.85	1.14
1913-1928	3.11	1.42	2.21	1.42
1928-1950	2.75	0.91	0.74	1.90
1950-1964	3.50	1.41	2.89	1.47
1964-1972	3.63	1.82	4.08	0.89
1972-1979	2.99	2.38	3.46	0.16
1979-1988	2.55	1.09	3.35	0.59
1988-1996	2.74	1.74	2.26	0.79
Long-term Trend				
Years	**Output**	**Labor**	**Capital**	**MFP**
1870-1913	4.42	3.24	4.16	0.77
1913-1964	3.06	1.20	1.76	1.64
1964-1996	2.97	1.74	3.25	0.61

Sources: Based on data from Kendrick (1961) for 1870-1929 and BEA for 1929-96.

Table 2

Has Productivity Growth Revived Since 1993?
Data Related to Productivity Growth, 1949-1997

	1949 -60	1960 -72	1972 -78	1978 -87	1987 -93	1993 -97
BLS Output per Hour in Business Sector						
Total (76% of GDP)	3.24	3.25	1.84	1.13	1.05	1.05
1. Manufacturing (17%)	1.85	3.23	2.63	2.59	2.13	3.45
a. Durable (9%)	1.43	3.64	2.33	3.02	2.97	4.43
b. Nondurable (8%)	2.79	2.94	2.93	1.89	1.16	2.04
2. Nonmanufacturing (59%)	3.63	3.26	1.61	0.71	0.74	0.36
3. Nonfinancial Corporate Sector[a] (52%)	-.--	2.53	1.51	0.58	1.05	2.00
4. Financial and Noncorporate Sector[a] (24%)	-.--	3.59	1.99	1.38	1.05	0.58

Note: a. Data on lines 3 and 4 are available only through 1997:Q3.

Sources: BLS release "Productivity and Costs, Fourth Quarter and Annual Averages, 1997," March 10, 1998, and associated historical data. Lines 2 and 4 are derived as residuals.

Table 3

Productivity Growth by Industry

	1948 -67	1967 -77	1977 -96	Slowdown 1977-96 vs. 48-67	Share in 1992 GDP
GDP	2.10	1.28	0.85	-1.25	100.00
Private Business[a]	2.21	1.23	0.90	-1.32	74.08
Agriculture, forestry, and fishing	3.87	0.12	2.80	-1.07	1.80
Mining	4.89	-2.61	2.56	-2.33	1.48
Construction	1.92	-2.63	-0.96	-2.88	3.68
Manufacturing	2.63	2.81	2.86	0.23	17.03
Durable Goods	2.31	2.35	3.32	1.01	9.18
Industrial machinery and Electronic and other electric equip.[b]	2.09	3.29	7.36	5.27	3.32
"Net" Durable Goods	2.47	1.96	0.65	-1.82	5.86
Nondurable Goods	2.99	3.56	2.26	-0.73	7.85
Transportation	1.97	2.78	0.38	-1.59	3.09
Railroad transportation	4.48	2.28	8.84	4.38	0.35
Local and interurban passenger transit	-3.59	-0.22	-1.20	2.39	0.17
Trucking and warehousing	3.82	3.57	-1.71	-5.54	1.32
Water transportation	0.95	5.54	0.00	-0.95	0.16
Transportation by air	7.11	1.75	1.15	-5.96	0.69
Pipelines, except natural gas	9.40	3.93	0.14	-9.25	0.08
Transportation services	-1.33	0.12	-0.10	1.23	0.31
Communications	5.21	4.69	3.56	-1.65	2.58
Telephone and telegraph	5.98	4.18	4.55	-1.43	2.08
Radio and television	1.39	2.41	-2.30	-3.69	0.50
Electric, gas, and sanitary services	6.08	3.33	1.25	-4.83	2.80

(continued on next page)

Table 3 (continued)

