KEO Discussion Paper No.97

Toward Reframing Capital Measurement in Japanese National Accounts*

Koji Nomura

Keio Economic Observatory, Keio University

nomura@sanken.keio.ac.jp

June 1, 2005

Keywords

age-efficiency profile, age-price profile, gross capital stock, productive capital stock, net capital stock, SNA, NIPA, BEA, Canberra I & II Group, geometric approach, hyperbolic, consumption of fixed capital, depreciation, constant-quality deflator, capitalization of software, information technology, land as capital, price and quantity of capital service, non-market production

Abstract

The Japanese national accounts are moving toward a sweeping improvement of the measurement of capital, which is one of the most difficult areas to reframe. The objective of this paper is to recognize current problems on the measurement of capital in the Japanese national accounts and to examine the direction for catching up and going forward. Our conclusion that ESRI should introduce capital services at the same time as reframing the measurement of capital stock, thereby anticipating SNA 2008.

* This paper was presented at the ESRI (Economic and Social Research Institution) Conference on Next Steps for the Japanese SNA: "Towards More Accurate Measurement and More Comprehensive Accounts", Tokyo, March 25, 2005. I have revised since this presentation. I am grateful to Dale W. Jorgenson for his valuable comments and Jon D. Samuels for his help at Harvard University, and Erwin Diewert (University of British Columbia), Steven Landefeld (BEA), and Paul Schreyer (OECD) for useful comments at the conference. This paper is preliminary. Comments welcome.

Contents

List of Figures

List of Tables

Toward Reframing of Capital Measurement in Japanese National Accounts

Koji Nomura (Keio University)

June 1, 2005

1 Introduction

The accumulation of theory and empirical studies brought some significant changes to the measurement of capital in national accounts in the 1990s in order to capture rapid changes in the production structure. Internationally, there are three important events in this area. The first was the clarification and extension on capital concepts in the United Nations (1993) System of National Accounts (1993 SNA), which was revised after an interval of a quarter of a century after 1968. However, the 1993 SNA was not necessarily a comfortable landing, and triggered intensive discussions on capital measurement. The second event was the Capital Stock Conferences by the so-called Canberra Group, organized by the Organization for Economic Cooperation and Development (OECD) in 1997, 1998, and 1999. The third event was the improvement of the measurement of capital stock and depreciation as a part of the comprehensive revision of the National Income and Product Accounts (NIPA) by the U.S. Bureau of Economic Analysis (BEA) in 1997.

Although the conceptual expansion of capital recommended in the 1993 SNA was applied in national accounts of many countries, it was not fully incorporated into the Japanese national accounts. As is widely well known, the Japanese national accounts still do not capitalize own-account software and prepackaged software. In international comparisons of economic growth and productivity based on the 1993 SNA, Japan must be treated as an exception. Can the Japanese stock statistics make up for lost time? Is it possible to turn the tables in the next revision of the SNA in 2008 (1993 SNA Revision 1)? Our objective in this paper is to recognize some defects on the measurement of capital in the Japanese national accounts and to examine the direction for catching up and going forward.

The Japanese economy expended many years eliminating worthless assets and reforming the economic system after the collapse of the bubble economy in the beginning of the 1990s. The period of the crises may have passed. For the Japanese national accounts, a turning point may be coming now. In order to catch up to international standards, Economic and Social Research Institution (ESRI), Cabinet Office, the producer of the Japanese national accounts, officially incorporated the chained index for the national accounts in the late of 2004. Likewise, ESRI is moving to consider sweeping improvement of the capital stock statistics, which is one of the most difficult areas for reframing the Japanese national accounts.

The intensive discussions by the Canberra Group and the revision by the BEA in the late of the 1990s provide valuable insights for improving the measurement of capital in Japan. In order to reframe capital measurement in the Japanese national accounts, it is appropriate to start with understanding some significant concepts. In section 2, we introduce the framework for measuring capital with some practical issues in this area, based on the theory for measuring capital proposed by Jorgenson and his associates: Jorgenson (1963, 1974, 1989), Hall and Jorgenson (1967), Jorgenson and Griliches (1972), Hulten (1990), and Diewert (2001).

In section 3, we briefly introduce the present measurement of capital in the Japanese national accounts and examine some problems to be overcome. In addition, as an alternative measurement of capital in Japan, we introduce our measurement for the stocks and services of capital. Our latest estimates for capital stock and service matrixes are based on 102 assets: 95 fixed assets, 3 types of inventory, and 4 types of land, and 70 capital holding sectors: 45 industries, government, household, and 23 infrastructures. One of the most significant conclusions from our measurement of capital is to indicate that there is no insurmountable obstacles to improve the Japanese capital statistics.

It may be valuable to note that the present defects of capital measurement in the Japanese national accounts do not necessarily mean that the accuracy of revised capital statistics will be inferior. In fact, the primary statistics in Japan are well above the international standard. The revised Japanese statistics will be able to propose an accurate and internally consistent stock measures and consumption of fixed capital. Moreover, it can contribute to international examination for the further improvement on measurement of capital, like measurement of price and quantity of capital services, and capital service cost for non-market production, which are discussed by Canberra II Group (Ahmad 2004; Diewert, Harrison, and Schreyer, 2004). We conclude in section 4, summarizing our proposals for sweeping improvement for measuring capital in the Japanese national accounts.

2 Capital: Two Aspects of One Entity

2.1 Concepts of Capital Stock

What is the role of measurement of capital? Like other factors of production, which are used in production processes, capital has a productive capacity. Unlike other factors of production, however, capital is not consumed, but used beyond a single accounting period. This durability lets the capital retain its value so that capital can be used in future production processes. Capturing the two aspects of capital: the productive capacity and the value of capital, is the main purpose for measuring capital.[*1]

[*1] The durability of capital makes the accounting difficult. See Hulten (1990) and Diewert (2001).

2.1.1 Traditional Gross and Net

Traditionally, two distinctive concepts for capital stock, gross capital stock and net capital stock, were used. The distinction of the two concepts is based on depreciation. Gross capital stock is defined before the deduction of depreciation and net capital stock is reduced by the depreciation. As the traditional gross concept still remains in the Japanese statistics of capital stock for production analysis, gross capital stock may have been sometimes thought suitable to measure the productive capacity of capital.

However, the traditional system of gross and net capital stock is incapable of portraying the two different aspects of capital, except under unrealistic assumptions. This was finally abandoned by BEA in 1997, a quarter century after the controversy between Jorgenson-Griliches (1972) and Denison, also Jorgenson (1989) had clearly pointed this out.

2.1.2 Gross, Productive, and Net

The intensive works of Dale W. Jorgenson, Robert E. Hall, Zvi Griliches, Charles R. Hulten, Walter E. Diewert, who marvelously were at the University of California, Berkley in the 1960s,[*2] and many other researchers and statisticians, have developed the theory for measurement of capital and accumulated the empirical results. The theory of capital measurement clarifies the distinction of these two aspects of capital, based on the concepts of age-efficiency profile and age-price profile. We use three distinctive stock concepts in this paper. Three concepts are gross, productive, and net capital stocks.[*3]

Figure 1 represents the three concepts of capital stock and their relationships. The gross capital stock (GCS): $S^{G,k,j}_{t,\tau}$ of asset k with age τ in industry j at time t is defined as:

$$S^{G,k,j}_{t,\tau} = A^{k,j}_{t-\tau}, \tag{1}$$

[*2] Griliches was at the University of Chicago in the 1960s, although he has collaborated with Jorgenson.

[*3] We use the name of productive capital stock after Triplett (1996a, 1997) and Hill (1998, 1999). Biørn (1989) and Biørn, Holmoy, and Oystein (1989) call a productive capital stock in this paper as a "gross" capital stock, since they do not need a traditional gross concept of capital stock. OECD (2001b) does not give a particular name for the productive capital stock.

Net capital stock in this paper is also called "wealth" capital stock, like Triplett (1997). The net capital stock is "generally, a synonym for the wealth capital stock. The "net" language thus distinguishes the depreciated capital stock (the wealth capital stock) from the undepreciated, or gross capital stock. However, the traditional "gross-net" capital dichotomy does not encompass the productive capital stock, which could cause confusion (because the productive capital stock is "net" of depreciation, compared to the undeteriorated gross stock). Once the distinction between productive and wealth capital stocks fully enter the lexicon, it will probably be preferable to avoid the net capital stock terminology." (Triplett, 1997) However, we use net capital stock in this paper, partly because we cannot find a adequate term in Japanese corresponding to the "wealth capital stock", and partly because net capital stock is identical with the traditional net capital stock although the concept is clarified.

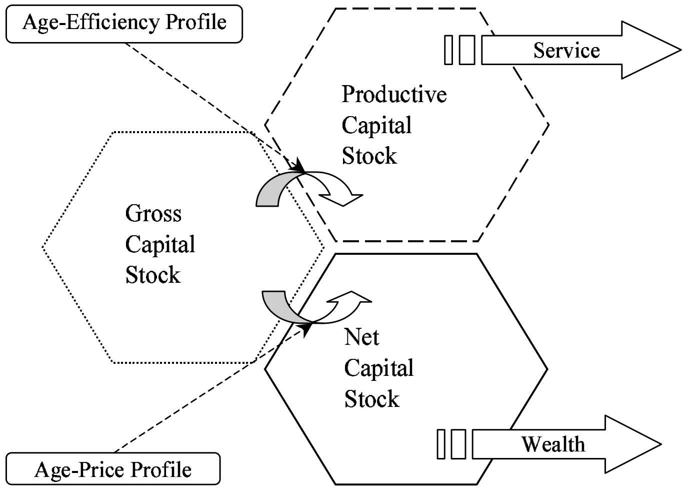


Fig. 1 Concepts of Capital Stock

where $A^{k,j}_{t-\tau}$ is quantity of investment measured in "efficiency units" among the existing assets with different vintages: $v = t - \tau$, although the GCS permits the difference of quality of assets with different ages: τ. In other words, the assets with different ages are evaluated at "as new" prices in the GCS, described in OECD (2001b). The GCS provides the conventional first step for measuring capital stock.

The age-efficiency profile (AEP) gives a schedule for the productive capacity associated with the pure aging of capital at the same point of time, taking an efficiency of a new asset as one to normalize. Assuming no change of the AEP over time, we write the AEP as d^k_τ, independently of time t. It satisfies the conditions below,

$$d^k_0 = 1, \;\; d^k_1 > 0, \;\; d^k_\tau - d^k_{\tau-1} \leq 0, \;\; \lim_{\tau\to\infty} d^k_\tau = 0. \tag{2}$$

These four conditions represent, respectively, normalization of AEP at $\tau = 0$, durability of the asset, monotonic decreases of relative efficiency, and finite durability. Note that the AEP is defined as the combined distribution of the survival distribution of an asset and the efficiency distribution for the surviving asset. Triplett (1997) uses the term "deterioration" to define the relative efficiency in the AEP. Deterioration arises from two sources, "retirement" and "decay" which is defined by the loss of efficiency of a surviving asset.

Applying the AEP to assets with different ages, the GCS will be transformed to the productive capital stock (PCS), as

$$S^{P,k,j}_{t,\tau} = d^k_\tau S^{G,k,j}_{t,\tau}. \tag{3}$$

The PCS is evaluated in the same efficiency unit among assets with different ages. Capital services can be produced from the PCS, as is discussed later. The AEP transforms assets with different ages to be perfectly substitutable, so that the PCSs with different ages can be simply added: $S^{P,k,j}_{t} = \sum_{\tau=0}^{\infty} S^{P,k,j}_{t,\tau}$.[*4] By the dual approach of capital, the capital service prices of assets with different ages have perfect complementary, so that they are equivalent: $P^{K,k}_t = P^{K,k}_{t,\tau}$, (Jorgenson, 1989).

The age-price profile (APP) gives a schedule of the capital value associated with its pure aging at the same point of time, normalizing the capital value of a new asset at one. The schedule of the capital value in the APP depends on future capital services described in the AEP, the expected capital service price, and the expected discount rate, as defined in Equation (19) later. Here, we write the APP as $d^{P,k}_{t,\tau}$. Assets with different ages normally have a different value because of a finite service life of the asset, even if the productive capacity the asset has is exactly same. We assume the conditions for the APP as:

$$d^{P,k}_{t,0} = 1, \;\; d^{P,k}_{t,1} > 0, \;\; d^{P,k}_{t,\tau} - d^{P,k}_{t,\tau-1} \leq 0, \;\; \lim_{\tau\to\infty} d^{P,k}_{t,\tau} = 0, \;\; \lim_{r_t\to\infty} d^{P,k}_{t,\tau} = d^k_\tau. \tag{4}$$

The conditions required for the APP are similar to Equation (2) for the AEP. The fifth condition represents that the APP converges to the AEP, when the discount rate r_t approaches infinity. Applying the APP to assets with different ages, the GCS will be transformed to the net capital stock (NCS):

$$S^{N,k,j}_{t,\tau} = d^{P,k}_{t,\tau} S^{G,k,j}_{t,\tau}. \tag{5}$$

Except the case that the AEP declines very rapidly, the APP may be smaller than the AEP: $d^{P,k}_\tau \leq d^k_\tau$. From the conditions for the AEP and APP in Equations (2) and (4), the order of magnitudes in three capital stocks may be as,

$$S^{N,k,j}_{t,\tau} \leq S^{P,k,j}_{t,\tau} \leq S^{G,k,j}_{t,\tau}. \tag{6}$$

For new assets with $\tau = 0$, the three measures of capital stock are identical: $S^{N,k,j}_{t,0} = S^{P,k,j}_{t,0} = S^{G,k,j}_{t,0}$, since $d^{P,k}_{t,0} = d^k_0 = 1$. The difference in the three measures occurs because of the durability of assets.

