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## A New Approach to Regional Capital Stock Estimation: Measurement and Performance

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# A New Approach to Regional Capital Stock Estimation: Measurement and Performance

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Regional productivity analysis has become a major topic of interest among regional economists and economic developers. The construction of a model to analyze regional productivity has, however, been stymied by the lack of regional capital stock data, which are a crucial input to productivity models.[1] In order to facilitate the analysis of regional productivity, we have formulated a method to estimate regional net capital stock (in constant dollars). Although we are not pioneers in estimating regional capital stock, we have introduced a practical modification to the traditional perpetual inventory approach, the most commonly used, that can successfully estimate capital stock from a limited time series of available regional data.

The perpetual inventory approach estimates net capital stock as being a function of previous gross investment net of depreciation and converted from historical to constant dollars. Because this standard technique requires a regional gross investment series that extends back to the early 1900s, it is hampered by a lack of regional data. Another disadvantage of this technique is that any estimation errors in the depreciation pattern and/or deflators used will be magnified over a relatively long time period. In order to mitigate these estimation problems, our model begins with 1982 regional net capital stock estimates and applies the perpetual inventory equation in reverse for the years 1955-1981 and forward for the years 1983 and 1984. Our net capital stock estimates cover the manufacturing sector in aggregate for each of the nine Census divisions.[2]

The purpose of this working paper is to provide a detailed explanation of our methodology and to compare it to the traditional perpetual inventory method. The paper is divided into five sections: methodology, data, depreciation, price deflators, and diagnostic checks of accuracy. The first section begins by describing the standard perpetual inventory method and its advantages and disadvantages over other methods. Next, we present our reverse perpetual inventory model. The second section describes the data used in our calculations. The third and fourth sections discuss two crucial

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used in our calculations. The third and fourth sections discuss two crucial components of the model, the depreciation rates and the deflators, and the debates surrounding them. The last section contains diagnostic checks of the accuracy of our net capital stock estimates by comparing the sum of our series across all regions to national totals compiled by the Office of Business Analysis (OBA). Comparisons are also made between our regional capital stock estimates and those calculated by Hulten and Schwab (1984).

# I. Methodology

### Perpetual Inventory Method

The most common method to estimate net capital stock is the perpetual inventory method. The Bureau of Labor Statistics (BLS) and OBA used it to construct their 1947-1982 gross capital stock and net capital stock series and the Bureau of Economic Analysis (BEA) currently uses it to calculate its fixed nonresidential private capital stock series (except for the capital stock series for autos). Nongovernmental organizations have applied it as well. For example, Jack Faucett Associates, Inc. uses a similar technique that is applied extensively by academicians (Faucett 1973 and 1975) (Garafalo and Malhotra 1987). More recently, Charles Hulten and Robert Schwab used it to construct a regional net capital stock series for their productivity model (1984).

Basically, the perpetual inventory method as it applies to the construction of net capital stock series involves the cumulative summing of past gross investment less depreciation. The sum is then adjusted by a price deflator, which converts historical dollars (i.e., capital goods valued at acquisition cost) to constant dollars. Constant dollar values are used because they most accurately reflect the actual change in net capital stock. The net capital stock for any one year is equal to the cumulative value of past real gross investment less cumulative depreciation. In mathematical form, the standard formula for real net capital stock (RNK) is:

$$RNK_t = \sum_{t=1}^{n} ((HGI - D)/PGI)_t$$

It comprises three components: firstly, a historical dollar gross investment time-series (HGI); secondly, annual depreciation (D); and thirdly, a price deflator which is a ratio of historical to constant dollars (PGI). Each component will be discussed in detail in their respective section below.

Although the perpetual inventory method proves to be the most feasible choice, it is hampered by four problems which are, fortunately, surmountable. In fact, the first two problems are avoided by our reverse perpetual inventory methodology and by the level of aggregation. The first problem is that the perpetual inventory method assumes that no capital goods are purchased prior to the first year of investment used. To mitigate this problem, BLS, OBA, and BEA extend their gross investment series as far back as possible.

