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Impacts of Information Technology on Productivity and Linkage of the US Economy*

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Abstract

This paper examines structural changes in the US economy in the context of interindustry linkages. Structural changes are studied in terms of factor saving in the input-output accounting which is in concept equivalent to productivity growth but whose sign of change is opposite. While the conventional growth accounting has developed to trace detailed industry sources of productivity growth, its methodology isolates each industry from the rest. On the other hand, the input-output accounting framework has inter-industry relations as its essential key features and can be extended smoothly to factor saving analysis.

This thesis reaches three conclusions. First, the I-O accounting produces comparable results in factor saving as in productivity growth. This paper shows the average annual rate of factor saving was -0.91 percent for 1987-1995 and -1.75 percent for 1995-2000. These figures are larger than the rates of productivity growth based on the growth accounting but the extent of difference is not very large. The fast growth in factor saving, particularly for the latter period, is not only noticeable in size but also qualitatively significant in the sense that active output growth was not accompanied by price increases. Second, Information Technology industries made substantial contributions to reduce inflation as well as to save factors by supplying cheaper intermediate inputs to the industries. The IT intermediate inputs contribute to factor saving by -0.20 percent for 1987 to 1996 and -0.41 percent for 1995-2000. Considering the small size of IT intermediate inputs, the contribution of IT intermediate inputs is significantly large. Third, the inter-industry context of I-O accounting provides a fertile ground to investigate the role of sectors in factor saving and output growth. This paper points out that, while the contraction of the manufacturing sector is taken as a serious problem, the expansion of trade and transportation which function as a partial operation of the manufacturing sector tends to be overlooked. Furthermore, the manufacturing sector contributes significantly to factor saving, while the services sector does so to employment, implying their cooperative relation which is in some sense a division of labor in an economy-wide scale.

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1. Introduction

The beginning of the 1980s was a gloomy period for the US economy. Financial markets were subject to continuous upheavals of crunches and crises, and the accumulating deficits both in the government and in the trade account led to a rather pessimistic scenario of the US economy. Japan's and Germany's strenuous innovations were taken as a serious threat to the competitiveness of the US economy in high-end markets such as cars and electronics. And the overseas outsourcing of the manufacturing also destabilized the job market of the US economy and resulted in sizable unemployment and consequently frequent strikes in a large scale.

After the painful recovery period of the 1980s, the US economy started to taste the fruits of success in the 1990s. The government made efforts to break the trend of rising budget deficits and signaled a sign of a soft landing on the path to a balanced budget. While the trend of the outsourcing of factories and goods continued, new high-technology businesses continued to start up and discovered a new promising market and created a new source of wealth. These emerging businesses helped the US to regain its global leadership in technology. In spite of the contraction of the manufacturing sector, services-providing sectors continued to expand and contributed to create jobs. Despite the continued trend of the outsourcing of manufacturing factories, the US economy increased jobs and GDP fast, resulting in a rapid rise of productivity, and regaining the level of productivity growth of the golden period of the 1960s.

Dazzling innovations, which may appear intuitively obvious as in the information technology (IT) sector in particular, can not easily be examined in formal economic analysis due to the abstract nature of technology. Productivity, which can be defined as production capability of a unit factor, has long been the most important toolkit for capturing the qualitative development of the economy, even before a rigorous definition was made and a systematic compilation of necessary data started. The first theoretically founded research of productivity dates back to Solow (1956; 1957), Nobel Laureate. He formulated total factor productivity (TFP), which is certainly a breakthrough in the analysis of productivity, which was before rather limited to labor productivity. By including capital as a factor, he defined technological development as a residual of output growth unexplained by the growth of factors. However, a huge inexplicable residual in the Solow model stimulated economists to clarify the details of the residual. Solow's single national growth accounting was generalized to cover industry-accounting and Solow's simple concept of total factor as the combination of labor and capital has become far more sophisticated. In addition to empirical sophistication of the research, theoretic challenges to Solow's simple neoclassical formulation have continued, giving birth to endogenous growth theory, which modifies and elaborates the neoclassical growth model, thanks to the economists such as Lucas (1988), Romer (1990), and Mankiw (1992), and Aghion P. and P. Howitt, (1998).

In contrast with the efforts to understand technological progress in the growth accounting framework, which assumes a certain form of a production function whose legitimacy is subject to questions, more intuitive approaches have developed as well. Qualitative discourses, from individual case studies of innovation to technology paradigms of the national economy, have competed with the growth accounting approach. In this approach, technology is a rather complicated evolutionary process of innovations (Nelson and Winter 1982). As it is hard to formulate evolution theory into a mathematical framework, birth and death of business, technological trends, and industries are traced in terms of detailed cases of innovation, leading firms or industries.

A union of the growth accounting approach and the qualitative discourses can be made at the input-output (I-O) framework, initiated by Leontief (1951), Nobel Laureate. The Input-output framework captures the factors (or factors' share) supplied to each industry. This accounting fairly resembles a factory's production schedule that reflects and is constrained by technological potential of production. Given that it is impossible to account for the current or possible production schedule of all the firms, the input-output framework is almost the best accounting convention to capture the production schedules or technological constraints of the economy.

The development of the input-output framework has enriched productivity analysis by tracing productivity growth of each industry with a comprehensive definition of the factor (encompassing intermediate inputs as well as capital and labor). Since industries never develop in a uniform way, the importance of tracing industry-sources of change in output and productivity does not need further emphasis. A difficulty is that a huge volume of data is needed and the theoretic underpinning for aggregation should be further refined. Such a daunting task has been challenged by economists such as Jorgenson, Grilliches, and Erwin (OECD 2001, *Measuring Productivity*) and resulted in industry-based productivity analysis.

As far as productivity by industry is concerned, the industry-accounting is superb empirically and theoretically. However, the shortcoming of the growth accounting is still inherent in the industry scale. Once factors are identified and reflected into the accounting, then each industry is again studied in isolation from others. If we define more detailed kinds of factors (in particular intermediate inputs), then each industry-accounting can reflect the inter-industry interaction through intermediate inputs. But the holistic picture is not yet much visible and only the aggregation result based on a certain formula for which some assumptions are unavoidable can be presented.

This paper focuses on the inter-industry relation as its key theme. The inter-industry relationship can be analyzed in two ways. We can study the input structure of each industry as well as the allocation of each input as a factor across industries. Based on the output multiplier concept which measures all the outputs (including intermediate inputs) to meet a given basket of final commodities, we can analyze all the reactions to final demands. The reactions on output initiated by the input structure of an industry is defined as backward linkage while those results passed through the supply chain of a commodity is defined as forward linkage. These two linkage concepts are basic instruments to analyze the structural change of the interindustry relation.

This paper also utilizes I-O analysis to develop an alternative measurement of productivity growth or factor saving. Under certain plausible assumptions, it is possible to construct mathematical formula connecting prime factors (labor and capital) and final expenditures (GDP) by way of the output multiplier. Conceptually, factor saving which is defined as the tendency of less prime factors to produce a unit final output is not different from productivity growth except the sign of change. But in order to emphasize the methodological difference, the term factor saving will be preferred when it is discussed in the framework of interindustry linkages. And the term productivity will be preferred in the growth accounting. Since the output multiplier is also the key instrument in measuring backward and forward linkage, not only the final results of factor saving but also the whole structure of the relations and the change of the structure that lead to a certain degree of factor saving can be understood. Since technological progress includes a network aspect of cooperation, the I-O framework can provide quite rich resources for understanding technological progress or, more neutrally, the structural change of the economy.

As this paper is concerned with a holistic aspect of the economy, many questions will be explicitly and implicitly raised and answered. But among many themes or questions, the following ones and consequent answers summarize well the main contribution of this paper.

(1) Can the I-O framework provide an alternative accounting of productivity growth called factor saving and how is this alternative method related to the conventional growth accounting?

(2) If the development of the economy is not uniform across industries but is led by a certain group of industries equipped with new technology and with new kinds of products, how can we identify those in a quantitative framework? And how can we specify the contribution of those industries to the economy or to other industries? Regarding this question, this paper plans to confirm the notion that intuitively obvious progress and influence of IT sectors can be comprehensively and precisely captured in the I-O framework.

(3) Can this analysis provide a quantitative framework or view to understand the relation between goods (more specifically manufacturing) sectors and service sectors? While the tendency of the contraction of the manufacturing sector and the expansion of the services sector is agreed well to, its implication or the interpretation is yet controversial. The aforementioned factor saving analysis can contribute to the understanding of the sectoral relations in terms of the factor saving. This analysis can decompose factor saving into the detailed sources that are carried through chain relations of intermediate inputs (otherwise saying forward and backward linkage).

The main body of this paper from section 2 to section 4, followed by *Section 5 conclusion*, is organized as follows. *Section 2 Performances of the US economy and the IT sector* examines the recent structural change in the US economy focusing on several large sectors and the IT sector. To gain insights on the US economy, the analysis of output and a prime factor labor and the relationship between them will be provided.

Section 3 Industry Productivity and Aggregation provides the method and empirical analysis of productivity based on the growth accounting. This section can be a simplified version of the recent work made by Jorgenson, Ho, and Stiroh (2003; 2004) (shortly, JHS) in the sense that the basic data sets are quite alike and the methodology is almost the same except rather a simplified specification of factors of this paper. But the classification of industries is more detailed than JHS. Their research serves as a benchmark to verify the legitimacy of the data and the validity of the results of this paper.

Section 4 Interindustry Linkage and Factor Saving is the main contribution of this paper. Backward and forward linkage of each industry and factor saving carried through the linkages is analyzed. Since this section uses almost the same sources of data and classification of industries of section 3, section 4 also investigate the different empirical implications due to the methodological difference of the growth accounting and the factor saving analysis.

The research in this paper covers different methodologies, large and small industries, and various angles to see the inter-industry structure of the US economy. In terms of immense efforts required for such a task, this paper follows the tradition of Leontief (1951) and Carter (1970). The author believes that the methodology taken in this paper can shed new light on the progress of the economy and hopes that the empirical details of this paper may make easy and expedite interindustry analyses.

2 Performances of the US economy and the IT sector

GDP growth by Sector

The BEA (Bureau of Economic Analysis, Department of Commerce)'s *Gross Product by Industry* (shortly, GPI) is the most authoritative industry accounts in the US. Based on the SIC of about two-digit depth, the data provides very detailed accounts of output and factors by industry. For output measurements, GPI provides both Gross Output (GO) (shipments value or sales in concept) and Gross Product Originating (GPO or Value Added as GO net intermediate inputs) in both constant and current dollars.[1] While the former is fully utilized in the measurement of productivity as in the next section, the latter is used widely as a performance index of the economy. In this section where the main concern is the sectoral performance of the US economy, GPO will be taken as the output measurement.

Since sectoral output GO is a combination of numerous commodities, we need to use constant dollar output measurements for aggregation of commodities to get quantity measurements. Constant dollar output measurement of GO in the GPI is based on the Fisher-ideal chain-weight index which is the geometric average of the Laspeyres and the Paache index.[2] This chain-weight index is introduced to correct the *substitution bias* originating from the fixed commodity basket of the Laspeyres or the Paache index. In the US, the BEA introduced the tenth comprehensive revision of the NIPA (effective at the end of 1995) with the Fisher chain-type measurements of real output instead of fixed-weight measurements (Landfeld and Parker 1995, *Survey of Current Business* (henceforth, *Survey*)).

The constant dollar measurement of GPO in GPI is based on the double deflation method, which is in concept deflated GO net deflated intermediate inputs (M).[3] However, since some aggregates considered in this section are not available directly from GPI, they are made by simply adding constant dollar GPOs available from GPI. A simple addition of chain-weighted outputs is not methodologically robust but if prices do not vary widely across sectors (which is true for highly aggregated sectors), errors are negligible.

According to GPI, the US economy experienced a long period of expansion from 1982 to 1990 and, after a short period of downturn in 1991, another expansion from 1991 to 2000 until it reached a downturn

[1] GPO provided by the BEA is slightly different from Value added provided by the US CENSUS; that is, while "other services" (SIC 89) is regarded as intermediate inputs by the BEA, it is not regarded as intermediate inputs by the CENSUS. Thus, for some industries, GPO can be larger than VA (ESA, 1999, *Emerging Digital Economy II*, Appendix to Chapter II)

[2] More detailed explanation of quantity measurements of outputs (GO and GPO) is well illustrated in System of National Accounts 1993 by UN.

[3] See Lum and Yuskavage (1997)'s article in *Survey* published by the BEA for the exact definition of constant dollar measurement of GPO.

in 2001 as seen in Table 2.1.[4] The intertemporal change of an economy is known to be best understood when it is analyzed by the period from peak to peak (Baumol and McLennan 1985). In a similar vein, the period of a whole business cycle from trough to trough in this section is adequate to analyze the intertemporal change of the US economy. Thus the two business cycles, 1982-1991 and 1991-2001, are taken for intertemporal comparison of the performance of the US economy. But two other periods, 1987-1995 and 1995-2000, are also taken for the period average of growth; first because in the forthcoming study of productivity the time span is limited by the coverage of data of prime factors; second because the year 1995-2000 is particularly regarded as the peak of the latest business cycle as in JHS (acronym of Jorgenson, Ho, and Stiroh 2002, 2003) and in *Digital Economy* (Department of Commerce, Economics and Statistics Analysis, 1998, 1999, 2000, 2002, 2003)

Table 2.1 Annual growth rates of real GPO by large sector

	Total	AMC	Md	Mn	TCU	Trade	FIRE	Services	Gov
1981-1982	-2.0	-5.7	-9.0	-1.0	-1.9	2.2	-0.8	0.7	0.1
-1983	4.3	-5.7	4.9	7.8	4.4	6.8	2.3	3.1	0.9
-1984	7.3	17.4	16.9	2.3	4.9	10.2	4.3	7.1	1.0
-1985	3.8	10.6	2.0	3.8	1.9	5.8	2.0	4.8	2.6
-1986	3.4	1.0	-1.5	-1.4	-1.5	7.3	2.6	3.4	2.3
-1987	3.4	2.7	8.6	9.0	10.2	-2.9	6.0	5.1	1.9
-1988	4.2	4.7	9.5	3.8	4.0	6.7	3.4	6.3	2.4
-1989	3.5	0.1	-0.4	-1.2	4.5	4.1	2.1	4.7	2.4
-1990	1.8	0.9	-0.8	-0.9	4.9	-0.7	1.3	3.7	2.4
-1991	-0.5	-4.6	-4.4	-1.8	3.4	1.7	1.6	-0.7	0.4
-1992	3.0	1.4	1.7	1.8	2.3	4.5	2.1	2.9	0.3
-1993	2.7	0.9	5.5	1.0	3.7	1.9	2.4	1.9	-0.2
-1994	4.0	7.6	9.4	4.9	5.2	6.2	1.4	2.8	0.3
-1995	2.7	-1.0	8.9	3.5	4.7	2.3	3.4	3.6	0.1
-1996	3.6	4.5	4.7	-0.5	5.0	8.2	3.1	3.6	0.3
-1997	4.4	4.5	8.6	1.3	0.4	9.3	5.9	4.3	1.5
-1998	4.3	4.9	9.8	-3.3	2.1	10.1	6.7	4.1	1.1
-1999	4.1	3.7	6.3	2.8	7.2	6.3	4.1	4.1	1.3
-2000	3.8	1.5	10.0	-2.2	6.8	6.7	6.2	3.3	2.6
-2001	0.3	-0.6	-5.2	-7.1	-0.2	2.4	2.8	0.9	1.7
Addendum: Period Average									
1982-2001	3.4	2.9	5.0	1.2	3.9	5.1	3.4	3.6	1.3
1982-1991	3.5	3.0	3.9	2.4	4.1	4.3	2.9	4.2	1.8
1991-2001	3.3	2.8	6.0	0.2	3.7	5.8	3.8	3.1	0.9
1987-2000	3.2	2.2	5.3	0.7	4.2	5.2	3.4	3.4	1.2
1987-1995	2.7	1.3	3.7	1.4	4.1	3.4	2.2	3.1	1.0
1995-2000	4.0	3.8	7.9	-0.4	4.3	8.1	5.2	3.9	1.4

Source: Author's compilation based on BEA, *Gross Product by Industry*.

Notes: Units are percentage. See Appendix Table for classification details. AMC is based on Agriculture, Mining, and Construction; Md is Manufacturing of durable goods; Mn is Manufacturing of nondurable goods; TCU is Transportation, Communication, and Utilities, or the SIC E category; Trade is Wholesale and Retail or the SIC F category; FIRE is Finance, Insurance, and Real estate or the SIC G category. Services is the SIC I category. Gov is government administration and government enterprises.

The former business cycle recorded a 3.5 percent average annual rate of growth. In particular, the beginning years of the period recorded rapid growths, including an outstanding growth rate of 7.3 percent in 1984, in comparison with the later years. The recession in 1991 was short in time and mild in degree with a -0.5 percent growth rate. Particularly, the latter business cycle for 1991-2001 (with a 3.3 percent average annual growth rate) has been paid a lot of attention because of its quality characterized with low inflation contributed by the information technology industries. The performance of the economy for the latter business cycle is concentrated in the period of 1995-2000, recording a 4.0 percent rate of growth. Since the year 2001 when the economy recorded only a marginal rate of growth, the economy has not yet showed an undoubted sign of recovery.

[4] This observation of business cycles is supported by the NBER's comprehensive report of business cycle (www.nber.org/cycles.html).

If we take a look at sectors in the same table above, we can observe that Md, TCU, Trade, and Services performed better than the economy average for the whole period 1982-2001. In particular, Md (Manufacturing of Durable Goods) performed the best for 1991-2001, recording the highest growth rate of 6.0 percent; if we narrow down to the period of 1995-2000, the growth rate of Md is even more remarkable recording 7.9 percent. Such an outstanding performance of Md is largely associated with the fast expansion of Information Technology (IT) industries. Furthermore, the Trade sector (Wholesale and Retail), which packages and distributes commodities, shows the highest growth rate of 5.0 percent for 1982-2001 and 8.1 percent for 1995-2000. This fast growth of the Trade sector is also related to the IT sector because a bulk of IT commodities are distributed by the Trade sector. The three sectors, TCU (Transportation, Communication, and Utility), FIRE (Finance, Insurance, and Real Estate), and Services, in order of performance, record about the economy's average in the growth rate for 1982-2001. Thus we can see that goods-producing sectors experience divergence within themselves; while Md expands fast, AMC (Agriculture, Mining, and Construction) and Mn (Manufacturing of Non-Durable Goods) relatively contract. In particular, Mn records the worst performance in the average annual growth rate for 1982-2001 (1.2 percent) with its performance even worse in the latter business cycle (0.2 percent) than in the former.

Information Technology Industries

The last decade watched the unprecedented phenomena, called "New Economy", in the US economy which is characterized with high growth and minimal inflation. Although many issues remain controversial, it is not of much doubt that IT industries did a great role to the admirable expansion of the economy. A branch of the US Department of Commerce, ESA (Economics and Statistics Administration), noticed the importance of IT in the 1990s and has continued to publish annual reports, *Digital Economy*, from 1998 through 2003, with only one skip in 2001, the year of the 9/11 terror. The first and the second publication were titled *Emerging Digital Economy*. The change of the title reflects that over time IT sectors placed themselves firmly in the economy. It is a rare case that government staffs continue to research about a single sector with such a deep and broad extent. The importance of IT industries grew both in qualitative and quantitative measures until 2001 when the economy turned into recession and the IT sector was hurt with far more extent than the other industries. As the economy started to show a recovery since 2002, the IT sector did so. But as of 2004, the economy and the IT sector have not shown a clear sign to resume the success of the last decade.

According to *Digital Economy* (2002), the post-1995 was particularly outstanding regarding the IT sector and the economy.[5] Productivity grew at an annual average of 2.4 percent for 1995Q4-2001Q3,

[5] The growth rates of two representative IT commodities, computer and semiconductors, are based on *hedonic* prices, which have been developed by the BEA and adopted into the official data including the *Digital Economy* in the measurement of sectoral output growth. Hedonic prices are not purely for actual measurements of prices, rather a statistical estimation to reflect the rapid advance of quality of the IT products in terms of the calculation speed of CPUs and the size of memory capability. Thus some criticism was raised about the possibility of the overestimation of the growth of the IT sector and consequently that of the whole economy. However, according to Landefeld and Grim (2000, *Survey*), the average price decline of 33 percent for 1995-1999 based on the hedonic measurement is not absurd in comparison with the measurements of more quality-adjusted physical units (new computers of much higher quality are sold at similar or even lower prices than the old ones) or various kinds of other hedonic measurements

reaching that level of the golden period of the US economy (an annual average of 2.8 percent for 1948Q4-1973Q4). In the meantime, productivity growth was only 1.4 percent on average. As a result of the latest data, more economists such as Solow, who were skeptical about the qualitative supremacy of the US economy of the mid 1990s, changed their views (*Digital Economy*, 2003, Executive Summary) and agreed on the significant role of IT.

Although over the years the classification of IT industries and statistics have been modified and updated in *Digital Economy*, the general concept of IT has not changed much. *Digital Economy* (2002) defines IT industry as:

> the industries that produce, process, and transmit information goods and services as either intermediate demand (inputs to production of other industries) or as final products (goods and services bought by consumers, business investors, government or for exports). The selected IT-producing industries also include those that supply the goods and services necessary for the Internet and electronic commerce (e-commerce) to operate—i.e., provide the products and services for the Internet infrastructure. (Appendix to chapter III)

This definition is more or less supportive of the IT industry as "New IT" or the convergence of information and communication as in Hall and Preston (1988). The IT sector is composed at large of the information sector (hardware and software/services) which produces and processes digitalized information packets and the communication sector (equipment/service) which transmits those digital information packets. While details are not the same, the definition of the IT sector in the following section will succeed the definition above in concept.

3 Industry Productivity and Aggregation

3.1 Methods

Methodology of Industry Productivity

Productivity calculation dates back to the neoclassical growth accounting by Solow (1956; 1957) and Abramovitz (1956). Since Solow's neoclassical growth accounting is more formally articulated than Abramovits's, Solow's method is popularly cited. While there can be variations of the accounting, the neoclassical growth accounting is still essentially the same as Solow's one.

Take a look at the two different formulas for the aggregate economy as follows:

(3.1) labor-augmented technology: $Y = K^a (AL)^{1-a}$, $0 < a < 1$; and

(3.2) output-augmented technology: $Y = AK^a L^{1-a}$, $0 < a < 1$,

where Y, K, L, and A denote output (e.g. GDP), capital, labor, and technology respectively and AL is called effective labor. In theory, under the assumption of perfect competition in output and factor markets, a and (1-a) are the marginal rate of capital and the marginal rate of effective labor respectively and at the same time the share of capital (K) in output and the share of (AL) respectively. This interpretation of a and (1-a) in terms of share provides an empirical convenience in measuring both parameters. In labor-augmented technology, technology factor affects the marginal rate of effective labor. Otherwise saying, (1-a) already reflects technological change over time, which is hard to implement in empirical study. Thus output-augmented technology is preferred in empirical studies.

By differentiating (3.2), we have

(3.3) $\dot{Y} = a\,\dot{K} + (1 - a)\,\dot{L} + \dot{A},$

where the over-dot denotes the growth rate of the underlying variable. $\dot{A}$ is defined as productivity growth in the economy.

The above equation can be used for industry productivity analysis called *VA-accounting*, if we take *Y* as value added (VA) of an industry. However, in an industry scale approach, neglecting the role of intermediate inputs (called secondary factors in contrast with prime factors such as labor and capital) is not methodologically recommendable because of their important role in production process. Although GPO is widely used to show the growth of sectors, GPO records only the final outcomes or the residuals of all economic activities because GPO is Gross Output (GO) net Intermediate inputs (M). From GPO data, we cannot see exactly why and how each sector produced such outcome. On the other hand, in the aggregate economy, the growth accounting including intermediate inputs is methodologically erroneous because in that case, prime factors (labor and capital) are counted twice, explicitly as themselves and implicitly as the embodied components of intermediate inputs.

In the industry level, we need to broaden the definition of output as gross output (GO) which is defined as the sum of intermediate inputs (M) and value added (VA) from each industry. The industry level approach to the growth accounting can lead to the following equation:

(3.4) $\dot{X} = v_M\,\dot{M} + v_K\,\dot{K} + v_L\,\dot{L} + \dot{A},$ with $v_M + v_L + v_K = 1,$

where X is GO and each coefficient has the same meaning as the marginal product of each factor or the share of each factor in output. All the coefficients sum up to one. Let's call this equation the *GO-accounting*. The GO-accounting is widely accepted to measure official industry productivities by many countries, including the US whose statistical resources are rich (Note that this accounting needs information of intermediate inputs and gross outputs).

One example that can contrast the above two accountings is the case of outsourcing. If an industry or a firm separates one of its divisions and now purchases intermediate inputs from it, then M will get larger while K and L will get smaller because of the allocated portions to the separated department. In this situation, intermediate inputs turn out to substitute for prime factors for the original industry. While the VA-accounting is likely to be insensitive to this substitution because VA may be decreased in proportion as workers and capital decrease, the GO-accounting can capture the extent of the substitution effect.

Changing the notation of A into T, we can rewrite (3.4) in a translog approximation form (the logarithmic difference between two discreet values) as follows:

(3.5) $\Delta Ln\, X^t = v_M\, \Delta Ln\, M^t + v_L\, \Delta Ln\, L^t + v_K\, Ln\Delta\, K^t + \Delta Ln T^t,$ with $v_M + v_L + v_K = 1.$

Under the competitive equilibrium assumption, the coefficient of each factor equals the marginal product of the factor and is supposed to be the same as the share of returns to the factor in the total expense for production. Thus in practice, each coefficient is approximated by each factor's share in output. Value of gross output or $P_X X$ (P_X: the price of output) is composed of the following expenditures:

(3.6) $P_X\, X = P_M\, M + P_L\, L + P_K\, K + B,$

where P with the respective subscript denotes the price of output or factor and B is the indirect business tax. Since B is not the expense that contributed to the production, in determining the shares, the total expense is taken as $P_X X - B$, similarly as in Jorgenson, Ho, and Stiroh (2002, 2003, shortly, JHS).[6] Thus the shares are respectively:

(3.7) $v_M = P_M M / (P_X\ X - B);$

$v_L = P_L L / (P_X\ X - B);$

$v_K = P_K K / (P_X X - B).$

In practice, since the Tornqvist index is the measurement of the change of a variable over adjacent periods, the share is calculated as the average of the shares in two consecutive years.