The concept of GCS is the same as the traditional gross concept of capital stock. In the three capital stocks, the GCS may have very limited purposes to be used. If we assume a vintage production function, the GCS may give an appropriate concept as the factor input. However, for the economic analysis using

[*4] Diewert and Lawrence (2000) and Diewert (2001) provide new approach in measuring capital and propose the use of a superlative index number formula to aggregate assets with different ages (or vintages, under the fixed point of time). In this paper, we assume perfect substitution in the PCSs with different ages, as if the AEP were specified independently.

an aggregate measure of capital with different ages, it may be no longer easy to find an appropriate role of the GCS.[*5]

The GCS is interpreted as a special case of the PCS, which is an appropriate concept for productive capacity of capital stock. Only if the AEP is "one-hoss shay", where the relative efficiency of capital is constant throughout the lifetime T^k, the GCS is identical with the PCS,

$$S_{t,\tau}^{N,k,j} \leq S_{t,\tau}^{P,k,j} = S_{t,\tau}^{G,k,j}, \tag{7}$$

where

$$d_\tau^k = 1(\tau < T^k), \;\; d_\tau^k = 0(\tau = T^k). \tag{8}$$

Only some exceptional assets like electric light bulbs provide an example. The one-hoss shay distribution can hardly be observed in the empirical studies for measuring the AEP. The clarification on concepts of capital stock no longer provide a role for the GCS.

2.1.3 Geometric vs Hyperbolic

In the framework for measuring capital stock, the key idea is the AEP. Based on the comprehensive empirical studies of Hulten and Wykoff (1981a, 1981b, 1981c), the geometric distribution in the AEP or APP is approximately accepted for many assets.[*6] Theoretically, the geometric distribution alone has the desirable property that the AEP and the APP are identical. Also, therefore, the PCS and the NCS are identical, as

$$S_{t,\tau}^{N,k,j} = S_{t,\tau}^{P,k,j} \leq S_{t,\tau}^{G,k,j}, \tag{9}$$

where

$$d_\tau^k = d_{t,\tau}^{P,k} = (1-\delta^k)^\tau. \tag{10}$$

This assumption is called as the "best geometric approach" (BGA). The two aspects of one entity of capital are captured by only one measure, based on the assumption of the BGA. Accepting the BGA makes

---

[*5] Conventionally, GCS is treated as a starting point for the measurement of capital stock, as represented in Equations (3) and (5). However, as the GCS is the same as the quantity of investment in Equation (1), the procedure for the measurement of the GCS need not be addressed.

[*6] Jorgenson (1996) gives a survey of empirical research on depreciation and its applications. There has been considerable debate about the appropriate depreciation rates for assets with constant-quality deflators. As pointed out by Oliner (1993, 1994) and, more recently, by Whelan (2002), if the quantity of investment is constructed with a constant-quality deflator, the depreciation rate should be obtained from constant-quality price data by age of asset. This corresponds to "partial depreciation" in Oliner's terminology.

it possible to neglect the age structure for aggregating assets with different ages, like a familiar perpetual inventory method (PIM),

$$S_t^{P,k,j} = (1-\delta^k)S_{t-1}^{P,k,j} + A_t^{k,j} = \sum_{\tau=0}^{\infty}(1-\delta^k)^\tau A_{t-\tau}^{k,j}. \tag{11}$$

On the revised measurement of capital stock and depreciation of the U.S. BEA, the BGA is used as a default, as discussed in section 2.3.2.

Alternatively, hyperbolic function, which used to be called β-decay, is assumed to describe the AEP. The hyperbolic function is defined as,

$$d_\tau^k = \frac{T^k - \tau}{T^k - \beta_\tau^k}, \tag{12}$$

where T^k and β_τ^k ($-\infty < \beta_\tau^k \leq 1$) are parameters for asset k. When β_τ^k is 0, 0< $\beta_\tau^k < 1$, and 1, the hyperbolic AEP will be straight-line, concave, and one-hoss shay, respectively. When $\beta_\tau^k < 0$, the hyperbolic AEP can simulate geometric distribution.

The advantage of the hyperbolic AEP, relative to the BGA, is that the hyperbolic function is more flexible and has a upper limit of the service life: $d_\tau^k = 0$ if $\tau = T^k$, by comparison the efficiency in the BGA never completely vanishes. On the other hand, the assumption of the hyperbolic AEP does not simplify the PIM like Equation (11) and some assumptions about real discount rates are required to define the corresponding APP, unlike the BGA.

The AEP can be determined empirically by modeling a time series of prices of an asset by age. Note that it is difficult to verify which approximation is most appropriate by the empirical studies to estimate the APP. As Fraumeni (1997) pointed out, BLS found there was no statistically significant difference between the geometric and the hyperbolic function, because both have an age-price counterpart that is convex, or bowed towards the origin. An alternative and more direct approach is modeling a time series of rental prices of an asset by age.

OECD (2001b) reports that the U.S. Bureau of Labor Statistics (BLS) and the Australian Bureau of Statistics (ABS) use the hyperbolic function and that the U.S. BEA and the Statistics Canada use the BGA. Although any other flexible functions can be assumed as the AEP, it may be a choice between two alternatives, geometric and hyperbolic distribution, to reframe the capital measurement in the Japanese national accounts, in practice.

2.2 Price and Quantity of Investment

Let us go back to the starting point. Prior to measuring capital stock, our starting point is the measurement of nominal investment, which is directly observable and evaluated in current prices at the times they are produced.[*7] We define nominal investment as:

$$I_t^{k,j} = P_t^{A,k} A_t^{k,j}, \tag{13}$$

where $P_t^{A,k}$ is investment price for acquisition of new assets in time t.

The assets invested and produced in different times have different vintages, $t = v$ since $v = t - \tau$ and $\tau = 0$, so that the technology embodied in the assets may be different. An adjustment for quality of assets with different vintages, therefore, is required to measure quantity of investment in efficiency units. Constant-quality prices for investment goods: $P_t^{A,k}$, include the adjustment coefficients. Rapid technological progress in information technology (IT) and the recent increase in its impact illuminate anew the importance of constant-quality prices. Here, we introduce the Japanese measurement of prices and discuss it by the comparison of price measures in the U.S. In center of the discussion, there are computer prices, where holding constant-quality has a significant role. First, we examine some issues in the measurement of investment prices.

2.2.1 Price on Investment as Composite Goods

In Equation (13), the price for acquisition of produced assets is defined not as a producer's price, but as a purchaser's price. The nominal investment value is written as the following identity,

$$P_t^{A,k} A_t^{k,j} = P_t^{C,k} X_t^{C,k,j} + P_t^{W,k} W_t^{k,j} + P_t^{T,k} T_t^{k,j}, \tag{14}$$

where

$$P_t^{C,k} X_t^{C,k,j} = P_t^{D,k} X_t^{D,k,j} + P_t^{M,k} X_t^{M,k,j} \tag{15}$$

In Equation (15), $P_t^{D,k}$ and $P_t^{M,k}$ represent constant-quality prices for domestic output and imports of asset k. Using an aggregator function of the two prices: $P_t^{C,k} = f^C(P_t^{D,k}, P_t^{M,k})$, the investment price: $P_t^{C,k}$, can be defined as the price for composite goods of domestically produced and imported assets, in producer's prices. In Equation (14), $P_t^{W,k}$ and $P_t^{T,k}$ are prices for wholesale and transportation costs needed for the acquisition of asset k. Using an aggregator function: $P_t^{A,k} = f^A(P_t^{C,k}, P_t^{W,k}, P_t^{T,k})$ of the three prices, the investment price: $P_t^{A,k}$, can be defined in purchaser's prices.[*8]

[*7] Measurement of nominal investment depends on two approaches: bottom-up and top-down. The bottom-up approach is based on the survey of investment, which depends on the custom in business accounts. On the other hand, top-down approach is based on the supply of investment goods by domestic production and net imports, as described at the commodity flow method in national accounts. Reconciling both approaches contributes to recognize the measurement error and the conceptual difference. Although this process has crucial significance to determine the accuracy of measurement of capital, it is too complicated to describe here. For the case in Japan, see Nomura (2004, Ch.2 and Ch.A-B).

[*8] For the prices in Equation (14) and (15), we neglect the difference among industries. In case that one asset at the most detailed

Surprisingly, as Nomura and Samuels (2004) pointed out, the BEA's price index for private fixed investment does not reflect margin rates, margin prices, and transportation costs. The BEA's investment price for computers actually falls a little more rapidly than output prices, reflecting import prices that fall more rapidly than domestically produced prices. For the price of computers during 1980-2000, the average decline rate of BEA's output price is 16.1 percent per year and the BEA's investment price declines 16.5 percent annually. After including the wholesale margins and transportation costs, the decline rate shrinks to 12.9 percent. During 1995-2000, the decline rates of the output price, investment price, and redefined investment price are 24.9 percent, 24.4 percent, and 18.7 percent, respectively.[*9] The numerous studies that analyze the contribution of computers to economic growth using this price and harmonized prices based on the BEA price discussed later, may overestimate declines of the computer prices and increases of capital inputs from computers.

A possible justification of the BEA's neglect of margins is that the change of margin price may be same as the price change of a product treated by a wholesaler, under the assumption of constant nominal margin rates. Based on the identity in Equation (14), we can get $P_t^{A,k} A_t^{k,j} = (1 + v_t^{W,k,j} + v_t^{T,k,j}) P_t^{C,k} X_t^{C,k,j}$, where $v_t^{W,k,j}$ and $v_t^{T,k,j}$ are the nominal rates of margin and transportation cost. As is sometimes assumed, if we think quantities of investment are identical: $A_t^{k,j} = X_t^{C,k,j}$, we get the simple relationship on the two prices: $P_t^{A,k} = (1 + v_t^{W,k,j} + v_t^{T,k,j}) P_t^{C,k}$. Therefore, under the constant rates: $v^{W,k,j}$ and $v^{T,k,j}$, the purchaser's price may be proportional to the producer's price.

Is this identity approach adequate for the asset that has an outstanding quality improvement over time? Under a more general aggregator function of prices: $P_t^{A,k} = f^A(P_t^{C,k}, P_t^{W,k}, P_t^{T,k})$, quantity of investment also should be defined to fulfill the price aggregator function and the nominal identity in Equation (14). Therefore, $A_t^{k,j}$ is defined as not only $X_t^{C,k,j}$, but also a composite goods of $X_t^{C,k,j}$, $X_t^{W,k,j}$, and $X_t^{T,k,j}$. Moreover, for a computer, the price changes in margin and transportation: $P_t^{W,k}$ and $P_t^{W,k}$, may be more moderate than the constant-quality prices: $P_t^{C,k}$, in computers. To estimate the margin price: $P_t^{W,k}$, we have to define

level consists of some detailed assets corresponding to the commodity flow data, the prices should be reflected the difference of asset composition invested by industries, as $P_t^{D,k,j}$. Moreover, we neglect indirect taxes, here. The indirect tax included in output prices, like a consumption tax, may be deducted from the purchase of investment goods. The consistent definitions of indirect taxes in output and investment prices should be of note. In Japan, the consumption tax was introduced in 1989 and the rate was increased from 3 percent to 5 percent in 1997.

[*9] Here, "computers" is defined as US-SIC-357 excluding 3578 and 3579. The wholesale margin rates and transportation costs are taken from the benchmark Input-Output Tables (1977, 1982, 1987, 1992, 1997), published by BEA. The U.S. prices for wholesale and transportation are from GDP-by-Industry data. Rates of margin and transportation for computers are 17.1 percent and 0.9 percent of the purchaser's price in 1997, respectively. The rates in the U.S. are similar to that in Japan: 19.0 percent and 0.9 percent in 1995, respectively. See Nomura and Samuels (2004).

the quantity of margin: $W_t^{k,j}$. Let us think an example. We assume a wholesaler buys in one unit of PC for one thousand dollar and sells it for two thousand dollar, last year and, also, this year. If the quality of the PC becomes twofold between the two periods, the constant-quality price for the PC is interpreted as decreases by fifty percent and the constant-quality quantity is treated as increases twofold. In this case, is quantity of margin unchanged or does it increase twofold also? The adequate answer may be that the quantity of margin is constant, because the quality improvement in the PC as a treated product may not affect any costs in the wholesaler. The quality change in the computer should not affect the productivity of the wholesaler, so that the quantity of margin, as a real "gross" output of the wholesaler, should be unchanged. Also, the price change of the margin should be zero, in this example. So, in usual, the decline of $P_t^{A,k}$ may be more moderate than that of $P_t^{C,k}$.

Another important note is on the recognition of investment goods as a compound goods of other investment goods. In practical, an asset is classified as the final goods to be invested. Some investment goods may be defined including embedded investment goods, which can be also classified as an asset, separately. For example, the investment of office building is defined including the elevator, lighting, furniture, and operating system, controlled by the computer. Also, computers are defined including the embodied software.

In the 2003 comprehensive revision of the NIPA, the BEA revised the prices for software, so that the prices for own-account software and custom software are defined by a weighted average of the input cost index for software and the quality-adjusted price for the prepackaged software. The vastly revised price for software, nevertheless, does not affect the price of computers or operating system of the office building, in which software is partly embedded. If a hedonic function for computer, in which software is one of characteristics, is estimated, the consistency with the constant-quality price for the software should be maintained. So far, the revisions of the investment prices are treated separately.

2.2.2 Constant-Quality Prices in the U.S. and Japan

The hedonic approach has been shown to be an effective technique for capturing quality changes.[*10] In the U.S. National Accounts, hedonically adjusted computer prices were introduced in December 1985 representing five types of computer equipment: processors, disk drives, printers, displays, and tape drives covering 1972-1984, by the work of BEA with IBM (Wasshausen, 2000). In 1987, a hedonic price was introduced for personal computers, beginning in 1983. BEA later developed estimates of computer hardware and software prices back to 1959 (Landefeld and Grimm, 2000). Triplett (1989) also extends the computer prices backward, based on indexes developed in several independent studies. In the early 1990s, Bureau of Labor Statistics (BLS), which is the main producer for price statistics in the U.S., began publishing the quality adjusted Producer Price Index (PPI) for computers. BEA now uses detailed BLS price indexes for computers, peripherals, parts and for some types of software: these indexes are aggregated using BEA chain weights to produce chain-type price indexes (Landefeld and Grimm, 2000).

