Preliminary - Comments Welcome

# The Industry Origins of the American Productivity Resurgence

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First Draft: October 6, 2006

**Abstract**

This paper analyzes the industry origins of the American growth resurgence by examining output, input, and productivity growth of 85 component industries for the period 1960 to 2004. We use this detailed industry data to examine trends in particular industry groups such as those that produce information technology (IT) or use IT most intensively and to perform a "bottom-up" comparison of alternative aggregation methodologies. The data show that while labor productivity growth was strong throughout the full period after 1995, there were important differences between 1995-2000 and 2000-2004. The period 1995-2000, for example, was marked by strong growth in labor input so aggregate output was robust, while labor input and output growth both declined substantially after 2000. IT remained an important source of both capital deepening and total factor productivity growth after 2000, but the contributions were not as large as during the technology boom of the late 1990s. We also show that the production possibility frontier, which recognizes differences in output prices across industries, remains the most appropriate methodology for aggregating industry data.

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## I. Introduction

The remarkable productivity growth in the U.S. economy since 1995 has received considerable attention and our previous work documents the growth and productivity resurgence of 1995-2000 in terms of the output, inputs, and productivity growth of 44 component industries for the period 1977-2000 (Jorgenson, Ho, and Stiroh (2005)). The behavior of the U.S. economy since 2000 has continued to surprise as the economy experienced the dot-com crash of 2000, the recession of 2001, a major slowdown of investment, and the war in Iraq even as aggregate productivity growth continued at a faster pace. In this paper, we extend our industry analysis backward to 1960 to provide a longer time perspective and forward to 2004 to capture this surprising acceleration of productivity growth. We examine the performance of 85 U.S. industries in order to provide greater detail on the origins of the growth and productivity resurgence after 1995.

Most attention in the academic literature and the business press focuses on the performance of the aggregate economy, as described, for example, by the Congressional Budget Office (2006), Jorgenson, Ho and Stiroh (2006), and Oliner and Sichel (2002). This reflects the obvious need for a timely overview of economic performance by policy-makers, the desire to make economic measures accessible to a broad audience, and the difficulties encountered in modeling complex industry interactions. The key modeling choice is to dispense with industry-level detail and present only economy-wide measures of output, capital and labor inputs, and productivity. These measures are often further decomposed to highlight the critical role of investment in information technology (IT) and productivity growth in IT-production.

By contrast, Jorgenson, Ho, and Stiroh (2005) develop detailed industry data and present industry-specific measures of performance.[1] The obvious question is: How do the industry growth accounts compare with the aggregate results? For example, does the extraordinary performance of the IT-producing industries combine with the slower growth of the declining industries to yield conclusions similar to the aggregate results? Is there an aggregation method that preserves the underlying industry detail yet maintains conclusions consistent with the aggregate results without arbitrary and inappropriate aggregation assumptions?

[1]This industry-level approach has also been taken recently by Triplett and Bosworth (2003, 2006), Corrado et al. (2006), and van Ark and Inklaar (2005).

This paper examines these questions and reports several estimates of aggregate U.S. economic growth and labor productivity based on a "bottom-up" approach to analyzing the U.S. economy. We present three approaches to aggregate the underlying industry-level data that yield alternative measures of economy-wide output, inputs, and total factor productivity (TFP). The first approach is an "aggregate production function," the second is an "aggregate production possibility frontier," and the third is a direct "aggregation across industries." These schemes differ in the restrictiveness of their assumptions and yield different estimates of aggregate growth. Comparison across methods provides insight into the validity of the assumptions and enables us to choose the aggregate production possibility frontier as the most appropriate approach for combining industry data.[2]

We can summarize our empirical results, briefly, by focusing on the acceleration of U.S. output growth in 1995-2000 and the subsequent slowdown in 2000-2004, as well as the surge of U.S. labor productivity growth that continued through both periods. This "second surge" in aggregate productivity, documented in Jorgenson, Ho, and Stiroh (2006) and investigated at the industry level by Stiroh (2006), is remarkable given the slowdown in the U.S. economy and investment around the 2001 recession.

For 1995-2000, U.S. economic growth increased by a full percentage point relative to 1960-1995. Rising investment in information technology (IT) equipment and software contributed 0.72 percent to the jump in growth, while faster TFP growth in IT-producing industries accounted for another 0.26 percent. This is a familiar story: more rapid TFP growth resulted in higher rates of decline in IT prices, stimulating decisions by firms, households, and governments to invest in IT equipment and software. Jorgenson (2001) has traced this rapid decline in prices to a substantially shorter product cycle in the production of semiconductors, the key electronic component in IT equipment.

The IT boom of the last half of the 1990s faded after the technology investment bust and dot-com stock market crash of 2000 when output growth slowed significantly. Slower growth of TFP in the IT-producing industries reduced the rate of decline of IT prices in 2000-2004, although investment in IT equipment and software remained a substantial source of growth, motivated by the low prices already in place. Reduced TFP growth in IT production was more

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[2]We summarize the underlying methods, but refer the interested reader to Jorgenson, Ho, and Stiroh (2005, chapter 8) for more detail.

than offset by a sharp improvement in TFP growth in IT-using industries. This had been slightly negative during the boom of the late 1990s, but turned very substantially positive after 2000. TFP growth in the non-IT industries also rose after 2000. When appropriately aggregated, TFP growth in the 85 industries jumped from 0.4% per year during 1960-95 to 1.2% during 2000-04. Non-IT investment continued to languish, while the contribution of labor input turned from strongly positive in 1995-2000 to modestly negative after 2000 due to much slower hours growth.

The output boom of 1995-2000 and the slowdown of 2000-2004 were both accompanied by further accelerations in labor productivity. Relative to 1960-1995, labor productivity growth rose by 0.45 percent in the boom period of 1995-2000, while hours worked rose by 0.54 percent. In sharp contrast, output growth slowed in 2000-2004 due to a startling decline in labor input of 2.18 percent during the “jobless recovery” that followed the 2001 recession, even as labor productivity growth increased by an amazing 1.58 percent relative to the pre-1995 rates![3] In 1995-2000, the acceleration in labor productivity growth was due primarily to more rapid IT capital deepening and secondarily to faster growth in TFP in the IT-producing industries. After 2000, non-IT capital deepening accelerated further, but more rapid TFP growth outside of IT-production emerged as the primary driving force. The change in the growth contribution of labor quality went from slightly negative to slightly positive.

The crucial role of IT in the labor productivity acceleration of 1995-2000 was evident in both IT capital deepening and faster TFP growth in IT-producing industries. IT has remained an important source of growth after 2000, although the magnitude of the contribution has decreased. IT capital deepening, for example, contributed about a quarter of the labor productivity acceleration after 2000, but slower TFP growth in the IT-producing industries acted as a brake on labor productivity growth. Non-IT capital deepening revived, TFP growth in IT-using industries sharply accelerated, and TFP growth in the non-IT industries continued to increase its contribution to labor productivity growth.

These results imply that prospects for future U.S. economic growth remain substantially brighter than suggested by growth trends before 1995, as shown by Jorgenson, Ho, and Stiroh (2006). While the output boom of the late 1990s was not sustainable due to limits imposed by

[3]We compare both periods to the pre-1995 rates to serve as a common benchmark.

the growth of the labor force, the output growth slowdown after 2000 with negative growth in hours worked is also unlikely to be prolonged.

We emphasize that the aggregate analysis presented by Jorgenson, Ho, and Stiroh (2006) is distinct from the results derived from the industry data presented here. These results are built up from industry sources and thus represent a "bottom-up" view of the U.S. economy that can be compared to the top-down results in our earlier work. A complete set of industry accounts requires large quantities of data available only with a considerable lag, while the aggregate data are more current. Finally, there are small differences in the treatment of the source data.

The remainder of the paper is organized as follows. Section 2 summarizes the methodology used to aggregate our industry data. For each approach we provide details on the methodology and discuss the necessary assumptions. Section 3 presents our results and interpretation. Section 4 concludes.

## II. Methodology

This section presents the methodology used to construct economy-wide estimates of output growth and the sources of growth for three alternative methods – aggregate production function, aggregate production possibility frontier, and direct aggregation across industries. In all cases, we use the same underlying industry data, namely, production data like those described in Jorgenson, Ho and Stiroh (2005). More precisely, we develop estimates of gross output, value-added, labor input, capital input, intermediate input, and total factor productivity (TFP) for 85 industries, and this section details the aggregation techniques used to transform the industry data into estimates for the U.S. economy as a whole.

The most restrictive aggregation approach is the "aggregate production function," which imposes strict assumptions about industry-level value-added functions and the relative prices and mobility across industries of the primary factors of production, capital and labor.[4] Moreover, the aggregation of heterogeneous types of capital and labor must be the same across industries, and each type of capital and labor must command the same price in each industry. Under these assumptions, the aggregate production function yields a valid representation of the underlying industry-level production structure.

[4] Jorgenson, Gollop, and Fraumeni (1987) show that the existence of an aggregate production function requires the very stringent assumptions that industry value-added functions exist and are identical across industries up to a scalar multiple.

A less restrictive approach is the "aggregate production possibility frontier," introduced by Jorgenson (1966) and recently employed by Jorgenson and Stiroh (2000). This approach relaxes the restrictions on industry value-added functions, so that value-added prices are not required to be identical across industries. This approach, however, retains the assumption that each input receives the same price in all industries. The aggregate production possibility frontier differs from the aggregate production function in the measurement of output, but not inputs.

A third approach is a "direct aggregation across industries," which relaxes these restrictions. Measures of industry output, input, and productivity growth are simply weighted by the relative size of the industry and summed across all industries. This approach makes no assumption about common prices for either outputs or inputs across industries, and treats the aggregate economy as a weighted average of the component industries. This is the least restrictive approach and can be used as a benchmark for comparison with the other aggregation schemes.

We estimate the growth of economy-wide output, inputs, and then calculate TFP for each aggregation method. Because all three aggregation schemes are implemented with the same underlying source data any divergence in results between the aggregate production function and the aggregate production possibility frontier indicates failure of the assumptions necessary for the representation of an economy value-added function. Further divergence in results for aggregation across industries reflects failure in the assumptions about mobility of the primary factors. We discuss this in some detail because there has been some confusion about the specifics of our aggregation procedures.[5]

*a) Aggregate Production Function*

The aggregate production function has a long history in economics, dating back at least to the work of Douglas (1948). Due to its simplicity and tractability, the aggregate production function has been a workhorse of applied macroeconomics. As discussed in detail in Jorgenson (1990), however, the existence of an aggregate production function requires a number of stringent assumptions for the existence. First, each industry must have a gross output production function that is separable in value-added, where value-added is a function of industry capital, labor, and time (which proxies for technology). Second, the value-added function is the same across all industries, up to a scalar multiple. Third, the functions that aggregate heterogeneous types of capital and labor must be identical for all industries. Fourth, each specific type of capital and labor must receive the same price in all industries. These assumptions have specific implications for internally consistent measures of aggregate output and inputs.

The first assumption guarantees that a measure of industry value-added is quantifiable, so that aggregate value-added can be defined as a function of industry value-added:

$$(1)\ V = V(V_1,...V_J)$$

where $V$ is the quantity of aggregate value-added and $V_j$ is a quantity index of industry value-added for industry $j$. Time subscripts are suppressed for convenience.

As an accounting identity, the nominal value of aggregate value-added equals the sum of the value of industry value-added across all industries:

$$(2)\ P_V V = \sum_j P_{V,j} V_j$$

where $P_{V,j}$ is the price of industry value-added. From this identity and Equation (1) we obtain the aggregate price of value-added $P_V$.

The second assumption – the existence of identical value-added functions across industries – implies that identical "price of value-added" functions (or the dual cost functions) exist across all industries. When combined with the fourth assumption that capital and labor components receive the same price in all industries, the industry price of value-added must be the same in all industries and at the aggregate level so that:

$$(3)\ P_V^{PF} = P_{V,j}\ \forall\ j$$

where $P_V^{PF}$ is the price of value-added for the aggregate production function and the superscript $PF$ denotes that is from the aggregate production function.

Equations (2) and (3) imply that the function defining aggregate value-added for the aggregate production function, given in Equation (1), is simply a summation across industries:

$$(4)\ V^{PF} = \sum_j V_j$$

where $V^{PF}$ is the quantity of aggregate value-added from the aggregate production function.

[5]Herkowitz (1998), for example, misreads Jorgenson (1966) in interpreting the production possibility frontier as representing output as a simple sum of the outputs of consumption and investment goods.

Equation (4) is the first key result. If the assumptions for an aggregate production function are valid, then aggregate value-added is a simple sum of industry value-added. This follows directly from the fact that the prices of industry value-added are the same in all industries, so that the quantities are perfect substitutes.

Turning to capital and labor inputs, industry production accounts like those presented by Jorgenson, Ho, and Stiroh (2005, Chapters 5 and 6) emphasize the heterogeneity of inputs within each industry, e.g., capital includes both computers and tractors, while labor includes high school educated men and college-educated women. The fourth assumption states that each type of capital and labor is identical in all industries and receives the same price everywhere. This is a market equilibrium condition when there is mobility of factors across industries; equilibrium exists only when all factors of the same type are paid the same price in all industries.

If each type of input receives the same price in all industries, the economy-wide quantity of each type of capital and labor is a simple sum across industries:

$$\begin{aligned} K_k &= \sum_j K_{k,j} \;\; \forall\, k \\ L_l &= \sum_j L_{l,j} \;\; \forall\, l \end{aligned} \tag{5}$$

where the *k* subscript indexes the type of capital and *l* indexes the type of labor. In this situation, the price of aggregate capital and labor of each type is the common price for all industries:

$$\begin{aligned} P_{K,k} &= P_{K,k,j} \;\; \forall\, j \\ P_{L,l} &= P_{L,l,j} \;\; \forall\, j \end{aligned} \tag{6}$$

Aggregate capital services and labor input are then defined as the Tornqvist aggregates of heterogeneous types of capital and labor, respectively, as:

$$\begin{aligned} \Delta \ln K &= \sum_k \overline{w}_k \Delta \ln K_k \\ \Delta \ln L &= \sum_l \overline{w}_l \Delta \ln L_l \end{aligned} \tag{7}$$

where the share of each type of capital in total capital input, and the share of each type of labor in total labor input, are defined respectively as:

$$(8)\qquad w_k = \frac{P_{K,k} K_k}{\sum_k P_{K,k} K_k} \qquad w_l = \frac{P_{L,l} L_l}{\sum_l P_{L,l} L_l}$$

and the two-period average share weights are defined as:

$$(9)\qquad \overline{w}_k = 0.5 * \left( w_{k,t} + w_{k,t-1} \right) \qquad \overline{w}_l = 0.5 * \left( w_{l,t} + w_{l,t-1} \right)$$

The aggregate prices of capital and labor inputs ($P_K$ and $P_L$) are derived from the accounting identity that defines the nominal factor payments as the sum of nominal values of the various types:

$$(10)\qquad P_K K = \sum_k P_{K,k} K_k \qquad P_L L = \sum_l P_{L,l} L_l$$

and the nominal values of each type of input for the aggregate economy are obtained by combining Equations (5) and (6).

Equation (4) defines the measure of aggregate value-added that can be generated from the industry-level data in a way that is consistent with the assumptions in the aggregate production function. Similarly, Equations (5) through (10) define the aggregate measures of capital and labor input that can be generated from the corresponding input data across industries. With these definitions, we can write the aggregate production function as:

$$(11)\qquad V^{PF} = f(K, L, T)$$

and the corresponding nominal value-added identity as:

$$(12)\qquad P_V^{PF} V^{PF} = P_K K + P_L L$$

At this point, it is useful to summarize. The four assumptions necessary for the existence of an aggregate production function allowed us to transform Equation (1), which represents aggregate real value-added as a function of industry real value-added, into the specific function in Equation (4) that yields $V^{PF}$ as a simple sum of industry real value-added. This is the aggregate value-added on the left-hand side of Equation (11). If the input assumptions hold, this implies that a production function with aggregate capital, labor, and technology as arguments exists and will generate this aggregate real value-added.[6]

We define aggregate total factor productivity (TFP) growth from the aggregate production function, $v_T^{PF}$, in the standard manner as:

$$(13) \qquad v_T^{PF} \equiv \Delta \ln V^{PF} - \bar{v}_K \Delta \ln K - \bar{v}_L \Delta \ln L,$$

where the share-weighted growth rates of capital and labor inputs are again defined as their respective contributions to output. The capital share and labor share of aggregate value-added are defined as:

$$(14) \qquad \begin{aligned} v_K &= \frac{P_K K}{P_K K + P_L L} \\ v_L &= \frac{P_L L}{P_K K + P_{L,} L} \end{aligned}$$

and the two-period average shares are defined as:

$$(15) \qquad \begin{aligned} \bar{v}_K &= 0.5 * \left( v_{K,t} + v_{K,t-1} \right) \\ \bar{v}_L &= 0.5 * \left( v_{L,t} + v_{L,t-1} \right) \end{aligned}$$

We further decompose the contribution of capital into an information technology (*IT*) component and a non-IT component (*NON*), and decompose labor input into the contribution of college-educated labor (*COL*) and non-college-educated (*NON*). Alternatively, we decompose the contribution of capital input into the contributions of capital stock (*Z*) and capital quality ($Q_K$) and the contribution of labor input into the contribution of hours (*H*) and labor quality ($Q_L$).[7]

These two decompositions of aggregate value-added growth are:

$$(16) \qquad \Delta \ln V^{PF} = \bar{v}_{K,IT} \Delta \ln K_{IT} + \bar{v}_{K,NON} \Delta \ln K_{NON} + \bar{v}_{L,COL} \Delta \ln L_{COL} + \bar{v}_{L,NON} \Delta \ln L_{NON} + v_T^{PF}$$

and

$$(17) \qquad \Delta \ln V^{PF} = \bar{v}_K \Delta \ln Z + \bar{v}_K \Delta \ln Q_K + \bar{v}_L \Delta \ln H + \bar{v}_L \Delta \ln Q_L + v_T^{PF}$$

[6]Official GDP is derived from both expenditures (C+I+G+NX) and incomes, and reconciled. In the above discussion, we do not use the expenditure data as employed in aggregate studies such as Jorgenson, Ho and Stiroh (2006). Furthermore, GDP here is at producer's prices, excluding production taxes.