Aggregation

Considering that productivity growth of an economy is not a uniform process across industries, we need both industry-level productivity growth and economy-wide productivity growth. This can be completed by a weighted sum of the industry GO-accountings with Domar-weights, which is adopted by JHS as well. The Domar weight is the share of each industry's VA in GDP (w_i) divided by the share of each industry's VA in its GO (v_{Vi}). The Domar weight of each industry i is:

(3.8) w_i / v_{Vi}

where $v_{Vi} = v_{Li} + v_{Ki}$, with $v_{Li} + v_{Ki}$ defined as in the GO-accounting before.

The underlying rationale of this weight is to make the Domar-weighted sum of industrial productivity growths equal the productivity growth of the hypothetically integrated economy where all the transactions of intermediate inputs disappear. This hypothetically integrated economy is indeed the same as the one to which VA-accounting applies at an aggregate scale, which can be proven analytically (Domar, 1961; cited from *OECD Productivity Manual* 2001, Annex 6). The introduction of the share of each industry's VA in GDP is easily understandable because we eventually want to calculate each industry' contribution to the growth of GDP. The denominator part in the Domar-weight can be understood in an intuitive way as follows. If the economy is composed of two industries A and B whose productivity growth is one percent respectively and whose share is exactly a half of GDP, the simple average is one percent. If two industries do not exchange any intermediate inputs, then the simple average is sensible. However, if industry A provides intermediate inputs to industry B, the productivity gain of A should be added to some degree to that of B. For B gets benefits of productivity gain by way of better or cheaper intermediate inputs supplied by A. That is, the GO-accounting reflects a certain degree of productivity growth embodied in intermediate inputs (M). The degree of reflection should be proportional to the share of intermediate inputs of GO of industry B and so can be inversely proportional to the extent of VA in GO of industry B.

The Domar-weighted productivity (T^t) constructed from individual productivities (T^t_i) is in a translog formula:

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[6] Indirect Business Tax B is excluded in calculation of shares in JHS. But the OECD's manual *Measuring Productivity* (2001) recommends for splitting the indirect business B proportionately into Labor part and capital part. The difference between the two is the size of VA and that of GO in current dollar measurements. Consequently, the coefficient or share for factor is different between the two methods. However, since the size of indirect business for most industries is not very large in comparison with that of output, the differences in coefficients are not significant.

(3.9) $\Delta Ln\ T^t = \sum_i (w^t_i / (v_{L}{}^t_i + v_{K}{}^t_i))\ \Delta Ln\ T^t_i$,

where w^t_i is the share of valued added (VA) of each industry i in total GDP. Since the translog formula is based on the two-period difference, w^t_i (like $v_L{}^t_i$ or $v_K{}^t_i$) is in practice defined as the average for period t-1 and t.

The Domar-weighted aggregation of industry productivities can also be driven from the VA-based growth accounting by defining constant dollar VA or V in a translog formula as follows:

(3.10) $\Delta Ln\ X^t_i = v_M{}^t_i\ \Delta Ln\ M^t_i + (v_L{}^t_i + v_K{}^t_i)\ \Delta Ln\ V^t_i$; or equivalently

$\Delta Ln\ V^t_i = (\Delta Ln\ X^t_i - v_M{}^t_i\ \Delta Ln\ M^t_i) / (v_L{}^t_i + v_K{}^t_i)$.

This definition of value added in constant dollars (or consequently the rate of growth of value added) based on the Tornqvist method is different from real GPO which is based on the double deflation method and adopted by the BEA's Gross Product by Industry (GPI). As superlative indexes, both indexes are designed to minimize the substitution bias. While the Fisher ideal fits well to a specific indifference curve that Fisher assumed, the Tornqvist index does so to a production possibility curve based on the translog formula and thus is preferred in productivity analysis (UN, 1993, A System of National Accounts). A practical advantage of the Tornqvist index of GPO is that we can avoid negative measurements of real value added in the double deflation method when the price of the industry product increases with a large extent.

The growth accounting to explain output growth measured by V in terms of prime factors and productivity is formulated as:

(3.11) $\Delta Ln\ V^t_i = [\ v_L{}^t_i / (v_L{}^t_i + v_K{}^t_i)\ \Delta Ln\ L^t_i + v_K{}^t_i / (v_L{}^t_i + v_K{}^t_i)\ \Delta Ln\ K^t_i] + \Delta Ln\ T^t_i\ / (v_L{}^t_i + v_K{}^t_i)$

Note that $[\ v_L{}^t_i / (v_L{}^t_i + v_K{}^t_i) + v_K{}^t_i / (v_L{}^t_i + v_K{}^t_i)\ ] = 1$ and each term is the share of the return to each prime factor in value added in current dollars. By denoting $\mu_L{}^t_i = v_L{}^t_i / (v_L{}^t_i + v_K{}^t_i)$, $\mu_K{}^t_i = v_K{}^t_i / (v_L{}^t_i + v_K{}^t_i)$, and $v_V{}^t_i = (v_L{}^t_i + v_K{}^t_i)$, (3.11) can be rewritten:

(3.12) $\Delta Ln\ V^t_i = \mu_L{}^t_i\ \Delta Ln\ L^t_i + \mu_K{}^t_i\ \Delta Ln\ K^t_i + \Delta Ln\ T^t_i\ / v_V{}^t_i$ with $\mu_{Li} + \mu_{Ki} = 1$.

The sum of the first two terms in (3.12) can be defined prime factor (P) as aggregation of labor and capital. In notation,

(3.13) $\Delta Ln\ P^t_i = \mu_L{}^t_i\ \Delta Ln\ L^t_i + \mu_K{}^t_i\ \Delta Ln\ K^t_i$.

By multiplying the share w^t_i to the rate of the growth of V_i (value added of industry i), we can define the contribution of each industry to the growth rate of the real VA of the economy, that is, real GDP. And economy-wide output growth can be defined as follows:

(3.14) $\sum_i \Delta Ln\ V^t_i = \sum_i w^t_i\ \Delta Ln\ V^t_i$.

$= \sum_i [\ (w^t_i\ \mu_L{}^t_i)\ \Delta Ln\ L^t_i + (w^t_i\ \mu_K{}^t_i)\ \Delta Ln\ K^t_i + (w^t_i / v_V{}^t_i)\ \Delta Ln\ T^t_i]$

$= \sum_i (w^t_i\ \mu_L{}^t_i)\ \Delta Ln\ L^t_i + \sum_i (w^t_i\ \mu_K{}^t_i)\ \Delta Ln\ K^t_i) + \sum_i (w^t_i / v_V{}^t_i)\ \Delta Ln\ T^t_i$

The last term of the second equation is the aforementioned Domar-weighted productivity of each industry or the contribution of industry productivity to the aggregate productivity. Similarly, the first and the second term of the second equation are respectively the contribution of each industry to labor inputs growth and capital inputs growth of the economy.

Based on the growth accounting of (3.12), VA-based labor productivity (V^t_i / L^t_i) of each industry is defined as follows:

(3.15) $\Delta Ln\ (V^t_i / L^t_i) = \mu_{K}{}^t{}_i\ \Delta Ln\ (K^t_i / L^t_i) + \Delta Ln\ T^t_i\ / v_V{}^t{}_i$.

K^t_i / L^t_i is capital density (or K-density) and $\mu_{Ki}\ \Delta Ln\ (K^t_i / L^t_i)$ is the contribution of capital density to labor productivity growth for each industry. Of course, it is possible to define GO-based labor productivity (X/L) from the GO-accounting (3.5) similarly as follows:

(3.16) $\Delta Ln\ (X_i / L_i)^t = v_M{}^t{}_i\ \Delta Ln\ M^t_i + v_K{}^t{}_i\ \Delta Ln\ K^t_i + \Delta Ln T^t_i$.

However, in the paper, only VA-based labor productivity will be analyzed; in the GO-accounting, only (total factor) productivity will be discussed. For only VA-based labor productivity can be aggregated as shown below and the aggregate VA-based labor productivity can decomposed into the contribution of capital density and total factor productivity. The word "VA-based" and "GO-based" will be omitted if the context provides enough information for distinction.

As we aggregate value added of industries by multiplying w_i, we can similarly aggregate VA-based labor productivity as follows:

(3.17) $\sum_i\ \Delta Ln\ (V^t_i / L^t_i) = \sum_i\ (w^t_i\ \mu^t_{Ki}\ \Delta Ln\ (K^t_i / L^t_i) + (w^t_i / v_V{}^t i)\ \Delta Ln\ T^t_i\ )$

$= \sum_i\ w^t_i\ \mu_K{}^t{}_i\ \Delta Ln\ (K^t_i / L^t_i) + \sum_i\ (w^t_i / v_V{}^t{}_i)\ \ \Delta Ln\ T^t_i\ w^t_i / v_V{}^t{}_i$

Capital density can be decomposed into the detailed type such as IT capital density and NonIT capital density, we can refine the contribution of capital density (K-density) into the contributions of both kinds of capital density (ITK density and NonITK density). In this case the share μ_{Ki} will further breakdown into that of IT capital and that of NonIT.

In presentation, growth of productivity index T^t is expressed either in ΔLn T^t or in its exponential form as [exp (ΔLn T^t) – 1] which equals (T^t/T^{t-1} – 1). For a small degree of change, say, a few percents, they are approximately the same. But as the size of change gets larger, the difference between them becomes widened. For example, 30 (or 40) percent growth in terms of the latter turns out to be 26 (or 34) percent in the former. Such a large increase in annual terms is rare but exists in IT industries such as computers and semiconductors. The OECD *Measuring Productivity* and JHS use the logarithmic approximation while the BLS (1997) uses the conventional percentage rate of change. The logarithmic approximation enables the decomposition as in (3.5) in the GO-accounting and in (3.12) in the VA accounting to exactly hold and so is taken in this paper. But we need to be cautious about its approximation nature.

3.2 Data of outputs and factors

The classification scheme of industries and the choice of data are related to each other because the availability and quality of data for industries puts constraints on the classification of industries. Not only in this section but also in the rest of the paper, the BLS I-O tables, nominal and real (1983-2000)[7] and the 62 industries aggregated from the 193-industry classification scheme of the BLS tables (based on the SIC) serve as the basic units of industry.[8] The codes and descriptions of the 62 industries are in Appendix Table.

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[7] This data is not available from the BLS website and was provided by Mr. Carl Chentrens, BLS staff on a personal request. The author appreciates a lot Mr. Carl Chentrens for his courtesy to provide and to explain the data. These tables will serve even more intensively as the core data sources of thesis paper in the next sections

[8] Sharing some features with Boer and Nunspeet (1998)'s classification scheme, the criteria considered in this paper are: (1) Manageable number of industries; (2) Intertemporal compatibility and availability of other corresponding

Among the 62 industries, the IT industries are defined in this paper as: D357 (computer), D367 (semiconductor and electronic components), D366 (communication equipment), E48x483 (communication), and I737 (software/programming). They cover IT industries as a total of information/communication goods and services and capture the IT concepts explained in section 2. Since the BLS tables are based on the three-digit level of the SIC, they are quite a refined level of definition to distinguish IT sectors. This definition is broader than that of JHS where E48x483 is excluded. On the other hand, this paper's definition is a little narrower than that of *Digital Economy*, as explained in section 2, which covers IT commodities traded by wholesale traders as well, for example.

The terminology about "industry", "sector", and "commodity" will be shortly clarified. Although there is no much conceptual difference in English, for a matter of convenience, "sector" will be more frequently used to indicate a large industry or an aggregation of some of the 62 industries defined above. Because each industry produces more than one commodity as secondary products, a commodity tends to indicate the specific physical output of production. But in the I-O accounting, a commodity can represent a specific production structure necessary to produce it. In this case, in order to emphasize the corresponding production characteristics, "industry" will be used ambiguously with "commodity." This is particularly the case of the next section where I-O tables in analysis are basically the commodity by commodity table which will be explained soon.

The methodology underlying the BLS tables is the RAS estimation method with the 1992 benchmark table as the reference table.[9] This data set includes *Commodity and Industry Outputs in current and constant dollars* from which we can get implicit price indices for commodity and industry output. These data are available for 193 industries or commodities and the BLS takes the Fisher ideal index for quantity (BLS 1997). But the higher aggregation into the 62 industries or commodities, this paper adopts the Tornqvist index for quantity measurements of outputs. The data source and basic methodology is similar as in JHS. Since the data of labor inputs are rather crude before 1987, the time period is set up as 1987-2000.

Labor inputs

For labor input data, this paper relies on EE (Employment, Hours, and Earnings) provided by BLS. EE provides employment data by industry based on the SIC: the number of all the workers and of the production workers. The definition of production workers is, in manufacturing and mining (or construction),

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industry data; (3) Meaningful and comparable size of industries; (4) Degree of details that satisfy research concerns or interests; (5) Homogeneity of component units within each industry; and (6) Degree of inter-dependence of industries.

[9] In most countries, the benchmark or surveyed I-O tables are released with the time interval of a few years. Thus annual I-O tables should be made based on certain estimation techniques. Among them, the RAS method has been at the central stage since a group of Cambridge University led by Stone, Nobel Laureate, initiated the ideas in the 1960s (Stone 1962; Stone and Brown 1962; cited from Lahr and De Mesnard 2004). The RAS needs just one reference table or the intermediate accounts of the use table at a certain year, the time series of commodity output used for intermediate inputs, and that of sum of intermediate inputs by industry. Then the RAS, by iteratively modifying the columns and rows of the reference table in certain proportions, can estimate I-O tables at any time. The row-wise adjustment is to multiply a row vector (denoted by R) left to the reference matrix (denoted by A) and the column-wise adjustment is to multiply a column-vector (denoted by S) right to the matrix. That is, all the elements of each row (or column) are adjusted by the same proportion assigned by the corresponding element of R (or S) and so the RAS method is also called the *biproportional iteration method*. A recent issue of Economic Systems Research (2004, June) covers the historical and up-to-date developments of the estimation technique, including the RAS method.

the employed people directly engaged in production (or construction) under supervision and, in other industries, most employees except those at executive and managerial positions. Note that the distinction between production and non-production is made better for the convenience of data collection rather than the qualitative nature of labor. In fact, labor hours and hourly wages are collected only for production workers.

In the BLS statistics of productivity, it is assumed that the hours for production workers are the same as for all the workers. Since it is not easy to collect data of hours of work for all the employed, such an assumption is inevitable and accepted in productivity analysis as in JHS. One note about the data of working hours is that in comparison with the number of all the workers, the data of production workers and working hours start to be collected late (particularly since 1988) for some detailed industries and are not yet compiled for some aggregated and detailed industries. Thus in this case, we simply should impute the number of all the employed workers to labor inputs. If the industry category also exists in the BEA's GPI, its data of the number of workers will be adopted as a complement since the GPI are complete since 1987.

Capital inputs

As for capital inputs, official statistics agents such as the BLS (1997) and OECD (2001) recommend capital service as capital inputs. Capital service is designed better to reflect sensitively the price change of capital (JHS). However, capital service needs more steps and data, which is too time-taking. Thus as we often approximate the number of workers to labor input as a shorthand method, we can still use capital stock data as approximation of capital service. Fortunately, according to the BEA (2003), both two measurements are not seriously out of tune. Just the BLS's capital service is higher in growth rates than the BEA's capital stock. For capital service reflects better the rapid price change of some types of capital such as IT capital.

The BEA provides *Fixed Assets and Consumer Durables* (explained in detail in BEA (2003)) which includes Fixed Assets by type (FAT) and Fixed Assets by industry (FAI) as well as cross-referenced data by type and by industry simultaneously (shortly, FATI).[10] In comparison with FAT and FAI, FATI, which we need to analyze IT-intensity in capital stock, is not reliable enough to be published and so is available only at the BEA's website (http://www.bea.doc.gov). For the latter is based on higher level aggregation and judgmental decisions. However, there is no any other directly available source of data, and the same data set is also utilized in ESA's *Digital Economy*.[11] This paper refers to both FAI and FATI. If we aggregate the latter data across all the types, we are supposed to get the former data except for a few industries in concept. Nonetheless, since the definition of FATI does not include residential buildings, there can be differences in FAI and FATI. However, this type of fixed assets exists only in a few sectors, agriculture (A), real estate (H65), and government (J and Gbus). Except for them, the difference is mostly statistical discrepancy and the extent of discrepancy is not large.

[10] The BEA defines fixed assets as a comprehensive measurement of capital stock as follows: "Fixed assets are producer's assets that are used repeatedly, or continuously, in process of production for more than one year. (Produced Assets are nonfinancial assets that have come into existence as outputs from a production process)" (BEA 2003, *Fixed Assets and Consumer Durables*)

[11] We can calculate them based on investments data by industry and capital flow data in an input-output format of a certain year, which is indeed the key part of the BEA's FA by industry and type as in JHS. But it is too time-taking for an independent project.

Fixed Assets data are based on the three methods of valuation: historical costs, current costs, and constant dollars. Historical costs are simply the price of capital at the time of purchase. Current costs are the recalculation of the old stock that can be purchased at the valuation period. The constant dollar (or volume index) measurement is to depreciate current cost valuation. The Fisher-ideal index is used for aggregation in FAI.

Fixed Assets are classified in detail to cover 62 types of capital, including IT kinds (seven computer-related equipment sectors, four software sectors, and one communication equipment). At large, fixed assets are of two kinds: (1) equipment and software and (2) structure. Software is classified into capital stock after the 1999 NIPA revision (Moulton, Parker, and Seskin 1999, *Survey*) (before, software was regarded as intermediate inputs). Structure includes infrastructure and residential or nonresidential buildings.

Although the industry classification of FAI is similar to that of GPI, there are a few sectors which differ between both classification schemes. E48 (communication) in FAI is composed of E483 (broadcasting) and the rest, while it is of E483,484 (broadcasting and cable television) and the rest in GPI. E49 (utility) in FAI is made up of three subsectors, E48elec (electricity), E48gas (gas), and E494- (sanitary), while E49 is the smallest unit in GPI. H60 (banking) is composed of Federal Reserves and commercial bank in FAI, while it is the smallest unit in GPI. But only H60 will be included in this section because Federal Reserves is a very small part of H60. I84 (museum sites), I86 (membership service), and I87 (professional services) are consolidated into one sector called "Other services" (I84,86,87) in FAI while they are independent accounts in the GPI. There are only two government related sectors in FAI: J (general government administration) and Gbus (government enterprise), though they are further decomposed into federal and state/local in the GPI. Private household (I88) is not available in FAI. As a result, 62 sectors at large are available for capital stock data.

For some industries covered in FAI need to be disaggregated in order to be fit the 62-industry classification scheme of this paper. In this case unavoidably capital stock of the larger industry is split in proportion to the share in capital return part of VA, or VA minus compensation minus Indirect Business Tax, as similarly done in JHS.

From the types of Fixed Assets, Computer, software, and communication equipment are classified as IT equipments. Note that the definition of IT differs between capital and intermediate inputs; D367 (semiconductors) and E48x483 are taken only as intermediate inputs. This classification of IT capital is the same as in JHS, but smaller than *Emerging Digital Economy 1999* (ESA), because it includes Instruments (D38).

3.3 Results: Industry Productivity and Aggregation

Industry Productivity: GO-accounting

In order to calculate productivity by industry defined as in Equation (3.5), we need to assign proper weights to factors as in Equation (3.7). The BEA's GPI provides very detailed accounts of factors including all the factors expressed in the equations above and serves as basic data to calculate the coefficients of the productivity equation. But it is not detailed enough to cover the industries of smaller levels than the SIC two-digit one, not providing the data for some IT industries. The benchmark I-O tables also cover the necessary expenditure composition of outputs but they are available only every five years. Thus the two-digit level data of GPI should be split proportionately to the smaller level of classification as similarly done for capital stock data. In both GPI and I-O accounts, the share of labor is captured by the *Compensation* account which covers broadly all the items, including wage and other benefits accruing to the employees. Indirect Business Tax is also similarly defined in both accounts. Thus the return to capital ($P_K K$ in equation (3.6)) is calculated as the subtraction of compensation and indirect business tax from GPO or Value added. The results are presented in the following tables. Recall that I88 (private household) does not have capital stock data. Thus its prime factor or total factor is based on labor only.

Table 3.1 presents average annual growth rates of Total Factor Productivity (TFP) by period along with the contributions of factors to GO growth for selected industries.[12] The results of TFP growth by industry are not significantly different from those of JHS and the BLS but they tend to be a little overstated. Since the growth rates of GO, M, and L are each not much different between this paper and JHS, the overstatement of TFP growth of this paper must be due to the overestimation of the growth rate of capital input.

The first section of Table 3.1 lists the top 20 industries in the growth rate of TFP for 1995-2000. Industries are mostly from goods-producing ones. In particular, there do not exist services industries (SIC I) except I88 (I88's high performance is due to the lack of its capital stock data). Recall that in the previous section, the services sector (SIC I) is very weak in productivity growth due to their fast growth in employment. Manufacturing industries are prevalent in the table, including IT industries. There are two IT industries, D367 (17.72 percent for 1995-2000) and D357 (13.96 percent) at the top. Two large FIRE sectors performed very well: H62 (security) with 7.63 percent and H60 (deposit institution) with 1.45 percent. However, other FIRE industries did not do so well in productivity, probably making FIRE as a whole be a mediocre sector in productivity growth. Several traditional industries, including two mining industries–B10 (metal mining) and B12 (coal)–and a few nondurable manufacturing industries–D22,3 (textile), D30 (rubber), D29R (petroleum-based product) are in the list.

Most industries in the first section of Table 3.1 performed better for the latter period than for the former period, backing up the optimism that prevailed in the US economy, or "the New Era of the US economy" largely attributed to the success of the IT sector. The contribution of IT industries in productivity growth will be discussed later in the aggregation of industry productivities.

The second section of Table 3.1 lists the top 20 industries whose growth rates in GO are large. In general, many services industries that were not listed in the first section appear now. The five IT industries (D357, D366, D367, E48x483, and I737) appear in the list with D367 and D357 at the top of the list. Communication equipments (D366) were more or less on a similar trend with D357 or D367 though the extent of expansion was about a third of that of IT hardware. Since the price indices for communication

[12] Since the methodology to calculate the growth rates is based on the translog approximation as mentioned in subsection 3.1, they are smaller than the percentage change of growth rates particularly for very fast growing industries such as D357 (computers) and D367 (semiconductor and electronic components).

equipments do not experience as outstanding downward trends in prices (though declining) as IT hardwares, the expansion of the communication equipments is mainly due to the actual increase in physical units and can be appreciated strongly by business in monetary sense.[13]

Table 3.1 Average annual growth rates of TFP in the GO accounting, selected industries