	1948 -67	1967 -77	1977 -96	Slowdown 1977-96 vs. 48-67	Share in 1992 GDP
Wholesale Trade	3.01	2.24	3.09	0.08	6.51
Retail Trade	1.69	0.89	1.07	-0.62	8.72
Finance, Insurance (excludes Real Estate)	0.24	0.96	0.55	0.31	6.61
Depository Institutions[c]	0.03	0.21	-1.19	-1.21	3.20
Nondepository institutions[d]	-0.26	0.34	4.81	5.07	0.45
Security and commodity brokers	0.11	0.14	4.31	4.20	0.79
Insurance carriers	0.75	2.28	0.86	0.11	1.34
Insurance agents, brokers, and service and Electronic and other electric equip.	0.36	-0.08	-0.60	-0.96	0.63
Holding and other investment offices	-0.23	0.08	-0.19	0.04	0.20
Services except household services	0.95	0.51	-0.86	-1.81	19.07
Hotels and other lodging places	0.93	0.56	0.02	-0.90	0.82
Personal services	1.86	0.90	-1.28	-3.14	0.66
Business services	-0.39	-0.16	0.50	0.88	3.51
Auto repair, services, and parking	3.39	1.60	-1.51	-4.90	0.82
Miscellaneous repair services	-0.12	0.16	-1.47	-1.35	0.28
Motion pictures	-0.74	0.85	0.42	1.15	0.32
Amusement and recreation services	1.40	-0.35	-0.13	-1.53	0.77
Health services	0.99	0.04	-1.81	-2.79	5.91
Legal services	0.23	-2.01	-2.13	-2.36	1.44
Educational services	-0.03	0.19	-0.64	-0.62	0.74
Social services and membership orgs	0.21	0.20	-0.01	-0.22	1.21
Other services[e]	0.38	0.08	0.09	-0.30	2.60
Sectors excluded from private business sector:					
Real Estate	4.78	-0.37	0.72	-4.06	11.77
Services: private households	0.42	0.78	0.58	0.16	0.16
Government: Federal, state, local	0.19	0.36	0.37	0.19	13.99

Notes to Table 3

Notes: Gross Product Originating by industry is currently published by the BEA only for 1977-96. Estimates are not published for years prior to 1977, because the methodology previously developed to develop estimates for those years has been discarded and is inconsistent with the data for 1977 to date. In this table all growth rates are calculated separately for the old and new data, and readers should be cautioned that growth rates for 1948-77 are based on a different methodology than for 1977-96.

The source for Gross Product Originating, 1987-96, is Lum and Yuskavage (1997). For 1977-87 the source was *Survey of Current Business*, August 1996, p. 153, and for a few industries with definitions that changed in 1987 was *Survey of Current Business,* May 1993, p. 53. All GPO data for 1948-77 are taken from the *National Income and Product Accounts of the U. S., 1929-82, Statistical Tables,* September 1986, Table 6.2. Persons engaged for 1996 were obtained from the NIPA revisions in the *Survey of Current Business,* August 1997. For 1977 and 1987 the source was the NIPA, vol. 2, 1959-88, September 1992, and for earlier years was the *NIPA 1929-82* cited above. Hours worked are provided in the NIPA only for one-digit industries and were obtained for two-digit industries by assuming that hours per employee across two-digit industries within any one-digit industry were identical.

a. Private business is equal to the NIPA private sector, minus real estate and private household services. These exclusions are listed separately at the end of the table.

b. "Industrial machinery" was ratio-linked to the earlier definition "Machinery, except electrical," at 1987. Similarly, "Electronic and other electrical equipment" was ratio linked in 1987 to the earlier definition "Electric and electronic equipment."

c. "Depository institutions" was ratio-linked in 1987 to the earlier definition "banking."

d. "Nondepository institutions" was ratio-linked in 1987 to the earlier definition "credit agencies other than banks.

e. "Other services" was ratio-linked in 1987 to the earlier definition "Miscellaneous professional services."