In Japan, the Bank of Japan (BOJ) and the Statistics Bureau, Ministry of Internal Affairs and Communications (MIC) are main producers of price statistics. On the Wholesale Price Index (WPI), the BOJ started to use the hedonic approach from the 1990 benchmark revision for personal computers (PCs), mainframes, and magnetic disk devices, modeling the hedonic function on an annual basis. The BOJ's WPI has been greatly revised and renamed to the Corporate Goods Price Index (CGPI) in 2000.[*11]

Compared to the WPI/CGPI, the MIC's Consumer Price Index (CPI) mainly used the matched model for quality adjustment. After the 2000 benchmark revision of the CPI, the MIC began estimating quality

---

[*10] Although hedonic approach is widely thought to be suitable to capture quality change, it is not necessarily that the traditional approach, like a matched model, is inferior to hedonic approach. Aizcorbe, Corrado, and Doms (2000) points out that matched model captures the rapid pace of quality change for high technology goods market, where the life of a product is relatively short and the varieties of products are sold at once. For computer prices, Landefeld and Grimm (2000) indicates that hedonic price indexes for computers produce results that are quite robust and that are virtually the same as those produced by a carefully constructed traditional price index for computers. The use of hedonic price indexes is increasing, and the components that are deflated by hedonic techniques account for 18 percent of GDP in the U.S. (Landefeld and Grimm, 2000). Also, Moulton (2001) provides the expanding role of hedonic approach in the U.S. and discusses some misconceptions about the technique.

[*11] The CGPI is composed of Domestic Corporate Goods Price Index (DCGPI), Export Price Index (EPI), and Import Price Index (IPI). BOJ increased the number of sample prices to be surveyed by 69 percent (63 percent only for DCGPI), from 4902 (3379 for domestically produced goods) in 1995 benchmark WPI to 8264 (5508) in the 2000 benchmark CGPI. Since the 2000 benchmark revision, the CGPI uses the hedonic approach for Servers, which is a component of General Purpose Computers & Servers, Digital Cameras, and Video Cameras, in addition to PCs. On the other hand, BOJ discontinued to use the hedonic approach for mainframe and magnetic disk devices after 2001, because of a lack of the credible common characteristics data. The BOJ estimates the hedonic function for two types of PCs, desktop-type and laptop-type below the commodity level, and raises the frequency twice per year. The functional form, data, and the estimated results by the hedonic approach are in BOJ (2002).

improvements for desktop and laptop PCs, adjusting these two items hedonically, using Point of Sales (POS) data, which covers all sales at 3400 major shops across Japan. CPI also starts incorporate hedonics for digital cameras after 2003.

The significant difference in price statistics of the U.S. and Japan is whether the prices of the commodity that has an outstanding quality improvement could be extrapolated backward or not. Although this function is carried out by BEA in the U.S., we may not find any similar function in the Japanese statistical system. In the Japanese national accounts, ESRI uses the WPI/CGPI and the CPI. However, ESRI, and BOJ also, does not extrapolate the prices based on the newly developed methodology backward. This should be noted as a defect in the Japanese system for price statistics. BOJ also publishes the Corporate Service Price Index (CSPI). In November 2004, the CSPI began to estimate the price for prepackaged software, based on cost evaluation method, beginning in 2000.

Another problem in Japan may be found in the index formula. BOJ estimates aggregate price indexes based on Laspeyres formula as a basic index and chained Laspeyres formula as a reference index in the WPI/CGPI after 1995. We should note that chained and un-chained versions of the two price indexes of WPI/CGPI are different even at the most detailed commodity level, reflecting different item weighting within the detailed commodities. One commodity usually consists of multiple items ("sample prices"), which are not published. At present, BOJ uses arithmetic aggregation, called a Carli price index by Diewert, of these item prices for the Laspeyres price index, while geometric aggregation, Jevons price index, for the chained version. The difference is large, especially for computers (Nomura and Samuels, 2004). In December of 2004, ESRI officially incorporated the chained Fisher index for the national accounts. At the most detailed commodities in the Japanese national accounts, however, ESRI uses the BOJ's basic index, the Carli index.[*12] Fisher and Diewert clearly indicate that the Carli index has a definite upward bias and urge statistical agencies not to use this formula.

2.2.3 Possible to Use Harmonized Prices?

In studies covering multiple countries, some studies have employed internationally harmonized prices, which translate U.S. prices to comparison country prices in order to control for the quality improvements in the comparison country.[*13] For countries with the statistical agencies, which do not adjust prices for IT for

---

[*12] In the Japanese national accounts, the commodity flow data is based on about 2200 commodities at the most detailed level, although commodities have each price index at the level of about 400 commodities.

[*13] Price harmonization is an attempt to control for these price differences, under the assumption that the comparison country's price data fails to capture quality improvements. Various studies have used different methods to construct harmonized prices, but the basic idea is the same. The relative price of IT to non-IT in the comparison country is set equal to the IT to non-IT price relative in the U.S. The harmonized price is formulated such that: $\Delta \ln p^{x}_{IT} = \Delta \ln p^{x}_{nIT} + (\Delta \ln p^{US}_{IT} - \Delta \ln p^{US}_{nIT})$, where the suffix

the quality change, the use of harmonized prices may be one possible approximation for quality-adjusted prices. However, in a country like Japan, the use of harmonized prices needs further justification.

Nomura-Samuels (2004) examines the IT prices in the U.S. and Japan at the SIC 3-, 4-, 5-digit level. Comparing the U.S. and Japan data for PCs and General Purpose Computers & Servers at the 5-digit level from 1995 to 2003, there is a small gap between the countries, as a consequence of the definition of index numbers for aggregation of the most detailed items. At the 4-digit level, after adjustment of the index numbers and the aggregation weights for the WPI/CGPI to be consistent with the BEA's output price, the resulting price declines for electronic computers are comparable, as prices fall 29.3 percent per year in the U.S. compared to 27.0 percent per year in Japan, during 1995-2003. Moving to the 3-digit level, the aggregate price of Electronic Computers and Peripheral Equipment shows that prices fall 23.8 percent per year in the U.S. compared to 15.5 percent per year in Japan. At the 3-digit level, a significant portion of the remaining price gap can be explained by the Peripheral Equipment price, which falls less rapidly in Japan and has a bigger share of total output when exports are included. After 1995 we conclude the computer prices at the SIC 3-, 4-, 5-digit level in the U.S. and Japan are appropriate.

During 1980-95, computer prices at the 3-digit level fall 13.1 percent per year in the U.S. based on the BEA data, while prices fall 7.6 percent per year in Japan. In 1980s, the Japanese PC market was dominated by the NEC Corporation, which had a 60-70 percent share of domestic demand. On the other hand, the international PC market was very competitive, with many manufacturers of IBM-compatible computers entering to combat the dominance of IBM in the early 1980's. Until 1991, the Japanese PC market was separated from the international market due to hardware and software differences and incompatibility issues, but the origin of DOS/V as a new Operating System (OS) in 1991 changed that.

DOS/V is a version of MS-DOS that provides both English and Japanese language command interfaces and can be used for applications designed for either or both English and Japanese. DOS/V includes all the English-based commands and specific Japanese DOS/V commands.[*14] Because DOS/V works on all IBM-compatible computers, foreign manufacturers were able to enter to the Japanese PC market. Competition brought prices down for computers. In 1993, NEC Corporation introduced a new model PC, priced 50 percent lower than the previous model. Import share of computer in Japan increased from 7.6 percent in 1990 to 14.3 percent in 1995, and it reached to 23.1 percent in 2000. Our observation indicates the use of the U.S. harmonized price should be rejected for the Japanese economy because of differences in market conditions.

---

x means the reference country, p_{IT} is the IT product price, and p_{nIT} is the non-IT price.

[*14] DOS/V gets its name because it requires a Video Graphics Array (VGA) display. In 1991, the Open Access Development Group (OADG), a consortium organized by IBM, developed DOS/V.

2.3 Capital Value and Depreciation

For reframing the measurement of capital in the Japanese national accounts, it is important to examine not only measurement of capital stock, but also the consumption of fixed capital in the production account. In this section, we start with the framework for describing capital value and depreciation. Based on this framework, we discuss the improvement in the U.S. National Income and Product Accounts (NIPA) and the measurement of depreciation rates in the Japanese economy.

2.3.1 Capital Value

The value of a new asset is assumed to be equal to the present value of future capital service income as,

$$P_t^{A,k} = d_0^k P_t^{K,k} + \frac{d_1^k P_{t+1}^{K,k}}{1 + r_{t+1}} + \frac{d_2^k P_{t+2}^{K,k}}{(1 + r_{t+1})(1 + r_{t+2})} + \cdots = \sum_{\tau=0}^{\infty} \frac{d_\tau^k P_{t+\tau}^{K,k}}{\Pi_{s=0}^{\tau}(1 + r_{t+s})}, \tag{16}$$

where $r_t = 0$ and $P_{t+\tau}^{K,k} (\tau = 0, \cdots, \infty)$ represents future capital service prices. In time $t + \tau$, the capital service prices of assets with different ages are equivalent. Using the normalized quantity of capital service, represented by the age-efficiency profile (AEP): d_τ^k, future capital service income is defined by $d_\tau^k P_{t+\tau}^{K,k}$.[*15] The value of a new asset in Equation (16) provides the investment price of the asset, examined in section 2.2.

The nominal value of assets with different ages is written as:

$$V_{t,\tau}^{S,k,j} = P_t^{A,k} S_{t,\tau}^{N,k,j}, \tag{17}$$

$V_{t,\tau}^{S,k,j}$ represents nominal value of net capital stock, which is capital wealth to be described in the balance sheet of the capital holders. The price for net capital stock $S_{t,\tau}^{N,k,j}$ is $P_t^{A,k}$.

Next, we define the value of assets with different ages τ,

$$P_{t,\tau}^{A,k} = d_\tau^k P_t^{K,k} + \frac{d_{\tau+1}^k P_{t+1}^{K,k}}{1 + r_{t+1}} + \frac{d_{\tau+2}^k P_{t+2}^{K,k}}{(1 + r_{t+1})(1 + r_{t+2})} + \cdots = \sum_{\tau'=0}^{\infty} \frac{d_{\tau+\tau'}^k P_{t+\tau'}^{K,k}}{\Pi_{s=0}^{\tau'}(1 + r_{t+s})}. \tag{18}$$

To measure nominal value of net capital stock, $P_{t,\tau}^{A,k} S_{t,\tau}^{G,k,j}$ provides alternative definition of equation (17).

[*15] In behalf of Equation (16) that is based on the discounted future rentals approach, Diewert (2001) uses the vintage approach as the "fundamental equation" relating the stock value of a new asset to the sequence of cross sectional vintage rental prices. In the Diewert's vintage approach, as a matter of form, d_τ^k in Equation (16) is replaced cross-sectional vintage rental prices: $P_{t,\tau}^{K,k}$, which is defined by $d_\tau^k P_t^{K,k}$ in our terminology, and $P_{t+\tau}^{K,k}$ in Equation (16) is replaced by the rental price escalation factor: $P_{t+\tau}^{K,k} / P_t^{K,k}$ in our terminology.

Using $P^{A,k}_{t,\tau}$, we can define the age-price profile (APP) as,

$$d^{P,k}_{t,\tau} = \frac{P^{A,k}_{t,\tau}}{P^{A,k}_{t}}. \tag{19}$$

The APP depends on the expectation in the future inflation of capital service prices and discount rates. Under static expectations on $P^{K,k}_t$ and r_t, the APP depends on the discount rate at time t. Therefore, even if the AEP is constant over time, the APP can change, associated with the change of r_t.

When an asset ages over time: $\tau \rightarrow (\tau+1)$ and $(t-1) \rightarrow t$, the difference in the values: $(P^{A,k}_{t-1,\tau} - P^{A,k}_{t,\tau+1})$, is written as the following identity,

$$E^k_{t,\tau} = D^k_{t,\tau} - \Pi^k_{t,\tau}, \tag{20}$$

where

$$E^k_{t,\tau} = P^{A,k}_{t-1,\tau} - P^{A,k}_{t,\tau+1}, \;\; D^k_{t,\tau} = P^{A,k}_{t,\tau} - P^{A,k}_{t,\tau+1}, \;\; \Pi^k_{t,\tau} = P^{A,k}_{t,\tau} - P^{A,k}_{t-1,\tau}. \tag{21}$$

Hill (1999) and Diewert (2001) call $E^k_{t,\tau}$ and $D^{P,k}_{\tau}$ as (ex post) "time-series depreciation" and "cross-section depreciation", respectively.*16 The cross-section depreciation is defined as the difference between the value of an asset of age τ and an identical asset of age $\tau+1$ at the same point of time t. The second term of the right hand of Equation (20): $\Pi^k_{t,\tau}$, is the difference between the value of an asset in $(t-1)$ and an identical asset in t for the asset with same age. This is called as an asset-specific "revaluation" term. The time-series depreciation consists of cross-section depreciation and revaluation.

Dividing this identity of price change by $P^{A,k}_{t-1,\tau}$, we can obtain,

$$\epsilon^k_{t,\tau} = (1+\pi^k_{t,\tau})\delta^{P,k}_{t,\tau} - \pi^k_{t,\tau}, \tag{22}$$

where

$$\epsilon^k_{t,\tau} = \frac{P^{A,k}_{t-1,\tau} - P^{A,k}_{t,\tau+1}}{P^{A,k}_{t-1,\tau}}, \tag{23}$$

$$\delta^{P,k}_{t,\tau} = \frac{P^{A,k}_{t,\tau} - P^{A,k}_{t,\tau+1}}{P^{A,k}_{t,\tau}}, \tag{24}$$

and

$$\pi^k_{t,\tau} = \frac{P^{A,k}_{t,\tau} - P^{A,k}_{t-1,\tau}}{P^{A,k}_{t-1,\tau}}. \tag{25}$$

*16 Although the importance of the distinction in two concepts of depreciation, the different names are used. Hulten and Wykoff (1981b, 1981c) calls the cross-section depreciation as "economic depreciation", which is also called as "Hicksian economic depreciation" in Hulten (1990), and the time-series depreciation as "economic depreciation and asset inflation". Oliner (1993, 1994) calls "partial depreciation" and "full depreciation", respectively.

$\epsilon^k_{t,\tau}$, $\delta^{P,k}_{t,\tau}$, and $\pi^k_{t,\tau}$ represent rates of time-series depreciation, cross-section depreciation, and revaluation, respectively. If we assume same inflation rate for assets k with different ages, $\pi^k_{t,\tau}$ will be written as π^k_t. In case of the geometric approach, $\delta^{P,k}_{t,\tau}$ will be identical for assets with different ages in different points of time, so that $\delta^{P,k}_{t,\tau}$ is written as δ^k. Under this simplification, time-series depreciation is also independent of age τ, as ϵ^k_t.