[7] The quality of capital is an index of the composition of the total stock where higher quality comes from a larger share of assets with high marginal products (JHS 2006, Chapter 5). Higher quality of labor comes from a bigger share of better educated or more experienced workers (JHS 2006, Chapter 6).

where the $v$ shares again represent the two-period averages of the sub-scripted input in aggregate value-added, e.g., $v_{K,IT}=P_{K,IT}K_{IT}/P_V V^{PF}$. The aggregate capital stock, capital quality, labor hours, and labor quality indices are defined precisely in Jorgenson, Ho, and Stiroh (2005, Chapters 5 and 6). Intuitively, capital and labor quality indices represent substitution among heterogeneous input with different marginal products and thus can be interpreted as the impact of the evolving composition of capital and labor, respectively.

Finally, we define aggregate labor productivity from the aggregate production function as aggregate value-added per economy-wide hour worked, $v^{PF}=V^{PF}/H$. Growth in aggregate labor productivity can be decomposed as:

$$(18) \qquad \Delta \ln v^{PF} \equiv \bar{v}_K \Delta \ln k + \bar{v}_L \Delta \ln Q_L + v_T^{PF}$$

where $k=K/H$ is capital per hour worked, and $Q_L$ is labor quality. The capital deepening term can be broken down into IT and non-IT components as:

$$(19) \qquad \bar{v}_K \Delta ln\, k = \bar{v}_{K,IT} \Delta ln\, k_{IT} + \bar{v}_{K,NON} \Delta ln\, k_{NON}$$

where the growth of IT capital per hour and non-IT capital per hour are weighted by the two period shares of IT and non-IT capital in value-added, respectively.

The decomposition of the labor quality contribution is somewhat more complicated. The quality of college labor input is defined as $Q_{L,COL}=L_{COL}/H_{COL}$ and non-college labor as $Q_{L,NON}=L_{NON}/H_{NON}$, where $Q$ again refers to quality, $L$ refers to labor input, and $H$ refers to hours worked. The contribution of aggregate labor input is the weighted sum of college and non-college components. Aggregate hours, however, is simply the sum of hours of each type so there is a reallocation term in the decomposition of labor quality:

$$(20) \qquad \begin{aligned} \bar{v}_L \Delta \ln Q_L &\equiv \bar{v}_L \Delta \ln L - \bar{v}_L \Delta \ln H \\ &= \bar{v}_{L,Col} \Delta Q_{L,COL} + \bar{v}_{L,NON} \Delta \ln Q_{L,NON} + \bar{v}_{L,Col} \Delta H_{COL} + \bar{v}_{L,NON} \Delta H_{NON} - \bar{v}_L \Delta \ln H \\ &= \bar{v}_{L,Col} \Delta Q_{L,COL} + \bar{v}_{L,NON} \Delta \ln Q_{L,NON} + REALL_H \end{aligned}$$

where the $REALL_H$ term is a residual that represents a reallocation of hours between these two groups.

A few remarks are in order at this point. First, the four assumptions enumerated above are maintained throughout this derivation of aggregate TFP growth and the decomposition of inputs. These assumptions are required for the existence of aggregate production function and the next section examines their validity using U.S. data. Jorgenson (1990) concluded that the aggregate production function was appropriate for analyzing growth for long periods of time, but highly inappropriate over shorter periods. Second, we maintain the assumption of constant returns to scale for industries and for the U.S. economy as a whole throughout this analysis. This is necessary for the exhaustion of income across inputs. Third, this is the most restrictive of our aggregation methods because it imposes constraints on both output and input aggregation.

*b) Aggregate Production Possibility Frontier*

A second, less restrictive, approach to aggregation is the production possibility frontier, originated by Jorgenson (1966) and recently employed by Jorgenson and Stiroh (2000), Jorgenson (2001), and Jorgenson, Ho, and Stiroh (2005). The key difference between the aggregate production function and the aggregate production possibility frontier is relaxation of the restriction that industries have identical value-added functions and prices. If value-added is not perfectly substitutable across industries, then an aggregate production function of the form in Equation (4) does not exist and aggregate value-added must also represent substitution between industries with different value-added prices. This is captured in the production possibility frontier, our preferred approach.

We define aggregate value-added from the production possibility frontier as a Tornqvist index of industry value-added:

$$(21) \quad \Delta \ln V = \sum_j \overline{w}_j \Delta \ln V_j$$

where $V_j$ is industry $j$'s real value-added and $w_j$ is the share of industry value-added in aggregate value-added:

$$(22) \quad w_j = \frac{P_{V,j} V_j}{\sum_j P_{V,j} V_j}$$

and the two-period average share is defined as:

$$(23) \quad \overline{w}_j = 0.5 * \left( w_{j,t} + w_{j,t-1} \right)$$

where $P_{V,j}$ is the price of industry value-added where $V$ without a superscript is from the production possibility frontier, while $V^{PF}$ is from the aggregate production function.

We maintain the same assumptions regarding capital and labor inputs, so that aggregate capital and labor are defined by Equations (5) through (10). These assumptions yield the following relationship between aggregate value-added, aggregate inputs, and technology for the aggregate production possibility frontier:

$$(24) \quad V = f(K, L, T)$$

We define TFP growth from the aggregate production possibility frontier in the same manner as Equation (13) above as output growth less capital and labor input growth weighted by their value shares:

$$(25) \quad v_T \equiv \Delta \ln V - \bar{v}_K \Delta \ln K - \bar{v}_L \Delta \ln L$$

This TFP growth may also expressed in terms of the decompositions of capital and labor as in Equations (16) and (17) as:

$$(26) \quad \begin{aligned} v_T &\equiv \Delta \ln V - \bar{v}_{K,IT} \Delta \ln K_{IT} - \bar{v}_{K,NON} \Delta \ln K_{NON} - \bar{v}_{L,COL} \Delta \ln L_{COL} - \bar{v}_{L,NON} \Delta \ln L_{NON} \\ &\equiv \Delta \ln V - \bar{v}_K \Delta \ln Z - \bar{v}_K \Delta \ln Q_K - \bar{v}_L \Delta \ln H - \bar{v}_L \Delta \ln Q_L \end{aligned}$$

We again define aggregate real value-added per hour worked as $v=V/H$, and express the sources of labor productivity growth from the aggregate production possibility frontier as capital intensity growth, labor quality growth and TFP growth as in Equations (18) to (20):

$$(27) \quad \begin{aligned} \Delta \ln v &\equiv \bar{v}_K \Delta \ln k + \bar{v}_L \Delta \ln Q_L + v_T \\ &\equiv \bar{v}_{K,IT} \Delta \ln k_{IT} + \bar{v}_{K,NON} \Delta \ln k_{NON} + \\ &\qquad \bar{v}_{L,COL} \Delta \ln LQ_{COL} + \bar{v}_{L,NON} \Delta \ln LQ_{NON} + REALL_H + v_T \end{aligned} .$$

An alternative decomposition of aggregate labor productivity begins with the definition of industry value-added from Jorgenson, Ho, and Stiroh (2005, Equation (4.11)), which expresses value-added as industry output less intermediate inputs.[8] Given the definitions of aggregate value-added growth, aggregate hours growth, and industry-level labor productivity growth, we can decompose aggregate labor productivity growth as:

$$(28) \quad \begin{aligned} \Delta \ln v &= \left( \sum_j \bar{w}_j \Delta \ln y_j \right) - \left( \sum_j \bar{v}_{X,j} \left( \Delta \ln X_j - \Delta \ln Y_j \right) \right) + \left( \sum_j \bar{w}_j \Delta \ln H_j - \Delta \ln H \right) \\ &= \left( \sum_j \bar{w}_i \Delta \ln y_j \right) - R^M + R^H \end{aligned}$$

where $Y_j$ is the gross output of industry $j$, $X_j$ is intermediate inputs, $H_j$ is hours worked, $y_j$ is industry labor productivity ($Y_j/H_j$), and $w_j$ is the value-added share of gross output.

The first term in Equation (28) is a "direct productivity effect" that equals the weighted average of industry labor productivity growth. As industry productivity improves, aggregate productivity rises in proportion to industry size. The second term $R^M$ is a "reallocation of materials," which reflects variation in intermediate input intensity across industries. It enters with a negative sign because using more intermediate inputs to raise gross output, $\left(\Delta \ln X_i > \Delta \ln Y_i\right)$ must be netted out to reach aggregate productivity; this interpretation is similar to the intermediate intensity term in Basu and Fernald (1997, Equation 17). The third term $R^H$ is a "reallocation of hours." Aggregate hours growth can be approximated as the weighted average of industry hours growth with lagged hours shares as weights, i.e., $\Delta \ln H \approx \sum_j h_j \Delta \ln H_j; \quad h_j = H_{j,t-1} / H_{t-1}$. Thus, aggregate productivity rises if $\overline{w}_j > h_j$, that is, if industries with higher average value-added shares experience faster growth in hours. This reallocation effect is a real economic force as resources move among industries.

We can simplify this expression by incorporating the value-added concept of industry labor productivity as:

$$
\begin{aligned}
\Delta \ln v &= \left( \sum_j \overline{w}_j \Delta \ln v_j \right) + \left( \sum_j \overline{w}_j \Delta \ln H_j - \Delta \ln H \right) \\
&= \left( \sum_j \overline{w}_j \Delta \ln v_j \right) + R^H
\end{aligned} \tag{29}
$$

where $v_j = V_j / H_j$ is industry value-added per hour worked.

In Equation (29), aggregate productivity growth reflects the direct contribution of industry value-added productivity growth plus the reallocation of hours worked to industries with higher marginal products of labor. The reallocation of materials is eliminated by the use of the value-added concept of industry output.

*c) Direct Aggregation across Industries*

Our third approach to measuring the sources of growth for the aggregate U.S. economy is direct aggregation across industries as in Gollop, and Fraumeni (1987, Chapter 2). This methodology employs the industry production accounts as the fundamental building blocks and begins with the industry-level sources of growth. We maintain the assumption that a value-added function exists for each industry, but impose no cross-industry restrictions on either value-added or inputs, which eliminates the assumptions of identical value-added functions, mobility of

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[8]This alternative decomposition was developed by Stiroh (2002) and also implemented by Bosworth and Triplett (2003). Nordhaus (2002) presents a similar decomposition.

inputs across industries, and equal factor prices for all industries.[9] In addition to being less restrictive, this approach allows one to trace the origins of aggregate productivity growth and input accumulation to the underlying industry sources.

*i) Aggregation for All Industries*

We begin with the decomposition of industry-level gross output growth, written as:

$$(30) \qquad \Delta \ln Y_j = \bar{v}_{K,j} \Delta \ln K_j + \bar{v}_{L,j} \Delta \ln L_j + \bar{v}_{X,j} \Delta \ln X_j + v_{T,j}$$

where industry gross output growth reflects the contribution of capital, the contribution of labor, the contribution of intermediate inputs ($X_j$), and TFP, all for industry $j$. The first three $v$'s are input shares in the value of industry gross output, while $v_{T,j}$ is the TFP growth rate.

Aggregate output, however, is a value-added concept, so we define industry value-added by decomposing output growth as the weighted sum of value-added growth and intermediate input growth:

$$(31) \qquad \Delta \ln Y_j = \bar{v}_{V,j} \Delta \ln V_j + \bar{v}_{X,j} \Delta \ln X_j$$

where $V_j$ is real value-added and $v_{V,j} = 1 - v_{X,j}$ is the share of value-added in industry gross output. Given data on output and intermediate inputs, this equation yields the real value-added growth of industry $j$. The above two equations can be rearranged to yield an expression for the sources of value-added growth:

$$(32) \qquad \Delta \ln V_j = \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}} \Delta \ln K_j + \frac{\bar{v}_{L,j}}{\bar{v}_{V,j}} \Delta \ln L_j + \frac{1}{\bar{v}_{V,j}} v_{T,j}$$

We define aggregate output, $V$, from the production possibility frontier, Equations (21) to (23), where aggregate output growth is the weighted average of industry value-added growth. Combining Equation (21) with (32) implies that aggregate value-added growth can be written as:

$$(33) \qquad \Delta \ln V \equiv \sum_j \bar{w}_j \Delta \ln V_j = \sum_j \bar{w}_j \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}} \Delta \ln K_j + \bar{w}_j \frac{\bar{v}_{L,j}}{\bar{v}_{V,j}} \Delta \ln L_j + \bar{w}_j \frac{1}{\bar{v}_{V,j}} v_{T,j}$$

Equation (33) defines aggregate value-added growth as the weighted average of industry value-added and shows that this reflects the weighted contribution of industry capital, industry labor, and industry TFP. The weights on capital or labor reflect three factors: the relative size of

[9] This method is similar to Domar (1961), except that Domar assumes factor mobility across industries.

industry value-added in aggregate value-added ($w_j$), the share of industry capital or labor income in industry gross output ($v_{K,j}$ and $v_{L,j}$), and the share of industry value-added in industry gross output ($v_{V,j}$). The weights on industry TFP reflect the relative size of industry value-added in aggregate value-added ($w_j$) and the share of industry value-added in industry gross output ($v_{V,j}$). All weights are two-period averages, as in the Tornqvist approach.

To quantify the impact of the assumptions behind the production possibility frontier, we compare this expression for the weighted average of the industry-level sources of economic growth to the aggregate decomposition derived from the production possibility frontier in Equation (25). More precisely, we subtract Equation (33) from Equation (25) and rearrange to find:

$$
\begin{aligned}
v_T = & \left( \sum_j \frac{\overline{w}_j}{\overline{v}_{V,j}} v_{T,j} \right) \\
& + \left( \sum_j \overline{w}_j \frac{\overline{v}_{K,j}}{\overline{v}_{V,j}} \Delta \ln K_j - \overline{v}_K \Delta \ln K \right) \\
& + \left( \sum_j \overline{w}_j \frac{\overline{v}_{L,j}}{\overline{v}_{V,j}} \Delta \ln L_j - \overline{v}_L \Delta \ln L \right) \\
v_T = & \sum_j \frac{\overline{w}_j}{\overline{v}_{V,j}} v_{T,j} + REALL_K + REALL_L
\end{aligned}
\tag{34}
$$

This expression shows how aggregate TFP growth from the production possibility frontier relates to the sources of growth at the industry-level. The first source of aggregate TFP growth is the weighted average of industry TFP growth rates. This is given by the first set of parentheses in Equation (34), which shows the sum of "Domar-weighted" rates of industry TFP growth.[10]

The second and third sets of parentheses in Equation (34) reflect the reallocations of capital and labor across industries, $REALL_K$ and $REALL_L$, respectively. These reallocations create a divergence between the growth rate of aggregate TFP and the sum of the Domar-weighted industry TFP growth rates. In terms of the theoretical framework we have described, the reallocation terms quantify the departure from the assumptions on inputs required for the aggregate production function. For example, TFP growth from the aggregate production

[10]Jorgenson, Ho and Stiroh (2005, Section 8.2.3) provide a longer discussion of the Domar weights. One important characteristic is that these weights sum to more than one.

possibility frontier exceeds Domar-weighted industry TFP when the reallocation terms are positive. This happens when capital and labor inputs are paid different prices in different industries and industries with higher prices have faster input growth rates. In this case, aggregate capital (or labor) grows more slowly than the weighted averages of industry capital (or labor).[11]

We also quantify the importance of the additional assumptions required for the existence of the aggregate production function. As discussed above, the aggregate production function assumes that the price of value-added is the same in all industries, while the production possibility frontier does not. This leads to different growth rates for the two alternative definitions of aggregate value-added. We define the reallocation of value-added as the difference between the growth rates of value-added from the aggregate production function and from the aggregate production possibility frontier as:

$$\begin{aligned} REALL_{VA} &= d\ln V^{PF} - d\ln V \\ &= d\ln V^{PF} - \sum_j \overline{w}_j d\ln V_j \end{aligned} \tag{35}$$

where $V^{PF}$ is aggregate value-added from the aggregate production function in Equation (4), $V$ is aggregate value-added from the production possibility frontier in Equation (21), and $V_j$ is valued-added for industry $j$.

*ii) Aggregation by IT groups*

An important feature of this aggregation methodology is the ability to identify the direct contributions of particular industries to aggregate economic growth and its sources. That is, we can explicitly quantify how much an individual industry (or set of industries) contributes to aggregate value-added growth, capital input, labor input, or TFP growth by applying the appropriate weight to the industry. We are particularly interested in the growth contributions of the industries that produce information technology goods (IT-producing), the industries that use information technology most intensively (IT-using), and the other industries (non-IT), as

[11] Note that if we used capital stocks rather than capital services, there would be no $REALL_K$ term because a given asset has the same price across all industries by construction. This implies that simple sums and Tornqvist indexes across industries are identical. Service prices for each asset, however, do diverge across industries due to differences in rates of returns and taxes, so the term $REALL_K$ is non-zero.

identified in the Appendix Table.[12] To analyze the contributions of these groups we simply rearrange the above decomposition equations.

Equations (33) and (34) show how much each industry contributed to aggregate value-added, aggregate capital input, aggregate labor input, and aggregate TFP. We refer to the components of Equation (33) as the industry contribution to aggregate value-added ($CT_{VA,j}$), the industry contribution to aggregate capital input ($CT_{K,j}$), the industry contribution to aggregate labor input ($CT_{L,j}$), and the industry contribution to aggregate TFP ($CT_{TFP,j}$), and these are defined as:

$$(36) \qquad \begin{aligned} CT_{VA,j} &= \bar{w}_j \, d\, lnV_j \\ CT_{K,j} &= \bar{w}_j \frac{\bar{v}_{K,j}}{\bar{v}_{V,j}} \Delta ln K_j \\ CT_{L,j} &= \bar{w}_j \frac{\bar{v}_{L,j}}{\bar{v}_{V,j}} \Delta ln L_j \\ CT_{TFP,j} &= \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j} \end{aligned}$$

To quantify the contribution of each set of industries to economic growth, we rewrite Equation (33) for the growth of aggregate value-added as the sum of the contribution of these three types of industries:

$$(37) \qquad \Delta lnV = \sum_{j \in IT-PRODUCE} \bar{w}_j \Delta lnV_j + \sum_{j \in IT-USE} \bar{w}_j \Delta lnV_j \sum_{j \in OTHER} + \bar{w}_j \Delta lnV_j$$

where each summation refers to the net contribution of the industries in each group to aggregate value-added growth. Similarly, we estimate the contribution of these sets of industries to aggregate TFP growth by breaking down the Domar-weighted contributions from Equation (34) as:

$$(38) \qquad \sum_j \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j} = \sum_{j \in IT-PRODUCE} \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j} + \sum_{j \in IT-USE} \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j} + \sum_{j \in OTHER} \frac{\bar{w}_j}{\bar{v}_{V,j}} v_{T,j}$$

Equation (29) gives the decomposition of aggregate labor productivity growth using output defined from the production possibility frontier. The direct contribution terms may be similarly reorganized for the same groupings of industries by IT roles:

[12]We identify IT-producing industries as Computers and Office Equipment; Communications Equipment; Electronic Components; and Computer Services. We identify IT-using as those with IT capital share greater than 15% in 1995. All other industries are labeled non-IT.