Table 4

The Productivity Slowdown Culprits, in Order

	Industry and Measurement Category		**Slowdown 1977-96 vs. 1948-67**	**Growth in Output/Hour BEA 1977 -96**	**Growth in Output/Hour BLS 1979 -95**	**Share in 1992 GDP**
1.	Pipelines, except natural gas	A	-9.25	0.14	1.22	0.08
2.	Transportation by air	A	-5.96	1.15	2.28	0.69
3.	Trucking and warehousing	B	-5.54	-1.71	2.70	1.32
4.	Auto repair, services, and parking	C	-4.90	-1.51	0.67	0.82
5.	Electric, gas, and sanitary services	A	-4.83	1.25	2.21	2.80
6.	Radio and television	D	-3.69	-2.30		0.50
7.	Personal services	A	-3.14	-1.28	0.58	0.66
8.	Construction	C	-2.88	-0.96		3.68
9.	Health services	D	-2.79	-1.81		5.91
10.	Legal services	C	-2.36	-2.13		1.44
11.	Mining	A	-2.33	2.56	2.42	1.48
12.	"Net" Durable Goods	B	-1.82	0.65	1.93	5.86
13.	Amusement and recreation services	D	-1.53	-0.13		0.77
14.	Telephone and telegraph	B	-1.43	4.55	5.28	2.08
15.	Miscellaneous repair services	A	-1.35	-1.47		0.28
	Private Business Sector		**-1.32**	**0.90**		**74.08**
16.	Depository Institutions	D	-1.21	-1.19	2.74	3.20
17.	Agriculture	A	-1.07	2.80		1.80
18.	Insurance agents	D	-0.96	-0.60		0.63
19.	Water transportation	A	-0.95	0.00		0.16
20.	Hotels and other lodging places	C	-0.90	0.02	0.24	0.82
21.	Nondurable manufacturing	B	-0.73	2.26	2.52	7.85
22.	Retail trade	C	-0.62	1.07	0.90	8.72
23.	Educational services	D	-0.62	-0.64		0.74
24.	Other services	D	-0.30	0.09		2.60
25.	Social services and membership organizations	C	-0.22	-0.01		1.21
26.	Holding and other investment offices	D	0.04	-0.19		0.20
27.	Wholesale trade	C	0.08	3.09		6.51
28.	Insurance carriers	C	0.11	0.86		1.34
29.	Business services	D	0.88	0.50		3.51
30.	Motion pictures	C	1.15	0.42		0.32
31.	Transportation services	D	1.23	-0.10		0.31
32.	Local and interurban passenger transit	A	2.39	-1.20		0.17
33.	Security and commodity brokers	B	4.20	4.31		0.79
34.	Railroad transportation	A	4.38	8.84	7.31	0.35
35.	Nondepository institutions	B	5.07	4.81		0.45
36.	Industrial machinery and equipment;	B	5.27	7.36	2.19	3.32

Notes to Table 4

General Notes: Slowdown, BEA ALP growth, and 1992 share are all copied from Table 2. BLS ALP growth from *Productivity by Industry 1995*, USDL 97-132, April 23, 1997. All BLS subindustries are aggregated into industries that correspond to BEA definitions, using 1995 employment weights provided in the BLS release.

BLS ALP growth is available for numerous industries in durable and nondurable manufacturing. These will be aggregated and included in the next version of this table.

Notes by Line Number:

3. BLS trucking excludes warehousing and local trucking and is available only through 1989.

7. BLS personal services refers to the aggregate of two categories, (1) laundry, cleaning, and garment services, and (2) beauty and barber shops.

Table 5

Annual Growth Rates BEA and BLS Output per Hour, Alternative Industry Aggregates, Weighted by BEA 1992 Nominal Output

	Growth in Output/Hour			
	BEA 1977-96	BLS 1979-95	BLS-BEA	Share in 1992 GDP
All Industries Covered by BLS, using BEA weight	1.69	2.11	0.42	40.05
All Industries excluding Industrial machinery and equipment; electronic/electrical equipment	1.18	2.11	0.92	36.73
All Nonmanufacturing Industries	0.95	2.01	1.06	23.02

Source: Computed from Table 4.

Table 6

**BEA Productivity Growth,
Alternative Weights and by Measurement Category**

	1948 -67	1967 -77	1977 -96	Slowdown 1977-96 vs. 48-67	Share in 1992 GDP
Alternative Weights for Private Business GDP					74.08
As Published, 1982 constant dollars for 1948-77, 1992 constant dollars for 1977-96	2.21	1.23	0.90	-1.32	
Quasi-Tornqvist	2.57	1.46	1.33	-1.24	
All periods with 1948-67 average nominal share	2.57	1.48	1.80	-0.77	
All periods with 1977-96 average nominal share	2.25	1.30	1.33	-0.92	
All periods with 1948 average nominal share	2.82	1.64	2.00	-0.82	
All periods with 1996 average nominal share	2.06	1.21	1.16	-0.90	
Private Business GDP by Measurement Category, weights within categories as published					
Category A (most accurate)	4.62	1.12	1.74	-2.87	8.47
Category B	2.89	2.94	2.52	-0.37	21.67
Category C	1.92	0.51	0.92	-1.00	23.52
Category D (least accurate)	0.41	0.24	-0.69	-1.10	19.71
Addendum: Categories A and B	3.38	2.43	2.30	-1.08	30.14

Notes: Measurement categories are defined as follows.