	1987-1995					1995-2000				
Industry	GO	M, cntr	L, cntr	K, cntr	TFP	GO	M, cntr	L, cntr	K, cntr	TFP
In the order of TFP growth for 1995-2000										
D367	17.05 (1)	6.42 (3)	-0.19 (51)	1.31 (5)	9.52 (2)	28.65 (1)	8.69 (3)	0.89 (17)	1.36 (10)	17.72 (1)
D357	16.10 (2)	6.87 (2)	-0.80 (57)	-0.15 (56)	10.19 (1)	28.05 (2)	14.03 (1)	-0.23 (52)	0.29 (41)	13.96 (2)
H62	6.96 (5)	1.48 (25)	1.03 (11)	1.21 (8)	3.24 (5)	19.90 (3)	7.70 (5)	3.21 (3)	1.35 (11)	7.63 (3)
B12	1.43 (43)	-1.35 (60)	-1.71 (59)	0.03 (45)	4.45 (3)	0.80 (55)	-1.57 (61)	-2.15 (62)	0.11 (50)	4.41 (4)
I88	1.86 (35)	0.00 (54)	-2.33 (62)	0.00 (50)	4.20 (4)	3.00 (31)	0.00 (55)	-1.17 (58)	0.00 (56)	4.17 (5)
D31	-3.11 (62)	-1.75 (62)	-0.88 (58)	-0.22 (57)	-0.25 (46)	2.78 (36)	0.83 (47)	-1.96 (61)	0.00 (58)	3.91 (6)
D29R	0.68 (51)	0.12 (53)	0.06 (37)	0.15 (36)	0.35 (35)	5.38 (19)	3.40 (17)	0.09 (39)	-1.29 (62)	3.18 (7)
D384,5	5.57 (8)	3.01 (9)	0.63 (19)	0.38 (20)	1.55 (9)	8.19 (7)	4.78 (9)	0.05 (41)	0.27 (42)	3.09 (8)
D33	2.03 (29)	1.73 (20)	-0.07 (45)	-0.04 (53)	0.41 (33)	3.04 (30)	0.15 (54)	0.05 (42)	0.01 (55)	2.84 (9)
D22,3	0.99 (50)	0.44 (48)	-0.48 (55)	0.02 (47)	1.01 (19)	-1.32 (61)	-2.13 (62)	-1.54 (60)	0.00 (57)	2.35 (10)
I78	5.58 (7)	3.67 (6)	1.67 (8)	1.30 (6)	-1.06 (58)	6.37 (12)	1.63 (33)	1.60 (9)	0.79 (20)	2.35 (11)
D25	1.58 (41)	0.89 (40)	-0.11 (48)	0.12 (37)	0.68 (26)	7.59 (8)	4.32 (11)	0.66 (23)	0.32 (36)	2.28 (12)
D26	1.47 (42)	1.57 (24)	0.05 (40)	0.30 (26)	-0.44 (48)	0.79 (56)	-1.25 (60)	-0.33 (55)	0.14 (48)	2.23 (13)
Gbus	1.95 (32)	0.95 (39)	0.14 (34)	0.22 (31)	0.64 (28)	3.69 (28)	1.45 (37)	0.00 (46)	0.26 (43)	1.98 (14)
D34	1.72 (37)	0.73 (44)	0.17 (32)	0.09 (40)	0.73 (25)	5.59 (18)	2.98 (24)	0.41 (25)	0.31 (37)	1.90 (15)
E46,491-3	0.26 (55)	-0.46 (58)	-0.14 (50)	0.62 (15)	0.25 (39)	1.46 (51)	-0.56 (59)	-0.26 (54)	0.42 (32)	1.87 (16)
B10	5.45 (9)	3.03 (8)	0.43 (25)	-0.06 (54)	2.05 (7)	0.65 (57)	0.34 (53)	-1.25 (59)	-0.29 (59)	1.85 (17)
D30	4.05 (14)	1.96 (16)	0.57 (21)	0.32 (24)	1.20 (14)	3.45 (29)	0.83 (48)	0.24 (34)	0.60 (29)	1.79 (18)
B13	-0.99 (60)	-1.32 (59)	-0.35 (52)	-0.43 (60)	1.11 (16)	1.12 (53)	-0.27 (58)	-0.37 (57)	0.29 (39)	1.46 (19)
H60	3.31 (21)	1.38 (27)	-0.37 (53)	0.85 (9)	1.44 (12)	6.22 (13)	3.73 (15)	0.03 (43)	1.00 (15)	1.45 (20)
Average	3.7	1.5	-0.1	0.3	2.1	6.8	2.5	-0.1	0.3	4.1
In the order of GO growth for 1995-2000										
D367	17.05 (1)	6.42 (3)	-0.19 (51)	1.31 (5)	9.52 (2)	28.65 (1)	8.69 (3)	0.89 (17)	1.36 (10)	17.72 (1)
D357	16.10 (2)	6.87 (2)	-0.80 (57)	-0.15 (56)	10.19 (1)	28.05 (2)	14.03 (1)	-0.23 (52)	0.29 (41)	13.96 (2)
H62	6.96 (5)	1.48 (25)	1.03 (11)	1.21 (8)	3.24 (5)	19.90 (3)	7.70 (5)	3.21 (3)	1.35 (11)	7.63 (3)
D366	6.36 (6)	5.10 (5)	-0.12 (49)	0.60 (16)	0.78 (23)	11.95 (4)	10.42 (2)	0.12 (35)	1.90 (4)	-0.49 (46)
I737	9.39 (3)	5.32 (4)	2.70 (2)	1.87 (1)	-0.50 (49)	11.70 (5)	7.82 (4)	5.64 (1)	3.24 (1)	-5.00 (60)
H61,67	1.03 (49)	1.40 (26)	1.21 (10)	-0.39 (59)	-1.19 (59)	9.05 (6)	7.08 (6)	2.72 (4)	-0.36 (60)	-0.39 (45)
D384,5	5.57 (8)	3.01 (9)	0.63 (19)	0.38 (20)	1.55 (9)	8.19 (7)	4.78 (9)	0.05 (41)	0.27 (42)	3.09 (8)
D25	1.58 (41)	0.89 (40)	-0.11 (48)	0.12 (37)	0.68 (26)	7.59 (8)	4.32 (11)	0.66 (23)	0.32 (36)	2.28 (12)
I73R	5.29 (11)	1.37 (28)	2.51 (3)	1.31 (4)	0.11 (40)	7.58 (9)	2.05 (29)	3.33 (2)	2.94 (2)	-0.74 (50)
E48x483	4.30 (13)	1.59 (22)	0.04 (41)	0.80 (10)	1.87 (8)	6.92 (10)	3.80 (14)	1.36 (11)	1.86 (6)	-0.09 (41)
I79	5.42 (10)	2.41 (12)	1.94 (5)	0.63 (14)	0.44 (32)	6.45 (11)	3.00 (23)	1.27 (12)	1.01 (14)	1.17 (24)
I78	5.58 (7)	3.67 (6)	1.67 (8)	1.30 (6)	-1.06 (58)	6.37 (12)	1.63 (33)	1.60 (9)	0.79 (20)	2.35 (11)
H60	3.31 (21)	1.38 (27)	-0.37 (53)	0.85 (9)	1.44 (12)	6.22 (13)	3.73 (15)	0.03 (43)	1.00 (15)	1.45 (20)
I87,89	3.53 (20)	1.96 (15)	1.71 (7)	0.45 (19)	-0.59 (50)	6.09 (14)	3.16 (19)	2.16 (6)	0.98 (16)	-0.21 (44)
D371	3.61 (19)	2.88 (10)	0.33 (26)	0.10 (38)	0.30 (37)	6.07 (15)	4.76 (10)	0.10 (37)	0.25 (44)	0.97 (26)
D37R	-2.27 (61)	-1.56 (61)	-2.03 (61)	0.02 (49)	1.31 (13)	5.99 (16)	4.17 (12)	0.27 (32)	0.11 (49)	1.44 (22)
D32	0.57 (53)	-0.04 (56)	-0.08 (46)	-0.06 (55)	0.75 (24)	5.60 (17)	3.06 (22)	0.49 (24)	0.74 (22)	1.32 (23)
D34	1.72 (37)	0.73 (44)	0.17 (32)	0.09 (40)	0.73 (25)	5.59 (18)	2.98 (24)	0.41 (25)	0.31 (37)	1.90 (15)
D29R	0.68 (51)	0.12 (53)	0.06 (37)	0.15 (36)	0.35 (35)	5.38 (19)	3.40 (17)	0.09 (39)	-1.29 (62)	3.18 (7)
I75	3.71 (16)	2.34 (13)	0.61 (20)	1.70 (2)	-0.94 (55)	5.06 (20)	3.18 (18)	0.81 (20)	1.17 (13)	-0.09 (42)
Average	3.7	1.9	0.7	0.6	0.5	7.9	4.5	1.4	0.9	1.1

Source: Author's compilation based on BEA, *Fixed Assets and Consumer Durables*, BEA, *Gross Product by Industry*, BLS, *Input-Output Transaction Tables* (1983-2000), and BLS, *Employment, Hours, and Earnings.*

Notes: Units are percentage. The figures in parentheses are the ranks along each column.

Three FIRE industries (H60, H61,67, and H62) and six Services industries (I737, I73R, I75, I78, I79, and I87,89) performed well in GO growth. H61,67 performed much better for 1995-2000 than for 1987-1995. Noticeable among the others are the four manufacturing industries: D371 (automobiles), D37R, D25 (furniture), D30 (rubber), and D35R (transportation equipments). These manufacturing industries performed much better for 1995-2000 than for 1987-1995.

From Table 3.1, we can notice that the contribution of the intermediate inputs (M) to output growth of each industry tends to be the largest among the components. This is due first to the fact that intermediate inputs grow much faster than prime factors and second to the fact that the share of M in GO tends to be larger than those of prime factors. The importance of intermediate inputs is confirmed again from

[13] In fact, the price estimation of D366 in BLS I-O Tables is conservative, not hedonic. On the other hand, JHS adopt the BEA's quality adjusted price for D366. As a result, JHS's measurement of output growth of D366 is almost twice larger than this paper. Accordingly, the growth rate of Value added measurements which will be introduced soon are much lower in this paper than in JHS.

individual industries. From the second part of Table 3.1 we can notice that the order of industries in terms of GO growth rates is not much different from that of industries in terms of M growth (contribution).

VA-based productivity and Aggregation

The aforementioned aggregation of industry productivity growth rates is easily understood in the VA-accounting framework as in Equation (3.12). Equation (3.12) shows how labor (contribution), capital (contribution), and TFP growth of each industry based on the GO-accounting is transformed into those based on the VA-accounting.

Table 3.2 illustrates the change of VA (value added) for selected industries. Capital is further decomposed of IT capital (IT-K) and NonIT capital (NonIT-K). In general, VA-based TFP growth of industries tends to be much faster than GO-based TFP growth. This tendency is even more evident for the top 20 industries whose VA-based TFP growth rates are very high as in the first section of Table 3.2. As for the top 20 industries in the second section of Table 3.2, VA growth tends to be faster than GO growth for the top 20 industries in second section of Table 3.1.

Table 3.2 Average annual growth rates of VA-based TFP, selected industries

	1987-1995					1995-2000				
Industry	VA	L, cntr	IT-K, cntr	NonIT-K, cntr	VA-TFP	VA	L, cntr	IT-K, cntr	NonIT-K, cntr	VA-TFP
In the order of TFP growth for 1995-2000										
D357	30.61 (1)	-2.60 (59)	0.06 (35)	-0.51 (56)	33.67 (1)	53.68 (1)	-0.86 (54)	0.36 (18)	0.74 (32)	53.44 (1)
D367	21.67 (2)	-0.33 (50)	0.31 (8)	2.35 (2)	19.34 (2)	42.40 (2)	1.91 (14)	0.54 (15)	2.34 (4)	37.60 (2)
H62	8.86 (3)	1.68 (13)	0.15 (15)	1.80 (6)	5.23 (7)	20.90 (3)	5.50 (3)	0.67 (11)	1.63 (11)	13.09 (3)
D31	-3.81 (61)	-2.45 (58)	0.06 (33)	-0.68 (57)	-0.74 (47)	5.25 (18)	-5.49 (62)	0.20 (24)	-0.21 (58)	10.76 (4)
D29R	1.78 (37)	0.20 (37)	0.05 (40)	0.47 (29)	1.06 (33)	6.33 (9)	0.27 (36)	-0.02 (59)	-4.30 (61)	10.36 (5)
D33	0.99 (46)	-0.24 (47)	0.01 (52)	-0.15 (54)	1.36 (29)	9.65 (5)	0.16 (39)	0.03 (52)	0.00 (56)	9.47 (6)
B12	5.04 (9)	-3.10 (60)	0.03 (48)	0.03 (46)	8.09 (3)	4.40 (23)	-4.00 (60)	0.03 (53)	0.17 (48)	8.21 (7)
D22,3	1.62 (39)	-1.37 (56)	0.06 (32)	0.00 (48)	2.93 (11)	2.30 (44)	-4.47 (61)	0.06 (47)	-0.06 (57)	6.77 (8)
D26	-0.29 (52)	0.13 (39)	0.06 (34)	0.76 (18)	-1.23 (52)	5.38 (16)	-0.83 (53)	0.07 (44)	0.29 (46)	5.85 (9)
D384,5	4.35 (14)	1.06 (23)	0.13 (19)	0.52 (26)	2.63 (14)	6.01 (12)	0.08 (42)	0.16 (27)	0.31 (44)	5.46 (10)
I78	4.41 (13)	3.89 (3)	0.84 (1)	2.16 (4)	-2.48 (58)	11.00 (4)	3.78 (6)	0.47 (16)	1.39 (14)	5.36 (11)
D25	1.54 (41)	-0.24 (48)	0.05 (39)	0.22 (37)	1.51 (24)	7.24 (7)	1.46 (18)	0.15 (30)	0.57 (36)	5.06 (12)
B10	6.22 (6)	1.09 (21)	0.04 (42)	-0.21 (55)	5.29 (6)	0.73 (55)	-3.24 (59)	-0.01 (58)	-0.74 (60)	4.72 (13)
D371	3.43 (18)	1.57 (14)	0.05 (38)	0.39 (31)	1.42 (27)	6.13 (10)	0.47 (34)	0.12 (36)	1.05 (25)	4.51 (14)
D34	2.27 (28)	0.38 (33)	0.07 (29)	0.14 (40)	1.68 (21)	5.90 (14)	0.93 (27)	0.16 (28)	0.54 (39)	4.28 (15)
I88	1.86 (32)	-2.33 (57)	0.00 (54)	0.00 (47)	4.20 (8)	3.00 (38)	-1.17 (57)	0.00 (55)	0.00 (54)	4.17 (16)
D30	4.76 (10)	1.30 (15)	0.05 (37)	0.68 (19)	2.73 (13)	5.92 (13)	0.54 (32)	0.12 (35)	1.23 (20)	4.04 (17)
Gbus	1.78 (36)	0.27 (35)	0.00 (54)	0.39 (32)	1.12 (32)	3.86 (27)	-0.01 (46)	0.00 (55)	0.45 (43)	3.42 (18)
E46,491-3	1.45 (42)	-0.27 (49)	0.05 (36)	1.18 (11)	0.49 (38)	3.64 (30)	-0.48 (50)	0.12 (37)	0.63 (34)	3.37 (19)
B13	0.72 (48)	-0.73 (52)	0.00 (57)	-0.88 (60)	2.33 (17)	2.83 (40)	-0.79 (52)	0.04 (51)	0.58 (35)	3.01 (20)
Average	5.0	-0.1	0.1	0.4	4.5	10.3	-0.3	0.2	0.3	10.1
In the order of VA growth for 1995-2000										
D357	30.61 (1)	-2.60 (59)	0.06 (35)	-0.51 (56)	33.67 (1)	53.68 (1)	-0.86 (54)	0.36 (18)	0.74 (32)	53.44 (1)
D367	21.67 (2)	-0.33 (50)	0.31 (8)	2.35 (2)	19.34 (2)	42.40 (2)	1.91 (14)	0.54 (15)	2.34 (4)	37.60 (2)
H62	8.86 (3)	1.68 (13)	0.15 (15)	1.80 (6)	5.23 (7)	20.90 (3)	5.50 (3)	0.67 (11)	1.63 (11)	13.09 (3)
I78	4.41 (13)	3.89 (3)	0.84 (1)	2.16 (4)	-2.48 (58)	11.00 (4)	3.78 (6)	0.47 (16)	1.39 (14)	5.36 (11)
D33	0.99 (46)	-0.24 (47)	0.01 (52)	-0.15 (54)	1.36 (29)	9.65 (5)	0.16 (39)	0.03 (52)	0.00 (56)	9.47 (6)
I73R	5.26 (7)	3.36 (5)	0.44 (5)	1.31 (9)	0.15 (41)	7.38 (6)	4.45 (4)	2.03 (4)	1.90 (8)	-0.99 (46)
D25	1.54 (41)	-0.24 (48)	0.05 (39)	0.22 (37)	1.51 (24)	7.24 (7)	1.46 (18)	0.15 (30)	0.57 (36)	5.06 (12)
I737	6.44 (5)	4.28 (2)	0.72 (2)	2.23 (3)	-0.79 (48)	6.44 (8)	9.35 (1)	2.40 (1)	2.97 (2)	-8.28 (59)
D29R	1.78 (37)	0.20 (37)	0.05 (40)	0.47 (29)	1.06 (33)	6.33 (9)	0.27 (36)	-0.02 (59)	-4.30 (61)	10.36 (5)
D371	3.43 (18)	1.57 (14)	0.05 (38)	0.39 (31)	1.42 (27)	6.13 (10)	0.47 (34)	0.12 (36)	1.05 (25)	4.51 (14)
I79	5.22 (8)	3.36 (4)	-0.01 (59)	1.11 (12)	0.77 (36)	6.07 (11)	2.24 (12)	0.09 (42)	1.68 (10)	2.06 (28)
D384,5	4.35 (14)	1.06 (23)	0.13 (19)	0.52 (26)	2.63 (14)	6.01 (12)	0.08 (42)	0.16 (27)	0.31 (44)	5.46 (10)
D30	4.76 (10)	1.30 (15)	0.05 (37)	0.68 (19)	2.73 (13)	5.92 (13)	0.54 (32)	0.12 (35)	1.23 (20)	4.04 (17)
D34	2.27 (28)	0.38 (33)	0.07 (29)	0.14 (40)	1.68 (21)	5.90 (14)	0.93 (27)	0.16 (28)	0.54 (39)	4.28 (15)
E48x483	4.59 (11)	0.07 (40)	0.53 (3)	0.82 (17)	3.17 (9)	5.54 (15)	2.40 (11)	2.03 (3)	1.27 (18)	-0.17 (41)
D26	-0.29 (52)	0.13 (39)	0.06 (34)	0.76 (18)	-1.23 (52)	5.38 (16)	-0.83 (53)	0.07 (44)	0.29 (46)	5.85 (9)
D32	1.28 (44)	-0.17 (46)	0.02 (51)	-0.14 (52)	1.58 (23)	5.31 (17)	1.02 (25)	0.16 (29)	1.38 (15)	2.76 (22)
D31	-3.81 (61)	-2.45 (58)	0.06 (33)	-0.68 (57)	-0.74 (47)	5.25 (18)	-5.49 (62)	0.20 (24)	-0.21 (58)	10.76 (4)
G	1.90 (30)	1.12 (20)	0.07 (30)	0.87 (16)	-0.16 (45)	5.01 (19)	1.39 (19)	0.19 (26)	0.92 (29)	2.50 (23)
I87,89	2.47 (25)	2.69 (9)	0.19 (13)	0.51 (28)	-0.93 (49)	4.81 (20)	3.55 (8)	0.67 (12)	0.93 (27)	-0.34 (44)
Average	5.4	1.0	0.2	0.7	3.5	11.3	1.6	0.5	0.8	8.3

Source: Author's compilation based on BEA, *Fixed Assets and Consumer Durables*, BEA, *Gross Product by Industry*, BLS, *Input-Output Transaction Tables* (1983-2000), and BLS, *Employment, Hours, and Earnings.*

Notes: Units are percentage. The figures in parentheses are the rank along each column.

Note that the industries in each section of Table 3.2 are not very different from those in the corresponding section of Table 3.1 and the order of industries is not significantly different either. But a few industries show large deviations between the two due to the disproportional (mostly larger than proportional) increase in the content of intermediate inputs. Among the industries in the second section of Table 3.1, D366, H61,67 show sharp falls in rank of VA growth in comparison with that of GO growth.

In comparison with *Digital Economy* that provided the detailed statistics of the IT sector's growth, the growth rate of D357's VA (53.68 percent) is overstated (about 40 percent in *Digital Economy2002* for 1995-2000). JHS's data for the same industry and period is even larger (65.5 percent). While both two figures of this paper and of JHS are based on the logarithmic approximation, the regular percentage rate of growth will be far lager. Since the ESA provides only final results of real VA data, it is not clear which data is more adequate. In the author's calculation of VA in terms of the Fisher-Ideal where the ESA is based on also produces much larger estimation of VA growth for both two industries than the ESA's. Thus at this stage, it seems that the ESA data is understated for D357. D367 is similar to D357 in comparison between this paper's estimation and that of *Digital Economy*.

The aggregation of industry productivity based on Equation (3.14) is illustrated in Table 3.3. Table 3.3 shows the multiplication of the weight (or the share of VA of each industry in GDP) to the VA–accounting as shown in Table 3.2 above. This multiplication of the weight to the VA-accounting is equivalent to the multiplication of the aforementioned Domar-weight to the GO-accounting as in Equation (3.5). The weighted VA-accounting by industry is ready to be summed up to the aggregate GDP (or VA) accounting as in Equation (3.14). Thus each component of the industry VA-accounting (L, IT-K, NonIT-K, and TFP) can be interpreted as the contribution of each industry to the corresponding component of the aggregate VA accounting. The first column in each period is the weight (w^t_i) and the rest components illustrate the components of the weighted VA-accounting by industry.

The first section of Table 3.3 lists the top 20 industries whose contribution to productivity growth rate for 1995-2000 is very high. Thanks to varying weights across industries, in comparison with the top 20 industries of high TFP growth as in the first section of Table 3.3 (non-weighted VA-accounting), we can observe the rearrangement of industries. Noticeable new entrants are G, H60, F, D34, D28, D35R, D37R, A, and D27, reflecting their size share in GDP. The aggregate of weighted TFP growths for the top 20 industries amounts to 1.62 percent, much larger than the aggregate of all the industries, implying the existence of industries whose TFP growth is negative.

The second section of Table 3.3 lists the top 20 industries whose contribution to GDP growth rate for 1995-2000 is very high. The industries that appear in the list are not very different from those in the order of VA growth in Table 3.3 above, but, as in the first section, reflecting their large shares, some industries appear newly in the list (G, F, C, J, and so on).

There are many industries appearing in both sections. In particular, D357, D367, and H62 (security brokers) are the top performers both in VA growth and in productivity growth. Noticeably many service industries appear only in the second section such as I737, EtransX46, I73R, and I79, which is consistent with the general trend that service industries are weaker in productivity growth than in output growth. The presence of I88 can be overlooked since I88's productivity is calculated on the assumption that it uses only one prime factor as labor.

Table 3.3 Weighted (VA-based) TFP Growth by Industry (selected) and Aggregation, selected industries

	1987-1995						1995-2000					
Industry	Weight	VA	L, cntr	IT-K, cntr	NonIT-K, cntr	VA-TFP	Weight	VA	L, cntr	IT-K, cntr	NonIT-K, cntr	VA-TFP
In the order of TFP growth for 1995-2000												
D367	0.69 (37)	0.14 (5)	0.00 (48)	0.00 (16)	0.02 (14)	0.13 (3)	0.81 (30)	0.34 (2)	0.02 (19)	0.00 (19)	0.02 (15)	0.30 (1)
D357	0.41 (46)	0.13 (7)	-0.01 (58)	0.00 (37)	0.00 (58)	0.14 (1)	0.41 (46)	0.22 (7)	0.00 (55)	0.00 (28)	0.00 (39)	0.22 (2)
G	7.26 (3)	0.14 (6)	0.08 (4)	0.00 (9)	0.06 (2)	-0.01 (53)	7.05 (3)	0.35 (1)	0.10 (7)	0.01 (9)	0.07 (4)	0.17 (3)
H62	1.00 (23)	0.08 (12)	0.02 (15)	0.00 (22)	0.02 (15)	0.05 (8)	1.21 (21)	0.26 (4)	0.07 (9)	0.01 (12)	0.02 (14)	0.16 (4)
H60	2.82 (10)	0.08 (11)	-0.02 (60)	0.01 (5)	0.02 (10)	0.06 (6)	3.12 (9)	0.13 (12)	0.00 (35)	0.04 (5)	0.02 (17)	0.08 (5)
F	5.68 (5)	0.24 (2)	0.04 (8)	0.02 (1)	0.04 (6)	0.13 (2)	5.74 (5)	0.26 (5)	0.08 (8)	0.06 (2)	0.05 (7)	0.07 (6)
E46,491-3	2.15 (11)	0.03 (21)	-0.01 (54)	0.00 (23)	0.03 (7)	0.01 (23)	1.93 (13)	0.07 (18)	-0.01 (61)	0.00 (25)	0.01 (23)	0.07 (7)
D33	0.72 (35)	0.01 (44)	0.00 (50)	0.00 (47)	0.00 (55)	0.01 (27)	0.67 (37)	0.07 (19)	0.00 (39)	0.00 (49)	0.00 (54)	0.06 (8)
D34	1.29 (21)	0.03 (23)	0.01 (29)	0.00 (24)	0.00 (34)	0.02 (16)	1.30 (20)	0.08 (16)	0.01 (23)	0.00 (26)	0.01 (32)	0.06 (9)
Gbus	1.51 (17)	0.03 (25)	0.00 (31)	0.00 (54)	0.01 (23)	0.02 (19)	1.54 (17)	0.06 (22)	0.00 (46)	0.00 (55)	0.01 (34)	0.05 (10)
D26	0.85 (27)	0.00 (53)	0.00 (39)	0.00 (30)	0.01 (20)	-0.01 (52)	0.81 (28)	0.05 (27)	-0.01 (60)	0.00 (41)	0.00 (41)	0.05 (11)
D22,3	0.77 (32)	0.01 (32)	-0.01 (59)	0.00 (29)	0.00 (47)	0.02 (13)	0.66 (38)	0.01 (42)	-0.03 (62)	0.00 (45)	0.00 (58)	0.04 (12)
D28	2.08 (13)	0.02 (27)	0.00 (30)	0.00 (13)	0.03 (9)	-0.01 (54)	2.04 (12)	0.07 (17)	0.00 (54)	0.00 (20)	0.03 (11)	0.04 (13)
D371	0.93 (26)	0.03 (20)	0.02 (17)	0.00 (32)	0.00 (29)	0.02 (20)	0.96 (25)	0.06 (21)	0.00 (31)	0.00 (29)	0.01 (26)	0.04 (14)
D35R	1.63 (15)	0.05 (15)	0.02 (14)	0.00 (18)	0.00 (25)	0.03 (11)	1.68 (16)	0.05 (23)	0.00 (40)	0.01 (16)	0.01 (29)	0.04 (15)
D30	0.85 (28)	0.04 (18)	0.01 (19)	0.00 (34)	0.01 (24)	0.02 (15)	0.87 (27)	0.05 (24)	0.00 (30)	0.00 (30)	0.01 (25)	0.04 (16)
D20	1.86 (14)	0.05 (16)	0.01 (23)	0.00 (21)	0.01 (17)	0.03 (12)	1.75 (14)	0.06 (20)	0.00 (32)	0.00 (24)	0.02 (16)	0.03 (17)
D37R	1.17 (22)	-0.01 (58)	-0.05 (62)	0.00 (57)	0.00 (42)	0.04 (10)	1.00 (24)	0.04 (29)	0.00 (34)	0.00 (36)	0.00 (46)	0.03 (18)
A	1.34 (19)	0.05 (17)	0.01 (26)	0.00 (28)	0.00 (57)	0.04 (9)	1.21 (22)	0.05 (25)	0.01 (21)	0.00 (34)	0.01 (27)	0.03 (19)
D27	1.53 (16)	-0.01 (57)	0.01 (28)	0.00 (10)	0.00 (26)	-0.02 (58)	1.50 (18)	0.04 (28)	0.00 (43)	0.01 (11)	0.01 (28)	0.02 (20)
SUM	36.5	1.13	0.13	0.06	0.25	0.70	36.3	2.32	0.25	0.15	0.29	1.62
In the order of VA growth for 1995-2000												
G	7.26 (3)	0.14 (6)	0.08 (4)	0.00 (9)	0.06 (2)	-0.01 (53)	7.05 (3)	0.35 (1)	0.10 (7)	0.01 (9)	0.07 (4)	0.17 (3)
D367	0.69 (37)	0.14 (5)	0.00 (48)	0.00 (16)	0.02 (14)	0.13 (3)	0.81 (30)	0.34 (2)	0.02 (19)	0.00 (19)	0.02 (15)	0.30 (1)
H65	11.57 (2)	0.34 (1)	0.01 (25)	0.02 (2)	0.23 (1)	0.09 (4)	11.65 (2)	0.29 (3)	0.02 (18)	0.03 (6)	0.24 (1)	-0.01 (45)
H62	1.00 (23)	0.08 (12)	0.02 (15)	0.00 (22)	0.02 (15)	0.05 (8)	1.21 (21)	0.26 (4)	0.07 (9)	0.01 (12)	0.02 (14)	0.16 (4)
F	5.68 (5)	0.24 (2)	0.04 (8)	0.02 (1)	0.04 (6)	0.13 (2)	5.74 (5)	0.26 (5)	0.08 (8)	0.06 (2)	0.05 (7)	0.07 (6)
I73R	3.05 (8)	0.14 (4)	0.09 (3)	0.01 (3)	0.04 (5)	0.00 (33)	3.53 (7)	0.26 (6)	0.16 (3)	0.07 (1)	0.07 (3)	-0.04 (58)
D357	0.41 (46)	0.13 (7)	-0.01 (58)	0.00 (37)	0.00 (58)	0.14 (1)	0.41 (46)	0.22 (7)	0.00 (55)	0.00 (28)	0.00 (39)	0.22 (2)
I87,89	2.99 (9)	0.07 (13)	0.08 (5)	0.01 (7)	0.01 (16)	-0.03 (59)	3.23 (8)	0.16 (8)	0.11 (4)	0.02 (7)	0.03 (9)	-0.01 (50)
I80	6.09 (4)	0.10 (9)	0.19 (1)	0.00 (11)	0.06 (3)	-0.15 (62)	6.21 (4)	0.15 (9)	0.10 (5)	0.01 (13)	0.06 (5)	-0.02 (54)
C	4.73 (6)	-0.06 (62)	0.03 (10)	0.01 (8)	0.02 (12)	-0.11 (61)	4.56 (6)	0.15 (10)	0.17 (1)	0.01 (10)	0.09 (2)	-0.12 (61)
J	12.68 (1)	0.15 (3)	0.10 (2)	0.00 (54)	0.04 (4)	0.01 (22)	11.93 (1)	0.13 (11)	0.10 (6)	0.00 (55)	0.03 (8)	0.00 (38)
H60	2.82 (10)	0.08 (11)	-0.02 (60)	0.01 (5)	0.02 (10)	0.06 (6)	3.12 (9)	0.13 (12)	0.00 (35)	0.04 (5)	0.02 (17)	0.08 (5)
E48x483	2.10 (12)	0.09 (10)	0.00 (37)	0.01 (4)	0.02 (13)	0.07 (5)	2.19 (11)	0.12 (13)	0.05 (11)	0.04 (3)	0.03 (10)	0.00 (44)
I737	1.29 (20)	0.07 (14)	0.05 (7)	0.01 (6)	0.02 (11)	-0.01 (48)	1.70 (15)	0.11 (14)	0.16 (2)	0.04 (4)	0.05 (6)	-0.14 (62)
EtransX46	3.11 (7)	0.12 (8)	0.06 (6)	0.00 (15)	0.00 (52)	0.06 (7)	3.05 (10)	0.10 (15)	0.06 (10)	0.01 (14)	0.02 (12)	0.00 (34)
D34	1.29 (21)	0.03 (23)	0.01 (29)	0.00 (24)	0.00 (34)	0.02 (16)	1.30 (20)	0.08 (16)	0.01 (23)	0.00 (26)	0.01 (32)	0.06 (9)
D28	2.08 (13)	0.02 (27)	0.00 (30)	0.00 (13)	0.03 (9)	-0.01 (54)	2.04 (12)	0.07 (17)	0.00 (54)	0.00 (20)	0.03 (11)	0.04 (13)
E46,491-3	2.15 (11)	0.03 (21)	-0.01 (54)	0.00 (23)	0.03 (7)	0.01 (23)	1.93 (13)	0.07 (18)	-0.01 (61)	0.00 (25)	0.01 (23)	0.07 (7)
D33	0.72 (35)	0.01 (44)	0.00 (50)	0.00 (47)	0.00 (55)	0.01 (27)	0.67 (37)	0.07 (19)	0.00 (39)	0.00 (49)	0.00 (54)	0.06 (8)
D20	1.86 (14)	0.05 (16)	0.01 (23)	0.00 (21)	0.01 (17)	0.03 (12)	1.75 (14)	0.06 (20)	0.00 (32)	0.00 (24)	0.02 (16)	0.03 (17)
SUM	73.6	1.95	0.72	0.11	0.65	0.47	74.1	3.37	1.19	0.37	0.86	0.94
Aggregation by IT and NonIT sectors												
IT	4.9	0.44	0.03	0.02	0.06	0.32	5.6	0.81	0.23	0.10	0.12	0.37
D357	0.41 (46)	0.13 (7)	-0.01 (58)	0.00 (37)	0.00 (58)	0.14 (1)	0.41 (46)	0.22 (7)	0.00 (55)	0.00 (28)	0.00 (39)	0.22 (2)
D366	0.43 (45)	0.01 (37)	0.00 (45)	0.00 (25)	0.00 (28)	0.01 (31)	0.49 (45)	0.02 (41)	0.00 (37)	0.00 (22)	0.02 (18)	0.00 (43)
D367	0.69 (37)	0.14 (5)	0.00 (48)	0.00 (16)	0.02 (14)	0.13 (3)	0.81 (30)	0.34 (2)	0.02 (19)	0.00 (19)	0.02 (15)	0.30 (1)
E48x483	2.10 (12)	0.09 (10)	0.00 (37)	0.01 (4)	0.02 (13)	0.07 (5)	2.19 (11)	0.12 (13)	0.05 (11)	0.04 (3)	0.03 (10)	0.00 (44)
I737	1.29 (20)	0.07 (14)	0.05 (7)	0.01 (6)	0.02 (11)	-0.01 (48)	1.70 (15)	0.11 (14)	0.16 (2)	0.04 (4)	0.05 (6)	-0.14 (62)
NonIT	95	1.89	0.81	0.11	0.67	0.29	94	3.21	1.15	0.35	0.95	0.76
SUM	100	2.33	0.85	0.14	0.73	0.61	100	4.02	1.38	0.45	1.07	1.13
Aggregation of Large sectors												
AMC	7.4	0.02	0.02	0.01	0.01	-0.02	6.9	0.23	0.17	0.01	0.10	-0.05
Md	11.0	0.40	-0.06	0.01	0.03	0.42	10.8	0.97	0.05	0.02	0.09	0.81
Mn	8.5	0.10	0.01	0.01	0.05	0.02	8.1	0.18	-0.04	0.02	0.06	0.14
TCU	7.7	0.25	0.06	0.01	0.03	0.15	7.5	0.28	0.11	0.06	0.07	0.05
Trade	12.9	0.38	0.13	0.03	0.10	0.12	12.8	0.61	0.18	0.07	0.12	0.25
FIRE	17.5	0.45	0.03	0.03	0.28	0.10	18.1	0.67	0.13	0.09	0.30	0.15
Service	20.8	0.56	0.56	0.04	0.18	-0.22	22.2	0.88	0.69	0.17	0.29	-0.26
Gov	14.2	0.17	0.10	0.00	0.04	0.03	13.5	0.19	0.10	0.00	0.04	0.05
SUM	100	2.33	0.85	0.14	0.73	0.61	100	4.02	1.38	0.45	1.07	1.13

