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Does Information Technology Raise Japan's Productivity?

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Abstract

A standard growth accounting exercise indicates that, after Japan's "lost decade," its overall total-factor-productivity (TFP) growth has increased notably since 2000. This productivity revival has been limited, however, to information technology (IT) *production*—has not been a broad-based productivity acceleration like that seen in the United States after the mid-1990s. This paper examines the relationship between IT and productivity gains by employing the "augmented" growth accounting framework for Japanese industry-level data from 1975 through 2005. In particular, we estimate "purified" technology change at industry level by accounting for cyclical mismeasurement of inputs. We find that the post-2000 increase in overall TFP growth does indeed appear to arise from an increase in technological change. Furthermore, the pickup in technology growth has occurred not only in the *production* of IT but also in the industries that *use* IT intensively. Our results suggest the possibility that stories of IT as a general purpose technology (GPT) could apply to Japan as well as to the United States.

Key Words: Total Factor Productivity, Information Technology, Japanese Economy

JEL classification: D24, E23, E32, O47, O53

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1. Introduction

After the mid-1990s, labor and total factor productivity (TFP) accelerated sharply in the United States, but not in Japan. A growing body of research has explored the robustness of the U.S. productivity acceleration; it generally concludes that information technology (IT) was a key driver of the U.S. acceleration.[1] By contrast, in terms of cross-country productivity evidence, Gust and Marquez (2002), among others, document that Japan (and many European countries) did not experience such IT-driven pickup in productivity growth in the late 1990s. Why did Japan not benefit from IT, even though it had access to the same technology as the United States did? To the extent that one expects ideas—especially when embedded in easily traded physical capital—to diffuse easily across borders, the lack of productivity acceleration in Japan has puzzled many economists and policymakers.

This paper sheds lights on the relationship between IT and productivity gains by employing the "augmented" growth accounting framework for Japanese industry-level data from 1975 through 2005. In particular, we estimate "purified" technology change at industry level by controlling for non-technological cyclical factors: varying utilization of capital and labor and non-constant returns and imperfect competition.[2] We then examine the post-1995 performance of purified technology for the individual industries that either *produce* IT, *use* IT, or are relatively isolated from the IT revolution. Through this type of disaggregated analysis, we seek to understand the impact of IT from the bottom up, rather than a top-down decomposition of aggregate data.[3]

Why do we care about the non-technological cyclical components of measured productivity? First, compared to the U.S. economy, which has shown relatively stable

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[1] See Jorgenson and Stiroh (2000), Jorgenson (2001) and Oliner and Sichel (2000) for early discussions of the role of IT in U.S. productivity acceleration.

[2] Kawamoto (2004) constructs a measure of purifed technology for Japanese industries over the years 1973-1998 by using the aumented growth accounting framework *a la* Basu, Fernald, and Shapiro (2001).

[3] For the United States, Stiroh (2002), Basu and Fernald (2007) and Bosworth and Triplett (2007), among others, examine the impact of IT on the post-1995 productivity acceleration by using detailed industry-level data. Oliner, Sichel, and Stiroh (2007) extend the standard growth accounting at industry

macroeconomic performance since the mid-1990s, Japan's economy experienced substantial business-cycle fluctuations during the 1990s and early 2000s. Following the collapse of the "asset price bubble" in the early 1990, Japanese growth rates steadily deteriorated through the first half of the decade, rebounded briefly at mid-decade, and fell again during the severe financial crisis in the last half of the decade. Since the IT boom and bust cycle at the beginning of the 2000s, the Japanese economy has enjoyed a long steady expansion from early 2002 forward. Thus, in contrast with the United States, cyclical mismeasurement of inputs plays a potentially important role in variations in Japan's productivity growth, and thereby masks the structural link between IT and productivity gains.[4] The second reason, which is closely related to the first, is that cross-industry comovements in Japan have notably declined in recent years, i.e., cross-industry heterogeneity in cyclical fluctuations is becoming stronger than before.[5] Thus, in seeking a structural link between IT and productivity from the variations in industry-level data, it is desirable to purge measured productivity of *industry-specific* transitory factors.

Looking at the result from traditional growth accounting, we first show that after the "lost decade" of sluggish growth, Japan's overall TFP growth shows a pickup since 2000. Furthermore, we find that the post-2000 acceleration in measured TFP was narrowly concentrated in IT *production*—not broad-based as in the U.S. productivity acceleration after the mid-1990s. This result is broadly consistent with recent studies on Japan's productivity. For example, based on the EU-KLEMS industry-level data for 1980-2004, Fukao and Miyagawa (2007) report that Japan had a similar TFP acceleration as the U.S. in IT *producing* sectors, but failed to achieve such a pickup in the sectors that *use* IT intensively. Jorgenson and Motohashi (2005), using Japanese aggregate data from 1975 through 2003 (which is adjusted to conform to

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level to account for time-varying utilization of inputs, adjustment costs of capital, and intangibles.

[4] See Basu and Fernald (2001) for reasons why measured productivity is procyclical over the business cycle.

[5] See Nishimura (2007) and Osada and Kawamoto (2007) for a variety of empirical evidence on the recent decline in output comovements across Japanese industries. For example, Osada and Kawamoto (2007) report that the average cross-industry correlation coefficient for manufacturing production used to be around 0.5 until the late 1990s, but has currently dropped to 0.1.

U.S. definitions), found that TFP for IT-goods sector substantially increased after 1995, while TFP for Non-IT-goods sector lagged far behind the United States.[6]

A somewhat different picture emerges, however, if we undertake the "augmented" growth accounting to account for cyclical mismeasurement of inputs. We first confirm that the post-2000 increase in overall TFP growth does appear to arise from an increase in technological change, making it unlikely that business cycle considerations hold down measured productivity. Even more importantly, our measure of "purified" technology indicates that the resurgence in Japan's technology growth in the 2000s has gone beyond the *production* of IT and has been based, at least in part, on increases in technology growth for the IT-*using* industries. Even when we focus on arguably "well-measured" industries (Nordhaus 2002; Basu and Fernald 2007), we still find a notable technology acceleration in IT-*using* industries.[7] Our results from augmented growth accounting thus suggest that information technology has been a key driver of the pickup in productivity growth in the 2000s.

Why do the two growth accountings yield different sectoral patterns in productivity or technology? The key to this difference is that the IT-using sector—comprised mainly of non-manufacturing industries—has shown weaker growth on the whole since 2000 than has the IT-*producing* sector, which consists of several process-manufacturing industries. Figure 1 presents annual growth rates of real value added for IT-producing and IT-using sectors in Japan. Clearly, the IT-using sector has relatively slow growth in the 2000s compared to the IT producing sector, because the recent cyclical expansions have been mainly driven not by an increase in domestic demand but by an increase in exports abroad. As a result, ignoring cyclical variations that differ substantially across the sectors tends to produce an underestimation of the

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[6] Jorgenson and Nomura (2005) also document that IT-manufacturing industries show much stronger TFP growth than IT-using industries do over the years 1995-2000, using the KEO data by disaggregated industries.

[7] Our industry-level results are consistent with firm-level evidence for an important role of the use of IT to affect measured productivity in Japan. For example, Motohashi (2007) finds the positive impact of information network use on productivity growth, using firm-level data for Japanese manufacturing and distribution sectors.

contribution of the IT-using sector to overall productivity growth.

Our finding—the pickup in technology occurred in industries that used, not merely in industries that produced, IT—has important implications for the role of information technology, because it suggests the possibility that stories of IT as a general purpose technology (GPT) could apply to Japan as well as to the United States.[8] GPT stories emphasize that reaping the full benefit of IT requires firms to accumulate a stock of intangible complementary capital through learning, reorganization, and the like.[9] Since intangible capital accumulation is a slow process, the benefits of the IT revolution show up in the IT-using sector with significant lags. Indeed, our sectoral results seem to be broadly consistent with this GPT view: Technology growth in Japan's IT-using sector has picked up with long lags of 5 to 10 years, following the post-1995 IT investment boom that was boosted by the advent of "Windows 95." Although much more work remains to be done to assess the plausibility of GPT hypothesis in Japan—for example, measuring intangible capital directly based on Japanese data (see Fukao, Hamagata, Miyagawa, and Tonogi 2007)—we believe that our results have taken a modest step toward deeper understanding of the role of information technology on productivity growth.

The organization of the paper is as follows. We present industry-level results from standard growth accounting in Section 2, and show that the post-2000 pickup in Japan's TFP has been narrowly located in the IT production sector. We then discuss our framework for purifying measured productivity in Section 3, and describe our estimation methods in Section 4. Empirical results from our augmented growth accounting are presented in Section 5. Conclusions with caveats are offered in Section 6.

[8] Basu, Fernald, Oulton, and Srinivasan (2003) and their subsequent work (Basu and Fernald 2007) provide a simple model of IT as a general purpose technology, along with the U.S. industry-level evidence in support of the GPT view.

[9] See, for example, Bresnahan, Brynjolfsson, and Hitt (2002) and Brynjolfsson and Hitt (2003) for firm-level evidence on the importance of complementary investment to reap the benefit of IT.

2. Results from Standard Growth Accounting

We begin with results from standard growth accounting to establish some stylized facts. We focus on disaggregated, industry-level measures of total factor productivity. We first describe our dataset and measurement method briefly, and then discuss results.

2.1 *Data and Measurement*

We constructed a 19-industry annual dataset covering Japan's private economy as a whole, mainly based on industry-level national accounts data. This dataset runs from 1975 to 2005 and is disaggregated at the two-digit SIC level within manufacturing and the one-digit level outside manufacturing. See Table 1 for the list of industries.[10] For industry gross output, intermediate-input use and labor input, we use the industry-level national accounts from the Cabinet Office.[11] We construct series of *real* gross output and intermediate input, bridging (i) 68SNA fixed-based series evaluated at constant prices in 1990 for the years 1975-1990, (ii) 93SNA fixed-based series evaluated at constant prices in 1995 for the years 1990-1996, and (iii) 93SNA chain-linked series for the years 1996-2006. As a measure of industry labor input, we use the product of the number of employed persons and hours worked per employee.[12] Note that we do not have industry measures of labor quality, only raw hours.

The barrier to measuring total factor productivity for Japanese industries is lack of reliable official data on capital input or capital stock. The Cabinet Office publishes disaggregated industry-level data on *gross* capital stock (Gross Capital Stock of Private Enterprises), which regards only retirement as "depreciation." For our purposes, however, we

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[10] Among the 22 industries in the national accounts, we focus on the 19 non-farm, non-mining private industries, i.e., exclude agriculture, mining and real estate. Real estate is excluded since its output includes the imputed housing rent.