2.3.2 BEA's Revision for Measuring Stock and Depreciation

As a part of the comprehensive revision of NIPA, the U.S. Bureau of Economic Analysis (BEA) revised the methodology for estimating their capital stock and depreciation in 1997.[*17] The revised methodology reflects the results of empirical studies, which have shown that depreciation for most types of equipment and structures does not follow a straight-line, but approximates the BGA. The improvement for the measurement of depreciation involves the use of the BGA as the default, instead of the use of combination of the straight-line depreciation and the survival distribution.[*18] On the other hand, the BEA no longer produces estimates of gross capital stock and discards.

As a result of their revision, the BEA resolved the internal inconsistency in measures of capital stock in wealth account and consumption of fixed capital (CFC) in production account. This point was emphasized by Jorgenson (1989, 1996) as an inconsistency in the NIPA.[*19] The importance for sustaining internal consistency in the measurement of capital stock and CFC became a common objective in the national accounts, as in the international methodological standards recommended by OECD (2001a, 2001b).

Jorgenson (1999) states that the incorporation of the appropriate definition of CFC is the most important innovation in BEA's revision. Jorgenson indicates that the BEA's definition of CFC is different from that in 1993 SNA. This definition identifies CFC as the decline "during the course of the accounting period" in the value of an asset.[*20] However, this decline has two distinct components: "depreciation" due to aging

[*17] See Fraumeni (1997), Katz and Herman (1997), and BEA (2003). The BEA defines depreciation as "the decline in value due to wear and tear, obsolescence, accidental damage, and aging", which included retirements, or discards (Katz and Herman, 1997; Fraumeni, 1997).

[*18] Exceptionally, the BEA uses non-geometric patterns of depreciation for autos, computers, missiles, and nuclear fuel (Fraumeni, 1997). Therefore, the use of BEA's stock as the productive capital stock is not appropriate.

[*19] Jorgenson (1989) pointed out, "the national accounts fail to provide an internally consistent set of measurement of capital stock, capital input, and depreciation. This is regrettable, since studies of productivity like those of Denison and Kendrick will continue to rely on national accounting data."

[*20] The 1993 SNA define CFC as, "Consumption of fixed capital is a cost of production. It may be defined in general terms as the decline, during the course of the accounting period, in the current value of the stock of fixed assets owned and used by a producer as a result of physical deterioration, normal obsolescence or normal accidental damage. It excludes the value of fixed assets destroyed by acts of war or exceptional events such as major natural disasters, which occur very infrequently.

and "revaluation" due to a change in the price of an asset of a given age, which is not part of CFC.[*21]

2.3.3 Possible to Harmonize Depreciation Rate?

As represented in the comprehensive empirical studies of Hulten and Wykoff (1981a, 1981b, 1981c), there are many empirical studies for measuring the age-price profile or age-efficiency profile. However, almost empirical studies are based on the U.S. data.

There are few empirical studies for the rates of depreciation or deterioration of assets using the Japanese data. Lee (1978) for fishing fleet and Kuninori (1988) for construction machinery give a few examples. Many studies of the Japanese economy use the depreciation rates of the BEA (Fraumeni, 1997). However, depreciation rates can differ between the U.S. and Japan, reflecting the difference in natural and environmental condition, utilization, maintenance, and composition of capital goods.

Nomura (2004a, Ch-2) estimates age-price profiles based on the Box-Cox transformed function using the data in the second-hand market for motor vehicle, and age-efficiency profiles based on the data rental market for housing in Japan. The geometric approach is approximately accepted for these assets. The estimated depreciation rates are 16.3 percent for passenger motor vehicles, 22.4-23.8 percent for trucks, and 3.1-4.8 percent for housing. In comparison with the U.S. depreciation rates of BEA, passenger vehicles and housing are less durable and trucks are more durable in Japan. Even for tradable goods, the difference in the depreciation rates should be considered, if possible. Although empirical studies for measuring the Japanese depreciation rates are preferable, the use of the U.S. depreciation rates may be acceptable. Practically, the use of the U.S. harmonized depreciation may not generate a larger bias in measurement of capital than that caused by the use of the harmonized prices.

We must also estimate the Japanese depreciation rates for other assets. For other assets, we estimate average service lives T^k based on the Japanese tax-lives and the arbitrary rates to effective service-life in each fixed asset. Based on the relationship: $\delta^k = R^k/T^k$, we compute the Japanese depreciation rates using the declining balance rates R^k originated in Hulten and Wykoff (1981b) and employed by the BEA.

For computer hardware, the BEA depreciation rates incorporate Oliner's (1993, 1994) estimates for all computer components except personal computers (Fraumeni, 1997). Jorgenson, Ho, and Stiroh (2005) uses 31.5 percent for computers based on the depreciation schedule of the BEA. In Japan, the tax-life is 4 years for personal computer and 5 years for other computers, which are abridged from 6 years after the

---

Such losses are recorded in the System in the account for "Other changes in the volume of assets". Consumption of fixed capital is defined in the System in a way that is intended to be theoretically appropriate and relevant for purposes of economic analysis. Its value may deviate considerably from depreciation as recorded in business accounts or as allowed for taxation purposes, especially when there is inflation." (paragraph 6.179).

[*21] See Hill (2000) for the different view of CFC.

2001 fiscal year. Based on the tax-lives, we assume 34.7 percent depreciation rate for computers in Japan. The depreciation rates used in our latest estimates for capital stock and service in Japan are represented in Table 5.

3 Measurement of Capital in Japan

3.1 Japanese National Accounts

In section 3.1, we briefly introduce the measurement of capital stock and consumption of fixed capital in the present Japanese national accounts and discuss some problems to be overcome. The Economic and Social Research Institution (ESRI) of the Cabinet Office (CAO), the producer of the Japanese national accounts, publishes two main estimates for capital stock. Figure 2 shows the concepts and rough coverage of stock measurement in Japan. The first estimate is net capital stock, which is described in the balance sheet of the Japanese national accounts. We refer to this measure as "JSNA-NCS".[*22] The second estimate is Gross Capital Stock of Private Enterprises (GCSPE), which is the main data source for analysis of production by industry. In addition, the ESRI irregularly publishes gross capital stock for infrastructure.

3.1.1 Net Capital Stock

The JSNA-NCS covers fixed assets, land, inventories, and consumer durables of all capital holders in Japan. Although nominal investment in the JSNA-NCS is consistent with that in the national accounts commodity flow for certain aggregates, it has only six classifications for tangible assets and one intangible asset. The tangible assets consist of (1) dwellings, (2) other building, (3) other structures, (4) transport equipment, (5) other machinery and equipment, and (6) cultivated assets.[*23] The only intangible asset included is custom software.[*24] Finally, the JSNA-NCS is not estimated by industry, but by five institutional sectors. Depreciation in the JSNA-NCS is based on the straight-line method for infrastructure and the geometric method for other assets. Conceptually, the JSNA-NCS provides total wealth of the Japanese

[*22] Conventionally in Japan, the Japanese national accounts is also called "SNA", which is should be identified with the U.N.'s recommendation for System of National Accounts.

[*23] The classification for consumer durables consists of (1) furniture and floor coverings, (2) household appliances, (3) personal transport equipment, (4) information transmission equipment, and (5) others.

[*24] In the Japanese national accounts, expenditures for plant engineering, mineral exploration, and custom software are treated as gross fixed capital formation (GFCF) of intangible assets, although plant engineering is not recommended to be treated as and intangible asset in the 1993 SNA. Furthermore, it is added to "tangible" assets in the Japanese stock accounts, so the treatment is a halfway. Also, mineral exploration is not treated in the Japanese stock accounts, based on the assumption that it has just one-year service life. Both these issues should be reconsidered.

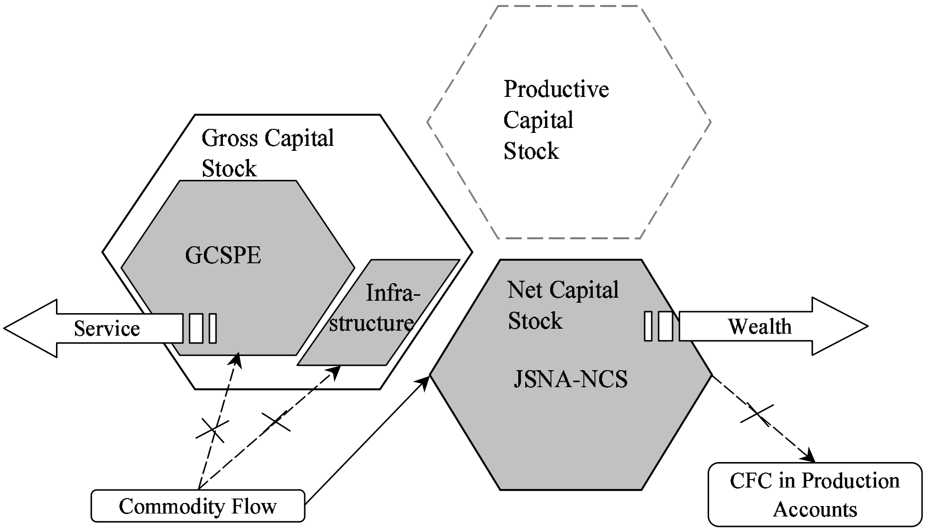


Fig. 2 Capital Stock in the Japanese National Accounts

capital stock. However, the assumed depreciation rates may be too high.*25

Although it is difficult to determine if JSNA-NCS is underestimated because of too high depreciation rates, Nomura (2004a, Ch.2) gives a comparison of net capital stock for fixed assets at current prices between the JSNA-NCS and his own estimates with identical nominal values of investment at the aggregate level.*26 In the comparison shown in Table 1, the JSNA-NCS is more than 30 percent lower in the 1990s. Nomura (2004a, Ch.2) defines the average rate of depreciation at the aggregate level as a weighted average of depreciation rates by assets, using the capital stock shares as the weights. The average rate of depreciation has an upward trend from 5.0 percent in the 1960s to 6.0 percent in 2000.*27 In comparison with the U.S., in which the average is 6.1 percent based on data from Dale Jorgenson, the computed average depreciation in Japan may be appropriate. The depreciation rates in the JSNA-NCS should be examined.*28

*25 Depreciation rates for assets except infrastructure are estimated using the average service life in the Japanese National Wealth Survey (NWS) from 1970, based on the assumption that the value of capital that has reached the end of its service life is ten percent of the original value (ESRI, 2000). The depreciation rates used in the JSNA-NCS are not published.

*26 Our estimates of capital stock are based on geometric depreciation for all assets. See Nomura (2004a) for the details.

*27 The capital stock used to estimate the average rate of depreciation is based on all fixed assets in Japan, including infrastructure. The average rate is 7.8 percent for the secondary industries and 9.2 percent for electric machinery industry in 2000.

*28 Alternative explanations are the differences of constant-quality prices and the benchmark stocks. Our stock estimate uses

Table. 1 Comparison of Capital Stock for Fixed Assets between the JSNA-NCS and Our Estimates

	a.JSNA-NCS	b.Nomura(2004a)	(a-b)	(a/b)
1990	936443	1351431	-414987	0.693
1995	1113173	1715143	-601970	0.649
2000	1192136	1899239	-707103	0.628

Unit: billion yen (current prices), evaluated at the end of the calendar year.

Stock does not include prepackaged and own-account software.

3.1.2 Consumption of Fixed Capital

In this paper, we call choose ”JSNA-CFC” to label consumption of fixed capital in the ”income and outlay accounts” and ”capital finance accounts” in the Japanese national accounts. The JSNA-CFC is defined by historical prices, based on the book value in corporate sector business accounts and on similar estimates for private unincorporated enterprises and general government. For the estimates by industry, the JSNA-CFC distributes the total CFC to industries, using the estimated industry shares, which are based on the share of CFC in gross output and the estimated values of gross output by industry (ESRI, 2000). Note that the assumptions to estimate the JSNA-CFC are not consistent with that in the JSNA-NCS.

Conceptually, CFC evaluated by historical prices should be revised. To determine the value of the CFC, the 1993 SNA points out: “Its value may deviate considerably from depreciation as recorded in business accounts or as allowed for taxation purposes, especially when there is inflation.” (paragraph 6.179). The JSNA-CFC evaluated by the historical prices generates a large bias when estimating net domestic product (NDP). NDP is a key economic concept that some argue should replace gross domestic product (GDP) as the appropriate measure of economic growth in the future.

3.1.3 Gross Capital Stock

For industry analysis of the Japanese economy, the GCSPE is a main data source for the Japanese capital stock. The GCSPE covers all fixed assets, excluding residential buildings owned by private corporations and unincorporated enterprises and fixed assets owned by private non-profit institutions. The GCSPE is sometimes used as a measure of the productive capacity of the private sector.[*29]

---

the Japanese National Wealth Survey (NWS) in 1955 as the benchmark stock. In comparison with the JSNA-NCS, whose benchmark stock is based on the 1970 NWS, our methodology is close to the perpetual inventory method.

[*29] To estimate productive capacity, the GCSPE intentionally excludes the residential capital owned by private sectors. There may be no longer any reason to exclude it, since the capital service produced by the residence owned by a company may be described as the consumption of fixed capital and operating surplus in the company. Also, it is difficult to identify it, in

However, it is misleading to use this data as a measure of productive capacity, for conceptual and empirical reasons. First, the GCSPE is defined by a traditional gross concept of capital stock. As we discussed the concepts for capital stock in section 2.1, the gross concept does not provide an appropriate measure for the productive capacity of capital. Second, the GCSPE does not have asset categories, so that the nominal investment in the GCSPE is not related to the commodity flow. Therefore, it is difficult for the GCSPE to measure quantity of investment $A_t^{k,j}$ in efficiency units and to consider the appropriate aggregation procedure for heterogeneous capital. Moreover, although the GCSPE publishes the estimates of gross capital stock and investment by industry at constant prices, it does not publish the nominal investment or investment prices by industry. The lack of reproducibility of the capital stock data does not allow the users of the GCSPE to test different assumptions for measuring capital.

Table. 2 Comparison of Capital Stock for Private Fixed Assets between the GCSPE and Our Estimates

	a.GCSPE	b.Nomura(2004a)	(a-b)	(a/b)
1995	971171	838238	132934	1.159
1996	1006469	862032	144437	1.168
1997	1047554	892533	155021	1.174
1998	1086240	918990	167251	1.182
1999	1120454	939743	180711	1.192
2000	1160232	965782	194450	1.201

Unit: billion yen (1995 constant prices), evaluated at the end of the calendar year.

The values does not include residence, prepackaged and own-account software.