Source: Author's compilation based on BEA, *Fixed Assets and Consumer Durables*, BEA, *Gross Product by Industry*, BLS, *Input-Output Transaction Tables* (1983-2000), and BLS, *Employment, Hours, and Earnings.*

Notes: Units are percentage. The figures in the tables are the period average of annual ones. The figures in parentheses are the rank along each column.

The last two sections show the aggregate productivity and its sectoral decomposition. The third section decomposes the aggregate productivity by the IT and the NonIT sector, while the last section does so by the large sectors introduced early in section 2. The row headed "SUM" of either the third section or the fourth section shows the components of the aggregate VA-accounting. According to that row, aggregate

VA grew at the 2.33 percent annual rate for 1987-1995 and 4.02 percent for 1995-2000, confirming again the acceleration of economic growth in the recent period. The largest contribution to VA growth came from labor (0.85 percent and 1.38 percent respectively for both periods), reaching about a third of VA growth. But the sum of the contribution of IT-K and NonIT-K is a little larger than that of labor. We can also see that the aggregate TFP growth rates were 0.61 percent and 1.13 percent respectively for both periods. The TFP growth rate for 1995-2000 is much larger than JSH's estimation of 0.63 percent due to the underestimation of capital growth in this paper as mentioned before.

From the third section, we can notice that for each period, the contribution of IT industries to aggregate TFP growth is respectively 0.32 percent and 0.37 percent while that of NonIT industries is 0.29 percent and 0.76 percent. While this paper's estimation of the contribution of IT industries is not very different from JSH (0.30 percent for 1990-1995 and 0.41 percent for 1995-2000), the contribution of NonIT industries is measured much higher in this paper than in JSH (0.05 percent and 0.22 percent respectively for each period). This disparity between this paper and JHS can be again attributed to the underestimation of capital inputs of this paper. Since most capital is concentrated in NonIT sectors, the underestimation of capital inputs growth affects far more the NonIT sector than the IT sector. In fact, D357 and D367 are also measured higher in TFP growth in this paper than JHS and I737 is measured lower (negative). (Recall that this paper's measurement of TFP growth tends to measure TFP growth larger in absolute terms than JHS.).

The intertemporal pattern of TFP growth is similar as in JHS. In comparison with IT industries, NonIT industries accelerated their TFP growth for the recent period. This result supports the wide-spread productivity growth for the recent years and can serve as empirical evidence of the "New Economy hypothesis" about the recent US economy.

From the last section of Table 3.3, we can observe the significant role of Md and Trade in TFP growth. The sum of the two sectors' contributions to aggregate TFP growth is 1.06 percent, almost the same as the aggregate TFP growth rate for 1995-2000. For 1987-1995, TCU had a similar role as Trade, while the dominant position of Md in TFP growth is unchanged. In combination of the results of IT industries, we can see that IT goods industries had a great role to increase TFP growth of the Md sector.

By comparing the size of weight and the contribution of VA growth of IT industries, we can confirm the important role of prices in measuring the growth rate of IT industries. While the IT sector as a whole grew from 4.9 percent in the former period (1987-1995) to 5.6 percent in the latter period (1995-2000) in share measured in current dollars, the contribution of the IT sector to aggregate VA growth grew from 0.44 percent (18.8 percent of the aggregate VA growth) in the former period to 0.81 percent (20.0 percent of the aggregate VA growth). All the IT industries except D357 tend to grow in their share in GDP; D357 was rather stationary in comparison between the former and the latter period. I737 (software/programming) increased very fast from 1.29 percent to 1.70 percent in share. As a result, the IT-services sector is much larger than the IT-equipment sector in current dollars in 2000. The role of price is clear for goods industries but for services industries, their contribution of VA growth (in constant dollars) is weaker than their expansion in terms of current dollars.

By comparing the results of VA growth for IT industries in the third section and those for traditional large sectors in the last section, we can analyze more precisely growth of traditional sectors. Notice that in spite of rapid growth of IT goods industries, the Md sector as a whole contracted in terms of current dollars from 11.0 percent (in the former period) to 10.8 percent (in the latter period). While the Md sector's contribution to VA growth increased much from 0.40 percent to 0.97 percent, the contribution of the Md net that of the three IT goods increased from 0.12 percent (0.40 minus 0.29) to 0.39 percent (0.97 minus 0.58). TCU contracted in current dollars from 7.7 percent to 7.5 percent while E48x483 (telecommunication) increased from 2.1 percent to 2.2 percent. On the other hand, Services net I737 increased in current dollars to a larger extent from 19.5 percent (20.8 minus 1.3) to 20.5 percent (22.2 minus 1.7) than I737. Notice that I73R (business services) had a significant role in the expansion of the Services sector as it increased from 3.05 percent to 3.53 percent.

VA-based Labor Productivity and Aggregation

We can measure labor productivity (LP) growth by industry based on the VA-accounting as addressed in Equation (3.15). The labor productivity growth rate is the VA growth rate minus the labor growth rate. Table 3.4 demonstrates the results. While the TFP growth rates in Table 3.3 do not change, the capital growth rate needs to be replaced with the capital density (K-density or K/L) growth rate defined as the capital growth rate minus the labor growth rate. Each K-density growth rate is decomposed into the ITK-density (or ITK/L) and the NonITK-density (or NonITK/L) growth rate.

The general levels of LP growth tend to be higher than those of TFP growth by the amount of the contribution of K-density to LP growth. The contribution of NonIT-K density growth tends to be larger than that of IT-K density growth for both periods. Note that the industry average contribution of K-density growth tends to increase much faster from the former to the latter period than the industry average of TFP growth.

The first section of Table 3.4 lists the top 20 industries in order of the growth rate of LP. The ranks of industries in LP growth are similar as those in (VA-based) TFP growth, which is consistent with the relatively low contribution of K-density. For the top 20 industries, the contribution of K-density tends to be even lower than for all the industries.

The second section of Table 3.4 lists the top 20 industries in order of IT-K density's contribution. Note that D357 and D367 appear in the list but do not show impressive contribution of IT-K density. As mentioned already, IT-capital density's contribution for these industries are likely to be understated due to a rather proportional assignment (or estimation) of IT capital across industries.

Table 3.4 Average annual growth rates of (VA-based) LP by industry, selected industries

	1987-1995				1995-2000			
Industry	LP, VA-based	ITK/L	NITK/L	TFP, VA-based	LP, VA-based	ITK/L	NITK/L	TFP, VA-based
In the order of LP growth for 1995-2000								
D357	33.96 (1)	0.11 (24)	0.18 (33)	33.67 (1)	54.75 (1)	0.41 (16)	0.89 (18)	53.44 (1)
D367	22.12 (2)	0.33 (6)	2.46 (1)	19.34 (2)	39.08 (2)	0.38 (17)	1.11 (14)	37.60 (2)
D31	0.19 (45)	0.10 (25)	0.84 (14)	-0.74 (47)	13.62 (3)	0.32 (19)	2.55 (4)	10.76 (4)
H62	6.82 (5)	0.13 (20)	1.47 (7)	5.23 (7)	13.59 (4)	0.47 (14)	0.03 (47)	13.09 (3)
B12	9.51 (3)	0.04 (44)	1.39 (8)	8.09 (3)	10.46 (5)	0.05 (50)	2.20 (5)	8.21 (7)
D33	1.32 (32)	0.01 (51)	-0.06 (49)	1.36 (29)	9.44 (6)	0.03 (54)	-0.05 (53)	9.47 (6)
D22,3	3.37 (10)	0.08 (28)	0.37 (24)	2.93 (11)	8.19 (7)	0.12 (38)	1.30 (12)	6.77 (8)
D26	-0.47 (50)	0.06 (33)	0.70 (17)	-1.23 (52)	6.73 (8)	0.09 (43)	0.79 (21)	5.85 (9)
E46,491-3	2.67 (18)	0.08 (29)	2.10 (2)	0.49 (38)	6.16 (9)	0.17 (28)	2.61 (3)	3.37 (19)
B10	3.86 (9)	0.05 (35)	-1.49 (60)	5.29 (6)	6.11 (10)	0.00 (55)	1.39 (11)	4.72 (13)
I78	-1.36 (55)	0.67 (1)	0.45 (20)	-2.48 (58)	6.09 (11)	0.27 (20)	0.46 (31)	5.36 (11)
D384,5	3.20 (12)	0.14 (15)	0.43 (21)	2.63 (14)	5.92 (12)	0.18 (27)	0.28 (37)	5.46 (10)
D29R	1.28 (34)	0.05 (40)	0.18 (34)	1.06 (33)	5.60 (13)	-0.03 (59)	-4.75 (62)	10.36 (5)
D371	1.06 (36)	0.04 (43)	-0.39 (54)	1.42 (27)	5.35 (14)	0.12 (39)	0.73 (22)	4.51 (14)
D25	1.79 (25)	0.05 (38)	0.23 (32)	1.51 (24)	5.27 (15)	0.13 (32)	0.07 (43)	5.06 (12)
D30	3.11 (15)	0.05 (39)	0.34 (27)	2.73 (13)	5.21 (16)	0.12 (37)	1.05 (15)	4.04 (17)
B13	2.77 (17)	0.01 (52)	0.42 (22)	2.33 (17)	4.92 (17)	0.05 (49)	1.86 (6)	3.01 (20)
D34	1.71 (27)	0.07 (31)	-0.04 (46)	1.68 (21)	4.47 (18)	0.15 (31)	0.04 (46)	4.28 (15)
I88	4.20 (8)	0.00 (54)	0.00 (43)	4.20 (8)	4.17 (19)	0.00 (56)	0.00 (48)	4.17 (16)
H60	4.60 (6)	0.51 (3)	1.78 (5)	2.31 (18)	3.92 (20)	1.25 (4)	0.28 (38)	2.39 (25)
Average	5.3	0.1	0.6	4.6	11.0	0.2	0.6	10.1
In the order of ITK density's contribution for 1995-2000								
E483	0.51 (38)	-1.30 (62)	-5.23 (61)	7.04 (4)	-4.93 (57)	1.88 (1)	1.02 (16)	-7.83 (57)
I73R	-0.12 (47)	0.00 (57)	-0.27 (52)	0.15 (41)	0.95 (38)	1.52 (2)	0.42 (34)	-0.99 (46)
I737	-0.43 (49)	0.13 (18)	0.23 (31)	-0.79 (48)	-7.02 (59)	1.32 (3)	-0.06 (54)	-8.28 (59)
H60	4.60 (6)	0.51 (3)	1.78 (5)	2.31 (18)	3.92 (20)	1.25 (4)	0.28 (38)	2.39 (25)
I81	-1.34 (54)	0.18 (11)	-0.50 (57)	-1.02 (50)	-1.31 (51)	1.12 (5)	0.18 (40)	-2.61 (54)
I76	0.39 (40)	0.51 (2)	-0.05 (47)	-0.07 (44)	-1.62 (52)	0.97 (6)	1.13 (13)	-3.72 (56)
F	3.12 (14)	0.39 (5)	0.34 (25)	2.39 (16)	2.58 (32)	0.94 (7)	0.36 (35)	1.28 (34)
H64	-0.23 (48)	0.23 (9)	1.05 (12)	-1.51 (55)	2.52 (33)	0.83 (8)	1.79 (7)	-0.11 (40)
E48x483	4.40 (7)	0.49 (4)	0.74 (15)	3.17 (9)	-0.22 (46)	0.77 (9)	-0.82 (59)	-0.17 (41)
H63	-6.63 (61)	0.19 (10)	0.50 (18)	-7.34 (62)	-6.65 (58)	0.70 (10)	0.63 (25)	-7.98 (58)
D27	-0.97 (51)	0.29 (7)	0.14 (36)	-1.41 (54)	2.73 (30)	0.69 (11)	0.48 (29)	1.56 (32)
D366	2.43 (19)	0.17 (12)	0.94 (13)	1.31 (30)	2.70 (31)	0.60 (12)	3.10 (2)	-1.01 (47)
I87,89	-1.01 (52)	0.12 (23)	-0.20 (51)	-0.93 (49)	0.26 (42)	0.55 (13)	0.05 (45)	-0.34 (44)
H62	6.82 (5)	0.13 (20)	1.47 (7)	5.23 (7)	13.59 (4)	0.47 (14)	0.03 (47)	13.09 (3)
D36R	3.30 (11)	0.15 (13)	0.71 (16)	2.44 (15)	3.84 (22)	0.41 (15)	1.44 (10)	1.99 (30)
D357	33.96 (1)	0.11 (24)	0.18 (33)	33.67 (1)	54.75 (1)	0.41 (16)	0.89 (18)	53.44 (1)
D367	22.12 (2)	0.33 (6)	2.46 (1)	19.34 (2)	39.08 (2)	0.38 (17)	1.11 (14)	37.60 (2)
D35R	1.91 (24)	0.10 (26)	0.04 (40)	1.77 (20)	3.15 (26)	0.36 (18)	0.43 (33)	2.36 (26)
D31	0.19 (45)	0.10 (25)	0.84 (14)	-0.74 (47)	13.62 (3)	0.32 (19)	2.55 (4)	10.76 (4)
I78	-1.36 (55)	0.67 (1)	0.45 (20)	-2.48 (58)	6.09 (11)	0.27 (20)	0.46 (31)	5.36 (11)
Average	3.6	0.2	0.3	3.1	6.4	0.8	0.8	4.8

Source: Author's compilation based on BEA, *Fixed Assets and Consumer Durables*, BEA, *Gross Product by Industry*, BLS, *Input-Output Transaction Tables* (1983-2000), and BLS, *Employment, Hours, and Earnings.*

Notes: Units are percentage. The figures in parentheses are the rank along each column.

As we constructed weighted VA growth and its decomposition into Labor, capital, and TFP growth (as in Table 3.3) from the VA-accountings (as in Table 3.2) by using the share of industry in GDP (or VA), we can construct the weighted LP growth and its decomposition into K-density and TFP growth. The weighted TFP growth, a component of the weighted LP growth, is the same as the relevant component of the weighted VA growth (Table 3.3). Table 3.5 illustrates the results.

The "SUM"of either the third or the fourth section illustrates aggregate Labor Productivity (LP) growth and its decomposition into IT-density and NonIT-density and TFP growth. Labor productivity of the whole economy grew at 1.09 percent for 1987-1995 and at 1.85 percent for 1995-2000. This paper's estimation of aggregate labor productivity growth for 1995-2000 is a little lower that that of JHS (2.21 percent). Aggregate TFP growth explains about 60 percent of labor productivity growth for both periods.

While IT-K density had a much smaller contribution (0.11 percent) than NonIT-K density (0.37 percent) for 1987-1995, IT-K density contributed as much as NonIT-K (about 0.36 percent) for 1995-2000. That is, while IT-K density's contribution accelerated, that of NonIT-K density was stationary. This result is contrasted with those shown in Table 3.3 (for the weighted VA-accounting) where the contribution of IT-

K to aggregate VA growth continued to be small than that of NonIT-K (0.14 percent versus 0.73 percent for 1987-1995 and 0.45 percent and 1.07 percent for 1995-2000). It is notable that for the recent period, IT capital density's contribution was close to that of Non-IT, which has a significant implication considering that the size of IT capital is still much smaller than that of Non-IT. Thus the rapid growth of IT capital contributed a lot to the growth of labor productivity in the recent period.

Table 3.5 Weighted (VA-based) Labor Productivity Growth by Industry, selected industries