A. Based on quantitative measures of output or deflation with no known reason for bias.

B. Based on quantitative measures of output or deflation subject to possible bias for quality change; unmeasured product attributes largely absent.

C. Based primarily on deflation which may be subject to bias for quality change; unmeasured product attributes relatively minor.

D. Based primarily on deflation which may be subject to bias for quality change; unmeasured product attributes may be substantial.

Figure 1
Share of Computers in PCE and GDP

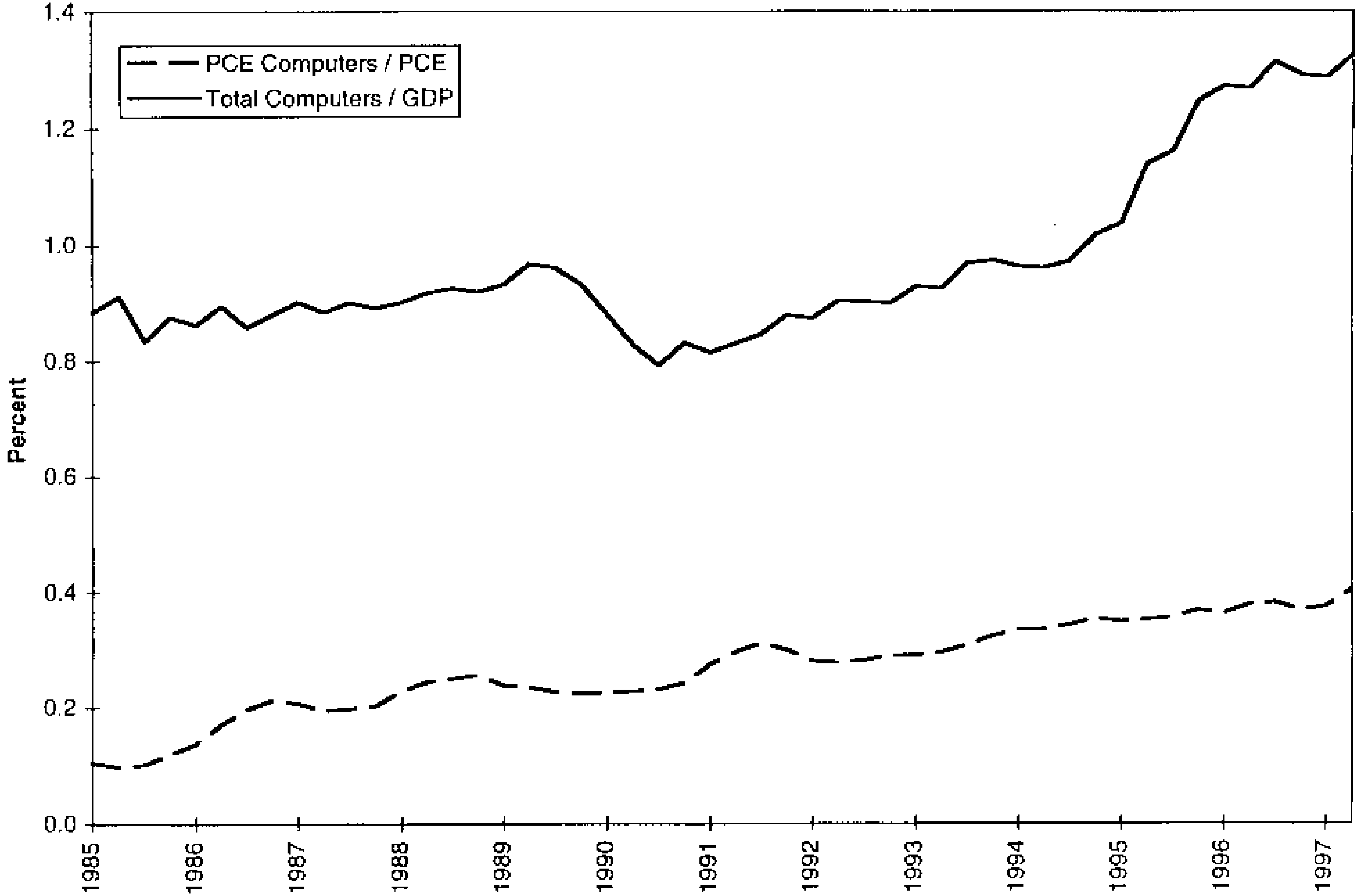

Figure 2

Implicit Price Deflators for Computers

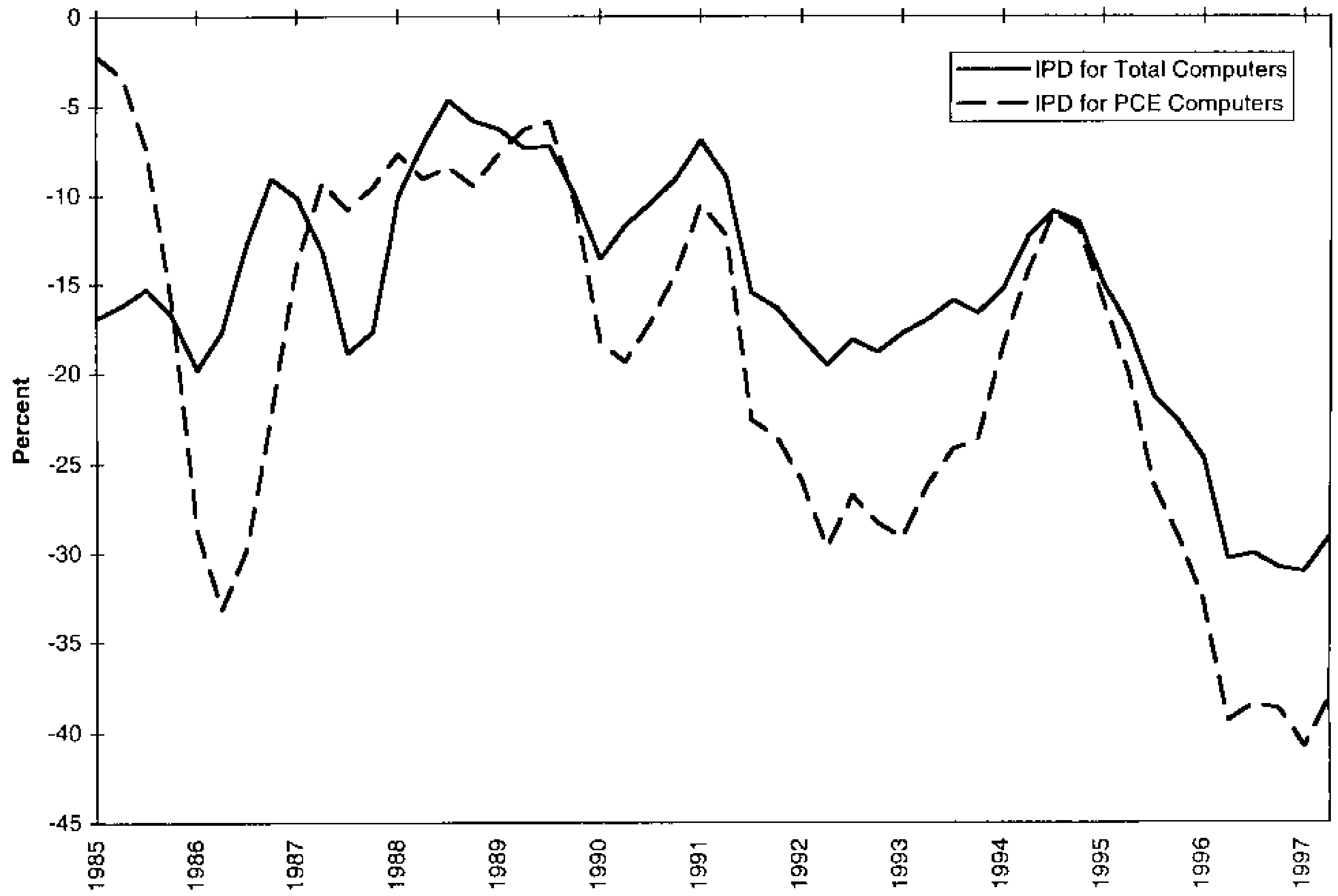

Figure 3
GDP Deflator-Based Alternative Measures of Inflation
Exclusion: Total Computers