(39) $$\sum_j \overline{w}_j \Delta \ln v_j = \sum_{j \in IT-PRODUCE} \overline{w}_j \Delta \ln v_j + \sum_{j \in IT-USE} \overline{w}_j \Delta \ln v_j + \sum_{j \in OTHER} \overline{w}_j \Delta \ln v_j$$

We note that these decompositions, like all decompositions, can be misleading if there is considerable heterogeneity within each category. Consider the simple example where two industries have the same value-added shares in aggregate value-added and in gross output, but one has positive TFP growth of 1.0 percent per year and the other has negative TFP growth of 1.0 percent per year. The sum of the Domar-weighted contributions would be zero, but it is clear that the first industry made a positive contribution to aggregate productivity growth.

## III. Empirical Results

This section reports estimates of output growth and the sources of growth for the aggregate U.S. economy. We begin with the estimates from our preferred method, the aggregate production possibility frontier that are constructed from the underlying industry data. We then compare results to the aggregate production function and the aggregation across industries approach by quantifying the magnitude of the reallocation terms. Finally, we examine the contribution of individual industries and groups of industries to U.S. economic growth and the sources of that growth.

We reiterate that all these alternative aggregation techniques use the same underlying industry data, which allows us to identify the impact of specific assumptions. These data are different from those reported by Jorgenson, Ho, and Stiroh (2005), which reflect earlier vintages of NIPA data, a different time period, and have some different treatments of the source data.

### *a) Estimates of the Production Possibility Frontier*

Table 1 presents estimates of the sources of growth for the aggregate U.S. economy from the production possibility frontier. The first line gives the growth rate of aggregate value-added, followed by the contribution of IT-producing, IT-using, and non-IT industries, as in Equation (37). The remainder of Table 1 presents the familiar estimates of the contributions of capital, labor, and the TFP residual as in Equation (26). All growth rates and contributions are average annual growth rates or contributions; the average shares used to calculate the contributions are given in Table 2.

Aggregate value-added from the production possibility frontier grew 3.20 percent per year for the full period 1960-2004. The decomposition into the three sets of industries from Equation (37) shows that the non-IT industries accounted for more than half of the aggregate growth. The magnitude of this contribution is not surprising, however, since these industries account for almost three-quarters of value-added over this period. The IT-using industries, which account for almost another quarter of value-added, contributed an additional 0.88 percentage point and the IT-producing industries, which account for the remaining two percent of value-added, contributed an additional 0.28 percentage points. Despite their small size, the rapid growth of the IT-producing industries enabled these industries to make a sizable contribution to U.S. economic growth over the last four decades.

The first productivity revival in 1995-2000 shows the disproportionate contribution from the IT-producing industries and highlights what many have called the "information age." These four industries accounted for only about three percent of value-added during 1995-2000, yet they contributed almost half of the output growth increase over the earlier 1960-95 period, given in the penultimate column of Table 1 (0.46 out of the 1.0 percentage point increase). In contrast, the non-IT industries accounted for more than 70 percent of value-added, but contributed less than a fifth of the post-1995 gain in value-added growth (0.19 of the 1.0 percentage point). The IT-using industries contributed the remaining 35 percent.

The final column of Table 1 shows a substantial decline of 0.60 percent in the growth rate of value-added when 2000-2004 is compared to 1960-1995. The IT-producing industries led this decline with a fall of 0.23 percent, the non-IT industries contributed 0.21 percent to the decline, and the IT-using industries followed with a fall of 0.16 percent.

The standard decomposition into primary inputs and the TFP residual in Equation (25) shows that capital input dominates the sources of growth for the period 1960-2004 with a contribution of 1.73 percentage points of the total of 3.20 percent. Labor input contributed 1.04 percentage points and aggregate TFP contributed the remaining 0.43 percentage points. Thus, capital and labor inputs account for a great preponderance of U.S. economic growth since 1960.

Two important features of the TFP contribution are the increase after 1995 and, especially, the remarkable second surge after 2000. The contribution of TFP was 0.50 percentage points for 1995-2000 and 1.10 after 2000, compared to 0.34 during the period 1960-1995. The results through 2000 are similar to those reported by Jorgenson, Ho, and Stiroh (2002, 2006) and Oliner and Sichel (2002), although we reiterate that the data presented in Table 1 are constructed from the underlying industry data and not from data on aggregate expenditures.

A further decomposition of capital and labor inputs into their components shows that non-IT capital has been the most important source of growth for the full period, but IT capital has made roughly a similar contribution for the recent periods 1995-2000 and 2000-2004. Given the relatively small share of IT capital, only 6.4 percent of value-added from 2000-2004 (Table 2), these contributions are very impressive. College-educated labor has been the most important source of labor input growth for all three sub-periods and the contribution of non-college labor actually turned negative after 2000. As described in greater detail by Jorgenson, Ho and Stiroh (2005, Chapter 6), the increase in non-college labor contribution during 1995-2000 was due to large declines in rates of unemployment among the least educated workers.

The bottom panel of Table 1 shows the alternative decomposition of capital and labor input into the stock and quality components as in Equation (26). As discussed earlier, capital and labor quality reflect the substitution between assets or workers with different marginal products. For both capital and labor, the stock component has predominated as a source of growth: capital stock accounted for about 63 percent of the contribution of total capital input, while labor hours accounted for more than 73 percent of labor's contribution. A detailed discussion of the changes in capital stock and quality is given in Jorgenson, Ho, and Stiroh (2005, Chapter 5), which also documents the rise in the capital quality contribution after 1995 as firms substituted toward high-tech assets with relatively high marginal products. This contribution receded to the level of 1960-1995 after 2000. On the other hand, the contribution of labor quality slowed from 0.28 percentage points during 1960-1995 to 0.22 during 1995-2000, as hours growth increased. This reflects the fall in unemployment rates during the boom and the relatively rapid growth of hours for workers with low education and wages. After 2000 the contribution of hours growth turned negative during the 2001 recession and subsequent recovery, while labor quality growth revived.

The top panel of Table 2 presents the raw growth rates of the various value-added, capital, and labor sub-aggregates, while the bottom panel presents the average shares of aggregate value-added. The IT-producing industries have made a relatively large contribution to value-added growth during 1995-2000 due to the extremely rapid growth rate, 24.25 percent per year, by comparison with 4.55 percent for the IT-using industries and 3.16 percent for the non-IT industries. Despite this rapid growth, the IT-producing industries have remained small in relation to the economy as a whole with only 2.9 percent of the aggregate value-added, as large declines in the relative prices of IT assets have kept nominal shares relatively small.[13] Growth in the IT-producing industries after 2000 fell precipitously to only 0.76 percent, contributing to the substantial slowdown in input growth, while IT-using industries grew at 2.66 percent, and non-IT industries at 2.59 percent. The slowdown in IT-producing industries illustrates the sizable impact of the bursting of the technology bubble in 2000 and the recession in 2001 on those industries.

A similar story can be seen on the capital input side. IT capital input grew much faster than non-IT capital or labor inputs, but remained relatively small in terms of the share of aggregate value-added. IT capital grew over 15 percent per year for the full period and over 19 percent during 1995-2000, before falling to 10.8 percent after 2000. These growth rates can be compared to the growth rate of non-IT capital of 3.13 percent for the period as a whole and 3.25, 3.12, and 2.15 for the three sub-periods. The data also show that the increased contribution of IT capital after 1995 is due to more rapid accumulation as firms responded to the acceleration in the rate of price decline of IT assets by changing investment patterns, as well as the growing share of IT capital. The share of IT capital input, for example, increased from 2.6 percent of aggregate value-added before 1995 to 5.7 percent for 1995-2000 and 6.4 percent after 2000.

In terms of labor, college-educated labor grew more than four times as fast as non-college-educated labor for the period 1960-2004. Although non-college-educated labor closed the gap in terms of growth rates during 1995-2000, the growth rate of non-college labor turned negative after 2000. While non-college-educated labor remains slightly larger in terms of value shares, 30.7 percent of total value-added vs. 25.9 percent for college-educated for 2000-2004, the rising relative wages of college-educated workers have reduced this gap.

Table 3 presents the decomposition of labor productivity shown in Equation (27). As in other research on aggregate productivity, our calculations show a substantial acceleration of labor productivity from 1.68 percent for 1960-1995 to 2.13 percent during 1995-2000. Labor productivity growth experienced a second surge after 2000, accelerating to 3.25 percent. We see a growing contribution of capital deepening (0.35 percentage points) and gains in TFP growth (0.16 percentage points) after 1995. By contrast, capital deepening jumped by 0.74 percent after

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[13]Note that the product of the average growth rate and the average shares does not equal the average contribution given in Table 1, which is calculated as the average of the product of the growth rates and shares. The growth of value-added for each set of industries is the growth of the Tornqvist index for these industries, as in Equation (37).

2000 and TFP growth soared by 0.76 percent. Labor quality made a smaller contribution after 1995 and was thus a drag on the acceleration of labor productivity, but revived after 2000.

There is substantial variation across types of inputs within the capital deepening and labor quality contributions. IT capital deepening, for example, showed a huge increase during 1995-2000, but receded to a more moderate level after 2000. Non-IT capital deepening actually made a smaller contribution in 1995-2000, but revived after 2000. Firms clearly responded to the incentives of cheaper IT assets, changed their investment patterns, and substituted toward the relatively cheap IT capital after 1995.

The contribution of labor quality, given in Equation (20), declined after 1995 due to a slowdown in non-college labor quality and a slower reallocation of hours. The trends in college and non-college labor quality continued after 2000, but reallocation of hours reversed course, making a positive contribution to aggregate labor quality. These disparate trends suggest significant substitution both within and between our broad categories of college-educated and non-college-educated workers. More precisely, these data indicated that relatively high-wage workers in each category were growing most rapidly. The ongoing reallocation of hours toward more highly compensated college-educated workers contributed to labor quality growth in all three sub-periods.

*b) Alternative Aggregation Methods and Reallocations*

We now compare the alternative estimates generated by the aggregate production function, the most restrictive of the approaches, and the least restrictive direct aggregation across industries. We begin in the top panel of Table 4 with the comparison of value-added growth from the production possibility frontier with growth from the aggregate production function in Equation (35). The reallocation of value-added term, $REALL_{VA}$, is the difference between these two estimates and quantifies the failure of the assumption that all industries face the same value-added price.

The results show the substantial similarity between the two approaches for the full period 1960-2004, when value-added growth from the production possibility frontier was 3.20 percent per year compared to 3.16 percent for the aggregate production function. The reallocation of value-added was a modest -0.04 percent. There are quite large differences, however, for the three sub-periods with value-added from the aggregate production function growing slower for the period 1960-1995 and considerably faster for the periods 1995-2000 and 2000-2004. For the period 1995-2000 growth in value-added from the aggregate production function averaged 5.03 percent per year compared to only 4.14 percent for the production possibility frontier, leaving a large reallocation of value-added of 0.89 percent. After 2000, growth in value-added from the aggregate production function fell to 3.56 percent compared to 2.54 percent for the production possibility frontier with an even larger reallocation of value-added of 1.02 percent. These results indicate that the aggregate production function may be appropriate for analysis over long time periods, but is highly inappropriate for shorter periods, a result that echoes Jorgenson (1990).

The substantial reallocation of value-added in recent years highlights a major violation of the assumption underlying the aggregate production function that the price of value-added is the same for all industries. For the most recent period since 1995, the positive reallocation terms indicate that industries with declining relative prices are growing the fastest, as consumers and firms respond to changing price signals and alter their investment and consumption decisions. The intuition behind the reallocation term is that growth of value-added from the aggregate production function can be approximated as the weighted average of growth rates of individual industries, where weights are lagged real shares, rather than two-period nominal shares, as in the Tornqvist index used in the aggregate production possibility frontier. If industries with relatively rapid real value-added growth have real shares that are large relative to nominal shares (as would be the case if relative prices were falling), the value-added reallocation terms are positive. After 1995, many of the high-tech industries saw declining relative prices and rapid growth, which led to the large, positive reallocation terms.

The bottom panel of Table 4 compares the production possibility frontier to the direct aggregation across industries through the decomposition of aggregate TFP. Equation (34) shows how aggregate TFP growth can be decomposed into the Domar-weighted TFP growth of component industries plus the reallocations of capital and labor. These input reallocations reflect deviations from the aggregation assumption that each capital and labor input faces the same price in all industries. We also report the decomposition of Domar-weighted productivity of industries into the IT-producing, IT-using, and other industries as in Equation (38).

Our main finding is that aggregate TFP growth primarily reflects TFP growth in the underlying industries. For the full period 1960-2004, for example, aggregate TFP from the production possibility frontier grew 0.43 percent per year, while the Domar-weighted contributions of TFP growth in the underlying 85 industries was 0.53 percent. Reallocations contributed -0.10 percent. The reallocations are similar in magnitude for the three sub-periods, which implies that the aggregate production possibility frontier is a reasonable approximation of the industry data, even for short time horizons. Some reallocation effects, however, are non-negligible. Capital is growing relatively rapidly in industries with high capital service prices in 2000-2004, so that the reallocation of capital is positive, while labor is growing relatively slowly in industries with high labor input prices so the reallocation of labor is negative in all periods.

The breakdown of Domar-weighted TFP into IT-producing, IT-using, and non-IT industries highlights the critical role of accelerating TFP in the high-tech industries. The four IT-producing industries, for example, accounted for nearly all of the acceleration of aggregate TFP in 1995-2000, but only 3 percent of value-added. The contribution of these industries to the much greater TFP acceleration in 2000-2004, however, was negative, while IT-using and non-IT industries drove the second surge. The IT-using industries made a negative contribution to aggregate TFP growth in 1995-2000, before reversing course and contributing almost three-quarters of the acceleration in 2000-2004. The non-IT industries showed a continuous acceleration, from a contribution of 0.22 percent for 1960-1995 to 0.39 percent for 1995-2000 and 0.54 percent for 2000-2004. These results support the findings of Jorgenson, Ho and Stiroh (2005, Chapter 7), showing the broad-based character of the U.S. productivity revival.[14]

Table 5 presents an alternative decomposition of labor productivity into the direct contribution of industry labor productivity, and the reallocation of materials and reallocation of hours as in Equations (28) and (29). We further break down the direct industry contribution into the three groups of industries. The results also indicate a broad-based productivity revival with all three sets of industries contributing to the acceleration of labor productivity of 0.95 percent in 1995-2000. Using gross output data for the industries, the contribution to the post-1995 productivity revival was 0.44 from the non-IT industries, 0.30 from the IT-using industries, and 0.21 from the IT-producing industries. The contribution of IT-producing industries to the second surge in labor productivity growth in 2000-2004 was small and negative as these industries slowed, while the contributions of IT-using and non-IT industries were positive and substantially larger.[15]

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[14]Bosworth and Triplett (2003) report a similar result, but with less detailed data on IT-producing industries.
[15]The differences among industry groups are in part due to the differences in the relative sizes of these groups. As shown in Table 2, the IT-producing industries accounted for only 3 percent of value-added after 1995, while the IT-using industries accounted for 26 percent and the non-IT industries the remaining 71 percent.

This decomposition shows that the post-2000 gains are somewhat broader than in the late 1990s, a result similar to Corrado et al. (2006), Baily et al. (2006), and Stiroh (2006). The widening of the ALP gains after 2000 suggests that different forces may be driving this second surge of aggregate productivity. This could reflect economy-wide factors such as the normal cyclical recovery of productivity or other forms of technological progress and capital deepening.

The decomposition of labor productivity in Table 5 shows similarities and differences compared to the decompositions presented by Bosworth and Triplett (2003) and Stiroh (2002, 2006). Those studies also show a broad-based productivity resurgence that is not concentrated in a few industries, and the major difference is the relative importance of the three sets of industries. Our estimates, for example, report a relatively large contribution from the non-IT industries, while Stiroh (2002) reported a much smaller contribution. This divergence can be explained mostly by the different sets of industries included in each class. Stiroh (2002), for example, identified IT-using industries as those industries with a 1995 IT capital share greater than the median for a set of 57 industries, while we place the cut-off for IT-use at 15% for our 85 industries and include only 28 industries. This leads to a smaller share of IT-using industries. Moreover, there are some important reclassifications of industries. Most importantly, we classify the large Retail and Eating industry as a non-IT industry as in Stiroh (2006) and Stiroh and Botsch (2006), while Stiroh (2002) included it as an IT-using industry.[16] O'Mahony and Van Ark (2003) also make the point that the classification of the large Retail Trade industry is important for this type of decomposition.

These differences across studies highlight two fundamental points of caution about this type of decomposition of aggregate data into the contributions of specific industries. First, the results and conclusions inevitably reflect the classification scheme. For example, we have broken our set of industries into IT-producing, IT-using, and non-IT industries and show that IT-producing industries made a large contribution relative to their size. Alternatively, Bosworth and Triplett (2003, 2006) focus on splitting industries between service-producing and goods-producing industries, and conclude that service-producing industries drove the revival of aggregate productivity growth. While seemingly in conflict, both can actually be correct because the attribution depends critically on industry classification systems that only partially overlap.

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[16]The change for Retail primarily reflects a large decline in measured software investment in the industry investment and capital stock data.

The second note of caution is that the relative importance of specific sets of industries is further obscured when there are some industries that make positive contributions and others that make negative contributions. These offsetting contributions make the net contribution smaller and thus make it easier for any particular group of industries to "explain" the total. The industry-level analysis in the next section shows that the U.S. economy consists of very heterogeneous industries with large positive and large negative rates of growth for output, labor productivity, and TFP, so this is of considerable importance. We conclude that it is useful to look at the full breadth of industry outcomes to understand the driving forces behind the U.S. productivity revival.

Finally, it is useful to compare the aggregated industry data in Table 1 through 5 to the more traditional expenditure-based results presented by Jorgenson, Ho, and Stiroh (2006). While the data periods and data vintages differ, the results are quite consistent in explaining the acceleration of output and labor productivity growth after 1995. In particular, both perspectives show a critical role of IT capital deepening that far exceeds non-IT capital deepening. Moreover, labor quality slowed, while TFP showed a strong revival that reflects a substantial contribution from IT-production.

*c) Industry Contributions*

Equation (33) shows that aggregate value-added growth from the production possibility frontier, defined as the weighted growth of industry value-added, also reflects the sum of the appropriately weighted growth of industry capital, labor, and TFP. The industry contributions to aggregate value-added, to aggregate capital input, to aggregate labor input, and to aggregate TFP are defined in Equation (36).