[11] These data are available from Supporting Table 2 (Gross Domestic Product and Factor Income classified by Economic Activities) and Table 3 (Employed Persons, Employees and Hours Worked classified by Economic Activities) in the *Annual Report on National Accounts* published by the Cabinet Office.

[12] The national accounts data on hours worked per employee only begin in 1980. For 1975-1980, we use total hours worked from *Monthly Labor Survey* published by the Ministry of Health, Labor and Welfare. The detailed industry definitions in the labor survey differ a bit from those in the national accounts. Thus we aggregate industry hours worked in the Monthy Labor Survey to the level in the national accounts, where definitions are reasonably close (See the Appendix Table 1).

need data on *net* capital stock that appropriately account for "economic depreciation," including wear and tear. Thus we use estimates of service flow of net capital stock from the EU KLEMS database, which are currently available from 1970 to 2005.[13] It should be noted that the EU KLEMS database constructs data on net capital stock by aggregating different types of tangible assets, each of which in turn is constructed by using a constant depreciation rate for the corresponding asset from the Bureau of Economic Analysis in the United States.[14] There is no guarantee, however, that Japan's depreciation rates for tangible assets are generally equal to those in the United States, and thereby we have to bear in mind possible measurement errors for capital input.

Several comments are in order. First, we estimate capital share as a residual (one minus the intermediate share and labor share), following the original work of Solow (1957). Second, consistent with the standard practice in the productivity literature, we allow the revenue shares to vary year by year, using average shares from adjacent periods. Third, we present industry TFP in a value-added basis below, since aggregate TFP is basically a value-added concept. To do so, we first calculate gross-output residuals with explicit accounting for intermediate use, and then convert these gross-output TFP to value-added terms by dividing through by one minus intermediate-input share. Thus, by controlling for cross-industry differences in intermediate-input intensity, our industry measures of TFP are "scaled" to be comparable to the aggregate measure of TFP. Finally, for aggregating industry-level TFP into an economy-wide index, we use the industry's share in aggregate value added.[15] As described

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[13] EU KLEMS database includes industry-level measures of output and inputs of IT capital, Non-IT capital, labor, and materials for European countries, Japan, and the United States from 1970 to 2005. Kyoji Fukao and Tsutomu Miyagawa are major contirubutors to constuctuing Japan's data. For a detailed diucussion on the EU KLEMS database, see Timmer et al. (2007). Detailed industry definitions in the EU KLEMS differ from those in the national accounts. Thus we aggregate industry's capital input in the EU KLEMS to a level in the national accounts, where definitions are reasonably close (See the Appendix Table 2).

[14] This is because there is no reliable, detailed study on how different types of tangible assets depreciate over time in the Japanese economy. See Fukao et al. (2006, Section 2) for a complete description of measuring net capital stock for Japanese industries in the EU KLEMS database.

[15] Our aggregate TFP growth is equal to a "Domar-weighted" sum of industry gross-output TFP growth. See Basu and Fernald (2001).

before, our data on *real* output for 1975-1996 are *fixed-based* series evaluated at constant base-year prices, whereas those for 1996-2006 are *chain-linked* series evaluated at current prices. Thus we use the industry's share in aggregate *real* value added for 1975-1996 and the share in aggregate *nominal* value added for 1996-2006.

2.2 *Results*

Table 2 provides standard estimates of TFP for various aggregates, including the 1-digit industry level. The first two columns show TFP growth rates in a value-added basis, averaged over the years 1990-2000 and 2000-2005. The next two columns show the acceleration from 1990-2000 to 2000-2005 and the sector's contribution to the overall acceleration. The final column shows the sector's nominal share of aggregate value-added averaged over 1990-2005. Focusing first on the entire private-sector economy, the average growth rate of TFP over 2000-2005 is 0.5 percent, compared to -0.1 percent for 1990-2000. Thus, after the lost decade, Japan's TFP growth shows a revival since 2000.

Next we examine the post-2000 productivity performance of the individual industries that either produce IT, use IT, or are relatively isolated from the IT revolution. If information technology is a driving force behind faster productivity growth in the 2000s, then industries that produce or use IT intensively should show larger productivity gains. For this purpose, we group 19 industries into the following three sectors: IT *producing*; IT *using*; and other industries. First, consistent with the standard practice in the literature, we identify the three manufacturing industries as IT *producing*: machinery; electrical machinery, equipment and supplies; and precision instruments. Second, following the spirits of Stiroh (2002) and Oliner, Sichel, and Stiroh (2007), we identify the industries as IT *using*, if the IT-capital income share, i.e., the ratio of profits attributable to IT capital to nominal value added, averaged over 1990-2005 is above the median across all the industries.[16] Consequently, the "IT-using sector" except the IT-producing industries includes the following six industries: chemicals, wholesale and retail

[16] Under the standard neoclassical assumption, the income share of input is equal to its output elasticity,

trade, finance and insurance, utilities, transport and communications, and service activities. Finally, all remaining industries are labeled “other industries” (see Table 1 for the industry list). Here we use industry-level data on IT capital income from the EU KLEMS database.[17] Figure 2 presents IT-capital income share for the three sectors. The IT-using sector shows a marked increase in IT-capital share since the mid-1990s, while the share for others has remained at a fairly low level until recently.

It is clear that, in our dataset, the post-2000 increase in measured TFP has been centered in process manufacturing, particularly the IT-*producing* sector (fourth line from bottom). This sector shows a remarkable acceleration in TFP growth, from 3.4 percent per year in the 1990s to 7.0 percent in the 2000s. This result appears to be uncontroversial, since in computers, telecommunications, and other areas of IT goods, technology has been improving at a rapid rate, a reflection of the advent of IT revolution. Figure 3 plots *cumulated* year-to-year TFP changes after 1995, i.e., post-1995 *levels* of aggregate TFP, with the sector’s direct contribution. Clearly, the recent productivity pickup has occurred primarily within IT *production*.

By contrast, the IT-*using* sector, which accounts for two-thirds of private-sector GDP, has shown little acceleration in TFP growth since 2000. It posted annual average TFP growth of 0.3 percent over 2000-2005, sustaining about the same pace as that seen in the 1990s. Nordhaus (2002) and Basu, Fernald, Oulton, and Srinivasan (2003) adopt a strategy of focusing on “well measured” (or at least, “better measured”) industries of the economy, because real output in many non-manufacturing industries is poorly measured. For example, for health-care services, hedonic issues are notoriously difficult. Similarly, how to measure the nominal and real output of financial services is a highly controversial issue. Motivated by this consideration, when we focus on the “well-measured” IT-using industries (second line from bottom), our basic result

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and thus the IT-using indsutries here have the higher contribution of IT capital to output.

[17] Detailed industry definitions in the EU KLEMS differ from those in the national accounts. Thus we aggregate industry’s IT-capital income in the EU KLEMS to a level in the national accounts, where

remains unchanged: well-measured IT-using industries show little acceleration in TFP growth rates after 2000.[18]

This cross-industry pattern—the post-2000 acceleration in measured TFP has been narrowly located in IT *production*, not broad-based as in the United States—is broadly consistent with recent studies on Japan's productivity. For example, based on the EU-KLEMS industry-level data for 1980-2004, Fukao and Miyagawa (2007) report that Japan had a similar TFP acceleration as the U.S. in IT *producing* sectors, but failed to achieve such a pickup in the sectors that *use* IT intensively. Jorgenson and Motohashi (2005), using Japanese aggregate data from 1975 through 2003 (which is adjusted to conform to U.S. definitions), also found that TFP for IT-goods sector substantially increased after 1995, while TFP for Non-IT-goods sector lagged far behind the United States.

Caution is needed, however, in interpreting this finding, because measured productivity is highly procyclical. Figure 4 presents annual percent changes in TFP and real GDP for both the IT-producing and IT-using sectors. Consistent with the widespread observations, both sectors show highly positive correlation between TFP and output growth over the sample period. Furthermore, as noted earlier in Figure 1, the IT-using sector has relatively slow growth in the 2000s compared to the IT-producing sector, since the recent cyclical expansions have been driven mainly by an increase in exports abroad, which in turn boosts the latter disproportionately. Hence, we need to cleanse the measured productivity of non-technological cyclical factors at a disaggregated industry level to assess the robustness of the sectoral patterns found here.

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definitions are reasonably close. See the Appendix Table 2.

[18] Other industries (bottom line in Table 2), which are isolated from the IT revolution, show an acceleration in TFP growth in the 2000s. However, annual average growth rate of TFP in these industries

3. Analytical Framework for Estimating Purified Technology

This section outlines the mechanics of correcting measured total factor productivity for cyclical factors. We estimate technical change at a disaggregated industry level, allowing for non-constant returns to scale and variations in the utilization of capital and labor. Our augmented growth accounting modifies Basu, Fernald, and Shapiro (2001) and Basu, Fernald, and Kimball (2006), which in turn extend the Solow-Hall production function approach.

We assume that the representative firm in each industry has a production function for gross output:

$$Y_i = F^i\left(U_i K_i, E_i H_i N_i, M_i, Z_i\right).$$

The firm produces gross output Y_i, using the capital stock K_i, employees N_i, and intermediate inputs of energy and materials M_i. To have a coherent model of variable factor utilization, we (implicitly) assume that the capital stock and number of employees are quasi-fixed, so that changing their levels involves adjustment costs. Yet, the firm may vary the intensity with which it uses these quasi-fixed inputs: H_i is hours worked per employee; E_i is the effort of each worker; and U_i is the capital utilization rate (i.e., capital's workweek). Total labor input L_i is the product $E_i H_i N_i$. The firm's production function F^i is assumed to be (locally) homogeneous of arbitrary degree γ_i in total inputs. Z_i indexes gross output-augmenting technology. We adopt the gross-output rather than value-added production function because the former is desirable when estimating production function with increasing returns to scale and imperfect competition (see Basu and Fernald, 2001).

We define c_{Ji} as the share of costs for input *J* in total cost and dj as its logarithmic growth rate ($d \log J$). The log-linearization of the production function and the standard first-order conditions from cost minimization imply

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actually remains *negative* in the 2000s, pulling down the overall productivity growth.

$$
\begin{aligned}
dy_i &= \left(\frac{F_1 UK}{F}\right)_i (du_i + dk_i) + \left(\frac{F_2 EHN}{F}\right)_i (de_i + dh_i + dn_i) + \left(\frac{F_3 M}{F}\right)_i dm_i + dz_i \\
&= \gamma_i \left[c_{Ki} (du_i + dk_i) + c_{Li} (de_i + dh_i + dn_i) + c_{Mi} dm_i \right] + dz_i .
\end{aligned} \tag{1}
$$

In practice, we assume that returns to scale γ_i do not vary over time. However, consistent with the standard practice in the productivity literature, we allow the cost shares to vary year by year.[19] To construct the cost shares c_{Ji}, one generally needs to calculate the rental cost of capital. Following Basu, Fernald, and Shapiro (2001) and many others, we avoid this difficulty by assuming that firms make zero economic profits in the steady state, so that we take total cost as approximately equal to total revenue and estimate capital's share as a residual, as in Solow (1957).