Nomura (2004a) includes fixed assets owned by private non-profit institutions.

Table 2 compares measure of capital stock of private fixed assets at constant prices between the GCSPE and estimates based on Nomura (2004, Ch.2). Our estimates include the fixed assets owned by private non-profit institutions. When GSCPE is interpreted as a special case of the productive capital stock (PCS), we can compare both estimates. The GCSPE is 16-20 percent higher than our estimates during 1995-2000, although the coverage of our estimates is broader than that in the GCSPE. However, it is possible to understand the overestimates of the GCSPE and bias in using GCS as a measure of PCS.

We can observe this by noting that the average rate of retirement in the GCSPE is 4.6 percent in the 1990s (Nomura, 2004a). The retirement rate is 1.3 percent point lower than the average rate of deterioration,

practice. The primary statistics to estimate nominal investment for corporations in the GCSPE is the Annual Report of Financial Statements of Corporations (ARFSC), by the Ministry of Finance. However, ARFSC does not investigate the investment for residence the company has, in particular.

which consists of retirement and decay in Triplett's terminology, in our estimates of productive capital stock. To be an appropriate measure of productive capacity, the GCSPE should be reformed to the PCS by asset and industry, sustaining the consistency with the JSNA-NCS in the national accounts.

3.2 Alternative Measurement

One of our aims is to measure productive capital stock (PCS). However, what is the role of productive capital stock in economic analysis? The direct use of productive capital stock may be limited. The concept of neoclassical production function, which is used as a basic framework for production analysis, requires the flow concepts of the factor inputs. Our major concern for measuring the PCS is mainly in measurement of capital services, which are not directly observed in the market because many assets are owned by users.

The most common assumption is that capital stock and capital services are proportional at the most detail asset level. Under this assumption, the two growth rates are identical. If we have only an aggregate measure of capital stock, there is no distinction between capital stock and capital services. The distinction is generated in the difference in both aggregate measures of heterogeneous capital. In this aggregation process, if we define Törnqvist quantity indexes for both aggregates, the difference is the weights - the nominal cost of capital stock for aggregating capital stock and the nominal cost of capital service for aggregating capital service. Although the difference is only the weights, the difference of the two aggregate measures is significant.

Although there is no place for capital service costs in the SNA and the U.S. NIPA at present, only three countries - Australia, the United States, and Canada - produce time series of capital services as a part of their official statistics; recently, work has also been taken up in the United Kingdom (Schreyer, 2003). The Canberra II Group supports for introducing measures of the cost of capital services into the national accounts (Ahmad 2004; Diewert, Harrison, and Schreyer, 2004). Also, they recommend that the value of capital services should be included as 'of-which' items in the production account. This introduction should not change the basic structure of the production account.

In section 3.2, as an alternative measurement of capital stock, we introduce our estimates of capital stock and capital services in the Japanese economy. Our stock estimates are based on the assumption of the geometric approach. Therefore, our net capital stock and productive capital stock are identical, as in Equation (9). After we formulate the price and quantity of capital service in addition to the framework above, we discuss some topics related to the capital measurement, based on Nomura (2004a) and our latest estimates in March 2005. Our measurement may provide some clues to consider the reform of the stock measurement in the Japanese national account.

3.2.1 Price and Quantity of Capital Service

Based on the geometric approach, where $\delta^k_\tau = \delta^{P,k}_{t,\tau} = \delta^k$, we start with the perpetual inventory method in Equation (11). Since quantity of investment $A^{k,j}_t$ is defined in terms of progress in construction, the productive capital stock $S^{P,k,j}_t$ defined in Equation (11) includes capital goods that are not yet installed. For each asset we assume that new investment becomes available for production at the mid-point of the year so the installed capital stock for each industry and each asset is assumed to the arithmetic average of the current and lagged capital stock. An exception to this, considering the time lag between progress in construction and installation, is that we assume the installed stock of buildings and structures is the lagged capital stock:

$$Z^{k,j}_t = \begin{cases} S^{P,k,j}_{t-1} & k \in \text{buildings and structures} \\ \left(S^{P,k,j}_{t-1} + S^{P,k,j}_t\right)/2 & \text{otherwise} \end{cases} \tag{26}$$

The installed productive capital stock $Z^{k,j}_t$ represents the accumulation of past investments, but we are primarily interested in $K^{k,j}_t$, the flow of capital services from that stock over a given period. This distinction is not critical for individual assets, but becomes essential when we aggregate heterogeneous assets to form an industry or economy-wide aggregate. We assume the flow of capital services for each industry and each asset is proportional to the installed stock of capital:

$$K^{k,j}_t = \phi^{k,j} Z^{k,j}_t, \tag{27}$$

where $\phi^{k,j}$ denotes the proportionality constant. The constant coefficient: $\phi^{k,j}$, is an "annualization factor", which transform capital stock into capital service.[*30]

We estimate a price of capital services that corresponds to the quantity of capital input via the cost-of-capital formula. In equilibrium, with no uncertainty about capital income, investors are indifferent between earning a nominal rate of return on a different investment or buying a unit of capital, collecting a rental fee, and then selling the depreciated asset in the next period, as described in Equation (16). For investors purchasing the asset the cost of capital equals the marginal product of the asset. This implies the familiar cost of capital, or user cost, for each asset in each industry:

$$P^{K,k,j}_t = (r^j_t - \pi^k_t) P^{A,k}_{t-1} + \delta^k P^{A,k}_t, \tag{28}$$

[*30] We assume the proportional relationship between productive capital stock and capital service. Hulten (1990) inquires, "Is a chair in "service" only when it is occupied? Or, does the availability of the chair for potential occupancy count for something too? If so, are potential services equivalent to actual services? *cdots* Is an office building utilized only during business hours, or is it utilized all the time to keep out thieves and inclement weather?"(Hulten, 1990, p.135).

where the asset-specific capital gains term is π_t^k defined in Equation (25) and r_t^j is the nominal rate of return in industry j.[*31]

The cost of capital accounts for the nominal rate of return, asset-specific depreciation, and an asset-specific revaluation term. An asset with a higher depreciation rate has a higher marginal product and must receive a higher capital service price as compensation. Similarly, if an investor expects a capital loss ($\pi_t^k < 0$), then a higher service price is required. Jorgenson and Stiroh (2000) and Oliner and Sichel (2000) discuss the importance of incorporating asset-specific revaluation terms for information technology assets experiencing rapid downward revaluations.

Tax considerations are also a key component of capital service prices, as discussed by Hall and Jorgenson (1967) and developed in detail by Jorgenson and Yun (2001) for the U.S. economy and Nomura (1998, 2004a) for the Japanese economy. Following Nomura (2004a, Ch.3) in accounting for capital consumption allowances: $z_t^{k,j}$, income allowances and reserves: ζ_t^j, special depreciation: $\mu_t^{k,j}$, corporate income tax:u_t^j, business income tax: v_t^j, property taxes: κ_t^j, acquisition taxes: ω_t^j, debt/equity financing: β_t, capital gain taxes: γ_t, and dividend tax: θ_t. We estimate an asset-specific, after-tax real rate of return for each asset in each industry, $r_t^{k,j}$, that enters the cost-of-capital formula:

$$p_t^{K,k,j} = \frac{1 + \omega_t^k - (u_t^j + v_t^j)\left(z_t^{k,j} + \omega_t^k - \mu_t^{k,j}\tilde{z}_t^{k,j} + \dfrac{\mu_t^{k,j}}{1 + r_t^{k,j}}\right)}{1 - \psi_t^j}\left\{(r_t^{kj} - \pi_t^k) + (1 + \pi_t^k)\delta_t^k\right\}p_{t-1}^{A,k} + \kappa_t^k P_t^{A,k}, \tag{29}$$

where

$$z_t^{k,j} = \sum_{\tau=1}^{\infty} \frac{\widehat{m}_\tau^k}{(1 + r_t^{k,j})^{\tau-1}}, \quad \tilde{z}_t^{k,j} = \sum_{\tau=1}^{\infty} \frac{\widehat{m}_{\tau+1}^k}{(1 + r_t^{k,j})^{\tau+1}}, \tag{30}$$

$$r_t^{k,j} - \pi_t^k = \beta_t\left\{(1 - \psi_t^j)i_t - \pi_t^k\right\} + (1 - \beta_t)\frac{\rho_t^j - \pi_t^k(1 - \gamma_t)}{(1 - \theta_t)\alpha_t^j + (1 - \gamma_t)(1 - \alpha_t^j)}, \tag{31}$$

$$\begin{aligned}\psi_t^j = \Big(&1 + \{1 + (u_t^j + v_t^j)(1 - \zeta_t^j)\}i_t \\ &- \sqrt{1 + 2\{1 - (u_t^j + v_t^j)(1 + \zeta_t^j)\}i_t + \{1 - (u_t^j + v_t^j)(1 - \zeta_t^j)\}^2 {i_t}^2}\Big)\Big/2i_t,\end{aligned} \tag{32}$$

where $z_t^{k,j}$ is the present value of capital consumption allowance for tax purpose.[*32] The rate of return $r_t^{k,j}$

[*31] Using the time-series depreciation rates in Equation (22), Equation (28) is also written as $P_t^{K,k,j} = (r_t^j + \epsilon_t^k)P_{t-1}^{A,k}$. The total capital service cost is the sum of the opportunity cost of financial capital of $P_{t-1}^{A,k}$, and the cost for time-series depreciation, which consists of cross-section depreciation: δ^k, and revaluation: π_t^k.

[*32] In the Japanese tax system, a business income tax is levied on revenue for some industries like electricity. A property tax for depreciable assets except motor vehicles and residence is levied on the book value, rather than the current value. Nomura (2004a, Ch.3) apply different cost-of-capital formulas, which are different from Equation (28), for some assets and industries.

is formulated as a weighted average of real, after-tax returns to debt and equity, where the rate of interest is i_t and rate of return on equity is ρ_t^j. The use of income allowance and reserves could reduce the effective tax rate for corporate income: ψ_t^j, so that Equation (32) represents effective tax rate for corporate income after the consideration. Inventories and land have a depreciation rate of zero and do not qualify for a capital consumption allowance for tax purposes, so the cost-of-capital formula is a simplified in Equation (29).

We then assume the after-tax rate of return: ρ_t^j, to all assets in the corporate sector of each industry is the same and exhausts the value of payments to capital across all assets in the corporate sector of each industry,

$$V_t^{K,j} = \sum_k P_t^{K,k,j} K_t^{k,j}. \tag{33}$$

The capital service: $K_t^{k,j}$, is defined by the observable variable: $Z_t^{k,j}$, in Equation (27). From the cost-of-capital formula in Equation (28) for each asset and Equation (33), the capital service prices: $(\phi^{k,j} P_t^{K,k,j})$, and the after-tax rate of return on equity: ρ_t^j, are endogenously imputed.[*33] Since $P_t^{K,k,j}$ represents index of capital service price, constant annualization factors: $\phi^{k,j}$, are computed in each asset and each industry, taking $(\phi^{k,j} P_t^{K,k,j})$ as normalized at one in the benchmark year.

3.2.2 Aggregating Heterogeneous Capital

We define the aggregate measure of capital service for the economy as a whole, by means of a Divisia index as:

$$\frac{\dot{K}_t}{K_t} = \sum_{k,j} v_t^{K,k,j} \left(\frac{\dot{K}_t^{k,j}}{K_t^{k,j}} \right), \tag{34}$$

where the weights: $v_t^{K,k,j}$, are nominal shares of each type of capital income in total capital income: $P_t^{K,k,j} K_t^{k,j} / \sum_{k,j} P_t^{K,k,j} K_t^{k,j}$.[*34] Similarly, we define the aggregate measure of capital stock by means of a Divisia index as:

$$\frac{\dot{Z}_t}{Z_t} = \sum_{k,j} v_t^{Z,k,j} \left(\frac{\dot{Z}_t^{k,j}}{Z_t^{k,j}} \right), \tag{35}$$

[*33] In our framework, $z_t^{k,j}$ is an endogenous variable, depending on the rate of return $r_t^{k,j}$, which is determined by the imputed rate of return on equity: ρ_t^j, although Jorgenson and Yun (2001) treat $z_t^{k,j}$ as exogenous. $z_t^{k,j}$ has significant role to determine the impacts of corporate income tax to the capital service price. In case of endogenous $z_t^{k,j}$, the elasticity of corporate income tax u_t^j to $P_t^{K,k,j}$ becomes small, in comparison with the case of exogenous $z_t^{k,j}$. See Nomura (2004a, Ch.3) for the details.

[*34] Hulten (1990) shows "the existence of a linearly homogeneous aggregator function K(·) allows this expression [Divisia index] to be integrated to obtain the "level" of the aggregate capital in each year (with one time period arbitrarily normalized at one)".

where the weights: $v_t^{Z,k,j}$, are nominal shares of each type of capital stock in total capital stock: $P_t^{A,k} Z_t^{k,j} / \sum_{k,j} P_t^{A,k} Z_t^{k,j}$.[*35] The corresponding price index of capital inputs P_t^K for K_t and of capital stock P_t^Z for Z_t are defined implicitly to make the value identities hold:

$$V_t^K = P_t^K K_t = \sum_{k,j} P_t^{K,k,j} K_t^{k,j}, \tag{36}$$

and

$$V_t^Z = P_t^Z Z_t = \sum_{k,j} P_t^{A,k,j} Z_t^{k,j}, \tag{37}$$

respectively. For the comparison of aggregate measures, we also define the simple sum of capital services and capital stocks,

$$K_t^* = \sum_{k,j} K_t^{k,j}, \tag{38}$$

$$Z_t^* = \sum_{k,j} Z_t^{k,j}. \tag{39}$$

Among four definitions of aggregate measure of capital in Equations (34)-(35) and (38)-(39), the adequate measure for capital inputs is only K_t in Equation (34).[*36] Note that we need the capital service prices that are not directly observed, to compute an adequate measure for capital inputs.