Table 6 reports the contribution of each industry to value-added and TFP growth for the period 1960-2004. For value-added we report the value-added share ($\overline{w}_j$), the growth rate ($\Delta lnV_j$), and the contribution to aggregate value-added growth ($\overline{w}_j \cdot \Delta lnV_j$). For TFP growth, we report the Domar-weight ($\overline{w}_j / \overline{v}_{V,j}$), the growth of industry TFP ($v_{T,j}$), and the Domar-weighted contribution to aggregate TFP ($\overline{w}_j / \overline{v}_{V,j} \cdot v_{T,j}$). Note that the value-added shares sum to 1.0, while the Domar-weights sum to 1.7. Note also that average contribution of each industry is calculated as the average over time of the product of the growth rates and shares, not the product of the average growth rate and the average shares.

The first thing to emphasize about Table 6 is the enormous variation across industries in contributions to both value-added growth and TFP growth. As discussed earlier, the IT-producing industries, particularly Computers and Office Equipment and Electronic Components, show extremely rapid growth in both value-added and TFP and have made important contributions to the aggregate. Other industries like Gas Utilities and Oil and Gas Mining show very slow growth in both, and make small or even negative contributions.

Figure 1 ranks the industries by their contribution to aggregate value-added growth for the period 1960-2004. The industries that make the largest contributions are Private Households, Wholesale Trade, and Real Estate. These large contributions reflect both relatively strong growth rates and also large value-added shares. These three industries, for example, accounted for almost a quarter of value-added over this period, with Households by far the largest single industry with a 13.7 percent share. In comparison, the value-added weights for Computers and Office Equipment (0.3 percent) and Electronic Components (0.5 percent) are quite small. Thus, even though these IT-producing industries experienced extraordinary growth, the relatively small nominal shares have prevented these industries from making large contributions to aggregate value-added growth.

As in the aggregate analysis, we are particularly interested in the acceleration of output and productivity growth in 1995-2000 and 2000-2004. Figure 2 ranks the 85 industries by the change in the industry contribution to value-added from 1960-1995 to 1995-2000. Of the aggregate acceleration of 1.0 percentage point (first line of Table 1), Non-deposit Finance made the largest contribution of more than 0.25 percent due to its relatively large size and the large acceleration in output growth after 1995. Decelerating industries like Petroleum Refining, Real Estate, and Wholesale Trade made negative contributions to the acceleration. Figure 3 ranks industries by the change in contribution from 1960-1995 to 2000-2004. Private Households contributed more that 0.2 percent, while Construction and Petroleum Refining made sizable negative contributions. The four IT-producing industries show sizable contributions to the first productivity surge after 1995, but negative contributions after 2000.

Table 6 and Figure 4 highlight the contributions of individual industries to aggregate TFP growth, giving the Domar-weighted contributions for 1960-2004. The results contrast sharply with those for value-added. Of the aggregate TFP growth of 0.53 percent per year, Computers and Office Equipment leads with a contribution of 0.11 percentage points. Other leading industries include Wholesale Trade, Electronic Components, Real Estate, Farms, Retail Trade, and Depository Institutions. Our data show that many industries (24 out of 76 for which we measure TFP growth) have negative TFP growth for the period 1960-2004.[17] In particular, Construction, Oil and Gas Mining, and Business Services all make large negative contributions that reduce the growth of aggregate TFP. This shows that industry-level productivity growth can be either negative or positive and one must recognize both when tracing the origins of aggregate growth to individual industries.

In terms of the acceleration of TFP growth in 1995-2000, Figure 5 ranks industries by the change in the industry contribution to aggregate TFP between1960-1995 and 1995-2000. The aggregate TFP acceleration was 0.16 percent, while the increase in the Domar-weighted industry TFP was 0.29 percent (Table 4). This figure shows considerable heterogeneity with 45 industries making a larger contribution after 1995, 31 making a smaller contribution and Private Households and the Government industries making zero contributions by definition. Electronic Components, Non-deposit Finance, and Computers make the largest contributions to the increase, while Real Estate, Wholesale, and Petroleum and Coal Products show the largest declines.

Figure 6 gives a similar ranking for the change from 1960-1995 to 2000-2004, when aggregate TFP increased 0.76 percent and the Domar-weighted increased was 0.78 percent. Retail Trade, Depository Institutions, and Business Services have made substantial positive contributions, while Petroleum and Coal Products, Construction, and Food have made large negative contributions.

Table 7 gives the contributions of capital and labor inputs by each industry to aggregate capital and labor inputs for the period 1960-2004 as in Equation (36). For capital, we present the industry contribution for total capital, as well as the breakdown into IT capital and non-IT capital. For labor, we present the industry contribution for total labor, as well as the breakdown into college-educated and non-college-educated labor. Each contribution reflects the weighted growth rate of the input, where weights depend on the industry's share of aggregate value-added, the share of the input in gross output, and the share of the value-added in gross output.

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[17] As discussed in Jorgenson, Ho, and Stiroh (2005, Chapter 6), we cannot estimate TFP growth for Private Households and the government industries.

The main conclusion is that sums of the industry contributions to capital and labor closely approximate the aggregate contributions from the production possibility frontier presented in Table 1. For example, the sum of capital contributions across industries equals 1.66 percentage points for 1960-2004 (last row of Table 7), compared to 1.73 for the production possibility frontier (Table 1). Similarly, the sum of labor contributions across industries equals 1.02 percentage points compared to 1.04 for the production possibility frontier. These small differences, which correspond to the reallocation terms in Table 4, show that assumptions of equal factor prices across industries appear to be appropriate for the U.S. economy. This makes the production possibility frontier the most appealing aggregation methodology.

Figure 7 ranks industries by the contribution of capital for the period 1960-2004. The large size and rapid growth of capital for Private Households make this sector the largest contributor, followed by Real Estate and Wholesale Trade. Note that capital input has been growing in almost all industries. Figures 8 and 9 provide similar rankings for IT and non-IT capital. We see that the largest contributions of the capital sub-components are in similar industries, which reflects the large relative size of these industries.

Figure 10 ranks industries by the contribution of labor for the period 1960-2004. Construction, State and Local Education, and Business Services make the largest contributions to aggregate labor input growth. Unlike capital, 13 industries show a negative contribution to aggregate labor input growth, with Farms, Railroad Transportation, and the Military making the largest negative contributions. For college-educated labor in Figure 11, State and Local Education makes the largest contribution, which shows both rapid the growth in the college-educated workers in this industry and the relatively large size of the industry. Figure 12 for non-college-educated labor shows that the negative contributions of some industries are due to non-college-educated labor, which has declined in 32 industries.

The major conclusion from our analysis of the industry-level contributions is that the U.S. economy consists of enormously heterogeneous industries that show fundamentally different patterns of output, input, and total factor productivity growth. This variation can be easily missed if one focuses exclusively on the aggregate data where the gains in one industry can partially or fully offset by losses in another. Only be examining the contribution of individual industries can we fully understand the complex and dynamic nature of the U.S. economy.

## IV. Conclusions

This paper aggregates estimates of value-added, capital and labor inputs, and total factor productivity across industries to provide a new perspective on recent economic trends. In particular, we show how fundamental changes in technology, production processes, and input decisions across industries contribute to changes in economic growth for the economy as a whole. Our comparison of aggregation schemes provides insight into the appropriateness of the assumptions underlying each framework, which assists in understanding the often conflicting results presented by different researchers.

Our principal finding is that the proper aggregation of industry-level data leads to an overall picture of the U.S. growth resurgence that is similar to the most recent expenditure-based studies. In particular, the U.S. economy experienced a sharp acceleration of output growth in 1995-2000 that can be attributed to more rapid accumulation of IT capital and faster TFP growth in IT-producing industries, as well as faster labor input growth. This is not surprising since the aggregate data used in earlier studies are based on the same underlying source data as our industry-level study. It is nonetheless important to show that a similar picture emerges from the industry perspective. Output growth receded in 2000-2004, but labor productivity continued to accelerate, driven by a surge in non-IT capital deepening and a sharp acceleration in TFP growth outside of IT-production.

A second main finding is that the aggregate production possibility frontier provides a close approximation to the underlying TFP growth derived from the industry-level data. That is, the aggregate estimate of TFP growth from the production possibility frontier is a good estimate of the Domar-weighted productivity growth rates from the industry data. The relatively small values of the capital and labor reallocation terms imply that the assumptions of input mobility and equal input prices across all industries are not grossly violated. This is reasonable in a relatively well-functioning and efficient economy like the U.S. and shows that the production possibility frontier is the most appropriate aggregation methodology.

Our third conclusion is that the widely used aggregate production function provides a very misleading perspective on economic growth. Our estimates show a substantial divergence between the estimates of value-added growth derived from the production possibility frontier and the aggregate production function, particularly for short time periods. This is apparent in the size of the value-added reallocation terms. This finding shows that the assumption of identical value-added prices necessary for the aggregate production function is highly inappropriate and can lead to a very distorted view of economic performance. At a fundamental level, this divergence reflects technological progress that is evolving at different rates across industries, leading to large changes in relative prices. We conclude that the production possibility frontier is the most appropriate tool for analyzing aggregate economic growth on the basis of industry-level data.

Analysis of aggregate data, even if done properly, has important drawbacks. Most important, the aggregate data obscure the enormous variation in performance across U.S. industries. Industries such as Computers and Office Equipment and Electronic Components have shown truly remarkable growth in total factor productivity that substantially outpaces that for the economy as a whole, while others like Petroleum Refining and Computer Services show significantly slower growth. This variation likely reflects fundamentally different production process, rates of technological innovation, and market conditions, all of which may lead to important differences in productive outcomes.

This caveat also applies to decompositions that break down aggregate growth into the contributions from particular sets of industries. Classification schemes that place industries into categories like IT-producing vs. IT-using vs. non-IT industries or goods-producing vs. service-producing industries, are inherently arbitrary, and there are many equally valid breakdowns. This leads to some divergence in conclusions across studies that can mask similarities in the underlying estimates of contributions of individual industries. Moreover, heterogeneity of performance within classes implies that summary numbers do not provide a complete picture. In a dynamic economy like the U.S. where different industries make positive and negative contributions to output and productivity growth, attribution of aggregate growth to groups of industries can be misleading. This point is underscored by our observation that many industries of different types contributed to the resurgence of aggregate TFP growth after 1995. This is also true for the industry decomposition of labor productivity growth, which shows considerable heterogeneity across industries.

Our fourth conclusion, therefore, is that one must examine the full range of industry-level data to fully understand the origins of the U.S. productivity revival. Aggregate data are more tractable, are available on a more timely basis than, and provide a good approximation to underlying industry trends. These data, however, conceal important variations among industries and prevent analysts from tracing the evolution of productivity to industry sources. It is only at the industry level that production analysts can seek to understand the specific changes in technology, business practices, and input choices that firms make in response to changing economic incentives and opportunities. While we recognize the challenges, we conclude that it will be fruitful to examine the full range of contributions across industries and to analyze the evolving sources of growth at the industry level.

*References*


Baily, Martin Neal, Diana Farrell, and Jaana Reemes. "Where US Productivity is Growing." McKinsey Global Institute, 2006.

Bosworth, Barry P., and Jack E. Triplett. 2003. *Services Productivity in the United States: Griliches' Services Volume Revisited*. Washington, DC: The Brookings Institution, September.

_____. "Is the 21st Century Productivity Expansion Still in Services? And What Should Be Done About It?" Paper presented at NBER Conference on Research on Income and Wealth, July 16, 2006.

Basu, Susanto and John G. Fernald. 1997. Returns to Scale in U.S. Production: Estimates and Implications. *Journal of Political Economy*105, no. 2 (April): 249-283.

Congressional Budget Office. The Economic and Budget Outlook, Fiscal Years 2007-2016, January 2006.

Corrado, Carol A, Paul Lengermann, Eric J. Bartelsman, and J. Joseph Beaulieu. "Modeling Aggregate Productivity at a Disaggregate Level: New Results for U.S. Sectors and Industries," Paper Presented at NBER Summer Institute, July 2006.

Domar, Evsey. 1961. On the Measurement of Technological Change. *Economic Journal* 71, no. 284 (December): 709-29.

Douglas, Paul H. 1948. "Are There Laws of Production?" *American Economic Review* 38, no. 1 (March): 1-41.

Hercowitz, Zvi. 1998. The "Embodiment" Controversy: A Review Essay. *Journal of Monetary Economics* 41, no. 1 (February): 217-24.

Jorgenson, Dale W. 1966. The Embodiment Hypothesis. *Journal of Political Economy* 74, no. 1 (February): 1-17.

_____. 1990. Productivity and Economic Growth. In *Fifty Years of Economic Measurement*, eds. Ernst R. Berndt, and Jack E. Triplett, 19-118.

_____ . 2001. Information Technology and the U.S. Economy. *American Economic Review* 91, no. 1 (March): 1-32.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni. 1987. *Productivity and U.S. Economic Growth*. Cambridge, MA: Harvard University Press.

Jorgenson, Dale W., Mun S. Ho, and Kevin J. Stiroh. 2002. Projecting Productivity Growth: Lessons from the U.S. Growth Resurgence. *Federal Reserve Bank of Atlanta Economic Review* 87, no. 3 (July): 1-13.

_____. 2005. *Information Technology and the American Growth Resurgence*. Cambridge, MA: MIT Press.

____. 2006. Potential Growth of the U.S. Economy: Will the U.S. Productivity Resurgence Continue." *Business Economics*, Vol. 41, No. 1, January 2006, pp. 7-16.

Jorgenson, Dale W., and Kevin J. Stiroh. 2000. Raising the Speed Limit: U.S. Economic Growth in the Information Age. *Brookings Papers on Economic Activity* 1: 125-211.

Nordhaus, William D. 2002. Productivity Growth and the New Economy. *Brookings Papers on Economic Activity* 2: 211-265.

Oliner, Stephen D., and Daniel E. Sichel. 2002. Information Technology and Productivity: Where are We Now and Where are We Going? *Federal Reserve Bank of Atlanta Economic Review* 87, no. 3 (July): 15-44.

O'Mahony, Mary, and Bart van Ark. 2003. *EU Productivity and Competitiveness: An Industry Perspective: Can Europe Resume the Catching-Up Process*. Luxembourg: Office for Official Publications of the European Communities.

Stiroh, Kevin J. "Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say?," *American Economic Review*, 92(5), December 2002, 1559-1576.

_____. "The Industry Origins of the Second Surge of U.S. Productivity Growth," Federal Reserve Bank of New York, Mimeo, July 2006.

Stiroh, Kevin J. and Matthew Botsch, "Information Technology and Productivity Growth in the 2000s," Federal Reserve Bank of New York, Mimeo, August 2006.

Van Ark, Bart and Robert Inklaar. "Catching Up or Getting Stuck? Europe's Troubles to Exploit ICT's Productivity Potential," Groningen Growth and Development Center, Working Paper GD-79, September 2005.

**Table 1: Growth in Aggregate Value-Added and the Sources of Growth**
**Aggregate Production Possibility Frontier**

| | 1960-2004 | 1960-1995 | 1995-2000 | 2000-2004 | 1995-2000 less 1960-1995 | 2000-2004 less 1960-1995 |
|---|---|---|---|---|---|---|
| | | | **Contributions** | | | |
| Value-Added | 3.20 | 3.14 | 4.14 | 2.54 | 1.00 | -0.60 |
| IT-Producing Industries | 0.28 | 0.25 | 0.70 | 0.01 | 0.46 | -0.23 |
| IT-Using Industries | 0.88 | 0.86 | 1.20 | 0.69 | 0.35 | -0.16 |
| Non-IT Industries | 2.04 | 2.04 | 2.23 | 1.83 | 0.19 | -0.21 |
| Capital Input | 1.73 | 1.68 | 2.28 | 1.49 | 0.60 | -0.19 |
| IT Capital | 0.49 | 0.38 | 1.11 | 0.69 | 0.72 | 0.31 |
| Non-IT Capital | 1.24 | 1.30 | 1.17 | 0.80 | -0.12 | -0.50 |
| Labor Input | 1.04 | 1.12 | 1.36 | -0.05 | 0.23 | -1.17 |
| College Labor | 0.64 | 0.66 | 0.78 | 0.37 | 0.12 | -0.29 |
| Non-college Labor | 0.39 | 0.46 | 0.58 | -0.43 | 0.12 | -0.89 |
| Aggregate TFP | 0.43 | 0.34 | 0.50 | 1.10 | 0.16 | 0.76 |
| | | | **Quality and Stock Contributions** | | | |
| Contribution of Capital Quality | 0.64 | 0.57 | 1.14 | 0.58 | 0.56 | 0.00 |
| Contribution of Capital Stock | 1.09 | 1.10 | 1.14 | 0.91 | 0.04 | -0.19 |
| Contribution of Labor Quality | 0.28 | 0.28 | 0.22 | 0.35 | -0.06 | 0.07 |
| Contribution of Labor Hours | 0.76 | 0.84 | 1.14 | -0.41 | 0.30 | -1.25 |

Notes: All figures are average annual percentages. The contribution of an output or input is the growth rate multiplied by the average value share. The IT-producing, IT-using, and non-IT industries are identified in the Appendix Table. IT capital input includes computer hardware, computer software, and telecommunications equipment.

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**Table 2: Growth and Shares of Aggregate Variables**
**Aggregate Production Possibility Frontier**

| | 1960-2004 | 1960-1995 | 1995-2000 | 2000-2004 | 1995-2000 less 1960-1995 | 2000-2004 less 1960-1995 |
|---|---|---|---|---|---|---|
| | | | **Growth Rates** | | | |
| Value-Added | 3.20 | 3.14 | 4.14 | 2.54 | 1.00 | -0.60 |
| IT-Producing Industries | 15.45 | 15.87 | 24.25 | 0.76 | 8.38 | -15.11 |
| IT-Using Industries | 3.80 | 3.83 | 4.55 | 2.66 | 0.72 | -1.16 |
| Non-IT Industries | 2.73 | 2.68 | 3.16 | 2.59 | 0.48 | -0.09 |
| Capital Input | 4.06 | 3.96 | 5.25 | 3.43 | 1.29 | -0.53 |
| IT Capital | 15.10 | 15.00 | 19.28 | 10.79 | 4.29 | -4.20 |
| Non-IT Capital | 3.13 | 3.25 | 3.12 | 2.15 | -0.13 | -1.09 |
| Labor Input | 1.82 | 1.96 | 2.40 | -0.08 | 0.44 | -2.04 |
| College Labor | 3.96 | 4.35 | 3.24 | 1.43 | -1.12 | -2.93 |
| Non-college Labor | 0.97 | 1.12 | 1.78 | -1.37 | 0.66 | -2.49 |
| | | | **Shares** | | | |
| Value-Added | 100.0 | 100.0 | 100.0 | 100.0 | 0.0 | 0.0 |
| IT-Producing Industries | 1.8 | 1.5 | 2.9 | 2.9 | 1.4 | 1.4 |
| IT-Using Industries | 23.4 | 22.7 | 26.3 | 26.2 | 3.6 | 3.5 |
| Non-IT Industries | 74.8 | 75.8 | 70.7 | 70.8 | -5.0 | -5.0 |
| Capital Input | 42.5 | 42.3 | 43.4 | 43.4 | 1.1 | 1.1 |
| IT Capital | 3.3 | 2.6 | 5.7 | 6.4 | 3.1 | 3.8 |
| Non-IT Capital | 39.2 | 39.7 | 37.7 | 37.0 | -2.0 | -2.7 |
| Labor Input | 57.5 | 57.7 | 56.6 | 56.6 | -1.1 | -1.1 |
| College Labor | 17.6 | 15.8 | 23.9 | 25.9 | 8.2 | 10.1 |
| Non-college Labor | 39.9 | 41.9 | 32.6 | 30.7 | -9.3 | -11.3 |

Notes: Growth rates are average annual percentages. Shares are the mean two-period average for each period.