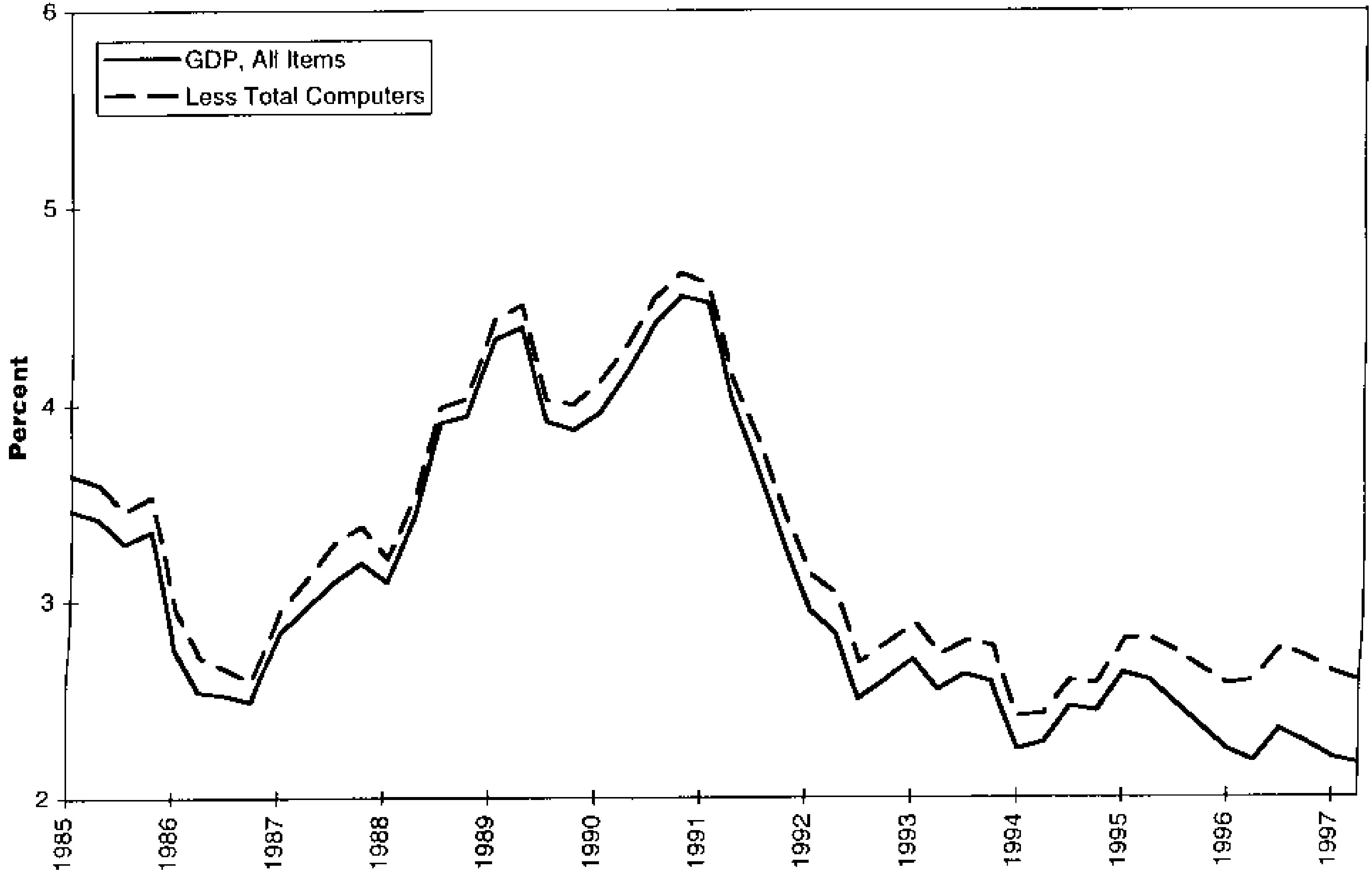

Figure 4
GDP Deflator-Based Alternative Measures of Inflation