Lack of observable counterparts to changes in capital utilization and labor effort is the barrier to estimating equation (1). We begin by deriving a proxy for capital utilization.[20] Following the spirits of Burnside, Eichenbaum, and Rebelo (1995) and Basu (1996), we assume the Leontief-type complementarity, i.e., a zero elasticity of substitution between intermediate-goods usage and *effective* capital services. This Leontief form appears to provide a good approximation to the structure of production, especially for the manufacturing and trade sectors, since movements in materials track movements in gross output very closely (Basu 1996). Changes in capital utilization are then given by

$$
du_i = dm_i - dk_i . \tag{2}
$$

The advantage of this specification is that we do not need data on capital stock or on the rental cost of capital, since in Japan no reliable, official data on net capital stock exist that are economically meaningful. The cost, of course, is that it imposes a relatively strong assumption for the firm's structure of production.

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[19] Our results remain virtually identical using time-invariant, sample-average shares.

[20] In Japan, the Ministry of Economy, Trade, and Industry (METI) publishes an index of "capacity utilization" for manufacturing industries. Note, however, that this is not necessarily an economically meaningful measure of "capital utilization." Indeed, METI's capacity utilization measures actual output

We next derive an expression for labor effort in terms of an observable variable. Basu, Fernald, and Kimball (2006) show that hours per worker can be used as a proxy for labor effort under the plausible assumption that when firms increase labor utilization, they must compensate workers for the increased disutility of effort with a higher wage. Their basic idea is that cost-minimizing firms will push on each utilization margin—hours of workers and effort—so as to equalize the cost of using each margin of adjustment. Specifically, Basu, Fernald, and Kimball (2006) derive the following expression:

$$de_i = \zeta_i dh_i, \tag{3}$$

where ζ_i is the elasticity of effort with respect to hours, evaluated at the steady state.

Combining equation (1), (2) and (3), we obtain the following estimating equation:

$$\begin{aligned} dy_i &= \gamma_i \left[c_{Li} \left(dh_i + dn_i \right) + \left(c_{Ki} + c_{Mi} \right) dm_i \right] + \gamma_i \zeta_i c_{Li} dh_i + dz_i \\ &= \gamma_i dx_i + \beta_i dh_i + dz_i \end{aligned} \tag{4}$$

where $dx_i = c_{Li} \left(dh_i + dn_i \right) + \left(c_{Ki} + c_{Mi} \right) dm_i$ and $\beta_i \equiv \gamma_i \zeta_i c_{Li}$. This specification controls for both labor effort and capital utilization, as well as non-constant returns to scale and imperfect competition. We interpret the resulting residual dz_i as representing "true" technical change for each industry.

4. Estimation

4.1 *Data and Estimation Method*

We begin by briefly describing the data used in estimation. Basically, we use the same industry data we used in Section 2. Note that we do not need capital-input data to estimate equation (4), since we replace the growth rate of *effective* capital input with that of materials usage. For the dh_i term for labor effort adjustment, we use the annual growth rate of industry's "nonscheduled hours" per worker, which is taken from the establishment survey conducted by

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relative to potential output rather than capital's workweek.

the Ministry of Health, Labor and Welfare. In this survey, the total number of hours per worker is divided into "scheduled" working hours and "nonscheduled" working hours.[21] Reflecting declines in scheduled hours—most of which are enforced by government fiat—total working hours have a low-frequency downward trend unrelated to cyclical fluctuations. Since our measure for labor effort is the cyclical change in hours per worker, we take the growth rate of nonscheduled hours as the dh_i term. However, using a series of log total working hours detrended with the Hodrick-Prescott (HP) filter does not affect our basic results.

Following Basu, Fernald, and Shapiro (2001) and Basu, Fernald, and Kimball (2006), we group all 19 industries into four broad sectors: processing manufacturing (eight industries), basic materials manufacturing (five industries), non-manufacturing (three industries), and semi-public (three industries).[22] See Table 1 for our grouping of industries. For the first three groups, we seek to obtain purified technology residuals by estimating equation (4). For the last semi-public industries that generally appear to be uncorrelated with business cycle fluctuations, we simply use uncorrected TFP growth as our measure of technological change—i.e., we make no correction for either time-varying utilization or non-constant returns to scale.

To conserve parameters, we follow Basu, Fernald, and Kimball (2006) and Alexius and Carlsson (2005) by constraining the labor-effort coefficient β_i to be equal across industries within the group. Thus, for each group, we estimate the system of the following equation:

$$dy_i = c_i + \gamma_i dx_i + \beta dh_i + dz_i. \tag{5}$$

We allow the returns to scale parameter γ_i to differ within a group, following Burnside (1996),

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[21] Scheduled hours are defined as the number of hours between the starting and ending time that are determined by the work regulations of the establishment, whereas nonscheduled hours are defined as the number of hours for which employees work early in the morning, overtime in the evening, and on a day off.

[22] The semi-public group includes utilities, transportation and communication, and service industries. In our dataset, pre-privatized Japan National Railway, Nippon Telegraph and Telephone (NTT), and Japan's Postal Service all belong to transportation and communication. Service industry in the national accounts includes community and social service activities such as medical and nursing care.

who emphasizes the significant heterogeneity of this parameter across industries. The estimated equations also include industry-specific constants c_i to allow for differences in secular technology growth rates across industries, i.e., the estimated equations have industry-level fixed effects. Given the widespread productivity slowdown in the 1990s, we experiment with including a 1990s decadal dummy variable in the industry constant for each group, but its coefficient is not statistically significant for all groups.[23] The residual dz_i plus the industry-specific constant c_i is our estimate of the period-by-period growth in technology for industry i.

Owing to the simultaneous determination of inputs and technology, we estimate each system by using standard 3SLS with instrumental variables. Valid instruments need to be uncorrelated with technology shocks and correlated with the inputs and hours growth on the right-hand side of the equation. We use the following Hall-Ramey-style, demand-side variables as instruments:

1. the growth rate of the import yen-price of petroleum deflated by the domestic Corporate Goods Price Index;
2. the growth rate of real government consumption from the national accounts;
3. the growth rate of real gross capital formation of public sectors from the national accounts.

We use once-lagged values of oil price change and current and once-lagged values of the other instruments. These instruments appear to be adequate in terms of first-stage fit. The qualitative features of the following results are quite robust to different combinations and lags of the instruments.

[23] We constrain the decadal-dummy coefficients to be equal within each group.

4.2 *Parameter Estimates*

Table 3A gives the estimates of the returns to scale and labor utilization parameters from equation (5). The returns to scale parameters γ_i are precisely estimated for almost all industries, except for a few industries such as petroleum and coal products and finance and insurance. For every group, the average returns-to-scale estimate is very close to one, although there is significant heterogeneity across industries. These estimates confirm the recent finding that widespread increasing returns to scale are generally absent in Japanese industry data.[24]

For the labor-effort-correction parameter β, processing manufacturing and basic materials manufacturing show positive and statistically significant estimates, both of which indicate the importance of variable labor utilization.[25] The estimate for non-manufacturing, however, is negative, and is not economically meaningful. We thus omit the labor-effort-correction term from equation (5) for the non-manufacturing group, and use the resulting estimated residuals as our measure of technology. (Omitting the term has little effect on the returns-to-scale estimates listed in Table 3.)

Table 3B shows the estimation results when constraining returns to scale to equal one for all industries within each group, but allowing for labor utilization effects. Again, both processing and basic materials manufacturing show positive and statistically significant estimates for β, but non-manufacturing does not. The resulting residuals for these constrained regressions will be used as a robustness check to our baseline measure of purified technology. (Again, for non-manufacturing, we use the residuals omitting the labor utilization term, thereby controlling only for capital utilization.)

[24] See Beason and Weinstein (1996; Table 3), Kawamoto (2005; Table 3) and Miyagawa, Sakuragawa and Takizawa (2006; Table 3) for the returns-to-scale estimates based on Japanese industry-level data.
[25] The estimate for processing manufacturing is statistically significant at the 5% level, whereas that for basic materials manufacturing is statistically significant at the 10% level.

5. Results from "Augmented" Growth Accounting

5.1 *Empirical Results*

In this section, we look at estimates of aggregate and sectoral technology growth from our "augmented" growth accounting. In particular, we address the following two questions: 1) does the post-2000 increase in aggregate productivity growth arise from an increase in aggregate technology change?; and 2) if so, where has the increase in technology growth taken place in the economy? Specifically, has the pickup been primarily centered in IT-*producing* or IT-*using* industries, or both?

Table 4 provides our baseline estimates of technology growth at an aggregate and sectoral level, comparable to the standard TFP in Table 2.[26] Looking at the top line, we find a notable acceleration in aggregate technology growth after 2000. During the period 2000-2005, we estimate that technology has grown at an annual rate of 1.2 percent, which is 0.6 percentage points faster than the 0.6 percent rate in the 1990s. This finding provides support for the view that the recent increase in measured productivity does correspond to an increase in the pace of technological progress; cyclical mismeasurement of inputs play little if any role in the post-2000 acceleration. This result remains virtually unchanged when we impose constant returns to scale for all industries. Table 5 presents estimates of technology change for the CRS production case. It also shows a pickup in aggregate technology growth similar to the baseline estimates. These empirical results suggest that a substantial portion of the post-2000 productivity gains can be attributed to structural technological changes.

We now turn to the sectoral results. It is worth noting that, in contrast with the cross-industry pattern observed in the standard TFP, the post-2000 acceleration in technology has occurred not only in the IT *production* but also in the sector that *uses* IT intensively. First, the IT-producing sector (fourth line from bottom) has the fastest rate of growth and the largest acceleration in the 2000s. Although the share of IT producing industries in private-sector GDP is

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[26] Following Basu, Fernald, and Kimball (2006), here we define aggregate technology change as the

only 8 percent over 1990-2006, just these industries "account" for close to half of the total acceleration of technology in the 2000s. This result is qualitatively similar to the result from the standard TFP. Figure 5A plots our estimated annual rate of technology growth for the IT-producing sector, plotted against its real GDP growth. Compared to the standard TFP (Figure 4A), the correlation coefficient of purified technology with GDP falls by about 20 percent. However, even after controlling for cyclical factors, we still find a remarkable acceleration in technology in the 2000s.