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**Table 3: Decomposition of Aggregate Labor Productivity**
**Aggregate Production Possibility Frontier**

| | 1960-2004 | 1960-1995 | 1995-2000 | 2000-2004 | 1995-2000 less 1960-1995 | 2000-2004 less 1960-1995 |
|---|---|---|---|---|---|---|
| | | | **Contributions** | | | |
| Average Labor Productivity | 1.87 | 1.68 | 2.13 | 3.25 | 0.45 | 1.58 |
| Capital Deepening | 1.16 | 1.05 | 1.40 | 1.79 | 0.35 | 0.74 |
| IT Capital | 0.45 | 0.34 | 0.99 | 0.74 | 0.65 | 0.40 |
| Non-IT Capital | 0.71 | 0.71 | 0.41 | 1.05 | -0.30 | 0.34 |
| Labor Quality | 0.28 | 0.28 | 0.22 | 0.35 | -0.06 | 0.07 |
| College Labor Quality | 0.00 | -0.01 | 0.00 | 0.02 | 0.01 | 0.02 |
| Non-college Labor Quality | 0.11 | 0.11 | 0.08 | 0.07 | -0.03 | -0.04 |
| Reallocation of Hours | 0.18 | 0.18 | 0.14 | 0.27 | -0.04 | 0.09 |
| Aggregate TFP | 0.43 | 0.34 | 0.50 | 1.10 | 0.16 | 0.76 |
| | | | **Growth Rates** | | | |
| Aggregate Value-Added | 3.20 | 3.14 | 4.14 | 2.54 | 1.00 | -0.60 |
| Average Labor Productivity | 1.87 | 1.68 | 2.13 | 3.25 | 0.45 | 1.58 |
| Hours | 1.33 | 1.47 | 2.01 | -0.71 | 0.54 | -2.18 |

Notes: Notes: All figures are average annual percentages. The contribution of an output or input is the growth rate multiplied by the average value share. IT capital includes computer hardware, computer software, and telecommunications equipment.

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**Table 4: Aggregate Reallocation Effects**

| | 1960-2004 | 1960-1995 | 1995-2000 | 2000-2004 | 1995-2000 less 1960-1995 | 1995-2000 less 1960-1995 |
|---|---|---|---|---|---|---|
| **Aggregate Production Possibility Frontier vs. Aggregate Production Function** | | | | | | |
| Aggregate Production Function Value-Added | 3.16 | 2.85 | 5.03 | 3.56 | 2.18 | 0.71 |
| Aggregate Production Possibility Frontier Value-Added | 3.20 | 3.14 | 4.14 | 2.54 | 1.00 | -0.60 |
| Reallocation of Value-Added | -0.04 | -0.29 | 0.89 | 1.02 | 1.18 | 1.31 |
| **Aggregate Production Possibility Frontier vs. Direct Aggregation Across Industries** | | | | | | |
| Aggregate TFP | 0.43 | 0.34 | 0.50 | 1.10 | 0.16 | 0.76 |
| Domar-Weighted Productivity | 0.53 | 0.42 | 0.72 | 1.20 | 0.29 | 0.78 |
| IT-Producing Industries | 0.19 | 0.17 | 0.43 | 0.08 | 0.26 | -0.09 |
| IT-Using Industries | 0.07 | 0.03 | -0.10 | 0.60 | -0.13 | 0.57 |
| Non-IT Industries | 0.27 | 0.22 | 0.39 | 0.53 | 0.17 | 0.31 |
| Reallocation of Capital Input | -0.07 | -0.07 | -0.14 | 0.04 | -0.07 | 0.11 |
| Reallocation of Labor Input | -0.03 | -0.01 | -0.07 | -0.14 | -0.06 | -0.13 |

Notes: Notes: All figures are average annual percentages. The contribution of an output or input is the growth rate multiplied by the average value share.

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## Table 5: Industry Decomposition of Labor Productivity Growth

| | 1960-2004 | 1960-1995 | 1995-2000 | 2000-2004 | 1995-2000 less 1960-1995 | 2000-2004 less 1960-1995 |
|---|---|---|---|---|---|---|
| Average Labor Productivity | 1.87 | 1.68 | 2.13 | 3.25 | 0.45 | 1.57 |
| **Decomposition using Industry Gross Output Productivity** | | | | | | |
| Weighted dlny | 2.04 | 1.80 | 2.75 | 3.32 | 0.95 | 1.52 |
| IT-Producing Industries | 0.16 | 0.14 | 0.35 | 0.09 | 0.21 | -0.05 |
| IT-Using Industries | 0.46 | 0.37 | 0.67 | 1.07 | 0.30 | 0.70 |
| Non-IT Industries | 1.42 | 1.29 | 1.73 | 2.16 | 0.44 | 0.87 |
| Material Reallocation, $-R^M$ | -0.05 | -0.03 | -0.17 | -0.01 | -0.14 | 0.02 |
| Hours Reallocation, $R^H$ | -0.12 | -0.09 | -0.45 | -0.06 | -0.36 | 0.03 |
| **Decomposition using Industry Value-Added Productivity** | | | | | | |
| Weighted dlnv | 1.99 | 1.76 | 2.58 | 3.31 | 0.82 | 1.55 |
| IT-Producing Industries | 0.23 | 0.20 | 0.49 | 0.15 | 0.29 | -0.05 |
| IT-Using Industries | 0.44 | 0.35 | 0.47 | 1.22 | 0.12 | 0.87 |
| Non-IT Industries | 1.33 | 1.22 | 1.62 | 1.94 | 0.40 | 0.72 |
| Hours Reallocation, $R^H$ | -0.12 | -0.09 | -0.45 | -0.06 | -0.36 | 0.03 |

Note: Decomposition framework is defined in Equations (28) and (29).

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**Table 6: Industry Contributions to Aggregate Value-Added and TFP Growth, 1960-2004**

| | Value-Added | | | Total Factor Productivity | | |
|---|---|---|---|---|---|---|
| | V-A Weight | V-A Growth | Contribution to Aggregate V-A | Domar Weight | TFP Growth | Contribution to Aggregate TFP |
| Farms | 0.018 | 3.176 | 0.050 | 0.047 | 1.529 | 0.064 |
| Agri services, forestry | 0.003 | 4.162 | 0.016 | 0.004 | 0.395 | 0.006 |
| Fishing | 0.001 | 1.844 | 0.002 | 0.002 | -0.195 | 0.000 |
| Metal mining | 0.001 | 0.432 | 0.000 | 0.002 | 0.054 | -0.001 |
| Nonmetal mining | 0.002 | 1.768 | 0.003 | 0.003 | 0.179 | 0.000 |
| Coal mining | 0.003 | 3.033 | 0.008 | 0.005 | 1.445 | 0.004 |
| Oil and gas extraction | 0.014 | 1.742 | 0.004 | 0.026 | -0.526 | -0.047 |
| Construction | 0.050 | 0.076 | 0.006 | 0.111 | -1.049 | -0.117 |
| Lumber and wood | 0.005 | 1.802 | 0.010 | 0.014 | 0.266 | 0.003 |
| Furniture and fixtures | 0.004 | 3.284 | 0.012 | 0.008 | 0.891 | 0.007 |
| Nonmetallic mineral products | 0.006 | 1.929 | 0.013 | 0.013 | 0.558 | 0.007 |
| Primary metals | 0.010 | 0.452 | 0.004 | 0.034 | 0.328 | 0.003 |
| Fabricated metal prd | 0.015 | 2.053 | 0.031 | 0.033 | 0.564 | 0.016 |
| Machinery excl computers | 0.018 | 1.718 | 0.029 | 0.036 | 0.191 | 0.000 |
| Computers & Office Eq | 0.003 | 32.253 | 0.117 | 0.010 | 10.368 | 0.107 |
| Insulated wire | 0.002 | 1.357 | 0.003 | 0.004 | 0.549 | 0.001 |
| Audio and video equip | 0.001 | 7.229 | 0.008 | 0.003 | 1.889 | 0.007 |
| Other Electrical machinery | 0.006 | 2.679 | 0.019 | 0.013 | 0.829 | 0.010 |
| Communications Equipment | 0.003 | 5.196 | 0.019 | 0.007 | 1.239 | 0.007 |
| Electronic Components | 0.005 | 18.913 | 0.094 | 0.009 | 7.937 | 0.080 |
| Motor vehicles | 0.009 | 2.798 | 0.031 | 0.040 | 0.285 | 0.013 |
| Aerospace | 0.009 | 1.396 | 0.013 | 0.019 | 0.743 | 0.016 |
| Ships and boats | 0.002 | 1.622 | 0.003 | 0.003 | 0.447 | 0.002 |
| Other Transportation equipment | 0.001 | 2.861 | 0.003 | 0.003 | 0.362 | 0.001 |
| Measuring instruments | 0.005 | 2.208 | 0.010 | 0.009 | 0.593 | 0.004 |
| Medical equipment and opthalmic goods | 0.002 | 6.129 | 0.014 | 0.004 | 1.708 | 0.006 |
| Other Instruments | 0.002 | 4.802 | 0.010 | 0.004 | 1.919 | 0.007 |
| Misc manufacturing | 0.003 | 2.281 | 0.008 | 0.007 | 0.505 | 0.004 |
| Food | 0.018 | 2.306 | 0.043 | 0.069 | 0.374 | 0.030 |
| Tobacco | 0.001 | -1.528 | -0.003 | 0.004 | -1.091 | -0.004 |
| Textile | 0.005 | 3.638 | 0.020 | 0.015 | 1.520 | 0.022 |
| Apparel | 0.006 | 0.868 | 0.011 | 0.014 | 0.787 | 0.011 |
| Leather | 0.001 | -2.503 | -0.002 | 0.003 | 0.175 | 0.001 |
| Paper and allied | 0.008 | 2.436 | 0.020 | 0.021 | 0.507 | 0.009 |
| Publishing | 0.007 | 0.982 | 0.007 | 0.013 | -0.717 | -0.009 |
| Printing and reproduction | 0.005 | 2.597 | 0.015 | 0.010 | 0.593 | 0.006 |
| Chemicals excl drugs | 0.015 | 2.774 | 0.043 | 0.038 | 0.502 | 0.017 |
| Drugs | 0.004 | 5.226 | 0.018 | 0.007 | 0.643 | 0.003 |
| Petroleum and coal products | 0.004 | -2.100 | -0.004 | 0.028 | -0.590 | -0.008 |
| Rubber and misc plastics | 0.007 | 5.323 | 0.034 | 0.015 | 1.162 | 0.018 |
| Railroad transportation | 0.006 | 0.382 | 0.004 | 0.009 | 1.618 | 0.017 |
| Local passenger transit | 0.003 | 0.592 | 0.002 | 0.004 | 0.024 | 0.002 |
| Trucking and warehousing | 0.014 | 3.396 | 0.046 | 0.026 | 0.564 | 0.014 |
| Water transport. | 0.003 | 1.549 | 0.005 | 0.006 | 0.341 | 0.004 |
| Air transport. | 0.005 | 7.065 | 0.034 | 0.011 | 1.101 | 0.010 |
| Transportation svcs & Pipelines | 0.002 | 4.474 | 0.010 | 0.004 | 0.893 | 0.003 |
| Telephone and telegraph | 0.016 | 6.214 | 0.098 | 0.028 | 1.423 | 0.039 |
| Radio and TV | 0.003 | 0.992 | 0.002 | 0.006 | -2.345 | -0.015 |
| Electric utilities (pvt) | 0.017 | 3.365 | 0.052 | 0.029 | 0.473 | 0.008 |
| Gas utilities | 0.003 | -6.329 | -0.017 | 0.013 | -1.113 | -0.021 |
| Water and sanitation | 0.001 | 2.381 | 0.002 | 0.002 | -0.582 | -0.002 |
| Wholesale trade | 0.050 | 5.420 | 0.272 | 0.078 | 1.294 | 0.103 |
| Retail trade exc motor veh | 0.043 | 3.201 | 0.138 | 0.066 | 0.934 | 0.060 |
| Retail trade; motor vehicles | 0.011 | 4.104 | 0.045 | 0.017 | 0.974 | 0.017 |
| Eating and drinking | 0.013 | 1.175 | 0.015 | 0.029 | -0.304 | -0.009 |
| Depository Inst | 0.018 | 6.055 | 0.107 | 0.028 | 1.830 | 0.054 |
| Nondeposit; Sec-com brokers;Inves | 0.011 | 5.290 | 0.076 | 0.019 | -0.977 | -0.005 |
| Insurance carriers, ins agents, services | 0.014 | 1.980 | 0.028 | 0.028 | -0.677 | -0.020 |
| Real Estate- other | 0.058 | 3.575 | 0.205 | 0.077 | 0.901 | 0.068 |
| Hotels | 0.007 | 2.039 | 0.013 | 0.011 | -0.214 | -0.003 |
| Personal services | 0.005 | 1.721 | 0.010 | 0.011 | 0.535 | 0.006 |
| Business svc exc computer | 0.020 | 4.406 | 0.098 | 0.029 | -1.362 | -0.035 |
| Computer services | 0.006 | 7.872 | 0.048 | 0.010 | -1.117 | -0.003 |
| Auto services | 0.006 | 2.457 | 0.016 | 0.013 | -0.708 | -0.008 |
| Misc repair | 0.004 | 1.322 | 0.005 | 0.007 | -0.684 | -0.005 |
| Motion pictures | 0.002 | 3.583 | 0.009 | 0.005 | -0.144 | 0.000 |
| Recreation services | 0.005 | 4.240 | 0.022 | 0.009 | 0.292 | 0.003 |
| Offices of health practitioners | 0.016 | 4.211 | 0.062 | 0.024 | 0.529 | 0.010 |
| Nursing and personal care facilities | 0.003 | 6.665 | 0.014 | 0.005 | 0.688 | -0.002 |
| Hospitals, private | 0.014 | 3.192 | 0.034 | 0.022 | -1.106 | -0.029 |
| Health services, nec | 0.003 | 3.171 | 0.014 | 0.006 | -0.984 | -0.005 |
| Legal services | 0.008 | 1.802 | 0.013 | 0.013 | -1.105 | -0.014 |
| Educational services (private) | 0.006 | 2.151 | 0.012 | 0.010 | -0.844 | -0.009 |
| Social svc and membership org | 0.010 | 3.402 | 0.033 | 0.019 | -0.026 | -0.001 |
| Research | 0.003 | 4.343 | 0.013 | 0.005 | -0.019 | 0.002 |
| Misc professional services | 0.016 | 3.995 | 0.059 | 0.025 | -0.563 | -0.014 |
| Private households | 0.137 | 4.069 | 0.554 | 0.137 | 0.000 | 0.000 |
| Federal gen govt excl health | 0.014 | 1.845 | 0.026 | 0.014 | 0.000 | 0.000 |
| Federal govt enterprises | 0.010 | 1.419 | 0.014 | 0.010 | 0.000 | 0.000 |
| Government Hospitals | 0.006 | 2.070 | 0.011 | 0.006 | 0.000 | 0.000 |
| Govt other health | 0.001 | 5.776 | 0.004 | 0.001 | 0.001 | 0.000 |
| S&L education | 0.045 | 3.307 | 0.147 | 0.045 | 0.000 | 0.000 |
| S&L excl health,educ | 0.037 | 2.587 | 0.095 | 0.037 | 0.000 | 0.000 |
| S&L govt enterprises | 0.007 | 2.812 | 0.018 | 0.007 | 0.000 | 0.000 |
| Military | 0.031 | -0.299 | -0.011 | 0.031 | 0.000 | 0.000 |
| Sum | 1.000 | | 3.201 | 1.695 | | 0.527 |

Notes: All figures are annual averages. Value-added weights are industry value-added as a share of aggregate value-added. Domar weights are industry output as a share of aggregate value-added. A contribution is a share-weighted growth rate. Growth rates and contributions are in percentages.