	1987-1995					1995-2000				
Industry	Weight	LP	ITK/L	NITK/L	TFP	Weight	LP	ITK/L	NITK/L	TFP
In the order of weighted LP growth for 1995-2000										
D367	0.7 (37)	0.14 (3)	0.00 (13)	0.02 (9)	0.13 (3)	0.8 (30)	0.31 (1)	0.00 (22)	0.01 (15)	0.30 (1)
D357	0.4 (46)	0.14 (4)	0.00 (32)	0.00 (36)	0.14 (1)	0.4 (46)	0.22 (2)	0.00 (27)	0.00 (30)	0.22 (2)
G	7.3 (3)	0.03 (16)	0.00 (7)	0.03 (4)	-0.01 (53)	7.1 (3)	0.21 (3)	0.01 (9)	0.03 (4)	0.17 (3)
H62	1.0 (23)	0.06 (8)	0.00 (23)	0.01 (11)	0.05 (8)	1.2 (21)	0.17 (4)	0.01 (16)	0.00 (47)	0.16 (4)
F	5.7 (5)	0.17 (2)	0.02 (1)	0.02 (7)	0.13 (2)	5.7 (5)	0.15 (5)	0.05 (2)	0.02 (5)	0.07 (6)
H60	2.8 (10)	0.12 (5)	0.01 (3)	0.05 (3)	0.06 (6)	3.1 (9)	0.12 (6)	0.04 (3)	0.01 (13)	0.08 (5)
E46,491-3	2.1 (11)	0.06 (7)	0.00 (17)	0.05 (2)	0.01 (23)	1.9 (13)	0.12 (7)	0.00 (21)	0.05 (1)	0.07 (7)
D28	2.1 (13)	0.01 (25)	0.00 (9)	0.02 (5)	-0.01 (54)	2.0 (12)	0.08 (8)	0.00 (18)	0.03 (3)	0.04 (13)
D33	0.7 (35)	0.01 (31)	0.00 (44)	0.00 (48)	0.01 (27)	0.7 (37)	0.06 (9)	0.00 (49)	0.00 (54)	0.06 (8)
Gbus	1.5 (17)	0.02 (21)	0.00 (54)	0.01 (18)	0.02 (19)	1.5 (17)	0.06 (10)	0.00 (56)	0.01 (22)	0.05 (10)
D34	1.3 (21)	0.02 (22)	0.00 (25)	0.00 (49)	0.02 (16)	1.3 (20)	0.06 (11)	0.00 (26)	0.00 (45)	0.06 (9)
D26	0.9 (27)	0.00 (50)	0.00 (29)	0.01 (14)	-0.01 (52)	0.8 (28)	0.06 (12)	0.00 (36)	0.01 (24)	0.05 (11)
D22,3	0.8 (32)	0.03 (15)	0.00 (27)	0.00 (23)	0.02 (13)	0.7 (38)	0.05 (13)	0.00 (34)	0.01 (16)	0.04 (12)
D20	1.9 (14)	0.03 (11)	0.00 (20)	0.01 (15)	0.03 (12)	1.7 (14)	0.05 (14)	0.00 (25)	0.02 (8)	0.03 (17)
D371	0.9 (26)	0.01 (24)	0.00 (35)	0.00 (55)	0.02 (20)	1.0 (25)	0.05 (15)	0.00 (28)	0.01 (21)	0.04 (14)
D35R	1.6 (15)	0.03 (13)	0.00 (19)	0.00 (35)	0.03 (11)	1.7 (16)	0.05 (16)	0.01 (15)	0.01 (19)	0.04 (15)
D30	0.8 (28)	0.03 (17)	0.00 (34)	0.00 (26)	0.02 (15)	0.9 (27)	0.05 (17)	0.00 (29)	0.01 (14)	0.04 (16)
D27	1.5 (16)	-0.02 (56)	0.00 (6)	0.00 (28)	-0.02 (58)	1.5 (18)	0.04 (18)	0.01 (10)	0.01 (18)	0.02 (20)
I73R	3.1 (8)	0.00 (48)	0.00 (58)	-0.01 (58)	0.00 (33)	3.5 (7)	0.03 (19)	0.05 (1)	0.02 (6)	-0.04 (58)
D37R	1.2 (22)	0.04 (9)	0.00 (36)	0.01 (19)	0.04 (10)	1.0 (24)	0.03 (20)	0.00 (30)	0.00 (34)	0.03 (18)
SUM	38.3	0.93	0.06	0.22	0.66	38.6	1.99	0.20	0.24	1.55
In the order of weighted ITK-density growth for 1995-2000										
I73R	3.1 (8)	0.00 (48)	0.00 (58)	-0.01 (58)	0.00 (33)	3.5 (7)	0.03 (19)	0.05 (1)	0.02 (6)	-0.04 (58)
F	5.7 (5)	0.17 (2)	0.02 (1)	0.02 (7)	0.13 (2)	5.7 (5)	0.15 (5)	0.05 (2)	0.02 (5)	0.07 (6)
H60	2.8 (10)	0.12 (5)	0.01 (3)	0.05 (3)	0.06 (6)	3.1 (9)	0.12 (6)	0.04 (3)	0.01 (13)	0.08 (5)
H65	11.6 (2)	0.23 (1)	0.01 (2)	0.13 (1)	0.09 (4)	11.7 (2)	0.02 (28)	0.03 (4)	0.00 (58)	-0.01 (45)
I737	1.3 (20)	-0.01 (51)	0.00 (22)	0.00 (29)	-0.01 (48)	1.7 (15)	-0.12 (62)	0.02 (5)	0.00 (40)	-0.14 (62)
I87,89	3.0 (9)	-0.03 (59)	0.00 (8)	-0.01 (56)	-0.03 (59)	3.2 (8)	0.01 (36)	0.02 (6)	0.00 (37)	-0.01 (50)
E48x483	2.1 (12)	0.09 (6)	0.01 (4)	0.01 (10)	0.07 (5)	2.2 (11)	-0.01 (49)	0.02 (7)	-0.02 (62)	0.00 (44)
I81	1.4 (18)	-0.02 (57)	0.00 (11)	-0.01 (57)	-0.01 (56)	1.3 (19)	-0.02 (57)	0.01 (8)	0.00 (35)	-0.03 (57)
G	7.3 (3)	0.03 (16)	0.00 (7)	0.03 (4)	-0.01 (53)	7.1 (3)	0.21 (3)	0.01 (9)	0.03 (4)	0.17 (3)
D27	1.5 (16)	-0.02 (56)	0.00 (6)	0.00 (28)	-0.02 (58)	1.5 (18)	0.04 (18)	0.01 (10)	0.01 (18)	0.02 (20)
C	4.7 (6)	-0.10 (61)	0.01 (5)	0.01 (21)	-0.11 (61)	4.6 (6)	-0.10 (61)	0.01 (11)	0.01 (20)	-0.12 (61)
I80	6.1 (4)	-0.14 (62)	0.00 (10)	0.01 (13)	-0.15 (62)	6.2 (4)	0.03 (22)	0.01 (12)	0.03 (2)	-0.02 (54)
H63	0.9 (25)	-0.06 (60)	0.00 (12)	0.01 (16)	-0.07 (60)	1.0 (23)	-0.07 (59)	0.01 (13)	0.01 (23)	-0.08 (59)
EtransX46	3.1 (7)	0.03 (10)	0.00 (16)	-0.02 (62)	0.06 (7)	3.0 (10)	0.00 (41)	0.01 (14)	-0.01 (60)	0.00 (34)
D35R	1.6 (15)	0.03 (13)	0.00 (19)	0.00 (35)	0.03 (11)	1.7 (16)	0.05 (16)	0.01 (15)	0.01 (19)	0.04 (15)
H62	1.0 (23)	0.06 (8)	0.00 (23)	0.01 (11)	0.05 (8)	1.2 (21)	0.17 (4)	0.01 (16)	0.00 (47)	0.16 (4)
H64	0.7 (40)	0.00 (47)	0.00 (18)	0.01 (12)	-0.01 (50)	0.6 (40)	0.02 (30)	0.01 (17)	0.01 (10)	0.00 (39)
D28	2.1 (13)	0.01 (25)	0.00 (9)	0.02 (5)	-0.01 (54)	2.0 (12)	0.08 (8)	0.00 (18)	0.03 (3)	0.04 (13)
E483	0.2 (54)	0.00 (45)	0.00 (62)	-0.01 (59)	0.01 (21)	0.2 (53)	-0.01 (53)	0.00 (19)	0.00 (36)	-0.02 (53)
I76	0.4 (47)	0.00 (41)	0.00 (14)	0.00 (46)	0.00 (43)	0.4 (47)	-0.01 (50)	0.00 (20)	0.00 (29)	-0.01 (52)
SUM	60.5	0.40	0.09	0.25	0.06	62.1	0.61	0.33	0.16	0.11
Aggregation by IT and NonIT sectors										
IT	4.92	0.38	0.01	0.04	0.32	5.60	0.43	0.05	0.01	0.37
D357	0.4 (46)	0.14 (4)	0.00 (32)	0.00 (36)	0.14 (1)	0.4 (46)	0.22 (2)	0.00 (27)	0.00 (30)	0.22 (2)
D366	0.4 (45)	0.01 (27)	0.00 (26)	0.00 (22)	0.01 (31)	0.5 (45)	0.01 (35)	0.00 (23)	0.01 (9)	0.00 (43)
D367	0.7 (37)	0.14 (3)	0.00 (13)	0.02 (9)	0.13 (3)	0.8 (30)	0.31 (1)	0.00 (22)	0.01 (15)	0.30 (1)
E48x483	2.1 (12)	0.09 (6)	0.01 (4)	0.01 (10)	0.07 (5)	2.2 (11)	-0.01 (49)	0.02 (7)	-0.02 (62)	0.00 (44)
I737	1.3 (20)	-0.01 (51)	0.00 (22)	0.00 (29)	-0.01 (48)	1.7 (15)	-0.12 (62)	0.02 (5)	0.00 (40)	-0.14 (62)
NonIT	95.08	0.71	0.10	0.33	0.29	94.40	1.42	0.31	0.35	0.76
SUM	100	1.09	0.11	0.37	0.61	100	1.85	0.36	0.36	1.13
Aggregation of Large sectors										
AMC	7.43	-0.02	0.01	-0.01	-0.02	6.88	-0.03	0.01	0.01	-0.05
Md	10.96	0.46	0.01	0.03	0.42	10.82	0.89	0.02	0.06	0.81
Mn	8.52	0.09	0.01	0.05	0.02	8.15	0.24	0.02	0.09	0.14
TCU	7.69	0.17	0.01	0.02	0.15	7.52	0.11	0.03	0.03	0.05
Trade	12.94	0.20	0.03	0.05	0.12	12.79	0.36	0.07	0.05	0.25
FIRE	17.46	0.33	0.03	0.20	0.10	18.15	0.26	0.08	0.02	0.15
Service	20.79	-0.20	0.01	0.00	-0.22	22.23	-0.05	0.13	0.08	-0.26
Gov	14.19	0.05	0.00	0.02	0.03	13.47	0.07	0.00	0.02	0.05
SUM	100	1.09	0.11	0.37	0.61	100	1.85	0.36	0.36	1.13

Source: Author's compilation based on BEA, *Fixed Assets and Consumer Durables*, BEA, *Gross Product by Industry*, BLS, *Input-Output Transaction Tables* (1983-2000), and BLS, *Employment, Hours, and Earnings.*

Notes: Units are percentage. The figures in the tables are the period average of annual ones. The figures in parentheses are the rank along each column.

The first section of Table 3.5 lists the top 20 industries in order of the weighted growth rate of LP. Reflecting the size of industries, there are shifts of positions of industries in comparison with the first section of Table 3.5. Noticeable industries newly joining the list of Table 3.5 are also similarly G, H60, F, D34, D28, D35R, D37R, and D27. The sum of the contribution of the 20 industries in aggregate LP growth is 1.99 percent for 1995-2000, which is larger than the sum of all the industries (1.85 percent).

The second section of Table 3.5 lists the top 20 industries in order of the contribution of IT-K density of each industry to the aggregate contribution of IT-K density growth. In comparison with the second section of Table 3.4, though many industries stay in the list, some industries were repositioned, reflecting the size of industries; e.g. C (Construction), G (Retail), and EtransX46 (transportation excl. pipelines) advanced much in rank. In particular, all the FIRE industries are included within the top 20 industries, implying that they increased their usage of IT capital. Regarding the contribution of IT-K density, note that except several industries, the degree of contribution is very low. Only top 7 industries record more than 0.01 percent. The sum of the 20 industries in the contribution of IT-K density growth is 0.33 percent for 1995-2000, being almost equal to the sum of all the industries.

The third section of Table 3.5 provides aggregation of industries in terms of the IT and the NonIT sector. If we take a look at detailed IT industries, we can see that the IT sector's performance in productivity contribution is concentrated in D357 (computer) and D367 (semiconductor); I737 record even negative performances for both periods and E48x483 does so for the latter period. The contribution of the IT (or NonIT) sector as a whole to aggregate LP growth was 0.38 percent (or 0.71 percent) for the former period and 0.43 percent (or 1.42 percent) for the latter period. The faster rate of LP growth of the NonIT sector than that of the IT sector in the latter period is noticeable. The negative contribution (-0.12 percent for 1995-2000) of I737 played some role in reducing the contribution of the IT sector in productivity growth for the latter period. Though JHS also measure the contribution of I737 as negative, the figure is only about -0.02 percent based on their results. The contribution of the IT sector based on JHS to aggregate LP growth is about 0.5 percent. Therefore it is likely that this paper's estimation of the contribution of the IT sector to aggregate LP growth may be understated. But still the contribution of the NonIT sector may be large in JHS as well, considering that this paper's estimation of aggregate LP growth is less than that of JHS. From this clarification of results, we can conclude that labor productivity growth spread across not only IT industries but also NonIT industries. Note and recall that TFP growth is also prominent for the NonIT sector for the recent years. Since labor productivity measurements are far simpler than TFP measurements as mentioned, the spread of labor productivity growth is quite a robust empirical result.

Regardless of the measurement issue of the contribution of the IT sector to aggregate LP growth, it is still much larger than the IT sector's share in GDP. The IT sector as a whole occupies a small portion of the economy in current dollars of about 5 percent for each period as in the first column of each period, which is a couple of percents lower than the relevant figure in *Digital Economy* because of the narrow definition of the IT sector in this section. But its intertemporal performances in growth of productivity are outstanding. Its contribution to labor productivity growth is roughly 25 percent for 1987-1995 (0.43/1.85) and its contribution to TFP growth is about 33 percent (0.37/1.13). On the other hand, the IT sector's contribution to capital density growth (as the sum of IT and Non-IT) is relatively low, less than 15 percent of the total (0.01 percent over 0.10 percent for 1987-1995 and 0.05 percent over 0.31 percent for 1995-2000), which is likely due to the underestimation of IT capital growth in the IT industries of the source data. Only two IT services industries (I737 and E48x483) show more contribution of IT-density than other IT goods industries.

The last section of Table 3.5 provides aggregation of industries across large sectors. The sectoral distribution of LP growth is not very different from that of TFP growth. One slight difference is that the services sector shows less negative growth in its contribution to aggregate LP growth for each period. As for K-density, note that for 1995-2000, the services, the trade, and the FIRE sector record large contributions to aggregate K-density growth. Particularly, the Service sector occupies a significant portion (0.13 percent) of aggregate IT-K density growth (0.36 percent). On the other hand, for 1987-1995, the contribution of K-density tends to be low except for the FIRE sector. Particularly, the FIRE sector made a significant contribution (0.20 percent) to aggregate NonIT-K density growth (0.37 percent).

4 Interindustry Linkage and Factor Saving

4.1 Concepts and Methods of Linkage

Input-output analysis in the early period was focused on the study of the structural characteristics of the economy, as represented well by the title of Leontief's (1951) memorable work *The Structure of the American Economy, 1919-1939*. By developing analytical tools to utilize I-O tables such as the coefficient matrix and the inverse matrix, Leontief made intensive and comprehensive studies of the US industries in the context of interindustry dependence. Rasmussen succeeded and further developed Leontief's analytical tools and motivations into succinct indexes, *power of dispersion* and *sensitivity of dispersion* which are still famous and powerful tools to understand the interdependence of industries.

Although the index of the power of dispersion is more popularly called *backward linkage* and the index of the sensitivity of dispersion *forward linkage*, forward linkage and backward linkage were defined initially by Hirschman (1956) in a different context or motivation. From his breakthrough study of the economic development of Latin American countries, Hirschman proposed to focus economic resources on the industries that can stimulate and create other domestic industries and that can provide necessary products as inputs for other industries. Such industries have strength in backward linkage in Hirschman's terminology and are called *key* industries by Rasmussen. Once such key industries are established, other industries that can take advantage of products produced by the key industries are likely to be set up, which is defined as forward linkage. Like Rasmussen, Hirschman recognized the importance and power of the analytical tools for input-output analysis, but his major motivation was to understand the possibility to create such industries. Given the situation that Harrod and Domar's *balanced growth* model was then regarded as the norm of economic growth theory, Hirschman's discourse provided strong imperative to so called *unbalanced growth theory* (Hirschman 1987).

The linkage concept by Hirschman is very dynamic and so is hard to capture in a standardized analytical framework, though the implication of Hirschman's conceptual clarification is anything but negligible. Because of such analytical difficulty to build operational tools, Hirschman's initial concept of linkage was superseded by more clear mathematical framework such as Rasmussen's. But Hirschman's concept still serves as a conceptual standard for any mathematical framework for linkage.

Leontief and Rasmussen were concerned with the structural change of the economy and they focused on the change of coefficients of the Leontief coefficient matrix which reflects the interdependence of industries. In addition to the detailed study of structural changes from individual coefficients, Rasmussen proposed the aforementioned indexes (Rasmussen 1958). Given the Leontief Requirement (or Inverse) matrix or Output multiplier, *the power of dispersion*, called later backward linkage (BL), of an industry is simply the evenly weighted sum of coefficients in the column representing the industry. The even weights are the inverse of the total number of industries. That is, denoting backward linkage (BL) of industry j by βj and the Leontief Requirement matrix (LR) or Ω, the formula for backward linkage is as follows:

(4.1) $\beta j = \sum_i \Omega_{ij} (1/n)$,

where n is the number of industries. Based on the assumption of the equal probability of the final demand for each industry's output, the expected final demand for industry j is 1/n. This expected amount of final demands will stimulate output of other industries as input to the industry j and the sum of such probable outputs is backward linkage of industry j. Since βj measures the contribution of industry j to spreading the shock of final demands to all the other industries, Rasmussen called it the *power of dispersion*. Rasmussen normalizes βj by dividing each βj by the sum of all βj's to make it possible to compare over time and across countries. If we do not multiply (1/ n) to each term in (4.1), then simply we can calculate the reaction of outputs to one unit of final demand for industry i.

(4.2) $\beta j = \sum_i \Omega_{ij}$

This simple formula is widely used since it has physical interpretation as the relation between final demands and output reaction.

On the other hand, we can focus our attention to the stimulated industry i, or the i-th row of the matrix. Under the same condition, industry i will react differently to the demand shock depending on the stimulating industry, say j. Thus the row sum of LR divided by n provides an index that shows how an industry i reacts to the one unit final demand as a composite commodity basket and is called the *sensitivity of dispersion* of the industry i by Rasmussen or later Forward Linkage (FL) more popularly. Denoting it ζ_i, the formula is:

(4.3) $\zeta_i = \sum_j \Omega_{ij} (1/n)$.

However, in forward linkage, the even weights are not quite realistic because an industry whose size of final demands is larger than others should be given a larger weight. If industry i provides a few small industries with relatively large inputs, then surely ζ_i will be large regardless of whether industry i's position as a supplier of intermediate inputs is large or small (Jones 1976). One of the best candidates of weights is then the set of the industries' shares in final demands. If we denote the size of total final demands (FD) or $Y = (Y_i)$ and the size of final demand for industry i Y_i, then in the place of (1/n) of (4.3), Y_i/Y should be used. Since the equally weighted forward linkage in (4.3) is not used in the paper, forward linkage is defined to be the unequally weighted case. In notation, forward linkage is now:

(4.4) $\zeta_i = \sum_j \Omega_{ij} (Y_i/Y)$.

Thanks to their simplicity and convenience, Rasmussen's indexes established themselves as the most popular representation of interindustry linkage. If we understand linkage as a summary of interdependence of industries, then the indexes are quite plausible and practical. Based on these indexes, we can compare industries of an economy and an industry over time and we can do comparative studies of industries' characteristics across countries. There were a flood of excellent empirical research projects in such a direction in the 1960s and the 1970s. For example, Chenery and Watanabe applied Rasmussen's (unweighted) linkage to international comparison of industries (1958) and Rasmussen's weighted index to the study of structural change of a country (1962). Yotopoulous and Nugent (1973) applied Rasmussen's weighted index to the international comparison of linkages to test Hirschman's linkage hypothesis.

However, it is also clear that Rasmussen's indexes stand on quite a different economy than the one that Hirschman was concerned with. Hirschman's economy is devoid of many domestic industries and has to depend on imports. And so how to successfully launch domestic industries was a key concern. But Rasmussen's economy is already equipped well with a range of necessary industries. Given the existence of the industries, a unit increase of final demands results in certain sequential reactions of domestic industries. Due to the different premises or characteristics of the economy, it is not easy to interpret Rasmussen's formula in terms of Hirschman's concept. But there are certain aspects that can link both. Hirschman agrees to Rasmussen's interpretation of the *key industry* which has larger backward linkage. Once domestic industries are in operation, backward linkage can be expressed as the reaction of industries to final demands. Or backward linkage based on a mature economy can serve as a guide to design efficient investment projects for a developing economy.

While Rasmussen's backward linkage can be an approximation of the concept of Hirschman's linkage, forward linkage does hardly attain such a position. As seen clearly in the formula, each component, say, Ω_{ij}, an element of the weighted row-sum of the Leontief Requirement (LR), represents simply a part of backward linkage of industry j. This coefficient assumes the existence of the demanding industry, which is quite contrary to the concept of forward linkage as a potential of the creation of a new industry. In this sense, Rasmussen's forward linkage can be characterized as "permissive" (Jones 1976) and makes sense only when it is interpreted as "descriptive" of the interdependence of industries (Cai and Leung 2004) or as "ex-post forward linkage" (Bulmer-Thomas 1982). Even a more fundamental question was raised about the demand-drive nature of the Leontief model (Ghosh 1958). Such dissatisfactions brought about alternative models of linkage such as Ghosh's supply-driven model (Ghosh 1958) and the hypothetical extraction method (See Strassert 2001 and Cai and Leung 2004).

4.2 Data Construction

The BLS real input-output tables (1983-2000) are the major data source for inter-temporal analysis of linkage in this paper. The BLS tables are estimated annual tables based on the establishment-based BEA benchmark I-O table 1992. The BEA benchmark I-O table comprises the Make and the Use table. In order to distinguish the primary and secondary commodities produced by each industry, the IO tables are provided in two forms: the Make Table and the Use Table based on the methodology recommended by the System of National Accounts (1968; 1993) by the UN. Figure 4.1 illustrates a make (Industry by Commodity) and a use table (Commodity by Industry) respectively. The make table describes the commodities (product mix) made by or supplied from each industry in the corresponding row and so the row-sum means the amount of industry output or gross output (GO). On the other hand, if we read the make table along each column, then we can obtain the market-share of industries for each commodity, and so the sum of each column of the make table means the amount of commodity output (CO).

The use table combines two accounts: industry and final demands. Industry accounts describe the kinds and amounts of commodities and value added by each industry and so the sum of each column in the industry account is gross output (GO) of each industry, equaling the sum of the corresponding row of the make table. The final demands account describes the kinds and amounts of commodities provided for each final user and so the sum of each column in the final demands account equals the component of GDP (consumption, investments, and so on).[14] The last three rows of Figure 4.1 indicate the composition of value added (VA): compensation, indirect business tax or non-tax liability, and “other value added” for each industry. Thus the cells at the cross of VA and Final demands are empty. Since each commodity produced is allocated either to industries or to final demands, the sum of each row in the use table is commodity output (CO) equaling the sum of the corresponding column of the make table. Note that the final demands columns and the VA rows in the use table do not have the corresponding rows and columns in the make table.

Although the Make and Use tables are relatively easy to build, I-O analysis needs a symmetric I-O table in order for the balance between the row-sum and column-sum to hold. Based on the symmetric I-O table, we can take full advantage of versatility of I-O tables such as linkage calculation.

[14] There are about twenty five categories in the BEA benchmark USE table classified as final users, which are aggregated into six broad ones: consumption, investments, exports, imports, government expenditure, and changes in business inventories. Except imports and changes in business inventories, the components are in general recorded as positive entries that contribute to outputs. Imports are recorded as negative entries, thus having a role to offset the size of outputs. In conventional I-O accounts inputs for industries are not distinguished whether they are of domestic origin or of foreign origin. Changes in business inventories can be positive or negative depending on situations.

		COMMODITIES									
		Agricultural products	Construction	Minerals	Manufacturing	Transportation	Trade	Finance	Services	Other*	Total Industry Output
INDUSTRIES	Agriculture										
	Mining										
	Construction										
	Manufacturing										
	Transportation										
	Trade										
	Finance										
	Services										
	Other*										
Total Commodity Output											

Total Commodity Output

Primary Product of the industry

Total Industry Output

		INDUSTRIES										Final Uses (GDP)							
		Agriculture	Construction	Mining	Manufacturing	Trans	Trade	Finance	Services	Other*	Total Intermediate use	Personal Consumption Expenditure	Gross Private Fixed Investment	Change in Business Inventories	Exports of goods and services	Imports of goods and services	Government Consumption and Gross Investment	GDP	Total Commodity Output
COMMODITIES	Agricultural products																		
	Construction																		
	Minerals																		
	Manufactured products																		
	Transportation																		
	Trade																		
	Finance																		
	Services																		
	Other*																		
	Noncomprable Imports																		
Total Inter-mediate inputs																			
Value Added	Compensation of Employees																		
	Indirect Business tax and nontax Liability																		
	Other Value added**																		
Total Industry Output																			

Figure 4.1 Make (at the top) and Use (at the bottom) Table

Source: BEA, Note: the basic structure is the same as in BEA, *Benchmark Input-Output Accounts of the United States, 1992*
Note: "Other" consists of government enterprises and other I-O special industries

There are two dimensions of presentation of symmetric I-O tables: commodity by commodity (CxC) and industry by industry (IxI). We have multiple ways to construct each symmetric I-O table, depending on different assumptions of the production and the market structure. Since the reason to provide make and use tables is to sort out secondary products, the assumptions are mostly about the relation between the primary product and the secondary products. Most representative two assumptions are *industry technology* and *commodity technology* (Bulmer-Thomas 1982). The assumptions are related to the reorganization of the use table which details the production structure of each industry in terms of the usage of factors. The former assumes that the production structure of secondary products is the same as that of the primary product, while the latter assumes that the production structure of a secondary product is the same as that of the industry that produces it as its primary product. The former can be supportive of such secondary products which are *by-products* from the production of the primary products: e.g. animal feedstuffs obtained as sludge from alcohol production. The latter *commodity technology* assumption can be supportive of *joint production* where one establishment provides different products based on different production methods: e.g. food service provided by hotels as their secondary product. While by-products are inseparable from the primary product (industry technology) from the production perspective, each joint-product can be consolidated into the industry whose primary product is the same as the joint-product. However, since there are many types of secondary products that cannot be categorized simply by-product or joint product, filtering out a high degree of homogeneous production is a very hard and painstaking job-almost an impossible task for an independent research. Thus they tend to simplify the assumption, either industry technology assumption or commodity technology assumption, in order to apply a simple mathematical algorithm.

In the official accounting such as the BEA's benchmark I-O tables, rather than the commodity technology assumption, the industry technology assumption is preferred. Since the joint-product can be relatively easily separated into a different account, the BEA provides *redefined* tables which consolidate such a joint product into the industry whose primary product is the same as the joint-product; e.g. food services of hotels are consolidated into the restaurant business in the redefined system. That is, official I-O tables are designed and facilitated based on the industry technology assumption. Thus after the redefinition process is made, we should better assume that each industry's production account is quite homogeneous or fit well the industry-technology assumption.

The commodity technology assumption has a practical calculation problem as well. That is, subtracting the secondary product from an industry A according to the assumption that it has the same production structure of another industry B has a possibility to leave negative entries in the column for industry A. A negative entry as intermediate inputs makes nonsense the I-O table. Thus for both practical and theoretical concern, the industry assumption will be taken in this paper.[15] The mathematical formula to construct symmetric I-O tables based on the industry technology assumption follows the method and notation suggested by the BEA 1992 benchmark table which is consistent with SNA (1968). The BLS also follows the BEA method.

The purpose of the BLS to compile I-O tables is to forecast industry's outputs and employments. Based on the product-mix of each industry from the BEA 1992 benchmark make table and the time series of GO (Gross Output) of each industry, a time series of make tables and consequently a time series of commodity outputs are estimated. However, the BLS make tables share some features with the benchmark 1997 table (establishment based) regarding the forced account (made and used by each industry itself) of construction and software; the 1992 benchmark make table (establishment based) reclassifies them into the construction and software industry but the 1997 benchmark (establishment based) leaves them to each industry.

[15] For pure practical concerns, different assumptions do not seriously matter because secondary production is not sizable. Thus, bearing a certain degree of errors, either assumption can generate a similar result, particularly in largely aggregated sectors. Even we can use the use table as an approximation (Bulmer-Thomas 1982; Blair and Wickoff 1988).

Since the BLS tables rely on the RAS method applied to the 1992 benchmark use table, the comparability question still remains: that is, to what extent such estimated series of I-O tables reflect the surveyed I-O tables. Since each benchmark I-O table is designed to better reflect the production structure of the current economy and so comparability is sometimes given up, we cannot expect the perfect comparability between the benchmark tables. In particular, the 1992 benchmark and the 1997 benchmark are very different because the latter is based on a totally new industrial classification system called the NAICS while the former on the SIC. However, as for the comparability of the I-O tables of different times, such a situation does not necessarily lead to pessimism. For the detailed cell-by-cell information does not need to be fully *correct* in the sense that slight incorrectness in each cell data is not crucial in the analysis. Rather the marginal statistics such as output may be more important for many I-O analyses as well as for productivity analysis in section 3. Thus we do not have to worry much about the cell-by-cell accuracy of the BLS time series of input-output tables.