Second, but even more importantly, the IT-using sector (third line from bottom in Table 4) shows an acceleration of about half a percentage point in the 2000s. Because IT using accounts for nearly two-thirds of private-sector GDP, the pickup in this sector, modest though it is, contributes significantly to the overall acceleration. (From an accounting point of view, technology acceleration in the IT-using sector accounts for more than half of the acceleration in aggregate technology.) This result is in sharp contrast with the result from standard growth accounting presented in Section 2. If we focus on the "well measured" IT-using industries, we still find a similar pickup in technology after 2000. Figure 5B shows our estimated technology growth for the "well-measured" IT using industries, plotted against their real GDP growth. This sector shows an increase in technology growth since around 2000, despite the weak output growth in the 2000s.

Figure 6 plots the levels of aggregate technology and quantifies each sector's direct contribution. It is clear that the technology pickup in the 2000s has not been solely concentrated among IT-producing industries; a surge in innovations in the IT-using industries also contributed significantly to aggregate technology growth. Indeed, *both* IT-producing and (well-measured) IT-using industries account for nearly all of the direct industry contributions to the Japan's technological revival in the 2000. Figure 7 plots the comparable figure for the CRS-production case. Here the basic sectoral pattern is intact: The pickup in technology growth has occurred in

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Domar-weighted sum of industry-level technology change.

industries that use, not merely in industries that produce, IT.

In sum, the industries that *produce* IT show particularly strong technology growth in the 2000s. This is not the whole story, however. We also estimate that the rate of change in IT-*using* technology has picked up notably since 2000. This suggests that, after accounting for non-technological factors, Japan's productivity revival in the 2000s is not confined to just a few IT-producing industries. Rather, the resurgence in technology growth is relatively broad-based, and is likely driven by information technology.

5.2 *Discussion*

Our results suggest that information technology has been a key driving force behind Japan's resurgence of technology growth that began around 2000. What kind of links might exist between information technology and industry-level production technology? The causes of the technology acceleration in IT production are reasonably well understood. New product development, resulting especially from R&D, has led to rapid improvements in computer technology.[27] In contrast, there is little information about the sources of the technology acceleration in IT-*using* industries. In particular, there is no presumption that the use of IT should have any particular effect on the industry's technology. It is true that a rapid decline in IT-goods prices has stimulated a rising flow of investment into IT equipment and software by the IT-using industries in Japan as well as in the United States. Factor price changes alone, however, do not shift their production functions.

One possible explanation for the technology pickup in the IT-using industries is that as a general purpose technology (GPT), information technology has led to a wide range of fundamental changes in the production process of these industries. (Brynjolfsson and Hitt 2000; Basu, Fernald, Oulton, and Srinivasan 2003). Such GPT stories emphasize that reaping the full benefit of IT requires firms to accumulate a stock of intangible complementary capital through learning, reorganization, and the like. Since intangible capital accumulation is a slow process,

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[27] See, for example, Jorgenson (2001) and Jorgenson and Motohashi (2005) for more on this point.

the benefits of the IT revolution show up in the IT-using industries with significant lags.[28]

Figure 8 presents cumulated year-to-year technology changes, i.e., the levels of technology for the "well-measured" IT-using sector, plotted against its IT-capital income share. Roughly speaking, the benefits of IT in terms of technology appear to be realized with long lags of 5 to 10 years. In particular, the technology gains observed since 2000 seem to reflect the follow-on innovations from the IT-investment boom in the late 1990s, which was in turn triggered by the advent of "Windows 95."[29] Although much more work remains to be done—for example, measuring intangible capital directly—to assess the robustness of this argument, our observation seems to be encouraging, to say the least, to the GPT view of information technology.[30]

6. Conclusion

This paper introduces new estimates of aggregate and sectoral technology growth for the Japanese economy over the years 1975-2005. The estimates are based on the "augmented" growth accounting framework controlling for non-technological cyclical factors. Using this approach, we were able to paint a rich picture of recent productivity developments in Japan. The Japanese economy has enjoyed since 2000 an increase in the rate of productivity growth, driven largely by an increase in the rate of technological progress. Furthermore, our industry results

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[28] For example, Brynjolfsson and Hitt (2003) find that in a sample of large U.S. firms from 1987 to 1994, the full benefits of computers for productivity do not appear to be realized for at least five to seven years. They interpret their results as suggesting the importance of combining computer investments with large and time-consuming investments in complementary inputs, such as organizational capital. Basu and Fernald (2007) find that the U.S. industry data are reasonably consistent with the predictions that, in IT-using industries, IT capital growth should, with long lags, be positively associated with TFP growth. In particular, they find evidence that IT capital investments in the 1980s and 1990s are positively correlated with the TFP acceleration in the 2000s.

[29] Deregulation in Japan's labor market since the late 1990s might play a role in promoting IT adoption for IT-using industries. Using panel data from 1992 to 1999 for 13 industrial countries including Japan, Gust and Marquez (2002) provide empirical evidence supporting the view that burdensome regulations affecting labor market practices impede the adoption of IT and slow productivity growth.

[30] Corrado, Hulten, and Sichel (2006) estimate intangible capital directly based on the U.S. data, incorporating it into a neoclassical growth accounting framework. Fukao, Hamagata, Miyagawa, and Tonogi (2007) attempt to apply their method to Japan's aggregate data.

indicate that the post-2000 resurgence in technology has been an IT-centered story, with increases in the rate of technology change for *both* IT-producing and IT-using sectors, partly offset by step-downs in other IT-isolated industries. If our results are accepted, the Solow paradox has been, at least in part, resolved in Japan after 2000, a lag of roughly five years behind the United States.

References

Alexius, Annika and Mikael Carlsson (2005). “Measures of Technology and the Business Cycle.” *Review of Economics and Statistics* 87(2): 299-307.

Basu, Susanto (1996). “Procyclical Productivity: Increasing Returns or Cyclical Utilization? *Quarterly Journal of Economics* 111: 719-751.

Basu, Susanto and John G. Fernald (2001). “Why Is Productivity Procyclical? Why Do We Care?” In C. Hulten, E. Dean, and M. Harper, eds., *New Developments in Productivity Analysis*, Chicago, IL: University of Chicago Press.

__________ and __________ (2007). “Information and Communications Technology as a General-Purpose Technology: Evidence from U.S. Industry Data.” *German Economic Review* 8(2): 146-173.

Basu, Susanto, John G. Fernald, Nicholas Oulton, and Sylaja Srinivasan (2003). “The Case of the Missing Productivity Growth, or Does Information Technology Explain Why Productivity Accelerated in the United States but Not in the United Kingdom?” In M. Gertler and K. Rogoff, eds., *NBER Macroeconomics Annual 2003*, Cambridge, MA: MIT Press.

Basu, Susanto, John G. Fernald, and Miles S. Kimball (2006). “Are Technology Improvements Contractionary?” *American Economic Review* 96(5): 1418-1448.

Basu, Susanto, John G. Fernald and Matthew D. Shapiro (2001). “Productivity Growth in the 1990s: Technology, Utilization, or Adjustment?” *Carnegie-Rochester Conference Series on Public Policy* 55: 117-165.

Beason, Richard and David E. Weinstein (1996), “Growth, Economies of Scale, and Targeting in Japan.” *Review of Economics and Statistics* 78: 286-295.

Bosworth, Barry P. and Jack E. Triplett (2007). “Is the 21st Century productivity Expansion Still in Services? And What Should Be Done About It?” Brookings Institution.

Bresnahan, Timothy F., Eric Brynjolfsson and Lorin Hitt (2002). “Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-level Evidence.” *Quarterly Journal of Economics* 117: 339-376.

Brynjolfsson, Eric and Lorin Hitt (2000). “Beyond Computation: Information Technology, Organizational Transformation and Business Performance” *Journal of Economic Perspectives* 14(4): 23-48.

__________ and __________ (2003). “Computing Productivity: Firm Level Evidence.” *Review of Economics and Statistics* 85(4): 793-808.

Burnside, Craig (1996). “Production Function Regressions, Returns to Scale, and Externalities.” *Journal of Monetary Economics* 37: 177-201.

Burnside, A. Craig, Martin S. Eichenbaum, and Sergio T. Rebelo (1995). “Capital Utilization and Returns to Scale.” In B. Bernanke and J. Rotemberg, eds., *NBER Macroeconomics Annual 1995*, Cambridge, MA: MIT Press.

Corrado, Carol A., Charles R. Hulten, and Daniel E. Sichel (2006). "Intangible Capital and Economic Growth." NBER Working Paper 11948.

Fukao, Kyoji, Sumio Hamagata, Tomohiko Inui, Keiko Ito, Hyeog Ug Kwon, Tatsuji Makino, Tsutomu Miyagawa, Yasuo Nakanishi, and Joji Tokui (2006). "Estimation Procedures and TFP Analysis of the JIP Database 2006 Provisional Version." Paper presented at the RIETI International Conference, July 24-25, Tokyo.

Fukao, Kyoji, Sumio Hamagata, Tsutomu Miyagawa and Konomi Tonogi (2007). "Intangible Investment in Japan: Measurement and Contribution to Economic Growth." RIETI Discussion Paper Series 07-E-034.

Fukao, Kyoji and Tsutomu Miyagawa (2007). "Productivity in Japan, the US, and Major EU Economies: Is Japan Falling Behind?" RIETI Discussion Paper Series 07-E-046.

Gust, Christopher and Jaime Marquez (2002). "International Comparisons of Productivity Growth: The Role of Information Technology and Regulatory Practices." *Labour Economics* 11(1): 33-58.

Jorgenson, Dale W. (2001). "Information Technology and the U.S. Economy." *American Economic Review* 91(1): 1-32.

Jorgenson, Dale W. and Kazuyuki Motohashi (2005). "Information Technology and the Japanese Economy." *Journal of the Japanese and International Economies* 19(4): 460-481.

Jorgenson, Dale W. and Koji Nomura (2005). "The Industry Origins of Japanese Economic Growth." *Journal of the Japanese and International Economies* 19(4): 482-542.

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

Kawamoto, Takuji (2004). "What Do the Purified Solow Residuals Tell Us about Japan's Lost Decade?" Bank of Japan, *Monetary and Economic Studie*s 23(1): 113-148.

Miyagawa, Tsutomu, Yukie Sakuragawa and Miho Takizawa (2006). "Productivity and the Business Cycles in Japan: Evidence from Japanese Industry Data." *Japanese Economic Review* 57(2): 161-186.

Motohashi, Kazuyuki (2007). "Firm-level Analysis of Information Network Use and Productivity in Japan." *Journal of the Japanese and International Economies* 21(1): 121-137.

Nishimura, Kiyohiko G. (2007). "Increased Diversity and Deepened Uncertainty: Policy Challenges in a Zero-Inflation Economy." *International Finance* 10(3): 281-300.

Nordhaus, William D. (2002). "Productivity Growth and the New Economy." *Brookings Papers on Economic Activity* 2: 211-244.