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**Table 7: Industry Contributions to Aggregate Capital and Labor Input Growth, 1960-2004**

| | Capital | | | Labor | | |
|---|---|---|---|---|---|---|
| | Total | IT | Non-IT | Total | College | Non-College |
| Farms | 0.006 | 0.000 | 0.006 | -0.020 | 0.002 | -0.022 |
| Agri services, forestry | 0.004 | 0.000 | 0.005 | 0.006 | 0.002 | 0.004 |
| Fishing | 0.002 | 0.000 | 0.003 | 0.001 | 0.000 | 0.000 |
| Metal mining | 0.001 | 0.000 | 0.001 | -0.001 | 0.000 | -0.001 |
| Nonmetal mining | 0.003 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| Coal mining | 0.004 | 0.000 | 0.004 | 0.000 | 0.001 | -0.001 |
| Oil and gas extraction | 0.046 | 0.003 | 0.038 | 0.006 | 0.004 | 0.002 |
| Construction | 0.020 | 0.003 | 0.017 | 0.104 | 0.023 | 0.081 |
| Lumber and wood | 0.004 | 0.001 | 0.004 | 0.003 | 0.001 | 0.001 |
| Furniture and fixtures | 0.002 | 0.001 | 0.002 | 0.003 | 0.001 | 0.001 |
| Nonmetallic mineral products | 0.005 | 0.001 | 0.003 | 0.000 | 0.001 | -0.001 |
| Primary metals | 0.005 | 0.001 | 0.004 | -0.005 | 0.002 | -0.006 |
| Fabricated metal prd | 0.011 | 0.002 | 0.009 | 0.004 | 0.002 | 0.002 |
| Machinery excl computers | 0.024 | 0.012 | 0.013 | 0.005 | 0.005 | -0.001 |
| Computers & Office Eq | 0.005 | 0.003 | 0.004 | 0.004 | 0.004 | 0.001 |
| Insulated wire | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 |
| Audio and video equip | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| Other Electrical machinery | 0.005 | 0.002 | 0.002 | 0.004 | 0.002 | 0.002 |
| Communications Equipment | 0.010 | 0.003 | 0.008 | 0.002 | 0.002 | -0.001 |
| Electronic Components | 0.012 | 0.004 | 0.010 | 0.002 | 0.004 | -0.002 |
| Motor vehicles | 0.011 | 0.001 | 0.009 | 0.007 | 0.004 | 0.003 |
| Aerospace | 0.001 | 0.002 | -0.001 | -0.003 | 0.005 | -0.009 |
| Ships and boats | 0.001 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 |
| Other Transportation equipment | 0.002 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 |
| Measuring instruments | 0.004 | 0.002 | 0.002 | 0.002 | 0.004 | -0.002 |
| Medical equipment and opthalmic goods | 0.003 | 0.002 | 0.001 | 0.005 | 0.003 | 0.001 |
| Other Instruments | 0.003 | 0.001 | 0.002 | 0.000 | 0.001 | -0.001 |
| Misc manufacturing | 0.003 | 0.001 | 0.002 | 0.002 | 0.002 | 0.000 |
| Food | 0.013 | 0.003 | 0.011 | -0.001 | 0.005 | -0.006 |
| Tobacco | 0.002 | 0.000 | 0.002 | -0.001 | 0.000 | -0.001 |
| Textile | 0.002 | 0.001 | 0.002 | -0.004 | 0.001 | -0.004 |
| Apparel | 0.003 | 0.001 | 0.003 | -0.004 | 0.001 | -0.005 |
| Leather | 0.000 | 0.000 | 0.000 | -0.003 | 0.000 | -0.003 |
| Paper and allied | 0.009 | 0.001 | 0.008 | 0.002 | 0.002 | 0.000 |
| Publishing | 0.011 | 0.005 | 0.006 | 0.006 | 0.007 | -0.001 |
| Printing and reproduction | 0.005 | 0.002 | 0.002 | 0.004 | 0.002 | 0.002 |
| Chemicals excl drugs | 0.022 | 0.003 | 0.019 | 0.005 | 0.006 | -0.001 |
| Drugs | 0.011 | 0.001 | 0.010 | 0.004 | 0.004 | 0.001 |
| Petroleum and coal products | 0.005 | 0.001 | 0.006 | -0.002 | 0.001 | -0.002 |
| Rubber and misc plastics | 0.007 | 0.001 | 0.006 | 0.010 | 0.003 | 0.007 |
| Railroad transportation | -0.002 | 0.001 | -0.002 | -0.012 | 0.000 | -0.012 |
| Local passenger transit | -0.001 | 0.000 | -0.002 | 0.001 | 0.001 | 0.000 |
| Trucking and warehousing | 0.010 | 0.001 | 0.008 | 0.022 | 0.005 | 0.017 |
| Water transport. | 0.001 | 0.000 | 0.001 | 0.001 | 0.002 | -0.001 |
| Air transport. | 0.009 | 0.002 | 0.006 | 0.016 | 0.008 | 0.008 |
| Transportation svcs & Pipelines | 0.003 | 0.002 | 0.001 | 0.004 | 0.001 | 0.002 |
| Telephone and telegraph | 0.051 | 0.033 | 0.017 | 0.008 | 0.007 | 0.001 |
| Radio and TV | 0.012 | 0.006 | 0.005 | 0.005 | 0.003 | 0.002 |
| Electric utilities (pvt) | 0.035 | 0.005 | 0.032 | 0.010 | 0.005 | 0.005 |
| Gas utilities | 0.005 | 0.002 | 0.004 | -0.001 | 0.000 | -0.001 |
| Water and sanitation | 0.002 | 0.000 | 0.002 | 0.001 | 0.000 | 0.001 |
| Wholesale trade | 0.105 | 0.045 | 0.060 | 0.064 | 0.035 | 0.029 |
| Retail trade exc motor veh | 0.035 | 0.007 | 0.028 | 0.043 | 0.025 | 0.018 |
| Retail trade; motor vehicles | 0.026 | 0.005 | 0.020 | 0.002 | 0.002 | 0.000 |
| Eating and drinking | 0.001 | 0.003 | -0.002 | 0.023 | 0.006 | 0.017 |
| Depository Inst | 0.037 | 0.011 | 0.022 | 0.016 | 0.010 | 0.006 |
| Nondeposit; Sec-com brokers;Inves | 0.052 | 0.023 | 0.027 | 0.029 | 0.020 | 0.010 |
| Insurance carriers, ins agents, services | 0.024 | 0.011 | 0.013 | 0.024 | 0.017 | 0.007 |
| Real Estate- other | 0.110 | 0.018 | 0.098 | 0.026 | 0.015 | 0.011 |
| Hotels | 0.006 | 0.001 | 0.005 | 0.010 | 0.004 | 0.006 |
| Personal services | 0.002 | 0.001 | 0.002 | 0.002 | 0.003 | -0.001 |
| Business svc exc computer | 0.062 | 0.037 | 0.022 | 0.070 | 0.029 | 0.041 |
| Computer services | 0.017 | 0.013 | 0.012 | 0.035 | 0.025 | 0.010 |
| Auto services | 0.012 | 0.001 | 0.012 | 0.012 | 0.002 | 0.010 |
| Misc repair | 0.003 | 0.001 | 0.002 | 0.007 | 0.001 | 0.006 |
| Motion pictures | 0.004 | 0.001 | 0.002 | 0.005 | 0.004 | 0.002 |
| Recreation services | 0.005 | 0.001 | 0.005 | 0.014 | 0.006 | 0.008 |
| Offices of health practitioners | 0.007 | 0.002 | 0.005 | 0.045 | 0.031 | 0.015 |
| Nursing and personal care facilities | 0.006 | 0.001 | 0.005 | 0.010 | 0.003 | 0.008 |
| Hospitals, private | 0.022 | 0.004 | 0.019 | 0.041 | 0.023 | 0.018 |
| Health services, nec | 0.001 | 0.000 | 0.001 | 0.017 | 0.009 | 0.008 |
| Legal services | 0.010 | 0.006 | 0.004 | 0.017 | 0.013 | 0.004 |
| Educational services (private) | 0.001 | 0.001 | 0.001 | 0.020 | 0.015 | 0.005 |
| Social svc and membership org | 0.005 | 0.003 | 0.002 | 0.030 | 0.015 | 0.014 |
| Research | 0.004 | 0.002 | 0.001 | 0.007 | 0.006 | 0.002 |
| Misc professional services | 0.010 | 0.007 | 0.003 | 0.063 | 0.045 | 0.017 |
| Private households | 0.554 | 0.084 | 0.470 | 0.000 | 0.000 | 0.000 |
| Federal gen govt excl health | 0.010 | 0.002 | 0.008 | 0.017 | 0.011 | 0.005 |
| Federal govt enterprises | 0.014 | 0.004 | 0.010 | 0.000 | 0.002 | -0.002 |
| Government Hospitals | 0.008 | 0.002 | 0.006 | 0.003 | 0.004 | -0.001 |
| Govt other health | 0.002 | 0.000 | 0.002 | 0.002 | 0.001 | 0.001 |
| S&L education | 0.047 | 0.010 | 0.037 | 0.101 | 0.097 | 0.004 |
| S&L excl health,educ | 0.034 | 0.008 | 0.026 | 0.061 | 0.021 | 0.041 |
| S&L govt enterprises | 0.011 | 0.003 | 0.008 | 0.008 | 0.002 | 0.006 |
| Military | 0.001 | 0.008 | -0.008 | -0.012 | 0.000 | -0.012 |
| Sum | 1.660 | 0.443 | 1.226 | 1.015 | 0.643 | 0.373 |

Notes: All figures are annual averages in percentages.

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**Appendix Table: Classification of Industries by IT Share**

| Industry | IT Share of Capital (1995) (%) | Classification |
|---|---|---|
| 1 Farms | 0.7 | Non-IT |
| 2 Agri services, forestry | 2.5 | Non-IT |
| 3 Fishing | 2.1 | Non-IT |
| 4 Metal mining | 5.7 | Non-IT |
| 5 Nonmetal mining | 3.1 | Non-IT |
| 6 Coal mining | 3.5 | Non-IT |
| 7 Oil and gas extraction | 2.9 | Non-IT |
| 8 Construction | 6.8 | Non-IT |
| 9 Lumber and wood | 3.7 | Non-IT |
| 10 Furniture and fixtures | 8.2 | Non-IT |
| 11 Nonmetallic mineral products | 5.4 | Non-IT |
| 12 Primary metals | 4.3 | Non-IT |
| 13 Fabricated metal prd | 7.0 | Non-IT |
| 14 Machinery excl computers | 19.8 | IT-Using |
| 15 Computers & Office Eq | 19.8 | IT-Producing |
| 16 Insulated wire | 15.5 | IT-Using |
| 17 Audio and video equip | 15.5 | IT-Using |
| 18 Other Electrical machinery | 15.5 | IT-Using |
| 19 Communications Equipment | 15.5 | IT-Producing |
| 20 Electronic Components | 15.5 | IT-Producing |
| 21 Motor vehicles | 4.5 | Non-IT |
| 22 Aerospace | 17.6 | IT-Using |
| 23 Ships and boats | 15.1 | IT-Using |
| 24 Other Transportation equipment | 17.6 | IT-Using |
| 25 Measuring instruments | 45.3 | IT-Using |
| 26 Medical equipment and opthalmic g | 45.3 | IT-Using |
| 27 Other Instruments | 45.3 | IT-Using |
| 28 Misc manufacturing | 6.9 | Non-IT |
| 29 Food | 4.4 | Non-IT |
| 30 Tobacco | 4.7 | Non-IT |
| 31 Textile | 9.6 | Non-IT |
| 32 Apparel | 8.5 | Non-IT |
| 33 Leather | 3.7 | Non-IT |
| 34 Paper and allied | 4.3 | Non-IT |
| 35 Publishing | 26.7 | IT-Using |
| 36 Printing and reproduction | 26.7 | IT-Using |
| 37 Chemicals excl drugs | 6.1 | Non-IT |
| 38 Drugs | 6.1 | Non-IT |
| 39 Petroleum and coal products | 3.0 | Non-IT |
| 40 Rubber and misc plastics | 7.5 | Non-IT |
| 41 Railroad transportation | 9.0 | Non-IT |
| 42 Local passenger transit | 8.6 | Non-IT |
| 43 Trucking and warehousing | 8.5 | Non-IT |
| 44 Water transport. | 5.3 | Non-IT |
| 45 Air transport. | 18.0 | IT-Using |
| 46 Transportation svcs & Pipelines | 26.2 | IT-Using |
| 47 Telephone and telegraph | 60.8 | IT-Using |
| 48 Radio and TV | 40.5 | IT-Using |
| 49 Electric utilities (pvt) | 5.6 | Non-IT |
| 50 Gas utilities | 19.1 | IT-Using |
| 51 Water and sanitation | 6.3 | Non-IT |
| 52 Wholesale trade | 34.2 | IT-Using |
| 53 Retail trade exc motor veh | 10.2 | Non-IT |
| 54 Retail trade; motor vehicles | 10.2 | Non-IT |
| 55 Eating and drinking | 10.2 | Non-IT |
| 56 Depository Inst | 12.0 | Non-IT |
| 57 Nondeposit; Sec-com brokers;Inve | 27.1 | IT-Using |
| 58 Insurance carriers, ins agents, servi | 26.5 | IT-Using |
| 59 Real Estate- other | 3.9 | Non-IT |
| 60 Hotels | 4.7 | Non-IT |
| 61 Personal services | 8.4 | Non-IT |
| 62 Business svc exc computer | 39.0 | IT-Using |
| 63 Computer services | 39.0 | IT-Producing |
| 64 Auto services | 2.8 | Non-IT |
| 65 Misc repair | 20.1 | IT-Using |
| 66 Motion pictures | 29.6 | IT-Using |
| 67 Recreation services | 5.5 | Non-IT |
| 68 Offices of health practitioners | 8.4 | Non-IT |
| 69 Nursing and personal care facilities | 8.4 | Non-IT |
| 70 Hospitals, private | 8.4 | Non-IT |
| 71 Health services, nec | 8.4 | Non-IT |
| 72 Legal services | 29.7 | IT-Using |
| 73 Educational services (private) | 18.6 | IT-Using |
| 74 Social svc and membership org | 35.1 | IT-Using |
| 75 Research | 35.1 | IT-Using |
| 76 Misc professional services | 35.1 | IT-Using |
| 77 Private households | 6.5 | Non-IT |
| 78 Federal gen govt excl health | 10.5 | Non-IT |
| 79 Federal govt enterprises | 10.5 | Non-IT |
| 80 Government Hospitals | 10.5 | Non-IT |
| 81 Govt other health | 10.5 | Non-IT |
| 82 S&L education | 10.5 | Non-IT |
| 83 S&L excl health,educ | 10.5 | Non-IT |
| 84 S&L govt enterprises | 10.5 | Non-IT |
| 85 Military | 10.5 | Non-IT |

Note: IT-using industries have 1995 IT capital share greater than 15%.

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**Figure 1: Industry Contributions to Value-Added, 1960-2004**