Table 3 represents the growth rates of capital stock: Z_t and Z_t^*, and capital service: K_t and K_t^*, at the aggregate level in Japan. Here, we compute two cases with the different coverage of capital: fixed assets and total assets that include land and inventories.[*37] In case of fixed assets only, the average annual growth rate of capital service: K_t, is 7.6 percent during 1960-2000, which is 1.4 percent point higher than the growth of the simple sum of productive capital stock: Z_t^*. In case of total assets, which includes land and inventories, the growth rates of K_t and Z_t^* are 5.9 percent and 3.3 percent per year, respectively. The difference of two measures is significant. By the quantity index to be normalized as one in 1960, K_t is 10.6 (20.8 in case of fixed assets) and Z_t^* is 3.8 (11.8) in 2000. If we use capital stock measures: Z_t^* or Z_t, as a

[*35] On the assumption of geometric approach, productive capital stock by asset and industry: $Z_t^{k,j}$, is identical with net (wealth) capital stock. Z_t^j in Equation (35) may provide the appropriate aggregate measure of real net capital stock. Note that capital service prices that are not directly observed need not be used, to compute it.

[*36] Using the other three inadequate measures, Nomura (2004, Ch.4) defines the three measures of capital quality as K_t/Z_t, K_t/K_t^*, and K_t/Z_t^*. Jorgenson and Stiroh (2000) uses capital quality as K_t/Z_t, although they take a simple sum among industries in each asset. Nomura (2004, Ch.4) uses K_t/Z_t^*, analogously with the definition of labor quality.

[*37] To keep consistency with the present Japanese national accounts, we do not include custom and prepackaged software in Table 3. The capital service prices: $P_t^{K,k,j}$, used in the two cases with the different coverage of capital are different even for same asset in same industry, because we impute the ex-post rate of returns in each case.

capital input, it underestimates the growth of capital inputs and, therefore, it overestimates the growth of total factor productivity (TFP).*38

Table. 3 Growth Rates of Capital Stock and Services in Japan

	Fixed Assets				Total Assets				
	Stock		Service		Stock		Service		(ref)
	Z_t	Z_t^*	K_t	K_t^*	Z_t	Z_t^*	K_t	K_t^*	GCSPE
1960–65	9.11	7.80	13.88	8.25	4.97	3.64	9.85	5.67	11.55
1965–70	10.44	9.53	12.27	10.24	5.94	4.93	9.76	6.86	12.45
1970–75	9.56	9.25	9.96	9.19	5.43	5.05	8.17	5.92	10.10
1975–80	6.15	6.18	5.81	5.95	3.79	3.57	4.67	3.91	6.38
1980–85	4.80	4.69	5.24	4.63	2.73	2.57	3.87	2.92	6.72
1985–90	5.04	4.87	6.02	5.38	2.69	2.68	4.94	3.46	6.79
1990–95	4.42	4.40	5.08	4.75	2.42	2.52	3.82	3.20	5.15
95–2000	2.56	2.60	2.49	2.50	1.74	1.73	2.05	2.06	3.48
60–2000	6.51	6.16	7.59	6.36	3.72	3.34	5.89	4.25	7.83

Unit: average annual percentage (%). "Total Assets" includes fixed assets, land, and inventories.

Assets only for industry use and owner-occupied housing (excluding custom and prepackaged software).

GCSPE is defined by tangible fixed assets, owned by private sectors only, excluding the residence.

Schreyer (2003) estimates capital service inputs for the G7 countries, using a hyperbolic age-efficiency profile. The estimate of the growth rate in the Japanese aggregate capital service, which is defined by the Törnqvist index of capital services for all fixed assets, is 4.9 percent per year during 1980-2000. This growth rate is close to our estimates (4.7 percent) for the same periods.*39 On the other hand, the GCSPE, which

*38 If we define aggregate measures as a simple-sum for labor and value added, like capital inputs: Z_t^*, that overestimates by 41 percent (18 percent in case of fixed assets) of average annual growth rate of TFP, at the aggregate level during 1960-2000 in Japan (Nomura, 2004a, Ch.4).

*39 Schreyer (2004) estimates the multifactor productivity and capital service, for fixed assets only, based on the two assumptions: exogenous rate of return (RoR) and endogenous RoR. In Japan, the growth rate of capital service inputs is reported as annually 4.6 percent by exogenous-RoR approach and 4.5 percent by endogenous-RoR approach during 1985-2000. Although the Schreyer's measure includes reallocation bias of capital service, the aggregate growth rate is also 4.5 percent for the same periods in our estimates, which is based on endogenous-RoR by industry on the Japanese tax structure described in Equation (29).

Although we don't introduce the details of our estimates of TFP in this paper, however, our TFP (or MFP) measures in Nomura (2004a, Ch.4) considerably different from Schreyer (2004) at the aggregate level. The main source of the gap is the definition of labor input. Schreyer defines the labor inputs as hours worked, in which the increase in labor quality is neglected. Our estimates based on the KEO (Keio Economic Observatory, Keio University) Database, which has chosen to classify the workers by sex, age (eleven classes), educational attainment (four classes for male, three classes for female), employment class (three types: employees, self-employed, and unpaid family workers), and industry.

is based on the traditional gross concept of capital stock, provides higher growth. During 1980-2000, the growth rate of the GCSPE is 5.5 percent per year. If the GCSPE is used as a capital input in production function, it overestimates the growth of capital inputs and, therefore, it underestimates the growth of TFP.

3.2.3 Land as a Capital

The stocks of land and inventories by industry are estimated in Nomura (2004a, Ch.C-D). In the Japanese economy, the value of land is particularly notable. In comparison with the 23.6 percent share of land to total nominal capital stock in the U.S. in 2000 (Jorgenson and Landefeld, 2005), the Japanese land share is 43.5 percent in 2000 (Nomura, 2004a, Ch.2), even though the Japanese economy has experienced a record decline of land prices in the 1990s.

Diewert and Lawrence (2000) indicate that neglecting land and inventories leads to a decline in average TFP growth rates of 0.1 percent per year in Canada. This is large in relative terms, since the average growth rate for the Canadian TFP averaged only 0.5-0.6 percent per year during 1963-1996. For the Japanese economy, Nomura (2004a, Ch.4) shows that neglecting land and inventories leads to a decline of 0.7 percent per year in the average TFP growth rate during 1960-2000, compared to 1.5 percent annual average growth rate for Japanese TFP. TFP growth is underestimated by a factor of almost fifty percent if land and inventories are ignored. Land has a significant role in the measurement of capital and productivity in Japan.

Table. 4 Relative Prices of Capital Stock and Services by Industry between the U.S. and Japan

	Fixed Assets			Total Assets		
	$RP_t^{Z,j}$	$RP_t^{K,j}$	$R\phi^j$	$RP_t^{Z,j}$	$RP_t^{K,j}$	$R\phi^j$
1.Agriculture	1.261	1.829	1.450	5.466	2.620	0.479
18.Machinery	1.120	0.886	0.791	2.009	1.415	0.704
19.Motor Vehicles	1.063	1.300	1.223	1.939	1.411	0.728
23.Transportation	1.267	1.602	1.265	2.252	1.671	0.742
24.Communication	1.262	1.014	0.803	1.694	1.131	0.668
25.Electiric Utilities	1.312	1.569	1.195	1.666	1.655	0.993
27.Trade	1.319	1.410	1.069	2.515	1.646	0.655
29.Other Service	1.282	0.945	0.737	2.738	1.088	0.397
Aggregate	1.314	1.360	1.035	3.050	1.701	0.558

Unit: Ratios of Japanese prices to the U.S. prices, evaluated in 1990 (exchange rate:144.8)

$RP^j_{Z,T}$ and $RP^j_{K,T}$ represent relative prices for capital stock and service, respectively.

$R\phi^j$ is relative measure of annualization factors.

All indexes are aggregated as Törnqvist index, for all assets within an industry.

In particular, for international level comparison of productivity or capital deepening, the land price has a significant role. Nomura (2004a, Ch.3) estimates relative prices of capital stock and service by asset and industry between the U.S. and Japan.[*40] Table 4 represents the relative prices for capital stock: $RP_t^{Z,j}$, relative prices for service: $RP_t^{K,j}$, and relative annualization factors: $R\phi^j$ between the U.S. and Japan in 1990, for some selected industries.

In the aggregate measures of the relative prices, defined by Törnqvist index using the average weights between the U.S. and Japan, if we neglect the land and inventories as capital, the Japanese prices in capital stock and service are 31.1 percent and 36.0 percent higher than that in the U.S., respectively. However, if we include land and inventories, the price-gaps increased to about 3 times for capital stock and 1.7 times for capital service. The land price-gap explains 56.1 percent of $RP_t^{K,j}$. Especially, for the industries like Agriculture, the consideration of land price has a big impact to the relative prices. In the aggregate measure of TFP-gap, Japan is 26.1 percent below to the U.S. in the case of neglecting land and inventories. The neglect leads to an underestimate of the Japanese TFP level, which is 17.9 percent less than the U.S. in 1990 (Nomura 2004a, Ch.4).

The clarification of the role of land as a capital input in production account is one of the most significant aspects of Jorgenson system of national accounts.[*41] Probably due to the incomplete definition of land as a capital input in the 1993 SNA, the cost of land has been neglected in many production studies. The capital service cost of land, however, should be interpreted as implicitly included in value added in the production account.

3.2.4 Capitalization of Software

The expenditure for own-account and prepackaged software are not capitalized in the official Japanese national accounts. Nomura (2004b) estimates own-account software investment by industry during 1955-2000 in Japan, based on the two kinds of methodology in the OECD Task Force on software measurement in the national accounts (Lequiller, Ahmad, Varjonen, Cave, and Ahn, 2003; Ahmad, 2003) and the U.S. BEA's methodology for estimating own-account software by industry (Grimm, Moulton, and Wasshausen, 2003).

International comparison of shares of own-account software investment to official GDP is in Figure 3(a) and for total software investment to GDP is in Figure 3(b).[*42] In Japan, the share of own-account software

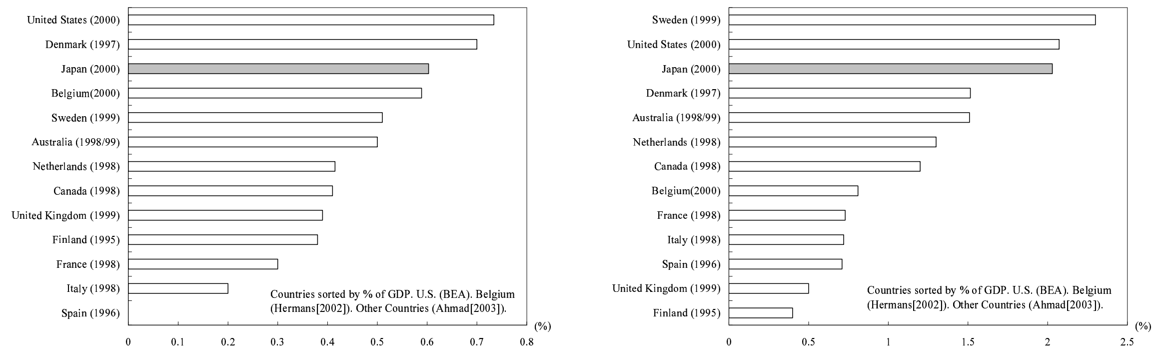
---

[*40] Relative price represents the price-gap index in both countries and is not unity even in the base year. To estimate relative prices for capital stock, we need relative prices for investment by commodity. See Nomura (2004a, Ch.3) for the details of framework and data. The U.S. annualization factors by asset and industry are based on the estimates by Jorgenson. Industry is classified, based on our common industry classification between the U.S. Jorgenson Data and the KEO Database in Japan.

[*41] A brief survey of the history of economic thoughts for land as a factor of production, see Ryan (2002).

[*42] In Figure 3, each share in each country is computed, based on the official national accounts. The share in Japan is estimates in

to the GDP, which is adjusted to include all software investment, is 0.60 percent in 2000. It is higher than that in the EU countries but Denmark. The U.S. has the highest share of own-account software (0.73 percent) among the countries. As for total software investment in Figure 3(b), Japan has 2.03 percent GDP attributed to software investment. It is slightly lower than that in the U.S. (2.07 percent). Although Sweden has the highest share in total software, we may take the difference in economic scales and industry structures into consideration. The relative scale of software investment between the U.S. and Japan may be appropriate.



(a) Own-Account Software Investment

(b) Total Software Investment

Fig. 3 Share of Software Investment in GDP: An International Comparison

Although the GDP-share of software investment is very close between the U.S. and Japan, the composition by type of software is significantly different. Figure 4 shows the changes of composition of software investment every five years from 1970 to 2000 in the U.S. and Japan. In 1970, own-account software has the largest share in software investment and prepackaged software is minor in both countries. The share of own-account software decreases in both countries through the 1970s and the 1980s. In the U.S., the diminution of the share of own-account software is reflected by the rapid expansion of prepackaged software. On the other hand, in Japan, the diminution is mainly reflected by the expansion of custom software. In 2000, custom software occupies the largest portion, the share of which is almost two thirds of the total software investment in Japan.

One of the reasons why own-account and prepackaged software are avoided to be capitalized in the present Japanese national accounts may be that benchmark 1995 input-output (IO) table, which is one

Nomura (2004b). The share in the U.S. is based on the NIPA. The others are based on Hermans (2002) for Belgium and Ahmad (2003) for the other countries.

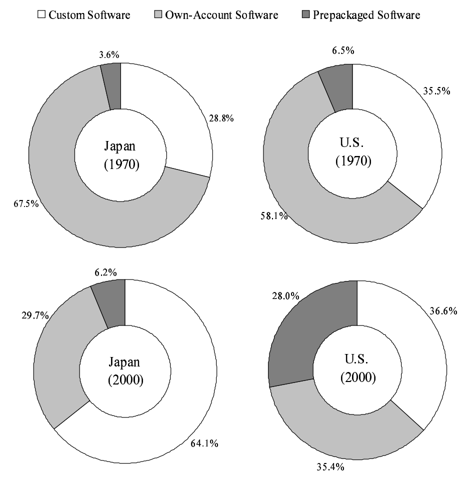


Fig. 4 Composition of Software Investment: Comparison between the U.S. and Japan

of basic statistics for estimating the national accounts, did treat only custom software as a software investment. In the summer of 2004, the benchmark 2000 IO table was published and began to treat prepackaged software as GFCF, in addition to custom software. However, capitalization of own-account software was postponed even in the benchmark 2000 IO table. ESRI (2000) pointed out that, in the Japanese statistics, it is difficult to identify own-account software and that R&D activity that is not recommended to be capitalized by the 1993 SNA. As the OECD Task Force on software measurement in the national accounts (Lequiller, Ahmad, Varjonen, Cave, and Ahn, 2003; Ahmad, 2003) also discusses, the difficulty is not peculiar to Japan. It is possible to estimate own-account software investment by industry in Japan, applying similar methodology as that the recommendation of the OECD Task Force on software and the BEA.