Oliner, Stephen D. and Daniel E Sichel (2000). "The Resurgence of Growth in the Late 100-s: Is Information Technology the Story?" *Journal of Economic Perspectives* 14(4): 3-22.

Oliner, Stephen D., Daniel E. Sichel and Kevin J. Stiroh (2007). "Explaining a Productive Decade." *Brookings Papers on Economic Activity* 1: 81-137.

Osada, Mitsuhiro and Takuji Kawamoto (2007). "Stabilization in the Volatility of Output: A Decline in Cross-industry Comovements." *Bank of Japan Review* 2007-E-6.

Solow, Robert M. (1957). "Technological Change and the Aggregate Production Function." *Review of Economics and Statistics* 39: 312-320.

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

Timmer, Marcel, Ton van Moergastel, Edwin Stuivenwold, Gerard Ypma, Mary O'Mahony and Mari Kangasniemi (2007). "EU KLEMS Growth and Productivity Accounts." Gronigen Growth and Development Centre, University of Gronigen.

Table 1. Industry Lists

Industry Name	IT Prod.	IT Using	Well measured IT using	Others	Processing Mfg.	Basic Material Mfg.	Non Mfg.	Semi Public
Food Products & Beverages				X	X			
Textiles				X	X			
Machinery	X				X			
Electrical Machinery, Equipment & Supplies	X				X			
Transport Equipment				X	X			
Precision Instruments	X				X			
Miscellaneous Manufacturing				X	X			
Pulp, Paper & Paper Products				X		X		
Chemicals		X	X			X		
Petroleum & Coal Products				X		X		
Non-Metallic Mineral Products				X		X		
Basic Metals				X		X		
Fabricated Metal Products				X		X		
Construction				X			X	
Wholesale & Retail Trade		X	X				X	
Finance & Insurance		X					X	
Utilities		X	X					X
Transportation & Communication		X	X					X
Service		X						X

Table 2. TFP Growth by Industry in Japan
(average annual percent change)

	TFP Growth [1] (average annual percent change)		Acceleration		Industry's GDP Share
	1990-2000 a	2000-2005 b	b-a	Contribution	1990-2005
Private Economy [2]	-0.1	0.5	0.6	0.61	100
Manufacturing	0.4	0.9	0.6	0.15	28.7
Processing	0.9	2.6	1.7	0.30	19.4
Basic Materials	-0.7	-2.6	-1.9	-0.15	9.3
Construction	-3.4	0.1	3.5	0.41	10.4
Utilities	-1.5	2.6	4.2	0.14	3.4
Wholesale & Retail Trade	2.3	1.1	-1.2	-0.19	17.6
Finance & Insurance	-0.3	0.5	0.7	0.06	7.6
Transport & Communications	0.4	1.4	1.0	0.09	8.7
Service Activities	-0.6	-0.7	-0.0	-0.04	23.6
IT-producing [3]	3.4	7.0	3.6	0.21	8.0
IT-using [4]	0.4	0.3	-0.0	0.01	63.2
Well-measured IT-using [5]	1.2	1.2	-0.0	-0.00	32.1
Others [6]	-1.8	-0.7	1.2	0.39	28.8

1. TFP growth is defined as (gross output TFP growth)/(1-share of intermediate inputs). Gross output TFP growth is measured as real gross output growth minus the share-weighted average growth in inputs of capital, labor, and intermediate goods. A group's TFP growth is calculated as a weighted average of industry-level TFP growth. The weight for each industry is the ratio of its value added to the sum of value added in each group.
2. We exclude agriculture, mining, and real estate.
3. IT-producing sector includes machinery, electrical machinery, and precision instruments.
4. IT-using sector is composed of six industries: chemicals, wholesale & retail trade, finance & insurance, utilities, transportation & communication, and service.
5. Well-measured IT-using sector is composed of four industries: chemicals, wholesale & retail trade, utilities, and transportation & communication.
6. Others include manufacturing excluding chemicals and IT-producing sector, and construction.

Table 3. Parameter Estimates

A. Baseline Case

$$dy_i = c_i + \gamma_i dx_i + \beta dh_i + dz_i$$

Processing Manufacturing		Basic Materials Manufacturing		Non-manufacturing	
Returns to Scale γ_i					
Food, Products & Beverages	0.75 (0.09)	Pulp, Paper & Paper Products	0.81 (0.11)	Construction	0.66 (0.15)
Textiles	0.44 (0.17)	Chemicals	1.69 (0.45)	Wholesale & Retail Trade	1.42 (0.27)
Machinery	0.83 (0.10)	Petroleum & Coal Products	0.17 (0.38)	Finance & Insurance	0.88 (0.56)
Electrical Machinery, Equipment & Supplies	1.11 (0.10)	Non-Metalic Mineral Products	1.09 (0.17)		
Transport Equipment	0.92 (0.30)	Basic Metal	1.02 (0.13)		
Precision Instruments	1.13 (0.09)	Fabricated Metal Products	0.98 (0.08)		
Miscellaneous Manufacturing	1.06 (0.12)				
Column Average	**0.89**		**0.96**		**0.99**
Weighted Average	**0.93**		**0.98**		**1.06**
Labor Utilization β					
Processing Manufacturing	0.056 (0.024)	Basic Materials Manufacturing	0.046 (0.025)	Non-manufacturing	-0.253 (0.085)

B. Imposing Constant Returns to Scale

$$dy_i - dx_i = c_i + \beta dh_i + dz_i$$

Labor Utilization β					
Processing Manufacturing	0.040 (0.015)	Basic Materials Manufacturing	0.068 (0.014)	Non-manufacturing	-0.183 (0.080)

Notes: Estimation by Three-Stage Least Squares pooling across industries within groups. Data are from national accounts and monthly labor survey and are at an industry level from 1975 to 2006. Instruments are growth in real oil price, growth in government consumption, and growth in public investment. Sectoral estimates include industry fixed effects (not reported). Standard errors are in parentheses.

Table 4. Purified Technology Growth by Industry in Japan: Baseline Case (average annual percent change)

	Purified Technology Growth [1] (average annual percent change)		Acceleration		Industry's GDP Share
	1990-2000 a	2000-2005 b	b-a	Contribution	1990-2005
Private Economy [2]	0.6	1.2	0.6	0.59	100
Manufacturing	2.1	2.7	0.6	0.08	28.7
Processing	2.3	4.1	1.8	0.28	19.4
Basic Materials	1.9	-0.1	-2.1	-0.20	9.3
Construction	-2.8	-1.9	0.9	0.14	10.4
Utilities	-1.5	2.6	4.2	0.14	3.4
Wholesale & Retail Trade	2.6	2.3	-0.3	-0.04	17.6
Finance & Insurance	0.4	3.1	2.7	0.22	7.6
Transport & Communications	0.4	1.4	1.0	0.09	8.7
Service Activities	-0.6	-0.7	-0.0	-0.04	23.6
IT-producing [3]	4.3	8.7	4.5	0.26	8.0
IT-using [4]	0.6	1.1	0.5	0.36	63.2
Well-measured IT-using [5]	1.6	2.1	0.5	0.18	32.1
Others [6]	-0.3	-0.5	-0.1	-0.03	28.8

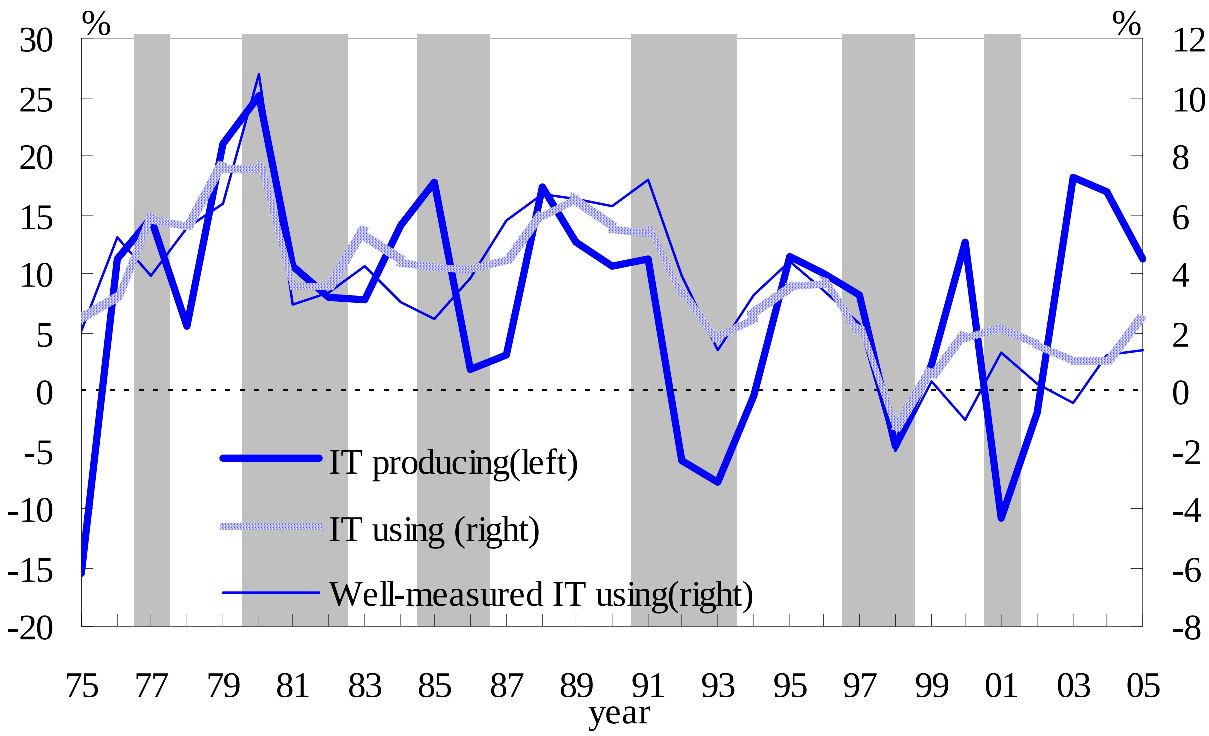
1. Purified technology growth is the residuals (including constant) from regression results in Table 3A, which is divided by (1-share of intermediate inputs). A group's purified technology growth is the Domar-weighted average of industry residuals. Industry Domar-weights are defined as (industry's share of aggregate value added in each group)/(1-share of intermediate inputs).
2. We exclude agriculture, mining, and real estate.
3. IT-producing sector includes machinery, electrical machinery, and precision instruments.
4. IT-using sector is composed of six industries: chemicals, wholesale & retail trade, finance & insurance, utilities, transportation & communication, and service.
5. Well-measured IT-using sector is composed of four industries: chemicals, wholesale & retail trade, utilities, and transportation & communication.
6. Others include manufacturing excluding chemicals and IT-producing sector, and construction.