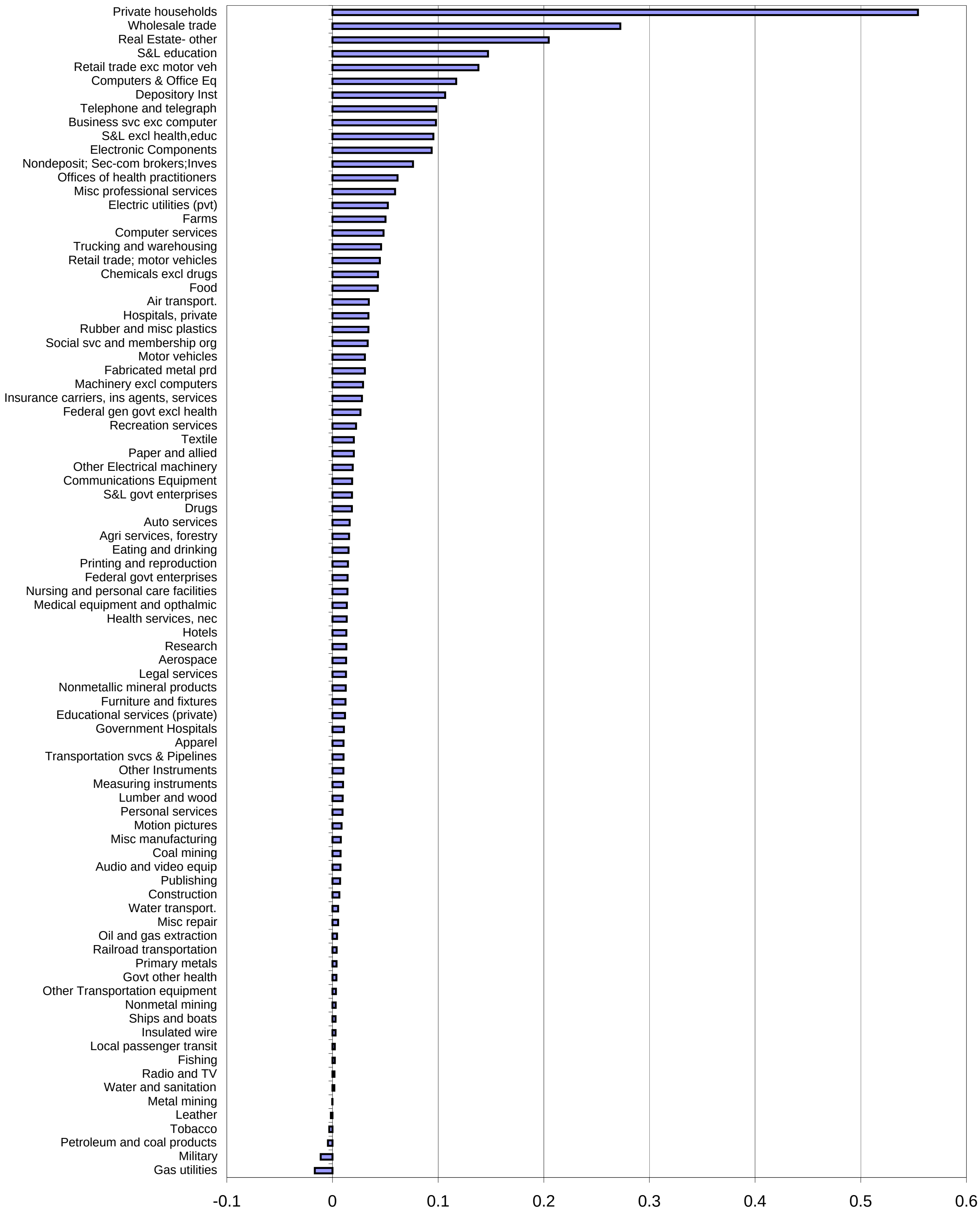


**Figure 2: Change in Industry Contributions to Value-Added, 1995-2000 less 1960-1995**

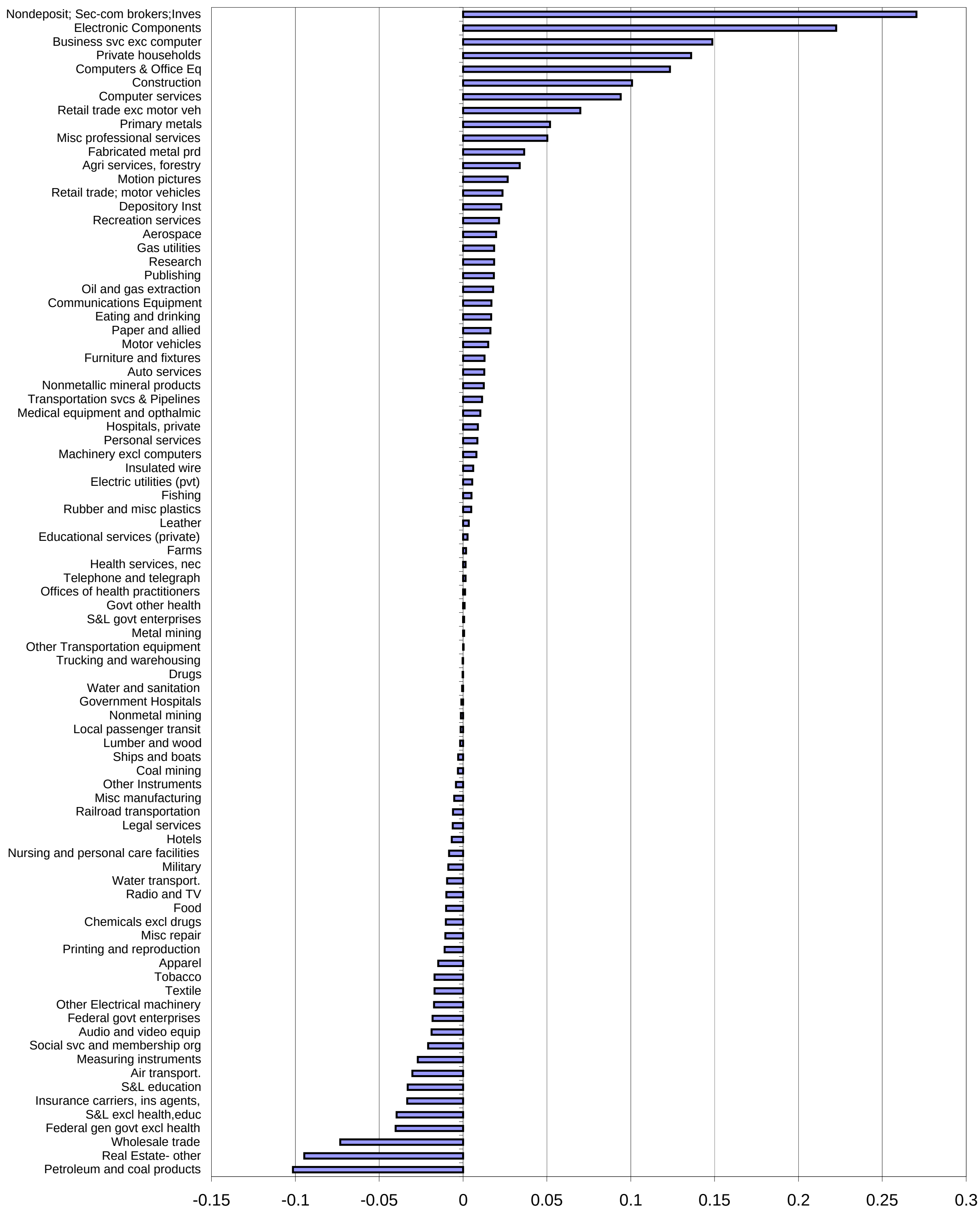
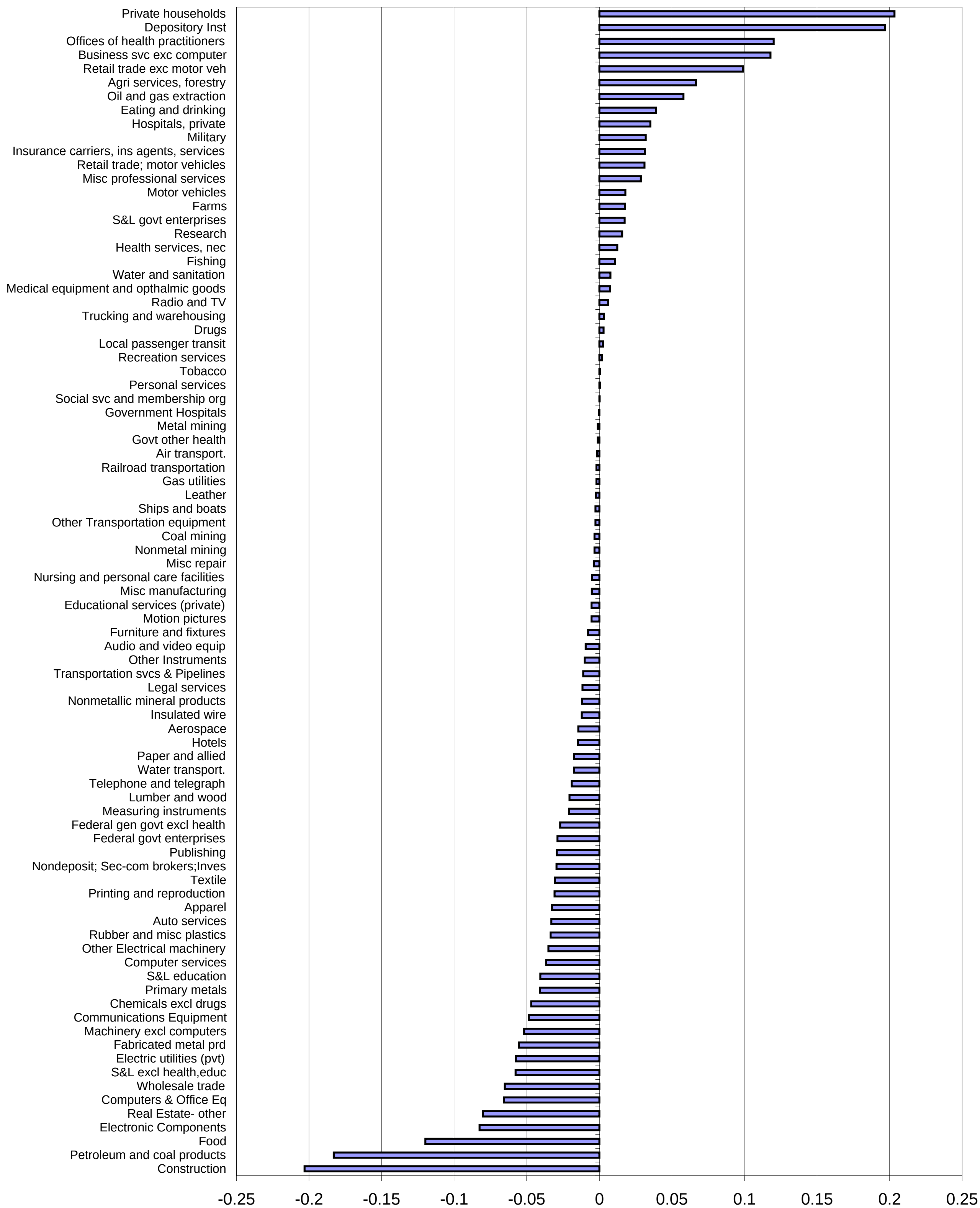


**Figure 3: Change in Industry Contributions to Value-Added, 2000-2004 less 1960-1995**



## Figure 4: Industry Contributions to Total Factor Productivity, 1960-2004

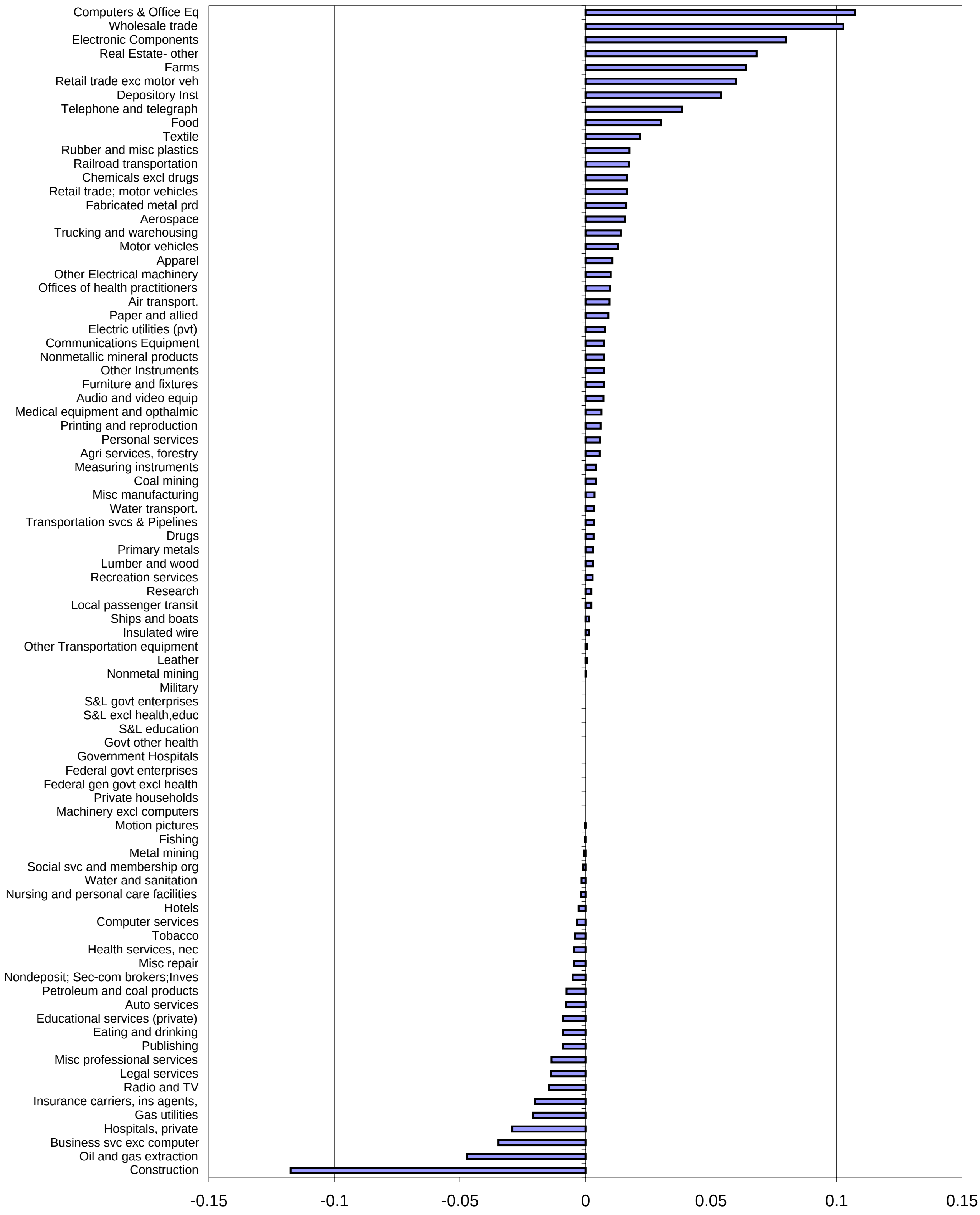


**Figure 5: Change in Industry Contributions to TFP, 1995-2000 less 1960-1995**

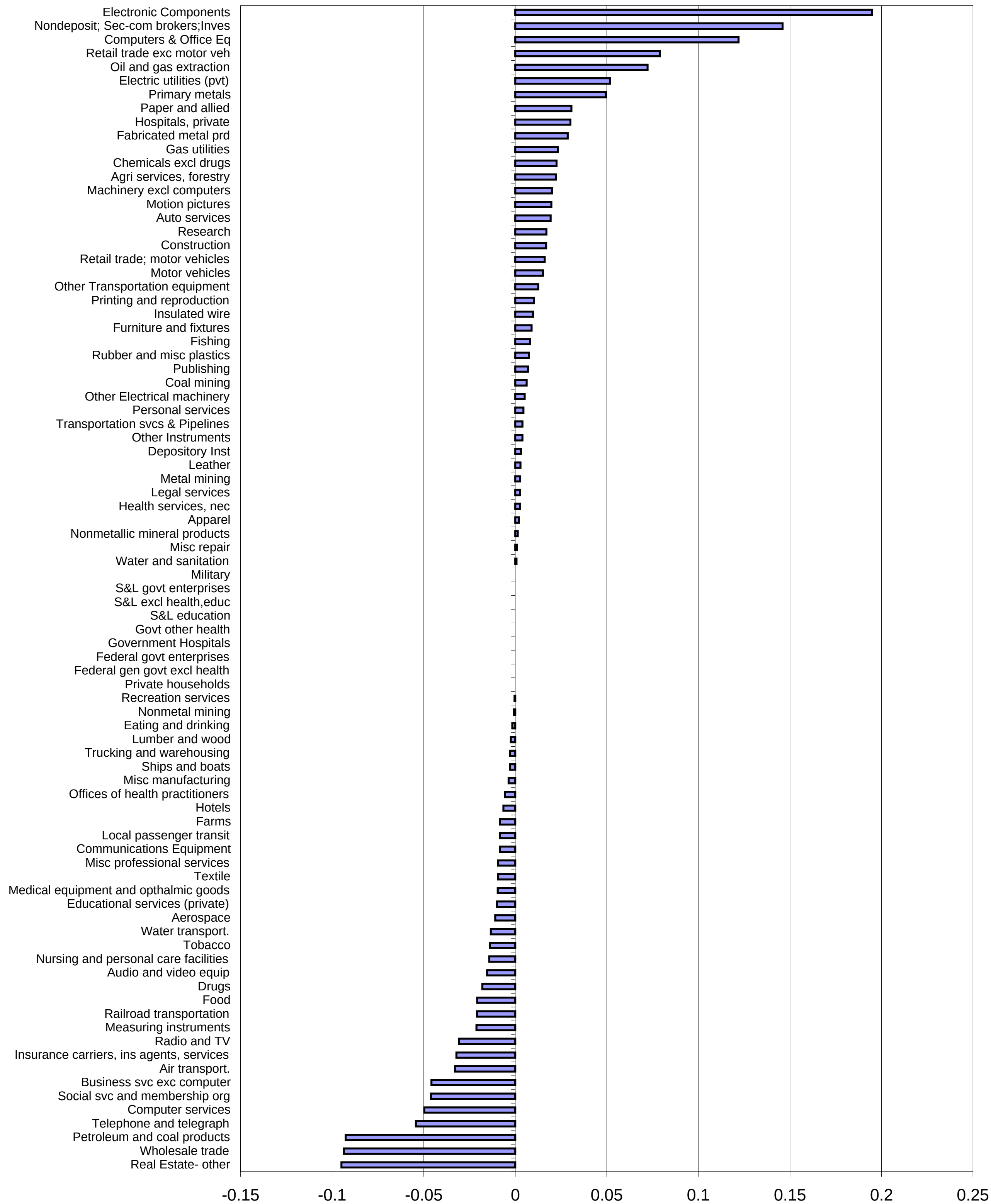


**Figure 6: Change in Industry Contributions to TFP, 2000-2004 less 1960-1995**

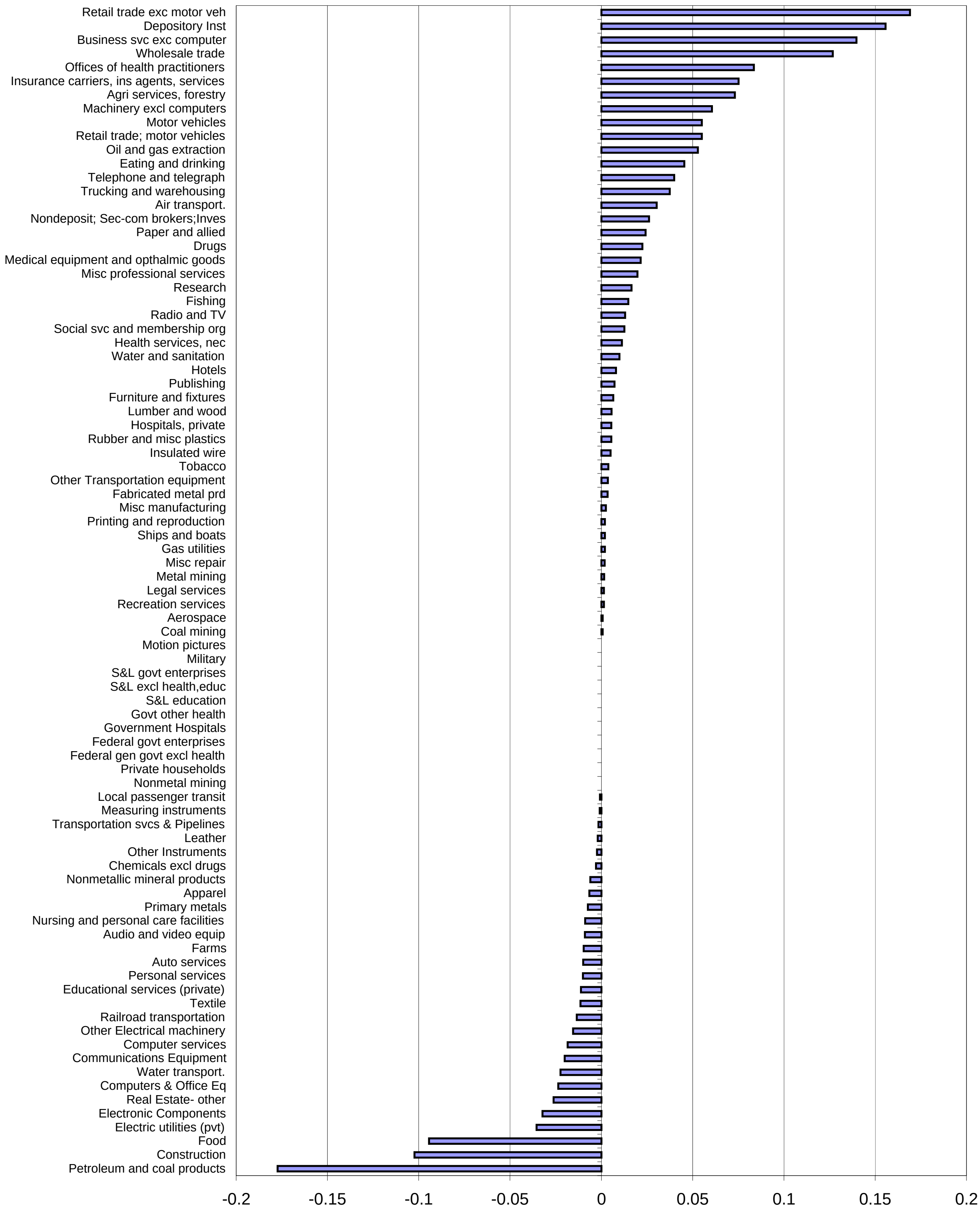
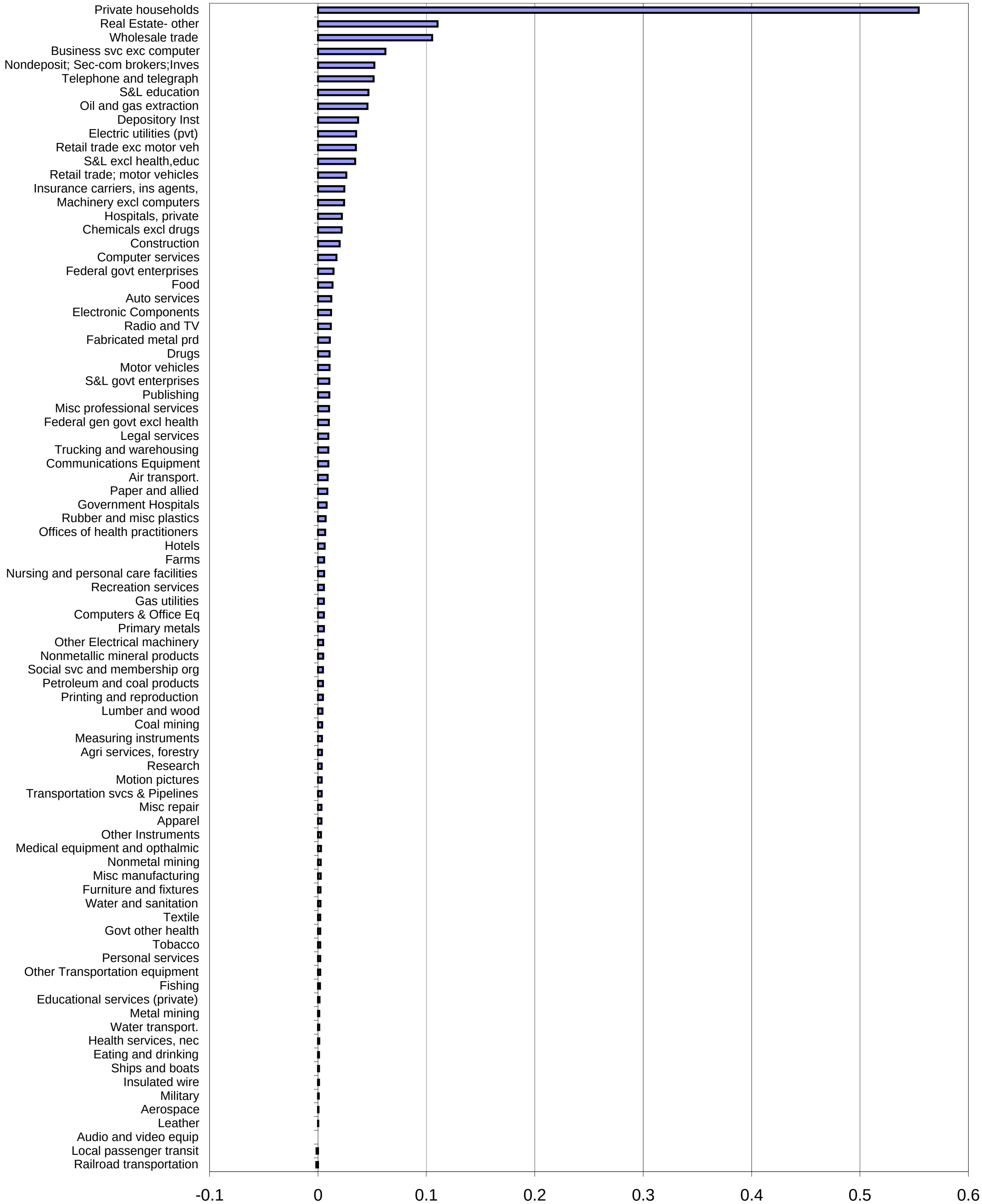