3.2.5 Impacts of IT Capital

To capture the impacts of capital related to information technology (IT), our latest estimates of capital stock and service have detailed asset classification. The capital stock and service matrixes are based on 102 assets shown in Table 5: 95 fixed assets, 3 types of inventory, and 4 types of land, and 70 capital holding sectors: 45 industries, government, household, and 23 infrastructures.[*43]

[*43] Although Nomura (2004a) estimated time-series capital formation matrixes during 1955-2000 with detailed asset classification, the assets were aggregated for the measurement of capital stock mainly because of the lack of the long-term investment prices. Author newly developed the prices and revised capital formation matrixes using 2000 benchmark capital formation matrix. Also, to compute the long-term CFC for infrastructure, the classification for assets and capital holding sectors was reformed. The productivity analysis in the Japanese industries, separately treating the IT-producing industries, is described in Jorgenson

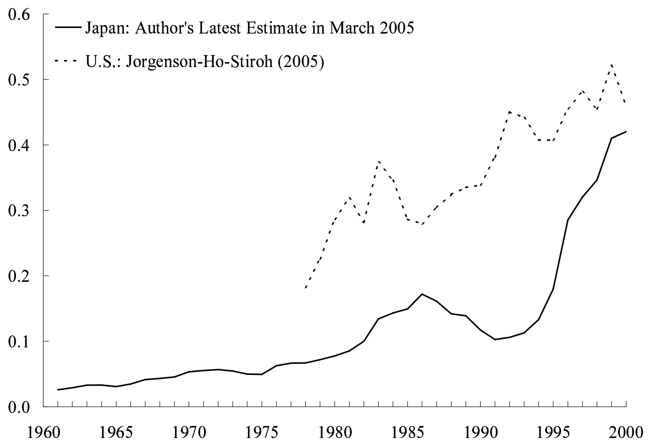


Fig. 5 IT Capital Contribution Share to Total Capital Service

Figure 5 shows the contribution share of IT capital to the growth of total capital service in the U.S. and Japan at the aggregate level. The U.S. measurement is from Jorgenson, Ho, and Stiroh (2005). Here, the IT capital is defined by computer hardware, computer software (custom, prepackaged, own-account), and communications equipment (37-40 and 93-95 in Table 5). The total capital consists of fixed assets, consumer durables, land, and inventories of all capital holders in each country. The growth rates are aggregated for the economies as a whole, based on the Törnqvist index, in both countries. In Japan, although the contribution share of IT capital gradually increases during 1960-1986, however, it still about 10 percent lower than that in the U.S. The share decreases in the bubble economy periods. As mentioned in section 2.2.3, the DOS/V as a operating system in PC was newly developed in 1991. The year of the introduction of the DOS/V is a turning point. Especially, after 1995, the IT contribution rapidly expands. In 2000, the contribution of the IT capital is 42.0 percent, approaching to the 46.0 percent in the U.S.

In nominal value of total capital stock, the share of IT capital is only 1.7 percent (3.2 percent of fixed capital) in Japan in 2000. However, the capital service cost of IT capital gradually increased to 9.8 percent in 2000 and the IT capital contributes more than 40 percent of the growth in total capital service inputs. Note that the deep impacts of IT capital can be found only in the measurement of capital service with detailed classification of assets, because the capital service prices, reflecting their marginal products, in IT capital is higher than that of other Non-IT capital due to the large depreciation rate and the rapid downward revaluation of the IT capital, as described in Equation (28).

---

and Nomura (forthcoming).

3.2.6 Capital for Non-Market Production

As the final topics related to capital measurement, we introduce our evaluation of capital service cost for non-market production. In the 1993 SNA and also in NIPA by the U.S. BEA, for non-market production, only consumption of fixed capital (CFC) is described in their production accounts. The CFC is only a part of the capital cost. Here, our accounting is based on the Jorgenson system of national accounts.[*44] The extension to the Jorgenson system of national accounts means the replacement of the CFC to the appropriate measure of capital service cost in non-market production, which will be considered in the next revision of SNA in 2008 (1993 SNA Revision 1) as also proposed by the Canberra II Group (Ahmad, 2004).

First, let us adjust the GDP in the present Japanese national accounts to the 1993 concepts of GDP. Figure 6(a) gives the capital service cost to be added, associated with the revision from the 1968 SNA to the 1993 SNA concepts of GDP. The custom software investment and the CFC for infrastructure is already considered in the present Japanese national accounts, and valued at 14.7 trillion yen in 2000.[*45] Capitalizing own-account and prepackaged software leads to an increase of 3.8 trillion yen in 2000 in the Japanese GDP. [*46]

Our measurement of capital service cost for non-market production includes capital services of public capital, land for owner-occupied housing by households, and consumer durables. Based on author's estimates, Figure 6(b) shows the cost of the three capital services, which is added to the 1993 SNA concepts of GDP. In the figure, the capital service cost of public capital that excludes the CFC for public capital, because it is already included in the estimates of the GDP. Introducing the three capital service costs leads to an increase 41.8 trillion yen in 2000 in the Japanese GDP.[*47] The largest part is the capital service cost of consumer durables, which is 25.5 trillion yen and accounts for 4.6 percent in the Jorgenson concepts

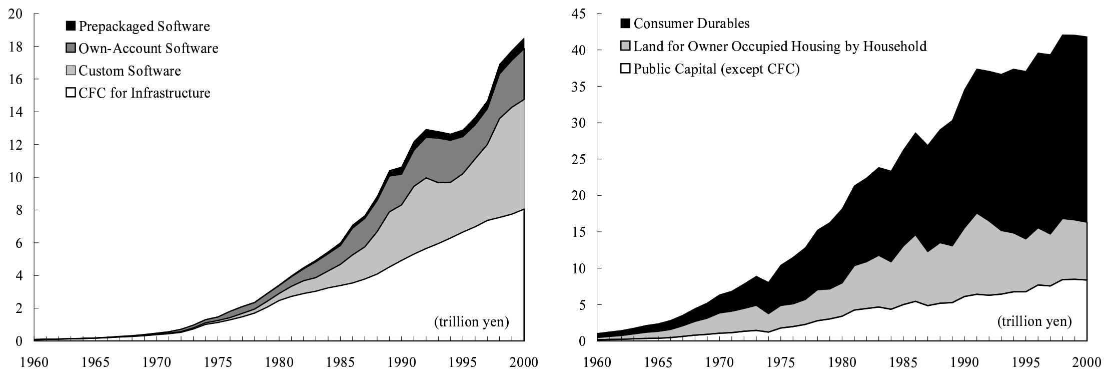
---

[*44] See Christensen and Jorgenson (1996), Fraumeni (2000), and Jorgenson and Landefeld (2005).

[*45] The Japanese national accounts does not still estimated before 1980, so far. Here, the CFC for infrastructure in Figure 6(a) is author's estimates, based on our capital stock estimates in 23 kinds of infrastructure during 1955-2000 (Nomura, 2004a).

[*46] Including this leads to a rebalancing of the IO tables with some difficulties to keep consistency with other data. See Nomura (2004b) for the detail. Since output of government sector is defined by the total costs, capitalization of software leads to the change of the government output. In the total economy, increase of the GDP is the sum of the increase of investment for own-account software and prepackaged software, the increase of consumption for both capitals in the government, and the decrease of own-account software produced and prepackaged software purchased by the government. The consumption for software capital is computed to be consistent with our estimates of software stock government sector holds.

[*47] We impute the capital service cost for non-market production using the average rate of return of all industries, weighted by the nominal share of capital stock in the industries. The rate of return in each industry is defined by the weighted average of rate of interest and the rate of return on equity. See Jorgenson and Nomura (forthcoming).



(a) for 93 SNA Concepts

(b) for Non-Market Production

Fig. 6 Additional Capital Service Cost for Non-Market Production

of GDP in 2000. In comparison with the U.S., the scale is about twofold, as Jorgenson and Landefeld (2005) estimates the consumer durables account for 9.6 percent in 2002, reflecting the difference the rates of return in both countries.

4 Concluding Remarks: Proposals for the Japanese National Accounts

As concluding remarks of this paper, we summarize our proposals for sweeping improvement for measuring capital in the Japanese national accounts. Our proposals are assorted into two groups. The first group: (i)-(v), is the proposals to catch up the international standard. The second: (vi)-(viii), is the proposals to be prepared for the next revision of SNA in 2008 (1993 SNA Revision 1) or for measurement of productivity. For the second group, we attach the mark of ∗. Each proposal may be ordered by urgency, rather than importance or ease of implementation.

- **(i)** **Capitalization of Software** (related to section 3.2.4)
- **(ii)** **Reframing Net Capital Stock and CFC** (related to section 2.3 & 3.1)
- **(iii)** **Gross Capital Stock to Productive Capital Stock** (related to section 2.1 & 3.1.3)
- **(iv)** **Constant-Quality Prices in Japan** (related to section 2.2)
- **(v)** **Empirical Studies for AEP and APP in Japan** (related to section 2.3.3)
- **(vi)*** **Measurement of Price and Quantity of Capital Service** (related to section 3.2)
- **(vii)*** **Land as a Capital** (related to section 3.2.3)
- **(viii)*** **Capital Service Cost for Non-Market Production** (related to section 3.2.6)

First, (i) capitalization of own-account and prepackaged software is the most urgent requirement. As Nomura (2004b) pointed out, it is possible to estimate own-account software investment by industry in Japan, applying similar methodology as that recommended by the OECD Task Force on software and the industry approach used by the BEA.

Our proposals: (ii) and (iii), are highly desired to improve the measurement of capital in the Japanese national accounts. The traditional system of gross and net capital stock is incapable of portraying the two different aspects of capital: the productive capacity and the value of capital, except under unrealistic assumptions. A quarter century after the controversy between Jorgenson-Griliches (1972) and Denison, measuring internally consistent estimates of capital stock, capital input, and depreciation became a common objective in the national accounts, as in the international methodological standards recommended by OECD (2001a, 2001b). Fortunately, ESRI can learn a lot from the BEA's revision in 1997.

The ESRI has a plan to spend the following three years reframing measurement of capital in the Japanese national accounts. Over this time, it is important to estimate the long-term constant-quality prices, as in our proposal (iv). The main purpose of price statistics is to measure of current movement of prices, which can only be captured with constant-quality prices. However, the national accounts, in particular measurement of capital, requires the constant-quality prices be extrapolate backward, sustaining the consistency with newly developed methodology, if possible. Although this function is carried out by BEA in the U.S., we may not find any similar function in the Japanese statistical system.

Empirical studies for estimating depreciation or deterioration in the Japanese economy is also required. In the framework for measuring capital stock, the key idea is the age-efficiency profile. The AEP can be determined empirically by modeling a time series of prices of an asset by age. An alternative and more direct approach is modeling a time series of rental prices of an asset by age. Although Nomura (2004a, Ch.2) accepted the geometric distribution as approximation based on Japanese data, passenger vehicles and housing are less durable and trucks are more durable in Japan, in comparison with the BEA depreciation rates. Further empirical studies for the Japanese economy are required.

The theory for measuring capital, proposed by Jorgenson and his associates, can provide a consistent framework for measures of both capital stock and capital services. As Jorgenson (1989) clearly pointed out, measures of net capital stock and asset prices can be employed in the national wealth accounts, while measures of capital service input and capital service prices can be utilized in national production accounts. At present, although there is still no place for capital service cost in the SNA and the U.S. NIPA, only three countries - Australia, the United States, and Canada - produce time series of capital services as a part of their official statistics. Recently, work has also been taken up in the United Kingdom (Schreyer, 2003).

We recommend that ESRI should introduce capital services at the same time as reframing the measurement of capital stock. In addition, the capital service cost of land should be evaluated. Land as a capital has a significant role in the measurement of capital and productivity in Japan, although almost empirical studies for the Japanese economy do not fully recognize the importance. Measuring capital service leads the additional imputation of capital service cost for non-market production. ESRI can accomplish sweeping improvement by overcoming all our proposals, thereby anticipating the SNA 2008 (1993 SNA Revision 1). The Canberra II Group supports for introducing measures of the cost of capital services into the national accounts, as 'of-which' items in the production account (Ahmad 2004; Diewert, Harrison, and Schreyer, 2004). The time has come to turn the tables!