Table 5. Purified Technology Growth by Industry in Japan: CRS Case
(average annual percent change)

	Purified Technology Growth [1] (average annual percent change)		Acceleration		Industry's GDP Share
	1990-2000 a	2000-2005 b	b-a	Contribution	1990-2005
Private Economy [2]	0.7	1.2	0.6	0.59	100
Manufacturing	2.3	2.5	0.3	0.00	28.7
Processing	2.6	4.0	1.4	0.20	19.4
Basic Materials	1.6	-0.4	-2.1	-0.20	9.3
Construction	-2.4	0.2	2.6	0.30	10.4
Utilities	-1.5	2.6	4.2	0.14	3.4
Wholesale & Retail Trade	2.7	1.6	-1.2	-0.19	17.6
Finance & Insurance	-0.4	3.2	3.5	0.28	7.6
Transport & Communications	0.4	1.4	1.0	0.09	8.7
Service Activities	-0.6	-0.7	-0.0	-0.04	23.6
IT-producing [3]	4.7	8.4	3.8	0.21	8.0
IT-using [4]	0.6	0.9	0.3	0.25	63.2
Well-measured IT-using [5]	1.6	1.6	0.0	0.00	32.1
Others [6]	-0.2	0.3	0.5	0.13	28.8

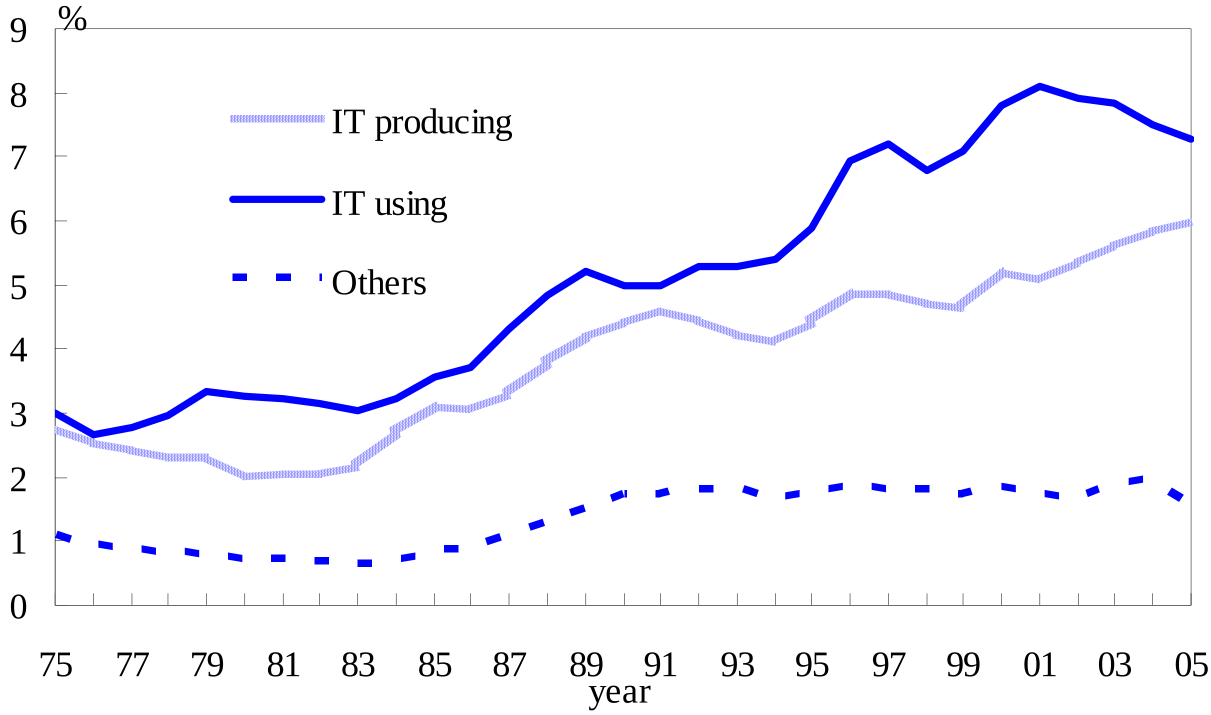
1. Purified technology growth is the residuals (including constant) from regression results in Table 3B which is divided by (1-share of intermediate inputs). A group's technology growth is the Domar-weighted average of industry's residuals. Industry Domar-weights are defined as (industry's share of aggeregate value added in each group)/(1-share of intermediate inputs).
2. We exclude agriculture, mining, and real estate.
3. IT-producing sector includes machinery, electrical machinery, and precision instruments.
4. IT-using sector is composed of six industries: chemicals, wholesale & retail trade, finance & insurance, utilities, transportation & communication, and service.
5. Well-measured IT-using sector is composed of four industries: chemicals, wholesale & retail trade, utilities, and transportation & communication.
6. Others include manufacturing excluding chemicals and IT-producing sector, and construction.

Figure 1. Sectoral Real GDP Growth
(annual percent change)



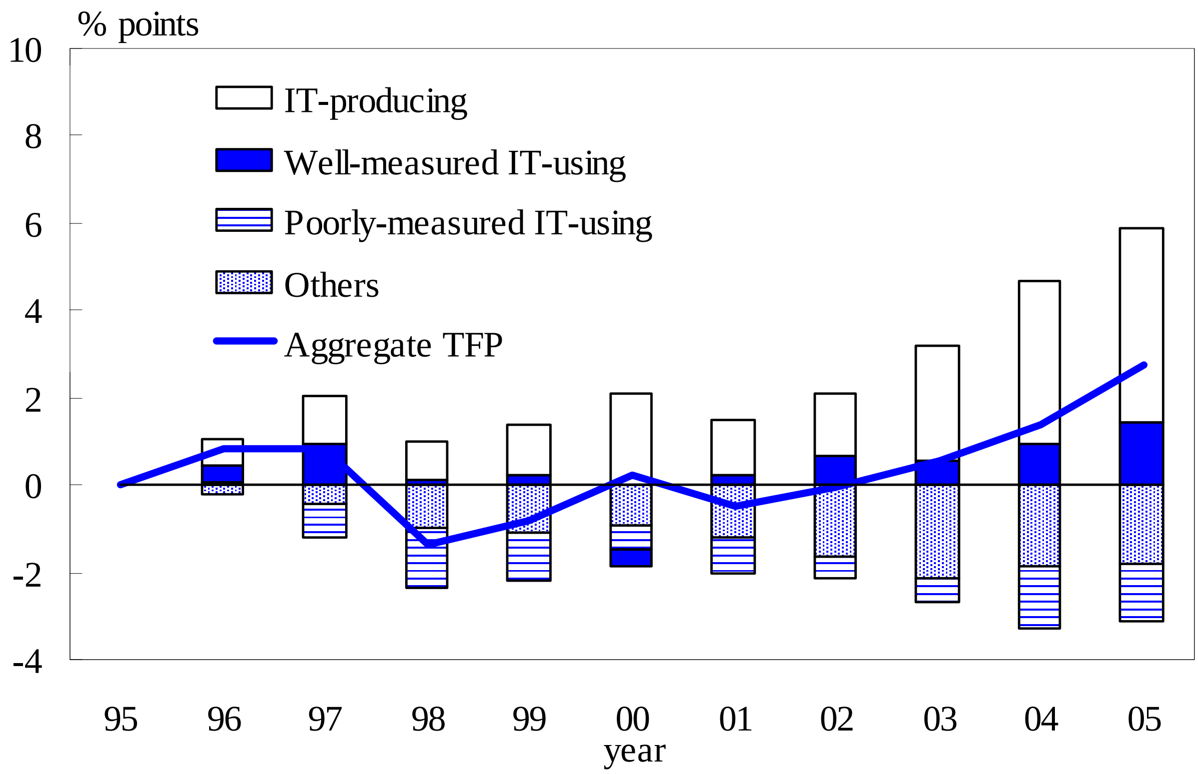
Notes: Real GDP growth is measured as real value-added growth. IT-producing sector includes machinery, electrical machinery, and precision instruments. IT-using sector is composed of six industries: chemicals, wholesale & retail trade, finance & insurance, utilities, transportation & communication, and service. Well-measured IT-using sector is composed of four industries: chemicals, wholesale & retail trade, utilities, and transportation & communication. Shaded regions show ESRI recession dates.

Figure 2. IT-Capital Income Share



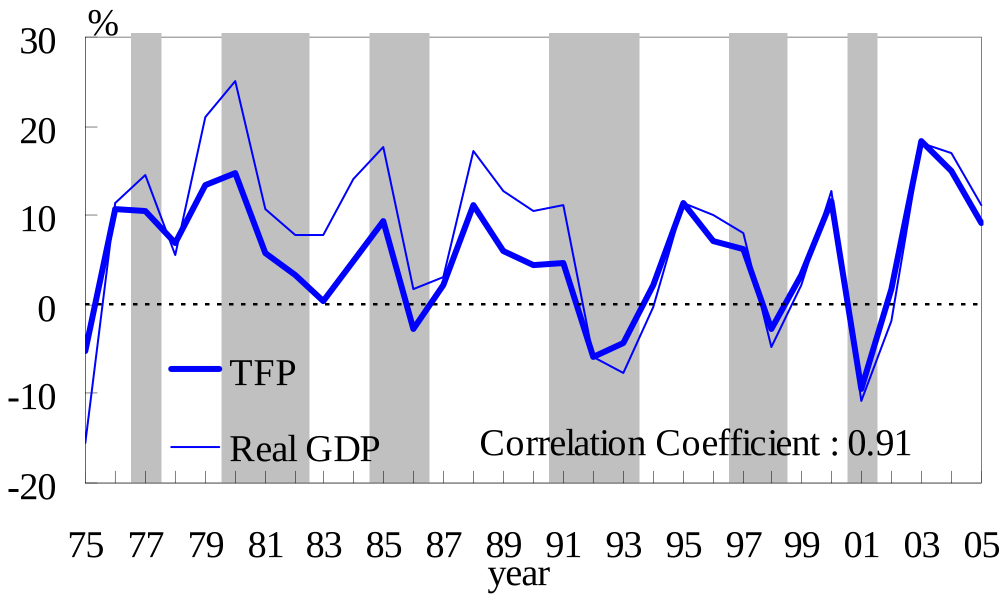
Notes: IT-capital income share is the ratio of profits attributable to IT capital to nominal value added. IT-producing sector includes machinery, electrical machinery, and precision instruments. IT-using sector is composed of six industries: chemicals, wholesale & retail Trade, finance & insurance, utilities, transportation & communication, and service.