For an intertemporal comparison of I-O tables, I-O tables need to be measured by physical units of commodity. That is, we may need Physical Input-Output Tables (PIOT) for best.[16] However, immense amount of work needed to build such PIOTs consistently over all the industries is a big hurdle and only recently a systematic PIOT has been compiled only in a few countries, which is yet at the stage of experiment.[17] In spite of (or because of) such difficulties to compile real I-O tables, official statistics has not yet well responded to the need of real I-O tables. The international guideline of national statistics, the SNA (System of National Accounts) provided by the UN (1968; 1993; 1973) just sketches the double deflation method for value added based on the Laspeyres volume index. It is not until recently European System of Accounts 95 (ESA 95) was published as a guideline about the real I-O tables that official institutions detailed the methodology and obliged the compilation (De Boer, Takema, and Verbiest 2000) in western countries.[18] The methodology is tested by some European countries and the results are encouraging: UK (Ahmad 1999) and Netherlands (De Boer and Van Nunspeet 1998). But this feedback of corrections is obviously an overload for an independent research.

Here lies the convenience and the economy of the method taken by the BLS for its real input-output tables, although the theoretic underpinning is weak. The BLS deflates each row (or each industry output) of the make table by the relevant producer price. Then from the make table, we can construct real dollar industry output (GO) and commodity output (CO). In combination with separate accounts of final demands, we can achieve the margin constraints of the use table: Gross Output as the column-sum constraint and the sum of intermediate inputs for each commodity (CO minus final demands) as the row-sum constraint. The question about the economic legitimacy of this method will be similar to that of current dollar projection of I-O tables. Real output constraints of the current year are not any different from the current output constraints of a different year. While the legitimacy is suspected, the BLS real I-O tables seem to be yet the most optimal choice for an independent research project before official institutions provide real I-O tables.

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[16] Indeed, many chapters of *Studies in the Structure of the American Economy* edited by Leontief (1952) are devoted to the efforts to construct inputs structure of several industries based on physical units.

[17] For example, Germany started to do that for 1990 and 1995 (Strassert, 2001).

[18] Japan and Korea provide both current and constant dollar I-O tables.

4.3 Intertemporal Change in Interindustry Linkage

Forward Linkage in Technological Sense

Forward linkage of each commodity is defined by Equation 4.5, written again:

(4.4) $\zeta_i = \sum_j \Omega_{ij} (Y_i/Y)$.

In this section, the Leontief requirement matrix (commodity by commodity) Ω is constructed from the BLS real make and use tables as mentioned above and Final demands Y is defined to be Final Commodity Flow net Final Imports (FCFnFM) equaling (f_d + x) (f_d is Final Domestic Demands net imports for final use and x is exports). The reason to use f_d + x as final demands is that a certain portion of imports used only for final expenditures and so cannot trigger linkage effects on domestic production. We define a column vector $W = (W_i) = (Y_i/Y)$ so that W represents a unit final expenditure of the composite basket.

Forward linkage can be calculated either from the *technological* I-O table which purely reflects the technological relation between output and input or from the *domestic* I-O table which leaves out leakages due to imports. Since the former is a conventional I-O table, the *technological* I-O table is simply called I-O table. In order to obtain the output multiplier matrix or the Leontief inverse matrix, the I-O tables should be symmetric. This paper regards the commodity by commodity I-O table as the standard.

On the other hand, the commodity by commodity *domestic* Leontief requirement matrix (DLR) is calculated from the domestic I-O table following the same method to calculate the technological I-O table except that instead of the use table, the domestic use table is used. The domestic part can be obtained as the subtraction of the imports-table. But not many countries including the US provide them.[19] And so we have to use some imputations. More concretely, if we define Domestic Supply of each commodity (DS) as domestic commodity output (CO) plus imports (MP) net exports (EX), we are assuming that the ratio of MP to DS for each commodity is faced equally by all the domestic users (industries and final domestic users) in their purchase of the commodity. The exclusion of exports is based on the fact that only partial of imports are re-exported in most economies (less than 5 percent according to BEA, *Benchmark Input-output Accounts 1992*). While this imputation is quite effective in terms of costs, such an assumption is not reliable of course (Bulmer-Thomas 1982, chapter 7; UN 1973, chapter III). The domestic I-O tables will be used when they need to be combined with factors of production in the following section.

In this subsection, forward linkage (FL) calculated from the (technological) commodity by commodity I-O table will be analyzed. The weighting (W), the normalized FCFnFM (Final Commodity Flow net Final Imports) will be used. Since this section is based on the *real* I-O tables, the weighting W or the normalized FCFnFM is also based on the constant dollars. The multiplication of LR and Final Expenditures (FE) equals commodity outputs (CO) and the multiplication of DLR and FCFnFM equals commodity outputs (CO). But, since FCFnFM differs from FE, FL as the multiplication of LR and W differs from CO, not only in the sense of scale (due to the normalization) but also of composition.

Since the change in forward linkage (FL) or ζ can come both from the change in the Leontief requirement matrix (LR) and from the change in the weighting (W), we can analyze each effect separately

[19] Korea and Japan provide import I-O Tables.

by a *structural decomposition method*. Structural decomposition methods have been widely used in I-O analysis since Leontief (1951) when it is necessary to separate the effect of a specific element of I-O tools such as the LR and W. The following formula is a popular case of structural decomposition analysis. Succeeding the notation in section 4.1for ζ (FL), Ω (Leontief Inverse), and W (weight),

(4.5) $(\zeta_i^{t+1} - \zeta_i^{t}) = {}_i(\Omega^{t+1} - \Omega^{t})\, W^t + {}_i\Omega^t\, (W^{t+1} - W^t) + {}_i(\Omega^{t+1} - \Omega^{t})\, (W^{t+1} - W^t),$

where the superscript t denotes the year and the subscript i denotes the commodity or the relevant row of Ω. The rate of change will be expressed by each term divided by ζ_i^t. The last term measures the combined effect of both changes in Ω and W. Since it is the multiplication of two incremental changes, the size is in general negligible. Thus the change in forward linkage can be approximated as the sum of the first and the second term. The first term is called LR-component of FL change and the second is W-component of FL change. In the following discussion, we will analyze each component for the period 1987-2000 and for its subperiods. In the period average of annual changes, notice that the average of each term does not reflect the pure change of Ω or W because Ω and W change simultaneously.

Table 4.1 presents the average annual growth rates of forward linkage (FL) and the decomposition into W-components and LR-components for selected industries, for two periods, 1987-1995 and 1995-2000. The reason to start from the year 1987 is that prime factor data, which will be combined later, are compiled from 1987 as mentioned in section 3. Since it is the period 1995-2000 when the growth of the IT sector and its positive impact on the economy is full fledged, the latter period is stressed out separately.

Table 4.1 Average annual growth rates of FL, W-comp, and LR-comp: selected industries

	1987-1995			1995-2000			Rank Difference
commodity	FL (1)	W-comp	LR-comp	FL (2)	W-comp	LR-comp	(1) - (2)
D357	16.7 (2)	11.8 (1)	4.6 (2)	24.0 (1)	29.8 (1)	-4.7 (59)	1
D367	16.9 (1)	6.1 (2)	10.3 (1)	22.5 (2)	11.9 (2)	9.7 (1)	-1
H62	4.8 (3)	2.7 (8)	2.1 (3)	15.8 (3)	7.4 (4)	8.3 (2)	0
D366	4.2 (5)	3.1 (6)	1.1 (5)	9.7 (4)	4.9 (5)	4.8 (4)	1
I737	4.7 (4)	5.1 (4)	-0.3 (34)	5.5 (5)	10.5 (3)	-4.9 (61)	-1
H61,67	-1.5 (49)	0.0 (34)	-1.5 (56)	4.2 (6)	0.6 (19)	3.7 (6)	43
D25	-1.1 (45)	0.0 (35)	-1.1 (50)	3.9 (7)	-0.1 (29)	3.9 (5)	38
D384,5	3.0 (7)	3.1 (5)	-0.2 (29)	3.6 (8)	1.0 (12)	2.6 (10)	-1
D37R	-4.7 (61)	-3.0 (62)	-1.7 (58)	2.3 (9)	0.4 (21)	1.8 (12)	52
E48x483	1.7 (10)	2.0 (11)	-0.3 (33)	2.2 (10)	2.3 (7)	-0.1 (29)	0
D371	1.1 (14)	0.8 (17)	0.4 (13)	1.8 (11)	0.7 (17)	1.2 (15)	3
I78	3.1 (6)	2.3 (9)	0.8 (7)	1.8 (12)	2.5 (6)	-0.6 (33)	-6
I73R	1.0 (15)	0.5 (27)	0.5 (11)	1.6 (13)	0.4 (22)	1.2 (14)	2
D36R	0.2 (25)	0.9 (14)	-0.7 (39)	1.6 (14)	0.8 (15)	0.8 (16)	11
I87,89	0.9 (17)	0.2 (31)	0.7 (9)	1.5 (15)	-0.3 (35)	1.8 (11)	2
H60	0.8 (19)	0.7 (22)	0.1 (19)	1.5 (16)	0.9 (14)	0.6 (17)	3
D34	-0.5 (33)	-0.3 (41)	-0.2 (28)	1.5 (17)	1.1 (11)	0.3 (20)	16
D32	-1.6 (51)	-0.8 (47)	-0.8 (45)	1.4 (18)	0.2 (23)	1.2 (13)	33
I79	2.2 (8)	2.8 (7)	-0.5 (36)	1.1 (19)	0.7 (16)	0.4 (19)	-11
I75	0.2 (26)	0.8 (16)	-0.6 (38)	0.7 (20)	0.2 (24)	0.5 (18)	6
B13	-2.0 (54)	-1.2 (51)	-0.7 (40)	0.5 (21)	-2.9 (57)	3.6 (8)	33
D29R	-1.8 (53)	-1.0 (49)	-0.7 (41)	0.1 (22)	-0.2 (32)	0.3 (22)	31
Average	2.20	1.66	0.51	4.95	3.31	1.65	

Sources: Author's compilation based on BLS, *Input-output Transaction Tables (Real, 1983-2000)*
Notes: The unit is percentage. The figure in parentheses is the rank along each column.

Table 4.1 lists the 22 commodities whose average annual growth rates in 1995-2000 are positive. The growth rate of forward linkage can be negative for some commodities because it is a relative performance index of a commodity both in terms of requirement and weighting. From the last column of Table 4.1, we can see that the ranks in the growth rates for 1987-2000 and those for 1995-2000 are not very different in general but that there are a few exceptions. Large positive figures in the last column demonstrate the commodities whose rank rose substantially for the latter period; except H61,67 (nondeposit banking), they are mostly goods such as D25 (Furniture), D37R (transportation equipments), D36R (electric equipments), D34 (fabricated metal), B13 (petroleum mining), and D29R (petroleum processing). This implies that the rapid expansion of the economy for the latter period boosted demands for these commodities. The existence of H61,67 and H62 (securities) in the list verifies their increasingly important position in linkage perspective; both commodities are ranked high in both W-component and LR-component.

The growth rates of FL for top-tier commodities tend to be much larger for the latter period than the former period, which is consistent with the average statistics (2.20 percent for 1987-1995 and 4.95 percent for 1995-2000). In any period, the growth rates of FL of IT-commodities are outstanding. Not only better are their performances than others but also superb are the extents of the changes. Led by D357 (computer) and D367, all the five IT commodities are in the top ten. D357 and D367 record almost about 15 percent annual growth in the former period. Their growth rates accelerated for 1995-2000 reaching about 25 percent. While there are three IT commodities in the top five, the appearance of H62 (security and commodity broker) at the third position is quite noticeable.[20] The commodities in the table are more or less evenly distributed between goods and services. Goods are mostly manufactured ones except B13. Manufactured commodities deserve attention because the manufacturing sector in general tends to show weak performances in output growth. The strength of manufactured commodities in the change of forward linkage is due to the fact first that forward linkage does not distinguish between domestic contents or foreign ones; and second that, even though the manufacturing sector is in general weak, several subsectors–representatively, IT sectors, D37's (motor vehicle and other transportation equipments), and D36R (electric equipment)–are still performing well, demonstrating their competitiveness. Notice that FIRE sectors performed very well. In addition to H62 mentioned above, two more FIRE industries are included in the table–H60 (deposit institution), and H61,67 (non-deposit and holding companies)–being consistent with their strong performances in output growth. Since they are almost non-tradable commodities, forward linkage and output is more or less equivalent for them. FIRE industries perform even better for 1995-2000 than for 1987-1995, demonstrating their recent rapid growth.

From Table 4.1, it is clearly seen that the major source of change in forward linkage is the change in weighting (W) for most industries in terms of the extent of change. The average statistics for the top-tier commodities confirms this; the average of W-comp's is quite close to FL in any period, while that of LR-comp's is much lower than that of W-comp's. Nevertheless, there are five commodities whose rank differs much between FL and W-comp by more than 10 between FL and W-component in the latter period: H61,67 (6-th and 19-th), D25 (7-th and 29-th), D37R (9-th and 21-th), I87,89 (15-th and 35-th, and B13 (21-th and 57-th). Several commodities also exhibit large rank differences between FL and LR-component. Among them, D357 draws attention because its LR-component of FL change for the latter period fell significantly while its LR-component of FL change for the former period was very high. Since D357

[20] While this commodity grew relatively fast in nominal output in comparison with other industries, its price tended to decline from 110.8 in 1987 to 83.87 in 2000 with 100 in 1996 in the BLS tables. This is similarly found in the BEA's GPI data where, however, prices inclined up to 1996 and then declined.

records very fast growth in FL for the same period, such negativity should be interpreted as a relatively fast growth in final demands than in intermediate input demands.

LR represents the relation between commodity output (CO) and final expenditures (FE). In particular, the size of output of a commodity is largely affected by the corresponding component in FE because the diagonal components of LR are significantly large. Thus sometimes we can loosely term the change in FE implicitly for that in the relevant component of FE to save words, as we use FL without exactly specifying the relevant component. Similarly, we can mean only a specific row of LR depending on the context. If commodity output changes more slowly than FE changes, then the change in LR can be slow or even be negative. For an intertemporal comparison, notice that most commodities are better or only a little worse in the LR-component for the last three years 1995-2000 than for the whole period 1987-1995.

Backward Linkage in Technological Sense

Backward linkage (BL) in this section measures each column-sum of the Leontief Requirement matrix (the same one used for forward linkage) or Ω based on Equation (4.2), we define BL or β_j in formula:

(4.2) $\beta_j = \sum_i \Omega_{ij}$.

The size of forward linkage depends on the extent of aggregation of industries and so does not deliver a qualitative characteristic of an industry. On the other hand, the size of backward linkage serves as an important structural or qualitative index of an industry. And its change over time reflects some degree of the structural change of the economy. But the extent of the change in BL is limited because BL is the column-sum of the Leontief requirement matrix which is based on the technological coefficient matrix whose column-sum is normalized. The requirement matrix is the same as that used to calculate forward linkage in the preceding subsection.

In order to understand the underlying mechanism of the change in BL, we may have to scrutinize each component of BL. But this is an unmanageable task, considering the dimension of BL. One clue or shortcut to circumvent the overloaded analysis is to separate BL into a few groups that illuminate well the characteristics of backward linkage. Backward Linkage as defined in Equation (4.2) takes the sum of the whole column. Instead, we can take a partial sum of the column elements if we want to see only the reaction of a group of commodities (as a partial sum) to a unit final demand. We call such a partial sum "group name-backward linkage" denoted by "group name-BL." By denoting the group, say, A, we can use the following notation to indicate the partial sum for BL:

(4.6) ${}_A\beta_i = \Sigma_{j \in A}\, \Omega_{ij},$

where A denotes the set of some components. Since we are particularly concerned with IT commodities, we divide commodities into two groups, IT (D357, D366, D367, E48x483, and I737) and NonIT (the rest). Thus we can present IT-BL and NonIT-BL, both of which should sum up to BL.

Table 4.2 presents the composition of BL in terms of IT-BL and NonIT-BL for 1987 and 2000, for the top 20 industries in the order of IT-BL in 2000. Since the share of IT commodities in intermediate inputs is not very large, the rank of BL is more or less similar to that of NonIT-BL except for several industries at the top. We can observe that all the industries whose IT-BL in 2000 is large are IT industries or IT-close industries. The IT industries record higher IT-BL than NonIT-BL. This implies that IT and IT-close industries form a cluster within themselves and so the development of IT industries can be amplified by the stimulation of demand for IT commodities in a virtuous cycle. Located right below the group of IT and IT-close industries are D37's (that is, D37R and D371, transportation equipments), recording about IT-BL of 0.1 in 2000. Noticeable among the rest of the industries are F and H62 (securities) and H63 (insurances).

Interesting are those commodities which experienced growth in IT-BL between 1987 and 1997. Most industries in the table experience increases in IT-BL except H62, H63, and I82. On the other hand, most industries experience falls in NonIT-BL except H62 and H63. From these findings, we can raise a hypothesis of *substitution effect* in input-mix: more IT-intermediate inputs and less NonIT-intermediate inputs. The substitution can happen when the substitution brings about productivity gains or when new intermediate inputs are needed. Productivity can be studied when the I-O analysis can be combined with prime factors, which is the topic of the next subsection.

Table 4.2 Components of backward linkage: IT- and NonIT- of selected industries for 1987 and 2000

	1987			2000		
commodity	B L	IT-BL	NonIT-BL	B L	IT-BL	NonIT-BL
D357	2.15 (20)	1.33 (1)	0.82 (58)	2.38 (6)	1.66 (1)	0.72 (58)
D366	1.77 (42)	1.18 (3)	0.59 (60)	2.11 (14)	1.57 (2)	0.55 (60)
D367	1.92 (31)	1.14 (4)	0.78 (59)	2.11 (15)	1.45 (3)	0.66 (59)
E48x483	1.68 (49)	1.21 (2)	0.47 (62)	1.71 (43)	1.28 (4)	0.43 (62)
I737	1.71 (46)	1.14 (5)	0.57 (61)	1.66 (47)	1.20 (5)	0.46 (61)
D365	2.71 (2)	0.22 (6)	2.49 (6)	2.67 (3)	0.51 (6)	2.16 (9)
D381,2,6,7	1.76 (43)	0.09 (7)	1.67 (43)	1.90 (33)	0.29 (7)	1.61 (45)
D384,5	1.82 (37)	0.06 (14)	1.76 (37)	1.81 (37)	0.14 (8)	1.67 (38)
D36R	2.12 (21)	0.04 (23)	2.08 (20)	2.08 (18)	0.13 (9)	1.95 (24)
D37R	2.11 (22)	0.05 (16)	2.06 (22)	2.02 (25)	0.12 (10)	1.90 (28)
D371	2.81 (1)	0.04 (22)	2.76 (1)	2.75 (1)	0.09 (11)	2.66 (2)
I76	1.64 (54)	0.05 (18)	1.59 (47)	1.59 (54)	0.08 (12)	1.51 (50)
E483	2.08 (24)	0.06 (13)	2.02 (24)	2.06 (22)	0.06 (13)	1.99 (21)
D39	2.21 (15)	0.03 (33)	2.18 (16)	2.01 (27)	0.06 (14)	1.95 (23)
F*	1.60 (55)	0.05 (20)	1.55 (51)	1.54 (57)	0.06 (15)	1.49 (52)
I87,89	1.64 (52)	0.06 (10)	1.58 (48)	1.61 (53)	0.06 (16)	1.56 (48)
H62	1.57 (58)	0.07 (9)	1.51 (53)	1.71 (44)	0.05 (17)	1.65 (40)
H63	1.94 (29)	0.06 (12)	1.89 (29)	2.00 (29)	0.05 (18)	1.95 (25)
I82	1.85 (36)	0.07 (8)	1.78 (36)	1.69 (46)	0.05 (19)	1.64 (41)
E494-	2.16 (19)	0.04 (21)	2.11 (19)	2.06 (20)	0.05 (20)	2.02 (17)

Sources: Author's compilation based on BLS, *Input-output Transaction Tables (Real, 1983-2000)*
Notes: The unit is natural. The figure in parentheses is the rank along each column.

4.4 Factor Saving by Industry

Methods

Data of prime factors can be linked with the Leontief Requirement matrix to analyze the relation between the changes in output and in factors for factor saving analysis, which is an I-O version of productivity analysis. The method is based on the definition of requirement of prime factors. Requirement for a prime factor of each industry (PR) or P_i is defined as the amount of the prime factor needed to produce one unit of gross output (GO) or X_i of an industry,

(4.7) $\theta = P\,\tilde{X}^{-1}$; or equivalently

$\theta_i = P_i / X_i$,

where $\tilde{X}$ means the diagonalization of the vector X. Depending on the context, prime factors can be individual capital or labor, or the aggregation of labor and capital. If prime factors should be defined exactly, then P and θ will mean the prime factor as the aggregation of labor and capital.

Since the data of prime factors are based on establishments or industries, the factor requirement vector can be multiplied to either an Industry-by-commodity (IxC) Requirement matrix or an Industry-by-Industry (IxI) Requirement matrix to calculate the amount of a prime factor to meet one dollar-amount of a commodity for final use. In this paper, the former requirement matrix is taken because it is an extension of CxC requirement matrix. The IxC matrix is the multiplication of the market share matrix obtained from the make table with the CxC requirement matrix as in the methodology introduced in BEA benchmark I-O table 1992.

Backward Linkage for Prime Factors (BLP) of industry (or commodity) i, denoted by λ_i, is defined as the amount of prime factors to meet one unit of final output i. λ_i or λ is calculated by multiplying the prime factor requirement per unit industry output (PR), denoted by θ as a row vector, to the industry-by-commodity (IxC) Leontief requirement matrix (LR), denoted by Ω. (the exact type of LR can be discerned from the context and so such a type as IxC does not have to be specified in notation). In notation,

(4.8) $\lambda = \theta\, \Omega$; *or*

$$\lambda_i = (\theta\, \Omega)_{i,} = \theta\, {}_i\Omega = \Sigma_j\, \theta_j\, \Omega_{ij,}$$

where the subscript i in front of Ω denotes the i-th column of Ω. BLP can be interpreted as the amount of prime factors for an artificial aggregate industry, denoted i, which is an aggregation of all the industries that contribut directly or indirectly to the final output of commodity i. Thus in such an interpretation, λ_i can be an inverse of productivity of the artificial (aggregate) industry i. In this sense, the index i can have multiple meanings: final commodity i, the industry i that produces the final commodity , and the artificial aggregated industry i. λ can be related to any prime factor in general or the exact prime factor as the aggregation of labor and capital. In this section, we only deal with the prime factor as the aggregation of labor and capital.

Since BLP (Backward Linkage for Prime Factor) is based on the link between the prime factors (which is by definition of domestic origin) and output requirement, the output requirement matrix should be the domestic one, that is, Domestic Leontief Requirement (DLR) as mentioned above.

A decrease in BLP means factor saving or, otherwise saying, productivity gain. Thus an analysis of intertemporal changes in BLP provides an alternative view to productivity change. Since factor saving is the result of the interaction between the change in PR and that in LR, not just final results but the detailed mechanism underlying factor saving can be revealed, which is the most strong motivation to take the method in spite of the complicated data process.

Data and Results

The I-O tables for analysis in this section are the same as before, BLS I-O tables (1983-2000). While the data source of prime factors is the same as the one in the previous section, the data should be further processed to fit the analytical framework.

The productivity analysis of section 3 was based on the data of growth rates of labor and capital of industries. Growth rate are easily transformed into indices (set as 100 at 1996, e.g.). On the other hand, in factor saving analysis, labor, capital, or prime factor (as an aggregate of labor and capital) should be comparable figures across industries in order to calculate BLP because the multiplication of factor requirement (θ) and Ω is the summation of the components of θ with a certain weighing based on each column of Ω. The number of employees (or hours) and the amount of capital stocks in current dollars are such comparable measurements of prime factors in a generic sense. Based on the indices, we can develop comparable measurements of prime factors across industries.

The transformation of prime factors from indices into comparable measurements can be made based on a normalization of prices of prime factors by setting the price of prime factors at 1996 as a unit in every industry. Then in 1996 the amount of the prime factor equals valued added. These measurements transform an index of prime factors into value-weighted units. For example, if industry A and B have the same amount of value added in 1996, then the amount of the prime factor is measured the same between the two industries in 1996 regardless of how many actual units of labor are put into production.[21] Such value-based weighting for prime factors is indeed already in use; different kinds of labor and capital are aggregated based on value-shares; prime factor as an aggregation of labor and capital is also based on value-shares as discussed in section 3. Similarly, we can define the price of labor and capital in such a way that in 1996 the value of labor and that of capital equal respectively the value-weighted labor index and capital index. In notations, prime factors for an industry are measured as follows:

(4.9) $L^{t+1} = L^t \exp(g^t_L\, t);$

$K^{t+1} = K^t \exp(g^t_K\, t);$

$P^{t+1} = P^t \exp(g^t_P\, t),$

where t=1996 is the base year, g^t_L, g^t_K, and g^t_P are growth rates respectively of L, K, and P as in section 3 (in the form of a translog) and the subscripts for industries are omitted.[22] Recall that g^t_P is an weighted average of g^t_L and g^t_K with weights as value shares of labor and capital respectively. That is, changing the notation of a translog, Equation 3.13 becomes:

(4.10) $g^t_P = \mu_L\, g^t_L + \mu_K\, g^t_K.$

While Prime Factor Requirement (PR) measures the prime factor requirement for each commodity output, BLP measures the amount of prime factors needed to produce each commodity unit only finally used. Thus the absolute level of BLP should tend to be larger than that of PR. BLP can be interpreted as a weighted sum of PR with the weighting based on each column of the Leontief inverse matrix. Thus BLP should be less variable across industries and times than PR.

Recalling that the IT-component of BL tends to substitute for NonIT-component of BL of industries (Table 4.2) and such a tendency is particularly strong for the industries with rapid productivity gain such as IT industries, we can predict that the decomposition of BLP change into IT-related and NonIT-related parts may provide a clue for underlying the sources of the change in BLP. Since industries tend to absorb more

[21] If the actual price difference of unit labor across industries is exactly proportional to the quality difference of labor, then such measurements can be a kind of quality-adjusted labor inputs. But these are not recommended with respect to quality of labor (Wolff and Howell 1988); more direct properties of labor such as education experience are used to discern the quality of labor as mentioned in section 3.

[22] In a conventional I-O analysis, a weighted *algebraic* average of labor and capital is preferred than the method addressed above because the additive formula of capital and labor makes it easy to deal with individual factors and the aggregation of both as in Carter (1970). But those two methods are not seriously different in actual measurement because the growth rates of labor and capital inputs are modest in general.

IT-intermediate inputs, which undergo a large extent of factor saving, the structural change with respect to BLP can be defined as the *usage of more intermediate inputs embodying less primary factors*.