Table. 5 Asset Classification and Depreciation Rates

Assets	δ	Assets	δ
1.Trees	0.200	52.Steel ships	0.108
2.Livestock	0.309	53.Other ships	0.166
3.Textile products	0.347	54.Railway vehicles	0.068
4.Wooded products	0.236	55.Aircraft	0.135
5.Wooden furniture and fixtures	0.171	56.Bicycles	0.498
6.Metallic furniture and fixtures	0.098	57.Transport equipment for industrial use	0.217
7.Nuclear fuel rods	0.413	58.Other transport equipment	0.332
8.Metallic products	0.086	59.Camera	0.210
9.Boilers and turbines	0.102	60.Other photographic and optical instruments	0.218
10.Engines	0.112	61.Watches and clocks	0.118
11.Conveyors	0.098	62.Physics and chemistry instruments	0.236
12.Refrigerators and air conditioning apparatus	0.116	63.Analytical, measuring instruments & testing machines	0.236
13.Pumps and compressors	0.118	64.Medical instruments	0.199
14.Sewing machines	0.112	65.Miscellaneous manufacturing products	0.274
15.Other general industrial machinery and equipment	0.142	66.Residential construction (wooden)	0.048
16.Mining, civil engineering and construction machinery	0.171	67.Residential construction (non-wooden)	0.031
17.Chemical machinery	0.143	68.Non-residential construction (wooden)	0.057
18.Industrial robots	0.150	69.Non-residential construction (non-wooden)	0.039
19.Metal machine tools	0.127	70.Road construction	0.020
20.Metal processing machinery	0.111	71.Street construction	0.020
21.Agricultural machinery	0.098	72.Bridge construction	0.020
22.Textile machinery	0.117	73.Toll road construction	0.020
23.Food processing machinery	0.113	74.River improvement	0.019
24.Sawmill, wood working, veneer & plywood machinery	0.137	75.Erosion control	0.019
25.Pulp equipment and paper machinery	0.104	76.Seashore improvement	0.018
26.Printing, bookbinding and paper processing machinery	0.127	77.Park construction	0.048
27.Casting equipment	0.107	78.Sewer construction	0.027
28.Plastic processing machinery	0.122	79.Sewage disposal facilities	0.027
29.Other special industrial machinery & nec	0.130	80.Waste disposal facilities	0.061
30.Other general machines and parts	0.208	81.Harbor construction	0.018
31.Office machines	0.347	82.Fishing port construction	0.018
32.Vending, amusement and other service machinery	0.210	83.Airport construction	0.054
33.Electric audio equipment	0.236	84.Agricultural construction	0.028
34.Radio and television sets	0.236	85.Forest road construction	0.034
35.Video recording and playback equipment	0.236	86.Forestry protection	0.019
36.Household electric appliance	0.196	87.Railway construction	0.030
37.Electronic computer and peripheral equipment	0.347	88.Electric power facilities	0.025
38.Wired communication equipment	0.206	89.Telecommunication facilities	0.035
39.Radio communication equipment	0.275	90.Other civil engineering and construction	0.025
40.Other communication equipment	0.118	91.Plant engineering	0.025
41.Applied electronic equipment	0.196	92.Mineral exploration	0.550
42.Electric measuring instruments	0.196	93.Custom software	0.330
43.Generators	0.079	94.Pre-packaged software	0.330
44.Electric motors	0.079	95.Own-account software	0.330
45.Relay switches and switchboards	0.079	96.Finished-goods inventory	0.000
46.Other industrial heavy electrical equipment	0.109	97.Work-in-process inventory	0.000
47.Electric lighting fixtures and apparatus	0.079	98.Material inventory	0.000
48.Passenger motor vehicles	0.163	99.Land for agricultural use	0.000
49.Trucks, buses and other vehicles	0.228	100.Land for industrial use	0.000
50.Two-wheel motor vehicles	0.218	101.Land for commercial use	0.000
51.Motor vehicle parts	0.208	102.Land for residential use	0.000

Represents geometric depreciation rates used in our latest estimates of capital stock and service.

Assets 48-49 and 66-67: estimates in Nomura(2004, Ch-2).

For other assets: author's estimates based the Japanese tax-lives, converting rates to effective service life, and the BEA's declining balance rates.

References

[1] Aizcorde, Ana, Carol Corrado, and Mark Doms (2000). Constructing Price and Quality Indexes for High Technology Goods, *CRIW workshop on Price Measurement*, August, 39p.

[2] Ahmad, Nadim (2003), Measuring Investment in Software, STI Working Paper Series, OECD, May.

[3] _____(2004). Introducing Capital Services into the Production Account, Meeting of the Advisory Expert Group on National Accounts, December.

[4] Bank of Japan (2002). Publication of "Domestic Corporate Goods Price Index using chain-weighted index formula", *Nihon Ginkou Chosa Geppou*, Research and Statistics Department, Bank of Japan, (in Japanese).

[5] Biørn, Erik (1989). *Taxation, Technology and the User Cost of Capital*, Amsterdam: North-Holland, 325p.

[6] Biørn, Erik, Erling Holmoy, and Oystein Olsen (1989). Gross and Net Capital, and the Form of the Survival Function: Theory and Some Norwegian Evidence, *Review of Income and Wealth*, 35, 133-149.

[7] Bureau of Economic Analysis (1997). Note on Alternative Measures of Gross Product by Industry, *Survey of Current Business*, November, 84-85.

[8] _____(1999). Fixed Reproducible Tangible Wealth in the United States, 1925-94, Washington, U.S. Department of Commerce.

[9] _____(2003), Fixed Assets and Consumer Durable Goods in the United States, 1925-99, Washington, DC: U.S. Government Printing Office, September.

[10] Christensen, Laurits R. and Dale W. Jorgenson (1996). Measuring Economic Performance in the Private Sector, in D.W. Jorgenson, *Postwar U.S. Economic Growth*, Cambridge, The MIT Press.

[11] Corrado, Carol, John Haltiwanger, and Dan Sicherl, eds. (2005), *Measuring Capital in the New Economy*, Chicago, University of Chicago Press.

[12] Diewert, Erwin W. (1980). Aggregation Problems in the Measurement of Capital, in D.Usher eds., *The Measurement of Capital*, Chicago, University of Chicago Press, 433-528.

[13] _____(2001). Measuring the Price and Quantity as Capital Service Under Alternative Assumptions, Department of Economics, University of British Columbia, Discussion Paper No.01-24, June.

[14] Diewert, Erwin W. and Denis Lawrence A. (2000). Progress in Measuring the Price and Quantity of Capital, in Lawrence J. Lau eds., *Econometrics and the Cost of Capital: Essays in honor of Dale W. Jorgenson*, Chapter 11, Cambridge, The MIT Press, 273-326.

[15] Diewert, Erwin W. Anne Harrison, and Paul Schreyer (2004). Cost of Capital Services in the Production Account, 20p.

[16] Doms, Mark E., Wendy E. Dunn, Stephen D. Oliner, and Daniel E. Sichel. (2003). How Fast Do Personal Computers Depreciate? Concepts and New Estimates, FRBSF Working Paper 2003-20, Novenmber, 57p.

[17] Economic and Social Research Institution (2000). The Explanation of the Japanese National Accounts Based on the 1993 SNA, November (in Japanese).

[18] Fraumeni, Barbara (1997). The Measurement of Depreciation in the U.S. National Income and Product Accounts, *Survey of Current Business*, July, 7-23.

[19] _____(2000). The Jorgenson System of National Accounts, in Lawrence J. Lau eds., *Econometrics and the Cost of Capital: Essays in honor of Dale W. Jorgenson*, Chapter 6, Cambridge, The MIT Press, 111-142.

[20] Grimm, Bruce T., Brent R. Moulton, and David B. Wasshausen (2003). Information Processing Equipment and Software in the National Accounts, revision of the paper prepared for Conference on Measuring Capital in the New Economy, NBER/CRIW, April 26-27, 2002, Federal Reserve Board, Washington, D.C., March.

[21] Hall, Robert E. and Dale W. Jorgenson (1967). Tax Policy and Investment Behavior. *Amrican Economic Review*, Vol.57, 391-414.

[22] Hermans, Tim (2002). Measurement of GFCF in Software in the Belgian National Accounts, Joint ECE/Eurostat/OECD Meeting on National Accounts, April.

[23] Hill, Peter (1998). Gross, Productive, Net Capital Stock, Second Meeting of the Canberra Group on Capital Stock Statistics, 20p.

[24] _____(1999). The Productive Capital Stock and the Quantity Index for Flow of Capital, Third Meeting of the Canberra Group on Capital Stock Statistics, 5p.

[25] _____(2000). Economic Depreciation and the SNA, Paper Prepared for the 26th General Conference of The International Association for Research in Income and Wealth, Cracow, Poland, 27 August to 2 September, 19p.

[26] Hulten, Charles (1990). The Measurement of Capital, in E. R. Berndt and J. E Triplett eds., *Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth*, Chicago: University of Chicago Press, 119-158.

[27] Hulten, Charles R. and Frank C. Wykoff (1981a), Economic Depreciation and the Taxation of Structures in United States Manufacturing Industries: An Empirical Analysis, in D. Usher eds., *The Measurement of Capital*, Chicago: University of Chicago Press, 83-120.

[28] _____(1981b), The Estimation of Economic Depreciation Using Vintage Asset Prices: An Application of the Box-Cox Power Transformation, Journal of Econometrics, April, 367-396.

[29] _____(1981c), The Measurement of Economic Depreciation, in C. R. Hulten eds., Depreciation, Inflation, and the Taxation of Income from Capital, Washington, D.C.: The Urban Institute Press, 81-125.

[30] Jorgenson, Dale W. (1963). Capital Theory and Investment Behavior, *American Economic Review*, Vol.53, No.2, 247-274.

[31] _____(1974). The Economic Theory of Replacement and Depreciation, in W. Sellekaerts, eds., *Econometrics and Economic Theory: Essays in Honour of Jan Tinbergen*, New York: Macmillan, 189-221.

[32] _____(1989). Capital as a Factor of Production, in D. W. Jorgenson and R. Landau, eds., *Technology and Capital Formation*, Cambridge: The MIT Press, 1-35.

[33] _____(1996). Empirical Studies of Depreciation, *Economic Inquiry*, 34, 24-42.

[34] _____(1999). New Methods for Measuring Capital, Third Meeting of the Canberra Group on Capital Stock Statistics, 17p.

[35] Jorgenson, Dale W., and Zvi Griliches (1967). The Explanation of Productivity Change, *Review of Economic Studies*, Vol.34, 249-283.

[36] _____(1972). Issues in Growth Accounting: A Reply to Edward F. Denison, *Survey of Current Business*, Vol.52, No.4, 65-94.

[37] Jorgenson, Dale W., Mun S. Ho, and Kevin J. Stiroh (2005). Growth of U.S. Industries and Investments in Information Technology and Higher Education, in Corrado, Haltiwanger, and Sichel (2005).

[38] Jorgenson, Dale W. and J. Steven Landefeld (2005). Blueprint for Expanded and Integrated U.S. National Accounts: Review, Assessment, and Next Steps, in D.W. Jorgenson, J.S. Landefeld, and W.D. Nordhaus, eds., *A New Architecture for the U.S. National Accounts*, Chicago, University of Chicago Press.

[39] Jorgenson, Dale W. and Koji Nomura (forthcoming). Growth of Japanese Industries and Investment in Information Technology, mimeo.

[40] Jorgenson, Dale W. and Kevin J. Stiroh (2000). Raising the Speed Limit: U.S. Economic Growth in the Information Age, in D.W. Jorgenson, *Economic Growth in the Information Age*, Cambridge, The MIT Press.

[41] Jorgenson, Dale W. and Kun-Young Yun (2001). *Lifting the Burden: Tax Reform, the Cost of Capital and U.S. Economic Growth*, Cambridge, The MIT Press.

[42] Kuninori, Morio (1988). Measurement of Depreciation of Japanese Construction Machinery, *Keizai Keiei Kenkyu*, Vol.9 (in Japanese).

[43] Lee, Bun S. (1978). Measurement of Capital Depreciation within the Japanese Fishing Fleet, *Review of Economics and Statistics*, 255-273.

[44] Lequiller, Francois, Nadim Ahmad, Seppo Varjonen, William Cave, and Kil-Hyo Ahn (2003): Report of the OECD Task Force on Software Measurement in the National Accounts, *OECD Statistics Working Paper Series*, OECD, March.

[45] Moulton, Brent R. (2001). The Expanding Role of Hedonic Methods in the Official Statistics of the United States, 15p.

[46] Nomura, Koji (1998). Measurement of Capital Service Price Based on Japanese Tax Structure, KEO Discussion Paper, No.53, (in Japanese), 56p.

[47] _____(2004a). *Measurement of Capital and Productivity*, Tokyo: Keio University Press. (in Japanese) , 633p.

[48] _____(2004b). Capitalizing Own-Account Software in Japan, Program on Technology and Economic Policy (PTEP), John F. Kennedy School of Government, Harvard University, 35p.

[49] Nomura, Koji and Jon D. Samuels (2004). Can We Go Back to Data? Reconsideration of U.S.-Harmonized Computer Prices in Japan, Program on Technology and Economic Policy (PTEP), John F. Kennedy School of Government, Harvard University, 43p.

[50] OECD (2001a), *OECD Productivity Manual: A Guide to the Measurement of Industry-Level and Aggregate Productivity Growth*, OECD, Paris, March.

[51] OECD (2001b), *Measuring Capital: A Manual on the Measurement of Capital Stocks, Consumption of Fixed Capital, and Capital Services*, Paris, OECD, April.

[52] Oliner, Stephen D. (1993). Constant-Quality Price Change, Depreciation, and the Retirement of Mainframe Computers, in Murray F. Foss, Marilyn E. Manser, and Allan H. Young, eds., *Price Measurement and Their Uses*, Chicago: University of Chicago Press, 19-61.

[53] _____(1994). Measuring Stocks of Computer Peripheral Equipment: Theory and Application, Washington, Board of Governors of the Federal Reserve System, May.

[54] Oliner, Stephen D. and Daniel E. Sichel (2000). The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?, *Journal of Economic Perspectives*, 14, 3-22.

[55] _____(2002). Information Technology and Productivity: Where are We Now and Where are We Going?, *Economic Review*, Federal Reserve Bank of Atlanta, 87(3), Quarter Three, 15-44.

[56] Parker, Robert P. and Bruce T. Grimm (2000). Recognition of Business and Government Expenditures for Software Investment: Methodology and Quantitative Impacts, 1958-98, paper presented for BEA's Advisory Committee, May.

[57] Ryan, Christopher K. (2002). Land as a Factor of Production, *American Journal of Economics and Sociology*, Vol.61, Issue 5, Nov., 7-25.

[58] Schreyer, Paul (2003). Capital Stocks, Capital Services and Multi-Factor Productivity Measures, OECD Draft Paper Economic Studies , 22p.

[59] _____(2004). Measuring Multi-factor Productivity When Rates of Return are Exogenous, Paper presented at the SSHRC International Conference on Index Number Theory and the Measurement of Prices and Productivity, Vancouver, 30 June-3 July, 35p.

[60] Triplett, Jack E. (1989). Price and Technological Change in a Capital Good: A survey of Research on Computers, in D. W. Jorgenson and R. Landau, eds., *Technology and Capital Formation*, Cambridge: The MIT Press, 127-213.

[61] _____(1996a). Depreciation in Production Analysis and in Income and Wealth Accounts: Resolution of an OLD Debate, *Economic Inquiry*, 34(1), 93-115.

[62] _____(1996b). High-Tech Industry Productivity and Hedonic Price Indices, Industry Productivity, International Comparison and Measurement Issues, Paris, OECD, 119-142.

[63] _____(1997). Concepts of Capital for Production Accounts and for Wealth Accounts: The Implications for Statistical Programs, First Meeting of the Canberra Group on Capital Stock Statistics, 57p.

[64] United Nations (1993). *System of National Accounts 1993*, New York, United Nations.

[65] Wasshausen, David (2000), Computer Prices in the National Income and Product Accounts, Draft Methodology Paper, Bureau of Economic Analysis, 24p.

[66] Whelan, Karl (2002), Computers, Obsolescence, and Productivity, *Review of Economics and Statistics*, 84, 445-62.