Figure 3. Cumulated Aggregate TFP (Breakdown by Sectors)

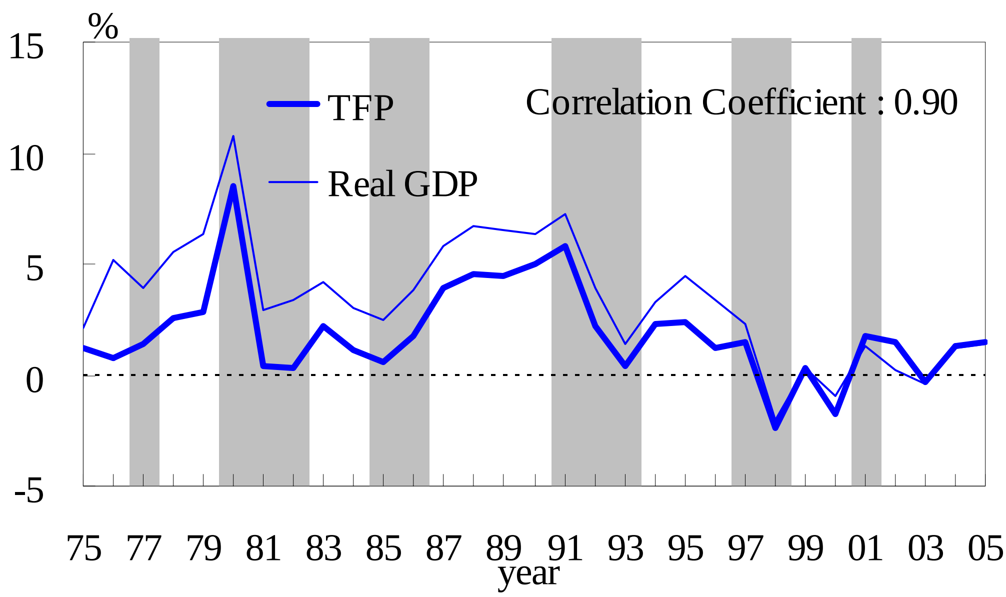


Notes: Calculated by cumulating year-to-year TFP changes. TFP growth is defined as (gross output TFP growth)/(1-share of intermediate inputs). Gross output TFP growth is measured as real gross output growth minus the share-weighted average growth in inputs of capital, labor, and intermediate goods. A group's TFP growth is the Domar-weighted sum of industry's gross output TFP growth. Industry Domar-weights are defined as (industry's share of aggregate value added)/(1-share of intermediate inputs). IT-producing sector includes machinery, electrical machinery, and precision instruments. Well-measured IT-using sector is composed of four industries : chemicals, wholesale & retail Trade, utilities, and transportation & communication. Poorly-measured IT-using sector includes finance & insurance, and service. Others include manufacturing excluding chemicals and IT producing sector, and construction.

Figure 4. TFP and Real GDP Growth
(annual percent change)
A. IT-producing Sector

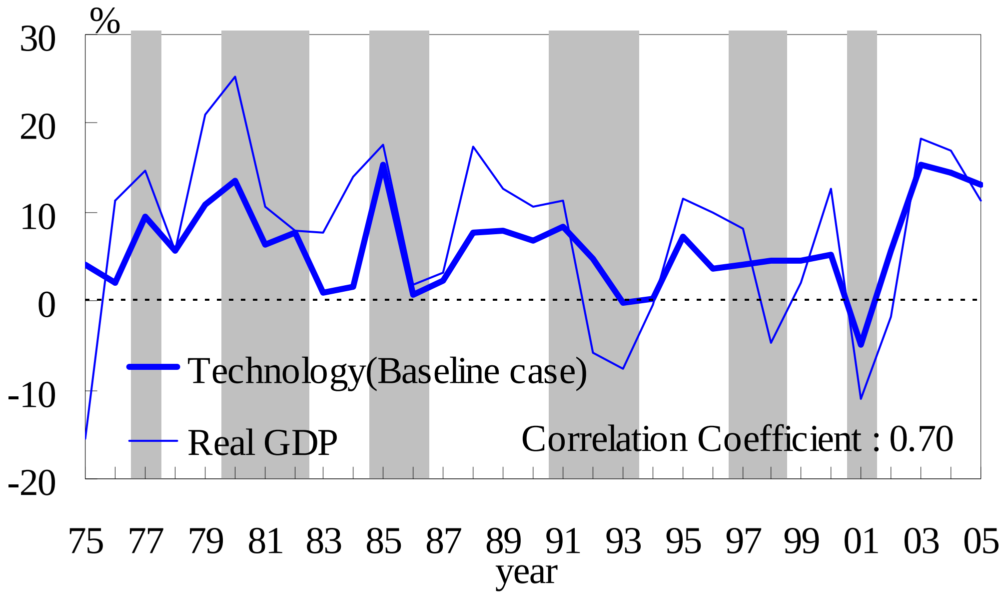


B. Well-measured IT-using Sector

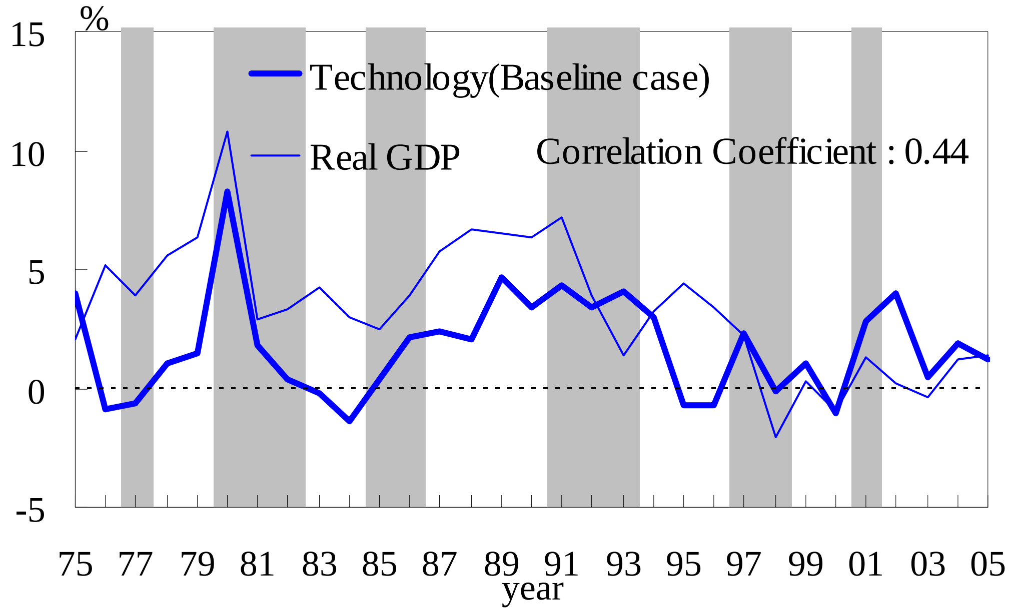


Notes: Real GDP growth is measured as real value–added growth. TFP growth is calculated as (gross output TFP growth)/(1-share of intermediate inputs). Gross output TFP growth is defined as real gross output growth minus the share-weighted average growth in inputs of capital, labor, and intermediate goods. A sector's TFP growth is the Domar-weighted average of industry-level TFP growth. This weights are defined as (industry's share of aggeregate value added in this sector)/(1-share of intermediate inputs). Correlation coefficients between TFP and GDP growth are calculated for 1975-2005. IT-producing sector includes machinery, electrical machinery, and precision instruments. Well-measured IT-using sector is composed of four industries: chemicals, wholesale & retail trade, utilities, and transportation & communication. Shaded regions show ESRI recession dates.

Figure 5. Baseline Purified Technology and Real GDP Growth
(annual percent change)
A. IT-producing sector