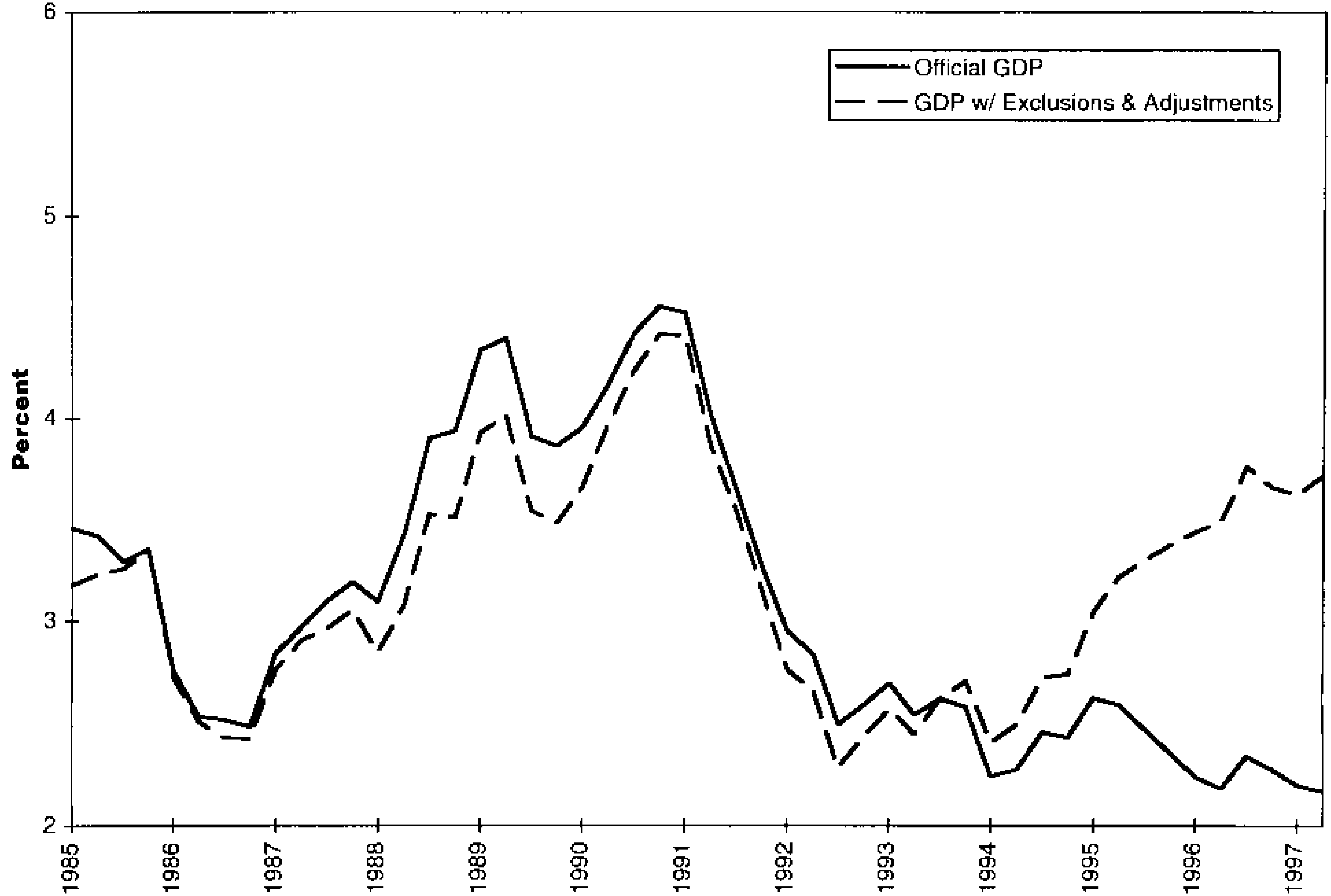

Figure 5
GDP Deflator-Based TV-NAIRUs, Std Dev = 0.2