**Figure 7: Industry Contributions to Capital Input, 1960-2004**



## Figure 8: Industry Contributions to IT Capital Input, 1960-2004

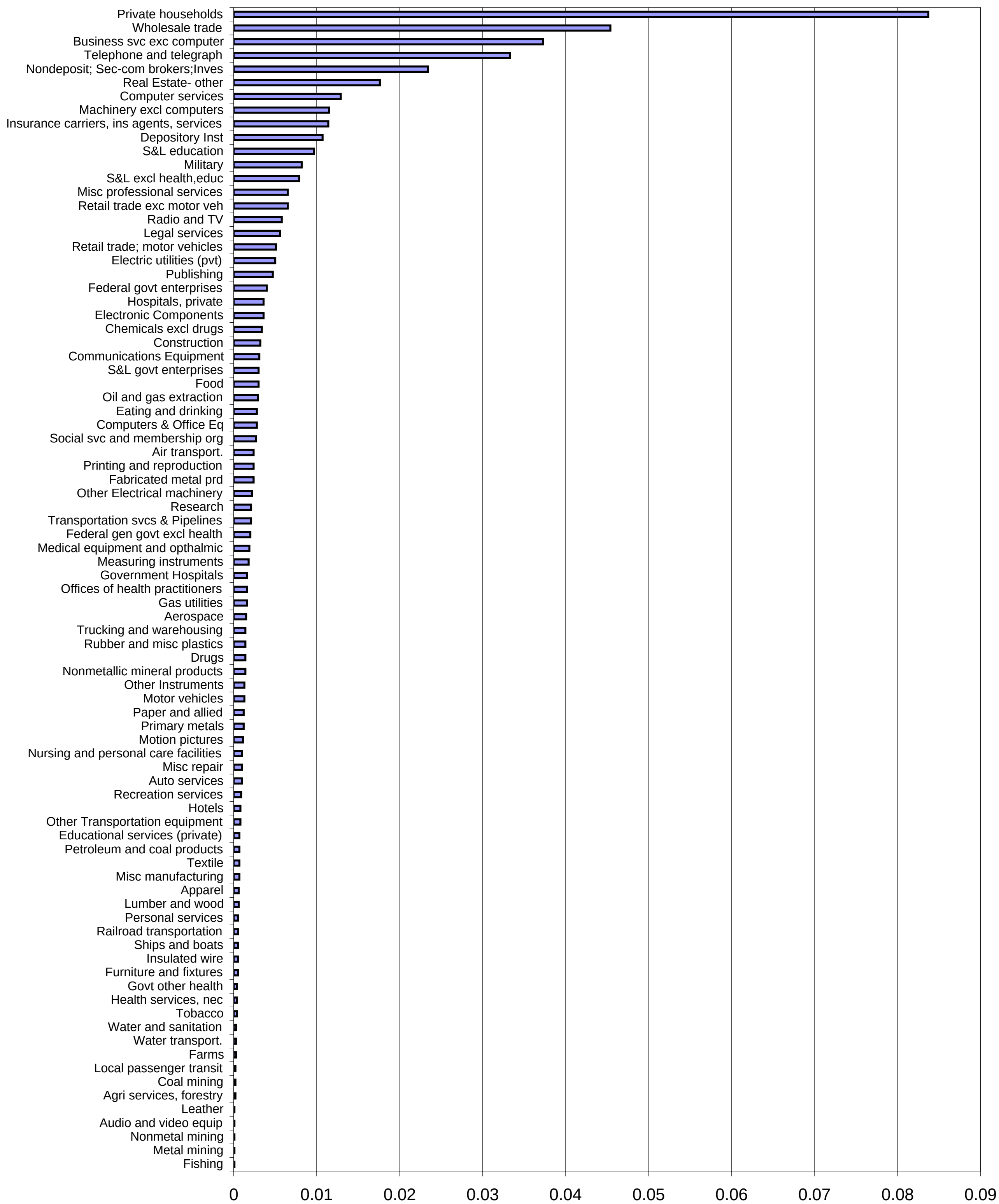
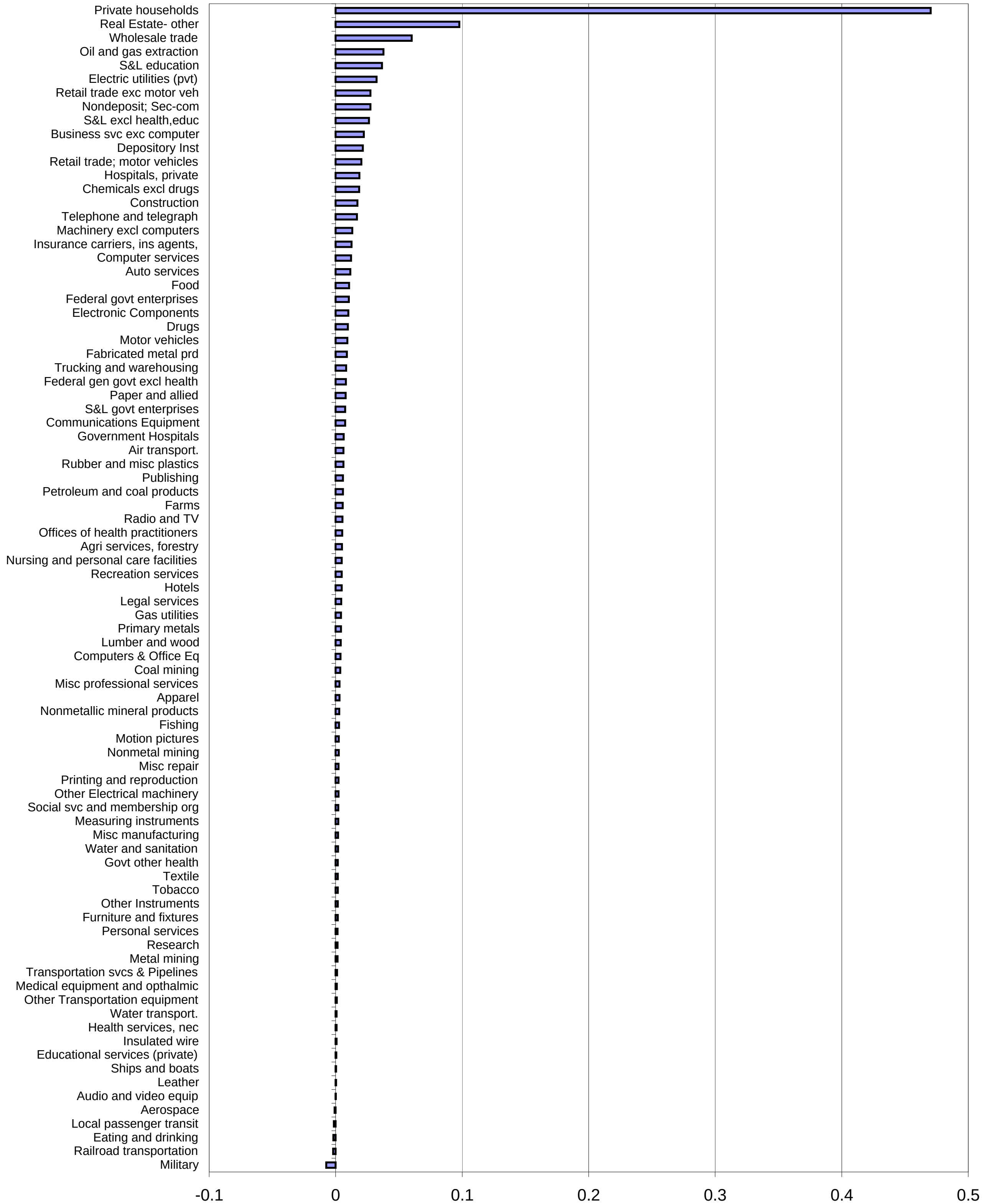
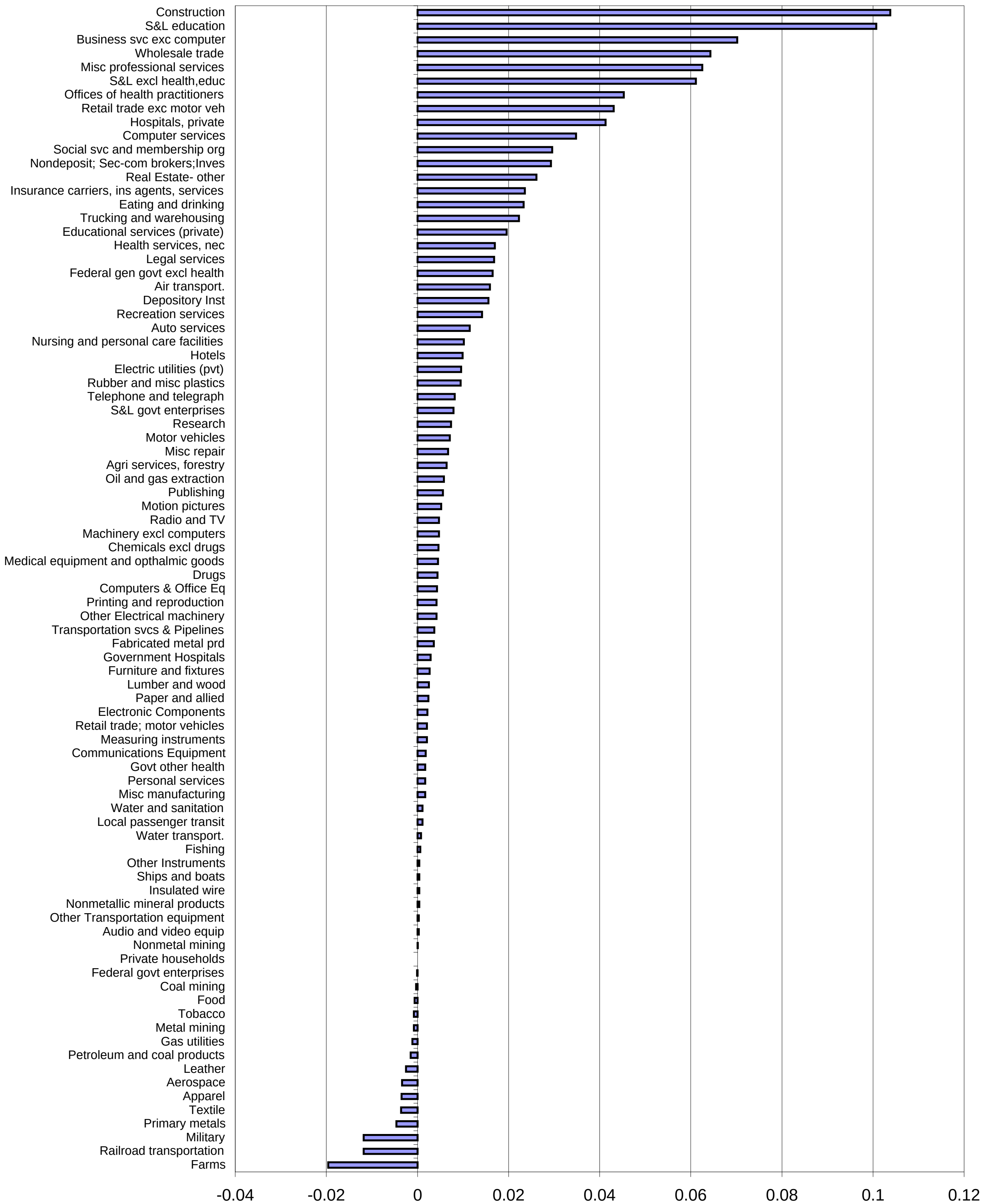


**Figure 9: Industry Contributions to Non-IT Capital, 1960-2004**



## Figure 10: Industry Contributions to Labor Input, 1960-2004



## Figure 11: Industry Contributions to College Labor Input, 1960-2004

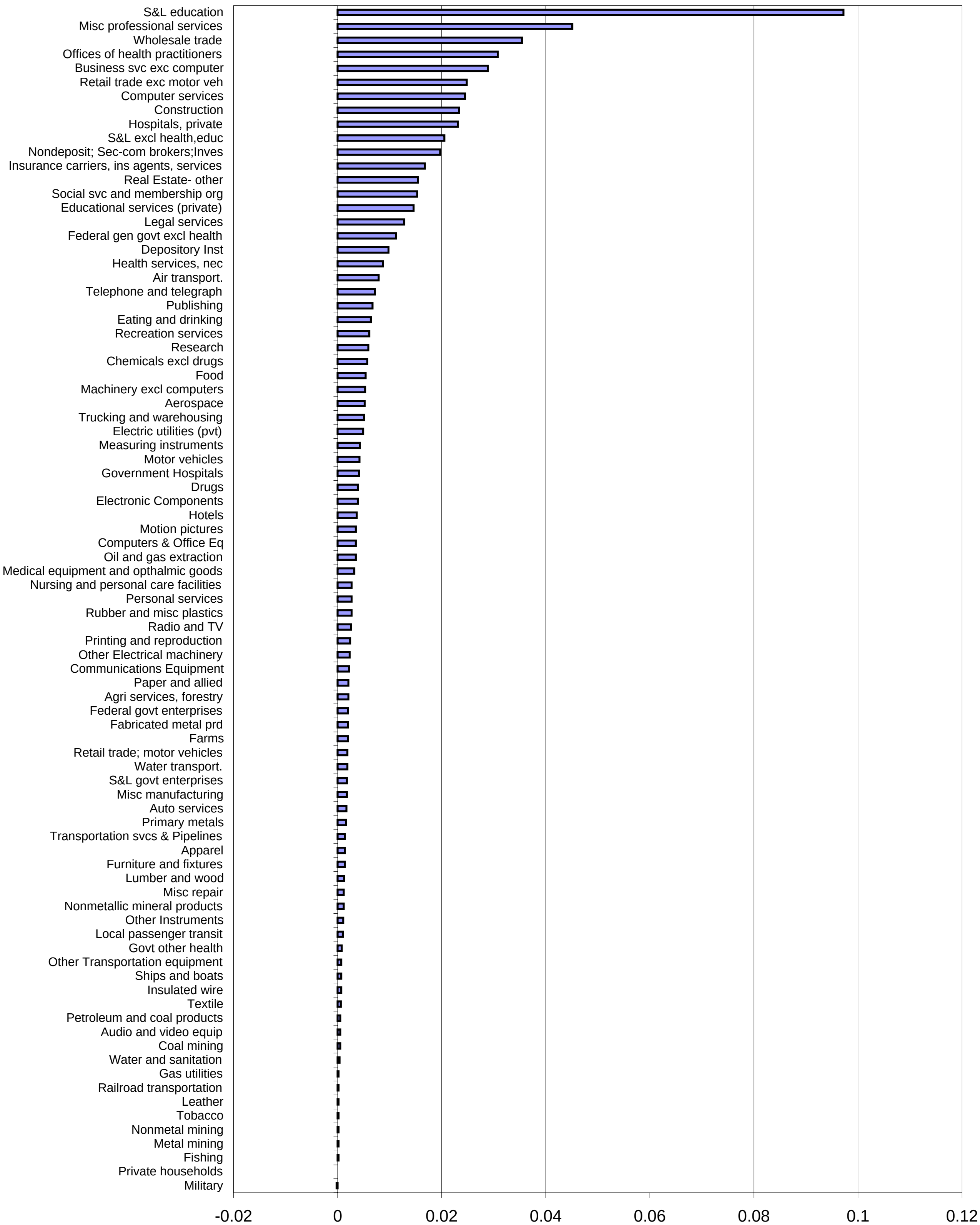


**Figure 12: Industry Contributions to Non-college Labor Input, 1960-2004**