We can denote a partial sum of λ_i by

(4.11) $\quad {}_A\lambda_i = \Sigma_{j \in A}\, \theta_j\, \Omega_{ij},$

where A denotes the set of components (j's). By partitioning industries into IT and NonIT kinds, we can decompose BLP into IT-BLP (or ${}_{IT}\lambda$) and NonIT-BLP (or ${}_{NonIT}\lambda$). In formula,

(4.12) $\quad \lambda_i = {}_{IT}\lambda_i + {}_{NonIT}\lambda_i.$

We can calculate the contribution of each part by multiplying the growth rate of each to the share of the size of each part in BLP. In formula, we have:

(4.13) $\quad d\,\lambda_i / \lambda_i = d\,{}_{IT}\lambda_i / \lambda_i + d\,{}_{NonIT}\lambda_i / \lambda_i.$

Table 4.3 shows a decomposition of the change in BLP in terms of IT-BLP and NonIT-BLP for selected industries. This table illuminates the effect of the substitution triggered by IT intermediate inputs upon the change in BLP. The first section of Table 4.3 lists the top 20 industries that showed fast rates of factor saving for 1995-2000. While IT goods industries (D357, D367, and D366) are prominent both in BLP change and in IT-BLP change, other industries receive much larger contributions from NonIT-BLP than from IT-BLP due to the small size of IT-intermediate inputs. The second section of Table 4.3 lists the top 20 industries that showed fast rates of the change in the contribution of IT-BLP for 1995-2000. Four IT industries and D365 record the contribution of IT-BLP change by less than minus one percent (in the absolute term).

Table 4.3 Decomposition of average annual growth rates of BLP: IT- and NonIT-, selected industries

	1987-1995			1995-2000		
commodity	BLP	IT-BLP	NonIT-BLP	BLP	IT-BLP	NonIT-BLP
In the order of change in BLP for 1995-2000						
D367	-10.14 (2)	-9.64 (2)	-.50 (46)	-13.05 (1)	-11.75 (2)	-1.30 (37)
D357	-12.61 (1)	-11.89 (1)	-.71 (40)	-12.75 (2)	-11.93 (1)	-.82 (46)
H62	-2.33 (15)	-.11 (18)	-2.22 (11)	-7.54 (3)	-.27 (12)	-7.27 (1)
D366	-4.35 (4)	-3.83 (3)	-.53 (45)	-6.25 (4)	-5.42 (3)	-.82 (45)
D384,5	-3.26 (8)	-.22 (8)	-3.05 (5)	-6.00 (5)	-.32 (10)	-5.68 (2)
D31	-1.29 (35)	-.04 (48)	-1.24 (30)	-5.45 (6)	-.10 (41)	-5.35 (3)
D29R	-1.13 (38)	-.05 (41)	-1.07 (33)	-5.13 (7)	-.12 (32)	-5.01 (4)
D37R	-2.77 (10)	-.13 (14)	-2.64 (7)	-4.56 (8)	-.26 (13)	-4.29 (6)
D25	-1.67 (26)	-.04 (56)	-1.63 (20)	-4.41 (9)	-.09 (51)	-4.32 (5)
D22,3	-2.58 (13)	-.04 (51)	-2.54 (8)	-4.17 (10)	-.10 (46)	-4.07 (7)
D371	-1.70 (25)	-.10 (22)	-1.60 (21)	-4.06 (11)	-.22 (15)	-3.84 (10)
I88	-3.84 (5)	.00 (61)	-3.84 (2)	-4.03 (12)	.00 (60)	-4.03 (8)
D34	-1.49 (31)	-.05 (45)	-1.45 (25)	-3.98 (13)	-.11 (35)	-3.87 (9)
D36R	-2.49 (14)	-.11 (17)	-2.38 (10)	-3.91 (14)	-.20 (17)	-3.70 (12)
B10	-2.70 (11)	-.03 (58)	-2.66 (6)	-3.80 (15)	-.09 (50)	-3.71 (11)
D381,2,6,7	-2.82 (9)	-.28 (7)	-2.54 (9)	-3.64 (16)	-.45 (6)	-3.19 (16)
H60	-2.04 (19)	-.10 (20)	-1.94 (14)	-3.58 (17)	-.35 (8)	-3.23 (15)
B12	-3.55 (7)	-.03 (60)	-3.52 (4)	-3.53 (18)	-.06 (57)	-3.47 (13)
D35R	-2.05 (18)	-.05 (42)	-2.00 (13)	-3.40 (19)	-.10 (42)	-3.30 (14)
D33	-1.93 (20)	-.05 (43)	-1.88 (15)	-3.31 (20)	-.14 (25)	-3.17 (17)
In the order of change in IT-BLP for 1995-2000						
D357	-12.61 (1)	-11.89 (1)	-.71 (40)	-12.75 (2)	-11.93 (1)	-.82 (46)
D367	-10.14 (2)	-9.64 (2)	-.50 (46)	-13.05 (1)	-11.75 (2)	-1.30 (37)
D366	-4.35 (4)	-3.83 (3)	-.53 (45)	-6.25 (4)	-5.42 (3)	-.82 (45)
D365	-5.19 (3)	-.95 (6)	-4.24 (1)	-3.30 (21)	-2.12 (4)	-1.18 (38)
E48x483	-2.61 (12)	-2.32 (4)	-.30 (50)	-1.69 (38)	-1.24 (5)	-.46 (50)
D381,2,6,7	-2.82 (9)	-.28 (7)	-2.54 (9)	-3.64 (16)	-.45 (6)	-3.19 (16)
I82	-.54 (48)	-.15 (10)	-.39 (48)	-.48 (50)	-.40 (7)	-.09 (54)
H60	-2.04 (19)	-.10 (20)	-1.94 (14)	-3.58 (17)	-.35 (8)	-3.23 (15)
I87,89	-.33 (51)	-.13 (12)	-.20 (52)	-1.30 (42)	-.34 (9)	-.95 (43)
D384,5	-3.26 (8)	-.22 (8)	-3.05 (5)	-6.00 (5)	-.32 (10)	-5.68 (2)
H61,67	-.30 (53)	-.13 (13)	-.17 (53)	-2.61 (28)	-.29 (11)	-2.32 (24)
H62	-2.33 (15)	-.11 (18)	-2.22 (11)	-7.54 (3)	-.27 (12)	-7.27 (1)
D37R	-2.77 (10)	-.13 (14)	-2.64 (7)	-4.56 (8)	-.26 (13)	-4.29 (6)
E483	-3.68 (6)	-.13 (15)	-3.55 (3)	-.11 (55)	-.25 (14)	.13 (57)
D371	-1.70 (25)	-.10 (22)	-1.60 (21)	-4.06 (11)	-.22 (15)	-3.84 (10)
EtransX46	-1.54 (30)	-.09 (27)	-1.45 (26)	-1.05 (47)	-.22 (16)	-.84 (44)
D36R	-2.49 (14)	-.11 (17)	-2.38 (10)	-3.91 (14)	-.20 (17)	-3.70 (12)
F*	-1.93 (21)	-.11 (19)	-1.82 (16)	-1.57 (40)	-.20 (18)	-1.37 (35)
I76	-1.48 (32)	-.20 (9)	-1.28 (29)	-.73 (49)	-.20 (19)	-.54 (49)
H63	.03 (59)	-.15 (11)	.18 (59)	1.19 (61)	-.18 (20)	1.37 (61)

Sources: Author's compilation based on BLS, *Input-output Transaction Tables (Real, 1983-2000)*, BLS, *Employment, Hours, and Earnings*, BEA, *Fixed Assets and Consumer Durables*, BEA, *Gross Product by Industry*
Notes: The unit is percentage. The figure in parentheses is the rank along each column.

4.5 Factor Saving in Aggregation

Methods of Aggregation

By multiplying BLP (Backward Linkage for Prime Factor), λ, to the normalized FCFnFM (Final Commodity Flows net Finally Used Imports), W (weighting), Prime Factor Requirement for a Unit Composite Final Output (PRF), denoted by *Π* as a scalar, can be defined. In notation,

(4.14) $\Pi = \sum_i \lambda_i W_i$; or equivalently

$$\Pi = \lambda W.$$

Π measures how much amount of prime factors is needed to meet a unit final demand and Π has an inverse relation with the productivity of the economy which is defined as GDP per a unit prime factor. The prime factor can be defined to be individual labor or capital or the aggregation of capital and labor, depending on the context. In this paper, we take only the prime factor as the aggregation of labor and capital. The underlying rationale for the aggregation represented by Π is similar to the calculation of forward linkage (FL) of each industry which is the multiplication of a row of LR and the same weighing column W. Recall that W can be interpreted as the one unit of the composite basket of final outputs and W_i is the share of an article i in the basket. By definition, the rate of change of Π is the factor saving of the economy. Factor saving resembles productivity gain except the sign of change. As productivity can be meant for an individual industry or for the economy as a whole depending on the context, factor saving can be so. To avoid confusion, a term sectoral factor saving (or sectoral productivity gain) would be better used for factor saving (or productivity gain) of a individual sector.

In equation (4.13), factor saving of industry i was defined as $d\lambda_i / \lambda_i$ where d means the differential between the two periods. Since this factor saving is embodied into a unit of final output i, an intuitive suggestion regarding the contribution of the industry i to the PRF is to define $d\lambda_i / \lambda_i\ W_i$ as the sectoral contribution; in formula,

(4.15) Sectoral Contribution to factor saving = $d\lambda_i / \lambda_i\ W_i$.

In consequence, factor saving of the economy is defined as:

(4.16) (Aggregate) Factor Saving = $\Sigma\ d\lambda_i / \lambda_i\ W_i = d\lambda\ \tilde{\lambda}^{-1}\ W$.

In practice, the weighting W should be calculated as the average of those in consecutive years. This aggregation scheme is based on the same rationale underlying the aggregation of sectoral productivities.

Though Equation (4.16) is based on a conceptual ground, we can also derive a similar formulation from a growth accounting based on Wolff (1985). While the formula of the rigorous aggregation is quite alike as (4.16) above, two noticeable differences that affect the results of the aggregation should be addressed. First, the weighting W in (4.16) is based on final demands measured at constant dollars, while the weighting in Wolf (1985) is measured at current dollars. In comparison with current dollar-based W, constant dollar-based W can *overstate* factor saving because commodities whose share gets large tend to experience a slower rise (even a fall) in price due to productivity gain; outstanding examples are IT commodities.

Second, recall that BLP or λ_i in (4.13) is based on domestic Leontief requirement (DLR) and W on the normalized Final Commodity Flow net finally used Imports (FCFnFM). The growth accounting is based on (technological) Leontief Requirement Matrix (LR) and Final Demands. In this accounting, all the imports are excluded from final demands. As mentioned, the technological representation of production structure and productivity analysis should better be based on LR. Factor saving based on the combination of DLR and W is likely to be *overstated* in the US economy because the components of DLR tend to fall faster than those of LR (due to fast rising imports), while the components of FCFnFM tend to fall less slowly than those of the column vector of final demands (since imports are reflected partially in FCFnFM in comparison with final demands). Since factor saving in this section is studied as an extension of linkage analysis, the method based on DLR and W is preferred. Thus in addition to the weighting scheme based on real dollars, the structure of the output multiplier can intensify the overstatement of factor saving in comparison with growth accounting.

Aggregation for the IT and the NonIT sector

In order to stress out the role of IT intermediate inputs in aggregate factor saving, we will apply the aggregation method to the decomposition of BLP change into IT-BLP change and NonIT-BLP change in (4.16). The aggregation formula is as follows:

(4.17) $\Sigma_i\ d\ \lambda_i / \lambda_i\ W_i = \Sigma_i\ (d\ _{IT}\lambda_i / \lambda_i)\ W_i + \Sigma_i\ (d\ _{NonIT}\lambda_i / \lambda_i)\ W_i$.

Thus by multiplying W_i to BLP growth (and its decomposition into IT-BLP and NonIT-BLP), we can calculate the contribution of each industry to aggregate factor saving. Table 4.4 shows the weighted BLP and its decomposition for selected industries and for the aggregate IT and NonIT sectors. The column "weight" in each period is the average share of each sector in FCFnFM (Final Commodity Flows net Final demand for imports) or W.

"SUM" in Addendum to Table 4.4 shows the rate of factor saving: -0.91 percent for 1987-1995 and -1.75 percent for 1995-2000. Recalling that TFP (Total Factor Productivity) grew at 0.61 percent and 1.13 percent for each period in section 3 (Table 3.5), the degree of aggregate factor saving, if it is taken to be approximately the same as the inverse of productivity, is overstated while the intertemporal pattern is not very different. This overstatement was predicted from the methods of aggregation. The use of DLR which tends to decline faster than LR and the weight W which is based on real final outputs can explain such overstatements.

The first section of Table 4.4 lists the top 20 industries according to their size of contributions to factor saving for 1995-2000. In comparison with the rate of change in BLP of Table 4.3, which is introduced again in the last column of Table 4.8, we can notice that several commodities joined newly the top 20 group: C (Construction), D20 (food), and D28 (chemicals) of goods sectors; Trade sectors, (G: Retail and F: Wholesale), E48x483 (telecommunication), Utility (E46,491-3), I75 (auto repairs). Their upward shifts in rank of contribution reflect their important position in final demands.

On the other hand, many industries that are ranked high in the rate of change in BLP have lower ranks in contribution, which is well demonstrated by the second section of Table 4.4. Only several industries have no lower ranks in the contribution of BLP than in the rate of change in BLP: D357 (semiconductor), D37R (transportation equipments), D371 (auto vehicles), H60 (deposit institutions), and D35R (industrial machinery). Notice that many IT industries are ranked lower in the contribution of BLP than in the rate of change in BLP, reflecting their small size. In particular, D367's lower rank in the contribution of BLP (-0.73 percent, ranked 6-th for 1995-2000) than in BLP change (1-st) is noticeable, which is due to the weak position of D367 in final demands.

We can present aggregation results focused on IT industries, which can answer one of the key questions of this research about the role of IT. Addendum to Table 4.4 highlights the five IT industries and shows the aggregation of their contributions along with the aggregation of NonIT industries' contributions. This aggregation scheme is similar to that in Table 3.5 (for aggregate LP and TFP growth). We can see that the contribution of the IT sector to aggregate factor saving is -0.16 percent for the former period and -0.34 percent for the latter period. In terms of the percentage share of the contribution to aggregate factor saving, the position of the IT sector grew from 17.2 percent to 19.7 percent. Considering that the weighting of W for the IT sector is only 3.7 percent and 7.1 percent respectively for the two periods, we can confirm the strength of the IT sector in terms of factor saving. Recall that in TFP analysis in Table 3.5, the contribution of the IT sector was 0.32 percent and 0.37 percent respectively for the two periods. While the size of the contribution of the IT sector to factor saving is similar to or smaller than that of the IT sector to TFP growth, the rate of aggregate factor saving is much larger than that of TFP growth. Thus, the contribution of the IT sector to factor saving is much lower in relative sense than that of the IT sector to TFP growth.

Table 4.4 Contribution of BLP to factor saving by IT and NonIT, selected industries

	1987-1995				1995-2000				1995-2000
	Weighting	Contribution of:			Weighting	Contribution of:			BLP change
industry		BLP	IT-BLP	NonIT-BLP		BLP	IT-BLP	NonIT-BLP	Table B.14
In the order of the contribution of BLP for 1995-2000									
D357	.36 (44)	-.048 (6)	-.045 (1)	-.003 (41)	1.75 (17)	-.210 (1)	-.194 (1)	-.016 (25)	-12.75 (2)
G	10.85 (2)	-.053 (5)	-.008 (6)	-.045 (6)	10.99 (1)	-.200 (2)	-.012 (5)	-.188 (1)	-1.81 (35)
D371	2.80 (8)	-.047 (8)	-.003 (13)	-.044 (7)	3.05 (8)	-.125 (3)	-.007 (10)	-.118 (2)	-4.06 (11)
H60	2.66 (9)	-.055 (3)	-.003 (14)	-.053 (3)	2.84 (9)	-.102 (4)	-.010 (7)	-.092 (3)	-3.58 (17)
C	8.46 (4)	-.002 (45)	-.006 (8)	.003 (60)	7.85 (4)	-.083 (5)	-.007 (9)	-.076 (4)	-1.06 (46)
D367	.22 (50)	-.024 (15)	-.023 (3)	-.001 (48)	.56 (36)	-.073 (6)	-.065 (2)	-.008 (35)	-13.05 (1)
D37R	1.79 (14)	-.053 (4)	-.002 (15)	-.050 (4)	1.49 (19)	-.069 (7)	-.004 (13)	-.065 (5)	-4.56 (8)
F*	3.85 (7)	-.074 (2)	-.004 (9)	-.070 (2)	4.38 (6)	-.069 (8)	-.009 (8)	-.060 (8)	-1.57 (40)
D35R	1.77 (15)	-.036 (11)	-.001 (25)	-.035 (8)	1.95 (13)	-.065 (9)	-.002 (24)	-.063 (6)	-3.40 (19)
H62	.44 (36)	-.011 (23)	.000 (35)	-.011 (18)	.84 (28)	-.064 (10)	-.002 (21)	-.062 (7)	-7.54 (3)
D20	3.99 (6)	-.047 (7)	-.002 (17)	-.046 (5)	3.57 (7)	-.062 (11)	-.003 (18)	-.059 (9)	-1.76 (36)
I80	8.26 (5)	.041 (62)	-.007 (7)	.048 (62)	7.81 (5)	-.058 (12)	-.010 (6)	-.048 (10)	-.76 (48)
D22,3	1.16 (20)	-.030 (12)	.000 (34)	-.029 (10)	1.16 (20)	-.049 (13)	-.001 (29)	-.047 (11)	-4.17 (10)
D28	1.82 (13)	-.020 (16)	-.001 (23)	-.019 (12)	1.90 (14)	-.041 (14)	-.002 (23)	-.039 (12)	-2.17 (31)
D366	.44 (38)	-.019 (19)	-.017 (5)	-.002 (42)	.63 (33)	-.040 (15)	-.035 (3)	-.005 (40)	-6.25 (4)
E46,491-3	1.92 (12)	-.019 (17)	-.001 (21)	-.018 (14)	1.77 (16)	-.039 (16)	-.002 (22)	-.036 (13)	-2.18 (30)
D381,2,6,7	1.01 (22)	-.028 (13)	-.003 (12)	-.025 (11)	.95 (26)	-.034 (17)	-.004 (12)	-.030 (15)	-3.64 (16)
I75	1.49 (16)	-.005 (36)	-.001 (19)	-.004 (34)	1.67 (18)	-.033 (18)	-.002 (20)	-.031 (14)	-1.98 (34)
E48x483	1.48 (17)	-.039 (9)	-.034 (2)	-.004 (32)	1.82 (15)	-.030 (19)	-.022 (4)	-.008 (34)	-1.69 (38)
D384,5	.38 (43)	-.013 (22)	-.001 (26)	-.012 (17)	.45 (38)	-.027 (20)	-.001 (25)	-.026 (16)	-6.00 (5)
SUM	0.55	-0.58	-0.16	-0.42	0.57	-1.47	-0.40	-1.08	
In the order of the rate of change in BLP for 1995-2000									
D367	.22 (50)	-.024 (15)	-.023 (3)	-.001 (48)	.56 (36)	-.073 (6)	-.065 (2)	-.008 (35)	-13.05 (1)
D357	.36 (44)	-.048 (6)	-.045 (1)	-.003 (41)	1.75 (17)	-.210 (1)	-.194 (1)	-.016 (25)	-12.75 (2)
H62	.44 (36)	-.011 (23)	.000 (35)	-.011 (18)	.84 (28)	-.064 (10)	-.002 (21)	-.062 (7)	-7.54 (3)
D366	.44 (38)	-.019 (19)	-.017 (5)	-.002 (42)	.63 (33)	-.040 (15)	-.035 (3)	-.005 (40)	-6.25 (4)
D384,5	.38 (43)	-.013 (22)	-.001 (26)	-.012 (17)	.45 (38)	-.027 (20)	-.001 (25)	-.026 (16)	-6.00 (5)
D31	.11 (55)	-.001 (49)	.000 (54)	-.001 (45)	.09 (56)	-.005 (40)	.000 (53)	-.005 (41)	-5.45 (6)
D29R	.04 (58)	.000 (55)	.000 (56)	.000 (53)	.04 (58)	-.002 (48)	.000 (55)	-.002 (47)	-5.13 (7)
D37R	1.79 (14)	-.053 (4)	-.002 (15)	-.050 (4)	1.49 (19)	-.069 (7)	-.004 (13)	-.065 (5)	-4.56 (8)
D25	.57 (32)	-.009 (26)	.000 (45)	-.009 (20)	.57 (35)	-.025 (24)	-.001 (41)	-.025 (17)	-4.41 (9)
D22,3	1.16 (20)	-.030 (12)	.000 (34)	-.029 (10)	1.16 (20)	-.049 (13)	-.001 (29)	-.047 (11)	-4.17 (10)
D371	2.80 (8)	-.047 (8)	-.003 (13)	-.044 (7)	3.05 (8)	-.125 (3)	-.007 (10)	-.118 (2)	-4.06 (11)
I88	.17 (52)	-.006 (32)	.000 (61)	-.006 (27)	.15 (53)	-.006 (38)	.000 (60)	-.006 (36)	-4.03 (12)
D34	.44 (37)	-.007 (31)	.000 (47)	-.006 (28)	.45 (40)	-.018 (27)	.000 (42)	-.017 (23)	-3.98 (13)
D36R	.59 (31)	-.015 (20)	-.001 (31)	-.014 (15)	.67 (31)	-.026 (22)	-.001 (26)	-.025 (18)	-3.91 (14)
B10	.02 (60)	-.001 (54)	.000 (58)	-.001 (52)	.02 (60)	-.001 (54)	.000 (57)	-.001 (52)	-3.80 (15)
D381,2,6,7	1.01 (22)	-.028 (13)	-.003 (12)	-.025 (11)	.95 (26)	-.034 (17)	-.004 (12)	-.030 (15)	-3.64 (16)
H60	2.66 (9)	-.055 (3)	-.003 (14)	-.053 (3)	2.84 (9)	-.102 (4)	-.010 (7)	-.092 (3)	-3.58 (17)
B12	.04 (57)	-.002 (47)	.000 (57)	-.002 (44)	.04 (57)	-.001 (50)	.000 (56)	-.001 (49)	-3.53 (18)
D35R	1.77 (15)	-.036 (11)	-.001 (25)	-.035 (8)	1.95 (13)	-.065 (9)	-.002 (24)	-.063 (6)	-3.40 (19)
D33	.15 (53)	-.003 (44)	.000 (52)	-.003 (40)	.19 (52)	-.006 (36)	.000 (48)	-.006 (37)	-3.31 (20)
SUM	15.2	-0.41	-0.10	-0.31	17.9	-0.95	-0.33	-0.62	

Addendum: Aggregation of IT sectors and NonIT sectors

	1987-1995				1995-2000			
	Weighting	Contribution of:			Weighting	Contribution of:		
industry	in percent	BLP	IT-BLP	NonIT-BLP	in percent	BLP	IT-BLP	NonIT-BLP
D357	0.04	-0.048	-0.045	-0.003	1.8	-0.210	-0.194	-0.016
D367	0.2	-0.024	-0.023	-0.001	0.6	-0.073	-0.065	-0.008
D366	0.4	-0.019	-0.017	-0.002	0.6	-0.040	-0.035	-0.005
E48x483	1.5	-0.039	-0.034	-0.004	1.8	-0.030	-0.022	-0.008
I737	1.2	-0.026	-0.019	-0.007	2.4	0.009	0.022	-0.013
SUM of ITs	3.7	-.16 (17.2)	-.14 (15.2)	-.02 (2.0)	7.1	-.34 (19.7)	-.29 (16.8)	-.05 (2.9)
SUM of NonITs	96.3	-.75 (82.8)	-.07 (7.2)	-.69 (75.5)	92.9	-1.41 (80.3)	-.12 (6.8)	-1.29 (73.6)
SUM of ALL	100	-.91 (100)	-.20 (22.5)	-.70 (77.5)	100	-1.75 (100)	-.41 (23.5)	-1.34 (76.5)

Sources: Author's compilation based on BLS, *Input-output Transaction Tables (Real, 1983-2000)*, BLS, *Employment, Hours, and Earnings*, BEA, *Fixed Assets and Consumer Durables*, BEA, *Gross Product by Industry*
Notes: The unit is percentage. The figure in parentheses in the main table is the rank along each column. The figure in parentheses in Addendum is the share in "SUM of ALL" for BLP.

The lowered (in relative sense) contribution of the IT sector can be explained by the combination of two factors: the unfavorable weighting scheme for the IT sectors and the overstated economy-wide factor saving. In the Domar-weighted productivity, high productivity growths of the IT sector are amplified in the weighting scheme. Recall the contribution of IT sectors to productivity or factor saving is made mostly by D375 (computers) and D367 (semiconductors and electronic components). In I-O analysis, while BLP growth of D357 and D367 (-13.05 percent and -12.75 percent respectively for 1995-2000) are each not very different from that of TFP of D357 and D367 (13.96 percent and 17.72 percent for 1995-2000, Table 3.1), but their contributions in sum are much lowered in factor saving (-0.21 and -0.07 percent each, Table 4.4) than productivity gain (0.22 and 0.30 percent, Table 3.5). The weak presence of D367 in final outputs lowers the contribution of D367 in factor saving. On the other hand, the three other IT commodities show more or less even degrees of contribution to factor saving, though not very large (the sum of them is -0.079 percent for BLP growth for 1995-2000, Table 4.4). In total factor productivity, the sum of the other industries' contribution was -0.14 percent (negative productivity growth is simply due to an abnormally low measurement of the contribution of I737). The large contribution of other IT industries in terms of factor saving is due to the nature of the methodology which is designed to capture the degree of the spread of factor saving.

From "SUM of ALL" in Appendum to Table 4.4, we can also see the sum of the contributions of IT-BLP and NonIT-BLP as intermediate inputs. IT-BLP contributes less to factor saving than NonIT-BLP: respectively (-0.20) percent and (-0.70) percent for 1987-1995; and (-0.41) percent vs. (-1.34) percent for 1995-2000. The contributions of IT and NonIT as intermediate inputs to aggregate factor saving are not very different from those of the IT and the NonIT sector as industries. For the contribution of IT and NonIT as intermediate inputs are concentrated respectively into the IT sector and NonIT sector. But still we can see that IT-BLP's contribution to the factor saving of the NonIT sector is much larger than the NonIT-BLP's contribution to the factor saving of the IT sector, confirming the impact of the IT intermediate inputs to the factor saving of the NonIT sector..