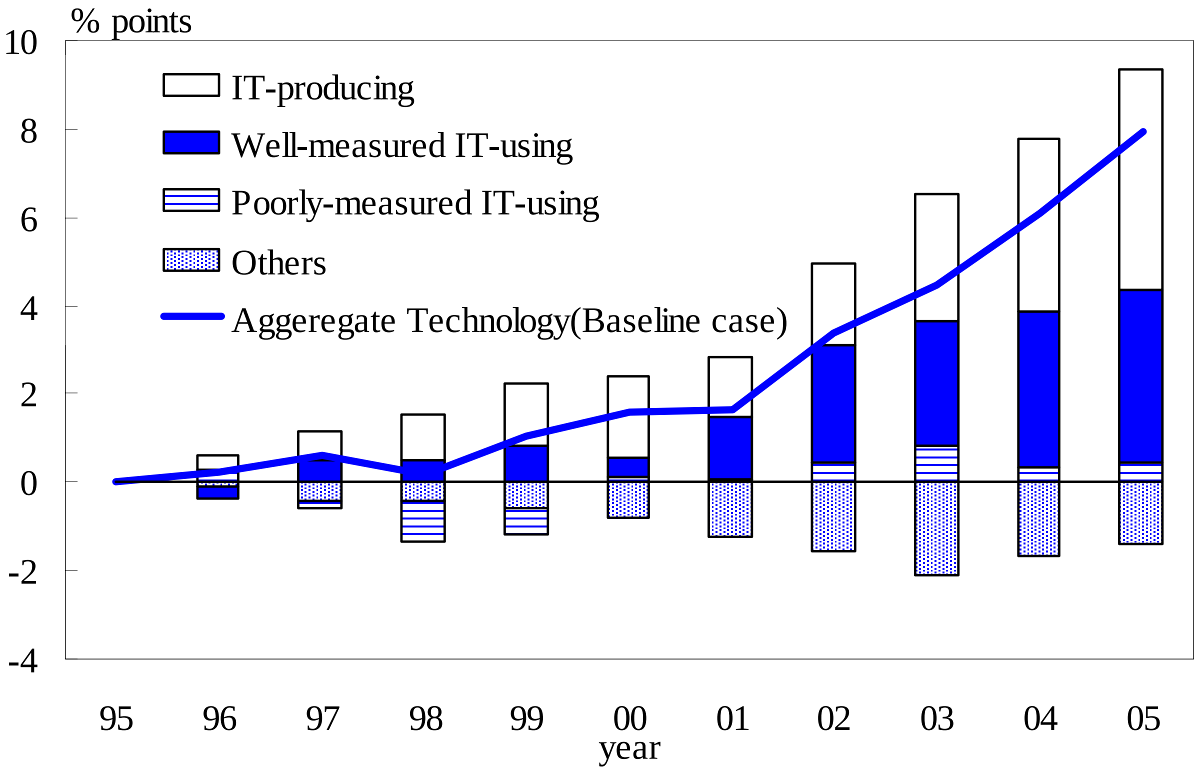


B. Well-measured IT-using Sector



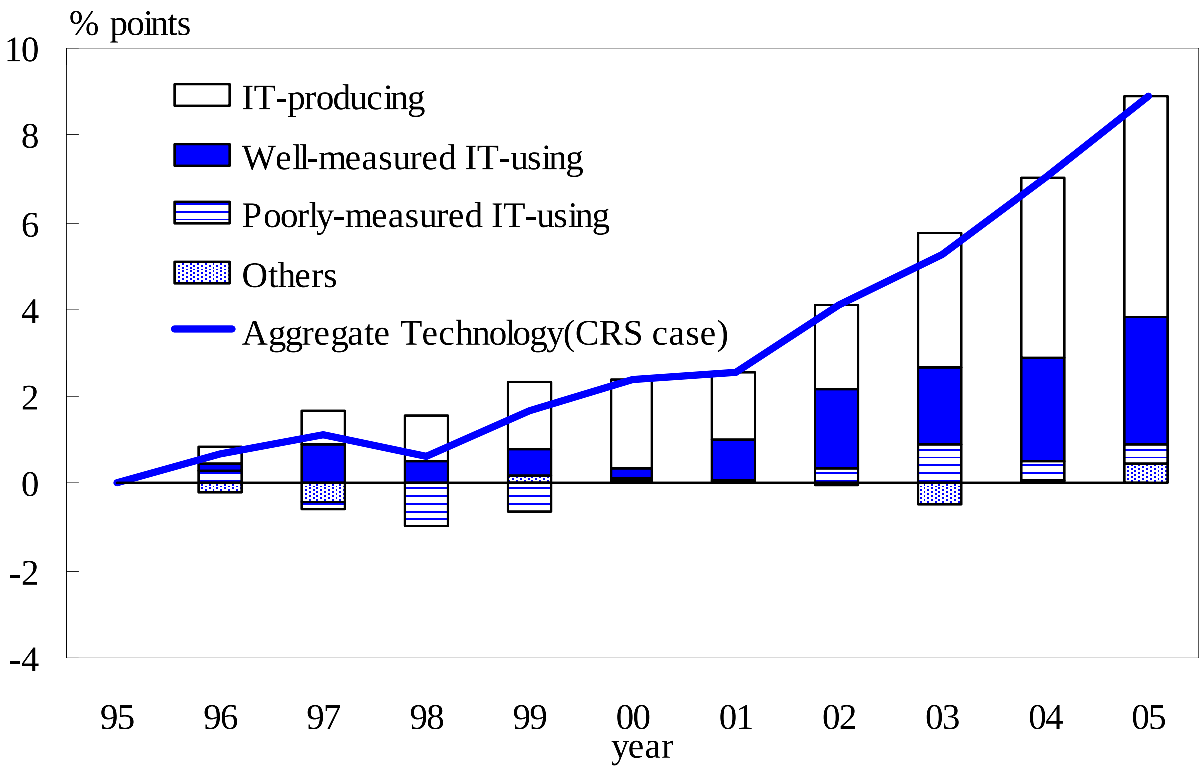
Notes: Real GDP growth is measured as real value–added growth. Technology growth is the Domar-weighted average of the residuals (including constant) from regression results in Table 3A. Conceptually our measure of purified technology controlls for unobserved utilization of inputs and deviations from perfect competiton and constant returns. Industry Domar-weights are defined as (industry's share of aggeregate value added in this sector)/(1-share of intermediate inputs). Correlation coefficients between technology and real GDP growth are calculated for 1975-2005. IT-producing sector includes machinery, electrical machinery, and precision instruments. Well-measured IT-using sector is composed of four industries: chemicals, utilities, wholesale & retail trade, and transportation & communication. Shaded regions show ESRI recession dates.

Figure 6. Cumulated Aggregate Technology (Baseline case, Breakdown by Sectors)



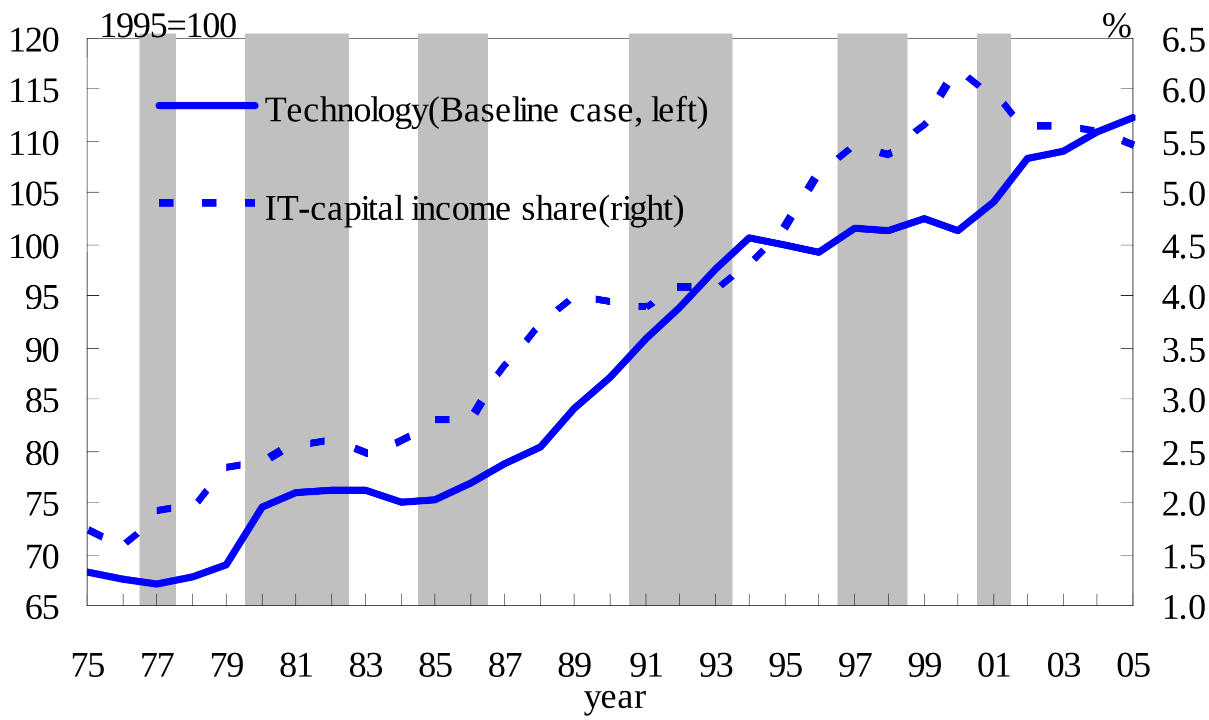
Notes: Calculated by cumulating year-to-year changes in baseline purified technology. Technology growth is the residuals (including constant) from regression results in Table 3A, which is aggregated by industry's Domar-weights. These weights are defined as (industry's share of aggregate value added)/(1-share of intermediate inputs). IT-producing sector includes machinery, electrical machinery, and precision instruments. Well-measured IT-using sector is composed of four industries: chemicals, wholesale & retail trade, transportation & communication, and utilities. Poorly-measured IT-using sector includes finance & insurance, and service. Others include manufacturing excluding chemicals and IT producing sector, and construction.

Figure 7. Cumulated Aggregate Technology (CRS case, Breakdown by Sectors)



Notes: Calculated by cumulating year-to-year changes in CRS purifed technology. Technology growth is the residuals (including constant) from regression results in Table 3B, which is aggregated by industry's Domar-weights. These weights are defined as (industry's share of aggregate value added)/(1-share of intermediate inputs). IT-producing sector includes machinery, electrical machinery, and precision instruments. Well-measured IT-using sector is composed of four industries: chemicals, wholesale & retail trade, transportation & communication, and utilities. Poorly-measured IT-using sector includes finance & insurance, and service. Others include manufacturing excluding chemicals and IT producing sector, and construction.

Figure 8. IT-Capital Income Share and Technology for the Well-measured IT-using Sector



Notes: IT-capital income share is the ratio of profits attributable to IT capital to nominal value added. The levels of technology are calculated by cumulating year-to-year changes in baseline purifed technology for the well measured IT using sector. Well-measured IT-using sector is composed of four industries: chemicals, wholesale & retail trade, utilities, and transportation & communication. Shaded regions show ESRI recession dates.

APPENDIX TABLE 1. Industry Classification in the SNA and Monthly Labor Survey

SNA	Monthly Labor Survey
Food products and beverages	Food products, beverages, tobacco, and feed
Textiles	Textile mill products
Pulp, paper and paper products	Pulp, paper and paper products
Chemicals	Chemical and allied products
Petroleum and coal products	Petroleum and coal products
Non-metallic mineral products	Ceramic, stone and clay products
Basic metals	Iron and steel Non-ferrous metals and products
Fabricated metal products	Fabricated metal products
Machinery	General machinery
Electrical machinery, equipment and supplies	Electrical machinery, equipment and supplies Information and communication electronics equipment Electronic parts and devices
Transport equipment	Transportation equipment
Precision instruments	Precision instruments and machinery
Others	Rubber products Leather tanning, leather products and fur skins Plastic products Allied industries Furniture and fixtures Lumber and wood products Apparel and other finished products made from fabrics and similar materials Miscellaneous manufacturing industries
Construction	Construction
Electricity, gas and water supply	Electricity, gas, heat supply and water
Wholesale and retail trade	Wholesale and retail trade
Finance and insurance	Finance and insurance
Transport and communications	Transport Information and communications
Service activities	Eating and drinking places, accommodations Medical Health care and welfare Education, learning support Compound services Services, N.E.C.

APPENDIX TABLE 2. Industry Classification in the SNA and EU-KLEMS

SNA	EU KLEMS
Food products and beverages	Food products, beverages, and tobacco
Textiles	Textiles, textile products, leather, and footwear
Pulp, paper, and paper products	Pulp, paper, paper products, printing, and publishing
Chemicals	Chemicals and chemical products
Petroleum and coal products	Coke, refined petroleum products, and nuclear fuel
Non-metallic mineral products	Other non-metallic mineral products
Basic metals Fabricated metal products	Basic metals and fabricated metal products
Machinery	Machinery, nec
Electrical machinery, equipment and supplies	Electrical and optical equipment
Transport equipment	Transport equipment
Precision instruments	Electrical and optical equipment
Others	Wood and products of wood and cork Rubber and plastics products Manufacturing nec
Construction	Construction
Electricity, gas and water supply	Electricity, gas and water supply
Wholesale and retail trade	Sale, maintenance and repair of motor vehicles and motorcycles Wholesale trade and commission trade Retail trade
Finance and insurance	Financial intermediation
Transport and communications	Transport and storage Post and telecommunications
Service activities	Hotels and restaurants Other community, social and personal services Renting of m&eq and other business activities