Aggregation for Large Sectors

The above discussion showed the decomposition of each BLP growth into IT-BLP growth and NonIT-BLP growth and consequently the decomposition of aggregate factor saving (BLP change) into aggregate IT-BLP change and aggregate NonIT-BLP change. And by partitioning industries into the IT and the NonIT sector, we were able to decompose factor saving in the form of a matrix. We can apply the same method to the eight large sectors: AMC, Md, Mn, TCU, FIRE, Trade, Services, and Gov in order to understand interdependence of sectors regarding factor saving.[23] The formula is written as follows. First, each BLP is decomposed as follows:

(4.18) $\lambda_i = \Sigma_A \; {}_A\lambda_i$,

where A's are AMC, Md, Mn, TCU, Trade, FIRE, Services and Gov and ${}_A\lambda_i$ denotes A-BLP similarly for IT-BLP or NonIT-BLP. Thus the change in BLP is:

[23] Fontella (1994) provides another way to measure interindustry spread of productivity focusing on cost saving enabled by lowered prices of intermediate goods.

(4.19) $d\lambda_i / \lambda_i = \Sigma_A\, d_A \lambda_i / \lambda_{i.}$,

Aggregate factor saving is now:

(4.20) $\Sigma_i\, d\lambda_i / \lambda_i W_i = \Sigma_i (\Sigma_A\, d_A \lambda_i / \lambda_{i.} W_i)$.

Or we can partition the aggregation into the large sectors. In formula,

(4.21) $\Sigma_i\, d\lambda_i / \lambda_i W_i = \Sigma_{i\in AMC} (\Sigma_A\, d_A \lambda_i / \lambda_{i.} W_i) + \Sigma_{i\in Md} (\Sigma_A\, d_A \lambda_i / \lambda_{i.} W_i) + \cdots + \Sigma_{i\in Gov} (\Sigma_A\, d_A \lambda_i / \lambda_{i.} W_i)$

Table 4.5 shows the results of sectoral aggregation. While each row shows the decomposition of weighted BLP change for each sector into different kinds of inputs, each column shows the effects of a specific sector's outputs embodying less prime factors as intermediate inputs. Each figure in parentheses are the ratio of the corresponding left-positioned figure to aggregate factor saving.

From this table, we can investigate the contribution of the sectors ("BLP" column) in comparison with the share in W ("weight" column). The sectors whose contribution is larger than the share in W are Md, Mn, TCU, and FIRE in 1987-1995 and Md and Mn in 1995-2000. The reason of the reduction of the number of those sectors over time is that Md's contribution in 1995-2000 was too large (42.3 percent of aggregate factor saving) in comparison with Md's contribution in 1995-2000 (34.9 percent of aggregate factor saving). Md-BLP made a significant contribution to such an increase (28.8 percent to 33.3 percent in parenthesized figures) and Trade-BLP did so (1.8 percent to 3.5 percent). In addition to Md, the sectors whose contribution (figure in parentheses) increased between the two periods are AMC (1.9 percent to 5.6 percent) and Services (4.8 percent to 8.3 percent). The underlying sources of the increase in contribution are noticeably Trade-BLP for the AMC sector (0.2 percent to 2.6 percent) and Services-BLP for the Service sector (-7.4 percent to -0.4 percent).

Table 4.5 Decomposition of aggregate factor saving by large sectors

1987-1995										
	Weighting		Contribution of:							
industry	percent	BLP	AMC	Md	Mn	TCU	Trade	FIRE	Services	Gov
AMC	9.4	-0.02 (1.9)	0.05 (-5.8)	-0.03 (3.3)	-0.01 (1.2)	-0.01 (1.0)	-0.02 (2.5)	0.00 (0.2)	0.01 (-0.6)	0.00 (0.1)
Md	11.4	-0.32 (34.9)	-0.01 (0.8)	-0.26 (28.8)	-0.02 (1.9)	-0.01 (1.2)	-0.02 (1.8)	0.00 (0.3)	0.00 (0.1)	0.00 (0.1)
Mn	10.2	-0.14 (15.1)	-0.03 (3.2)	-0.01 (1.4)	-0.06 (7.1)	-0.02 (1.8)	-0.01 (1.6)	0.00 (-0.2)	0.00 (0.1)	0.00 (0.1)
TCU	6.2	-0.10 (11.5)	-0.02 (1.7)	-0.01 (1.3)	0.00 (0.5)	-0.06 (7.1)	-0.01 (0.7)	0.00 (0.1)	0.00 (0.2)	0.00 (0.1)
Trade	14.7	-0.13 (13.9)	-0.01 (1.4)	-0.01 (1.5)	-0.01 (1.6)	-0.02 (2.0)	-0.06 (6.3)	-0.01 (0.9)	0.00 (0.0)	0.00 (0.2)
FIRE	16.3	-0.15 (16.7)	-0.01 (1.6)	-0.01 (1.5)	-0.01 (0.8)	-0.01 (1.4)	-0.01 (1.1)	-0.09 (9.4)	0.00 (0.5)	0.00 (0.3)
Services	19.2	-0.04 (4.8)	-0.01 (1.4)	-0.03 (3.3)	-0.02 (2.5)	-0.02 (2.1)	-0.02 (1.8)	-0.01 (0.8)	0.07 (-7.4)	0.00 (0.4)
Gov	12.6	-0.01 (1.2)	0.00 (0.1)	0.00 (0.1)	0.00 (0.0)	0.00 (0.1)	0.00 (0.1)	0.00 (0.0)	0.00 (0.0)	-0.01 (0.8)
SUM	100	-0.91 (100)	-0.04 (4.4)	-0.37 (41.0)	-0.14 (15.7)	-0.15 (16.6)	-0.14 (15.8)	-0.10 (11.5)	0.06 (-7.1)	-0.02 (2.1)
1995-2000										
	Weighting		Contribution of:							
industry	percent	BLP	AMC	Md	Mn	TCU	Trade	FIRE	Services	Gov
AMC	8.8	-0.10 (5.6)	0.04 (-2.4)	-0.04 (2.2)	-0.02 (1.3)	-0.01 (0.6)	-0.06 (3.6)	-0.01 (0.6)	0.00 (-0.2)	0.00 (0.1)
Md	13.6	-0.74 (42.3)	-0.01 (0.3)	-0.58 (33.3)	-0.05 (2.6)	-0.02 (1.1)	-0.06 (3.5)	-0.01 (0.7)	-0.01 (0.7)	0.00 (0.1)
Mn	9.5	-0.21 (12.0)	-0.02 (1.1)	-0.02 (0.9)	-0.10 (5.9)	-0.02 (1.1)	-0.03 (1.9)	-0.01 (0.7)	-0.01 (0.3)	0.00 (0.1)
TCU	6.5	-0.10 (5.8)	-0.01 (0.3)	-0.01 (0.5)	-0.01 (0.4)	-0.05 (2.8)	-0.01 (0.7)	-0.01 (0.4)	-0.01 (0.6)	0.00 (0.1)
Trade	15.4	-0.27 (15.4)	-0.01 (0.4)	-0.01 (0.8)	-0.03 (1.9)	-0.02 (1.0)	-0.17 (9.9)	-0.02 (1.3)	0.00 (-0.3)	0.00 (0.2)
FIRE	15.7	-0.17 (9.7)	0.00 (-0.2)	-0.01 (0.4)	-0.01 (0.5)	-0.01 (0.5)	-0.01 (0.6)	-0.12 (7.1)	-0.01 (0.4)	-0.01 (0.3)
Services	20.0	-0.14 (8.3)	0.00 (0.1)	-0.03 (1.7)	-0.04 (2.1)	-0.02 (0.9)	-0.03 (1.7)	-0.02 (1.3)	0.01 (-0.4)	-0.01 (0.3)
Gov	10.6	-0.02 (0.9)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	0.00 (0.1)	0.00 (0.0)	0.00 (0.0)	0.00 (0.0)	-0.01 (0.8)
SUM	100	-1.75 (100.0)	0.01 (-0.4)	-0.70 (39.8)	-0.26 (14.8)	-0.14 (8.2)	-0.38 (22.0)	-0.21 (12.2)	-0.02 (1.2)	-0.03 (1.9)

Sources: Author's compilation based on BLS, *Input-output Transaction Tables (Real, 1983-2000)*, BLS, *Employment, Hours, and Earnings*, BEA, *Fixed Assets and Consumer Durables*, BEA, *Gross Product by Industry*

Notes: The unit is percentage. The figure in parentheses in is the share in "SUM" for BLP.

The sectors whose contribution (in "BLP" column) is larger than its contribution in terms of intermediate inputs (in "SUM" row) are: for 1987-1995, FIRE (16.7 percent vs. 11.5 percent) and Services (4.8 percent vs. -7.1 percent); and for 1995-2000, AMC (5.6 percent vs. -0.4 percent), Md (42.3 percent vs. 39.8 percent), Mn (15.1 percent vs. 15.7 percent), and Services (8.3 percent vs. 1.2 percent). These sectors benefit from other sectors in inter-sector spread of factor saving than they benefit other sectors. The increase of the number of the sectors that benefit from other sectors shows that factor saving was achieved by more sectors for 1995-2000 than for 1987-1995. For example, Md benefit from other sectors by only about 6 percent (34.9 minus 28.8 percent) for 1987-1995 but by about 9 percent (42.3 minus 33.3 percent) for 1995-2000. It is noticeable that the Services sector benefits from other sectors. While its contribution in "BLP" is 4.8 percent, its contribution in terms of Services-BLP is -7.1 percent for 1987-1995. The figures are 8.3 percent and 1.2 percent respectively for 1995-2000. This shows that even though the services sector did not contribute to other sectors in factor saving (in terms of Services-BLP), the sector benefit much from other sectors.

In order to examine the extent of the contribution of "sector-BLP" to factor saving of other sectors, we can count the sectors whose contribution (in "SUM" row) minus whose contribution to itself (each diagonal element) is larger than 5 percent (in parenthesized figures): for 1987-1995, Mn (15.7 minus 7.1 percent), TCU (16.6 minus 7.1), Trade (15.8 minus 6.3); for 1995-2000, Md (39.8 minus 33.3), Mn (14.8 minus 5.9), TCU (8.2 minus 2.8), Trade (22.2 minus 9.9), and FIRE (12.2 minus 1.3). The increase in the number of sectors between the two periods shows that the intersector spread of factor saving became more active over time. Except Md, the sectors mentioned above shows their contribution to other sectors via intermediate inputs is even larger than to itself, verifying their important role not only for intermediate inputs but also factor saving carried by intermediate inputs.

The contribution of TCU-BLP and Trade-BLP to factor saving of other sectors can be understood in a way that the role of TCU and Trade are to serve goods sectors for the delivery of goods to users (a division of labor) and their output is measured as the trade margin (the purchase price minus the producer price). They perform at large a partial operation of goods sectors. And so sectoral factor saving achieved in Trade can be easily translated into that of goods sectors; or their increase in output (measured as margin) and likely increase in factor saving may be due to the increase in output of goods sectors. Indeed, we can see that both sectors' contribution is concentrated to the goods sectors. That is, along each column of TCU and Trade, we can see that goods sectors benefit much from TCU or Trade.

Based on the explanations, a brief summary of sectors is made as follows. AMC shows a declining trend both in output (final demands) and in factor saving. Md and Mn contribute significantly to factor saving in terms of "sector-BLP". While Md inclines in share in W (based on constant dollars), Mn declines.[24] TCU and Trade became important not only in terms of W but also in terms of "sector-BLP." FIRE slightly declines in W but increase in its contribution as FIRE-BLP (Also recall that FIRE increases in share in current dollar measurements). Services sector increased in W and Service-BLP though the contribution of Service-BLP is a miniscule of aggregate factor saving and still the services sector benefit

[24] But in current dollars the share of Md declines. The price index tends to be lowered for Md's outputs.

much from other sectors by way of “sector-BLP.” Recall that the services sector grows much faster in current dollar measurement of output than in constant dollar measurement.

The interindustry relation in terms of factor saving and employment can be summarized as follows. From the data of this paper and from other sources of official data about the price and output of services-providing sectors, we can see that services contribute much to the creation of jobs at the expense of productivity or factor saving. On the other hand, the manufacturing sector contributes to productivity at the expense of employment. We can consider TCU and Trade as partial operations of manufacturing in the sense that they also contribute a lot to aggregate factor saving. The contraction of the manufacturing sector is well agreed upon by many studies (Guo and Planting, 2000; Blair and Wickoff, 1988). But in the context of inter-dependence of industries, there is a tendency of the spread of factor saving achieved by an industry. In particular, the services sector that contributes substantially to employment but does negatively to productivity benefits from the productivity gains transferred from the other sectors by way of intermediate inputs. This shows that there would be a division of labor in the economy in employment and productivity. Thus it makes us view the recent structural issue of the US economy regarding the uneven developments of sectors as an optimization process rather than as a pathway to perils of the economy.

5 Conclusion

This last section will recapitulate the three questions posed in section 1 introduction and provide answers based on the results of the analysis done so far.

The first question is concerned with the legitimacy of factor saving which is an I-O approach to productivity. Factor saving is defined as the decrease of factors required to meet a unit of final expenditures. On the other hand, productivity is defined as the amount of final expenditures produced by a unit factor. Thus in concept, both are not particularly different. Just the sign of the change is opposite; that is, factor saving as a negative entry is equivalent to productivity gain as a positive entry. But both measurements are distinguished by the methodological difference in this paper. While productivity analysis is based on the growth accounting by industry, factor saving is on interindustry linkage analysis extended to prime factors. The former method isolates each industry, but the latter comprehends the dynamics of the interactions of industries from the interindustry linkage analysis.

Productivity growth based on the growth accounting is well summarized in Table 3.5. The total factor productivity (TFP) growth rate of the US economy was 1.13 percent for 1995-2000 while labor productivity (LP) growth rate was 1.85 percent. Labor productivity growth estimation of this paper is not much different from that of Jorgenson, Ho, and Stiroh (2002; 2003, JHS shortly) but the productivity growth rate is about twice higher than that of JHS. This disparity is mostly due to the methodological difference in measuring capital input growth. While this paper measures capital input in terms of capital stock, JHS measure it in terms of capital service. Although the rate of productivity growth is overestimated, the time trend of productivity growth is not very different from JHS, characterized as the acceleration of growth for the late 1990s. For 1987-1995, TFP growth and LP growth was 0.61 and 1.09 percent respectively.

Differences in the contribution to TFP growth between this paper and JHS also show up in terms of the IT and Non-IT sector. The sectoral contribution to productivity growth in terms of IT and NonIT also answers the second question of the paper about the key sector driving innovation and economic growth. Section 3 estimates the contribution of the IT sector to productivity gain as 0.38 percent for 1987-1995 and 0.43 percent for 1995-2000. The level of the IT sector's contribution to productivity gain is similar to that of JHS. Thus that of the Non-IT sector's contribution is overestimated. This is again due to the overestimation of productivity growth rates of Non-IT sectors; since capital stocks are larger at Non-IT sectors than at IT sectors, Non-IT sectors benefit more from the underestimation of capital input growth. In spite of the difference in the degree of contributions, the intertemporal trend is again similar; that is, recently the Non-IT sectors' contribution increased, which implies that the productivity gains spread more widely across industries.

The results of factor saving (exactly Prime factor as the aggregation of labor and capital) based on the interindustry linkage analysis are well summarized in Table 4.4. The degree of factor saving was -1.75 percent for 1995-2000 which is much larger than the aforementioned TFP growth rate (1.13 percent). This accentuated degree of factor saving can be attributed first to the different weighting scheme in I-O analysis which is based on real dollar final demands and so is likely to favor industries that record a large extent of factor saving and a little increase (or even a fall) in prices. Second, the use of the domestic Leontief requirement matrix instead of the technological Leontief requirement matrix also contributes to the estimation of large factor saving because the domestic Leontief requirements tend to fall due to fast rising imports. However, in spite of differences in the level of growth rates, the degree of factor saving tended to accelerate for the recent period as that of productivity growth; for 1987-1995, the rate of factor saving was -0.91 percent.

The IT sector's contribution to factor saving was -0.16 percent and -0.34 percent. While the level of the contribution of the IT sector to factor saving is similar to or smaller than that of the IT sector to TFP growth since the rate of aggregate TFP growth is much larger than that of factor saving. Thus, the contribution of the IT sector to factor saving is much lower in relative sense than that of the IT sector to TFP growth. The (relatively) lowered contribution of the IT sector can be explained by the combination of two factors: the unfavorable weighting scheme for the IT sectors and the overstated economy-wide factor saving. In particular, the weight for D367 (semiconductors), which is the largest contributor to factor saving along with D357 (computers), in the I-O analysis (as the share of semiconductors in final expenditures) is much smaller in comparison with the Domar-weight assigned to the semiconductor industry in the growth accounting.

The explanation of the contribution of the IT and Non-IT sectors already addressed the second question. In terms of productivity in section 3, the IT sector contributed to productivity growth (or factor saving) exceeding its due in terms of the size of output and served as the engine of the US economy in the 1990s. Non-IT sectors which had been more or less stagnant in productivity showed a sign of recovery.

The effects of IT industries can also be revealed by their contribution to labor productivity by their position in capital inputs. In Table 3.5, the contribution of IT-capital density (IT capital per capita) to labor productivity has accelerated recently from 0.11 percent for 1987-1995 to 0.36 percent for 1995-2000. On the other hand, the contribution of NonIT capital density was rather stationary: 0.37 percent for 1987-1995 and 0.36 percent for 1995-2000. This tendency is also found in JHS. Considering that the size of IT capital is quite smaller than that of Non-IT capital, again IT capital contributed far more than its due.

The I-O framework in section 4 presents an alternative lens to view the influence of IT goods in terms of the exchange of IT-intermediate inputs. IT intermediate inputs carry less embodied prime factors over time. Thus by tracing the usage of IT-intermediate inputs, we can quantify the influence of IT-intermediate inputs to factor saving of other industries. According to Table 4.4, the contribution of IT intermediate inputs to factor saving was -0.20 percent for 1987-1995 and -0.41 percent for 1995-2000. This level is similar to the level of the contribution that the IT sectors achieved in their production activity. The benefits from IT intermediate inputs are well received by IT industries themselves and some Md (Durable Manufacturing) sectors that are akin to IT goods, in terms of supplier or user, such as machines (D35), electronics (D36), and instruments (D38). Among the services, it is particularly noticeable that FIRE sectors and I73 (Business services, including I737) receive benefits from IT intermediate inputs. Since the Financial sector (FIRE)'s important capital equipment is the integrated computer system, the sector needs a large amount of IT goods and services.

Finally, the I-O analysis addresses the third question concerning the inter-sector relation of the US economy focusing on the manufacturing sectors and services sectors. The contraction of the manufacturing sector (in current dollars) is perceived as the result of outsourcing and regarded as undesirable. While outsourcing of manufacturing in the international context can be taken as a serious problem in relation with domestic jobs, domestic outsourcing which refers to allocating some part of inner operation of manufacturing to external establishments such as trade, transportation (as a major part of TCU), and other business services can be understood as a result of the maximization of economic efficiency. A justification of domestic outsourcing is provided in terms of factor saving in section 4 and is summarized in Table 4.5. Unlike old days, trade and transportation are quite specialized divisions and they exploit the scale of economies based on a huge and sophisticated global network. Thus we can see the expansion of the two sectors, trade and transportation, as a result of the industries' efforts to seeking for economies of scale and can regard them as part of manufacturing in a broad sense. Indeed, their outputs are measured as the margin of trade and transportation generated from the delivery of goods. Another domestic outsourcing is related to management operation, which was before an integral part of manufacturing. The outsourcing of management such as personnel managements and secretarial jobs are quite common. In this sense, recent statistics and classification schemes of industries have been revised to reflect such a trend. In any case, this domestic outsourcing is targeted for productivity gain on the side of the manufacturing sector.

But the services sector (particularly sector I as denoted in the SIC) does not afford many options in productivity gain. Besides the measurement issue involved, it is intuitively true that the services sector in general depends a lot on labor due to its nature of business and so serves as a power engine of job creation. Low productivity of the services sector is consistent with its low compensation for labor.

If we observe each sector in isolation, then the theory that the US manufacturing sector loses high-paying jobs through overseas outsourcing and the Services sector absorbs only surplus workers into low-paying jobs may sound attractive. However, if we analyze the development of the US industries in an inter-industry context, we get a different insight on the same phenomenon. As shown in the paper, by way of supplying cheaper and better intermediate commodities, the manufacturing sector along with the trade and the transportation sector contributed substantially to factor saving of other industries. In other words, we are purchasing services that embody much less amount of factors than before. Thus in an inter-industry context, consumers can enjoy cheaper and better commodities. The hypothesis that there may be a division of labor between manufacturing and services by exchanging job creation and productivity holds valid.

From the perspective of the network of industries, we have in our hands comprehensive analytical tools about technological progress and policy implications to expedite it. If particular technology needs more cooperative relations with other existing industries or institutions or even a new institutional environment that can take a full advantage of it, then the analytical tools to figure out all the related effects are more desired. This thesis has shown that IT industries have a strong potential to serve as a cluster of industries.

In fact, the necessary market and institutional environment for IT are not up to business only. For example, the more accessible and necessary the Internet is, the more innovations can emerge that make the

Internet a more useful and convenient tool; the more useful and necessary the Internet is, the more people may be willing to pay for it; the more people are hooked up to the Internet, the cheaper the costs of any Internet service might be. Such a virtuous cycle may be brought about within the market mechanism. But in many cases, the costs to build the network infrastructure are too huge for individual firms or industries. Proper policies that take into account the network aspect of IT can make the progress faster and more robust, reducing the costs of investments. If they find a serious bottleneck that blocks the virtuous cycle, then policy makers can introduce new laws, tax breaks, or government expenditure plans for social and physical infrastructure, and so on. Despite many remarkable innovations that have already been made in the Internet in terms of speed, contents, and connection devices, the majority of households in the US are still stuck to very slow dial-up connections to the Internet which renders useless all the innovative efforts and penalizes innovative firms. This thesis depicts a broad picture about IT from the inter-industry perspective and helps to justify the need for policy initiatives that can fully develop IT potentials.

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Appendix Table The 62-industry classification scheme

	62-codes	62-codes	Descriptions
1	A		Agriculture, forestry, and fishing
2	B10		Metal mining
3	B12		Coal mining
4	B13		Oil and gas extraction
5	B14		Nonmetallic minerals, except fuels
6	C		Construction
7	D24		Lumber and wood products
8	D25		Furniture and fixtures
9	D32		Stone, clay, and glass products
10	D33		Primary metal industries
11	D34		Fabricated metal products
12	D357		Computer and office equipment
13	D35R		D35 net D357, Other Industrial machinery and equipment
14	D365		Household audio and video equipment
15	D366		Communication equipment
16	D367		Electronic components and accessories
17	D36R		D36 net D365-7, Other Electronic and other electric equipment
18	D381,2,6,7	D381,6,7; D382	Instruments
19	D384,5		Medical equipment
20	D371		Motor vehicles and equipment
21	D37R		Other transportation equipment
22	D39		Miscellaneous manufacturing industries
23	D20		Food and kindred products
24	D21		Tobacco products
25	D22,3		Textile mill products (D22); Apparel and other textile products (D23)
26	D31		Leather and leather products
27	D26		Paper and allied products
28	D27	D271,2;D273;D274-9	Printing and publication
29	D28		Chemicals and allied products
30	D291		Petroleum refining
31	D29R		Miscellaneous petroleum and coal products (D295, D299)
32	D30		Rubber and miscellaneous plastics products
33	EtransX46		Transportation, excluding Pipelines (E46)
34	E48x483		Telephone and telegraph (E481,E482,E489); Cable and pay television services (E484)
35	E483		Radio and television
36	E46,491-3		Pipelines (E46); Electric and Gas Utilities (E491-3)
37	E494-7		Water and sanitation
38	F		Wholesale trade
39	G	G58;G, excl. 58	Retail trade
40	H60		Depository institutions
41	H61,67		Nondepository; holding and investment offices
42	H62		Security and commodity brokers
43	H63		Insurance carriers
44	H64		Insurance agents, brokers, and service
45	H65	S135;S136;H65	Real Estate and Lessors
46	I70		Hotels and other lodging places
47	I72		Personal services
48	I737		Computer Programming, Data processing, and computer related services
49	I73R		Other Business Services
50	I75		Auto repair, services, and parking
51	I76		Miscellaneous repair services
52	I78		Motion pictures
53	I79		Amusement and recreation services
54	I80		Health services
55	I81		Legal services
56	I82		Educational services
57	I83		Social services
58	I84,86		Museums, botanical and zoological gardens (I84); Membership organizations (I86)
59	I87,89		Engineering, Accounting, Research, Management, And Related Services (I87); other services (I89)
60	I88		Private households
61	J		Government administration
62	Gbus	S178;S179;S182;S183;S184;S189	Gbus
I-O specific sectors			
63	S800000	S189	Noncomparable imports
64	S810000	S190	Scrap, used and secondhand goods
65	S830001	S191	Rest of the world industry
66	S850000	S192	Inventory valuation adjustment

Source: BLS I-O transaction tables (1983-2000); BEA Gross Product by Industry; BEA Fixed Assets and Consumer Durables
Note for selected industries;
(1) A047 (veteneray services) moved to I80 and A078 (landscape and horticuture) moved to I87,89;
(12) and (13) has correpending data in GPI and FAI only in aggregated to D35;
(14) to (17) has the corresponding data in GPI and FAI only in aggregation of D36;
(30) D291 and (31) D29R are not independently not available from the BEA's GPI and FAI;
(34) D48x483 and (35) D483 are not independently available in the GPI (GPI's aggregates broadcasting E483 and cable TV (E484) but are so in the FAI;
(39) Pipelines (E46) moved to E491-3 as it carries natural gas;
(45), (62)-(66) not classified in the SIC, the code (starting with "S") denotes simply the order in the BLS I-O;
(45) S135 (royalty) roughly in the SIC 67, but better be here in the IO tables;
(58), (59), and (60) have a corrsponding data set in FAI only in aggregation;
(63)-(66) included as only special commodities in IO tables.