For plants, data begin in the 1800's and for equipment, in the early 1900's.[3] Faucett applied the perpetual inventory method using investment flows back to 1890 (Faucett 1973 and 1975). The problem of underestimating capital stock is, however, attenuated for later years because the portion of unaccounted for capital decreases as the capital goods depreciate and are finally discarded. Thus, for the post-1950 years, the capital stock series are more accurate than they are for the pre-1950 years. We have circumvented this problem by estimating 1982 regional net capital stock values and then building the time-series backwards and forwards using the perpetual inventory method.

The second problem is that the allocation of capital goods to specific manufacturing industries is permanent. Thus, no account is taken for transfers of capital goods from one industry to another or for the reclassification of an establishment to a different industry. Because our capital stock series are not disaggregated by industry, they are not distorted by this problem.

The third problem is that the depreciation pattern, a crucial component of the equation, is hard to specify. As a result, many different methods have been applied and are discussed in *Section III.* The primary source of the problem is that there is a wide variation in the service lives and depreciation pattern among types of capital goods and a paucity of data to determine these variations. The problem of estimating service lives is mitigated in part by disaggregating the capital stock series into different categories of asset types as BLS and BEA do. Because of the lack of regional data, we could only separate the capital goods into plant and equipment and have used averages of BEA service lives.

The fourth problem is the uncertain magnitude of the "values" of the net capital stock series in constant dollars and their intertemporal comparability. Problems arise from the two assumptions that are made when historical dollar values are converted into constant dollars. The first assumption called into question is that old and new capital goods are materially the same. Because of the potential differences in old and new capital goods, the accuracy of the use of "value" as a proxy for quantity is uncertain. The second assumption called into question is that any change in technology and productive capability is reflected only in the change in real costs. Thus, costless improvements in capital goods are excluded. If these improvements are significant, the perpetual inventory method would underestimate the "value" of the capital stock in later years. Thus, setting a benchmark against which constant dollar capital stock can be compared is made difficult. These problems, however, can and have been mitigated by adjusting price deflators for quality changes.[4] The details of the debate regarding price deflators are discussed in Section IV.

**The Perpetual Inventory Method Compared to Other Methods**

Other methods to construct capital stock series have been proposed, but because there are significant problems with these methods, they are less preferable than the perpetual inventory method. Among these other methods are the book-value technique and the combined book-value/perpetual inventory technique.[5] These two techniques use IRS and Annual Survey of Manufactures and Census of Manufactures (ASM/CM) data on the gross book-value of depreciable assets.

There are two advantages in estimating capital stock values from book-value data as opposed to gross investment data and the perpetual inventory method. Firstly, book-value data are relatively more accurate at the detailed industry level because they account for the transfer of capital goods from one industry to another. Secondly, the use of book-value data avoids measurement error resulting from estimates on asset service lives. These advantages, however, are counteracted by disadvantages.

Both the book-value and combined techniques are mined with problems stemming from the availability and questionable accuracy and comparability across years of the book-value data. The IRS data have two limitations: they exclude noncorporate assets and do not take into account physical depreciation. Using ASM/CM data avoids the first problem but results in a shorter time series because separate plant and equipment data are available only from 1967 on. More of a problem is that both IRS and ASM/CM data are in historical dollars. Estimation of a constant dollar series is extremely difficult, if not impossible, because it requires data on the age distribution of the capital which are not available. The second alternative, the combined technique, tries to overcome the historical-constant dollar conversion problem by using the relationship between historical and constant dollar capital stock series derived from the perpetual inventory technique. Although the combined technique may overcome the deflation problem (although this is uncertain), it still is faced with book-value data problems.

In contrast to book-value data, gross investment data—the key input of the perpetual inventory method—are relatively reliable and consistent in their definition. In addition, in terms of availability at the regional level and length of time series, gross investment data have an advantage over ASM/CM book-value data.

### A Reverse Perpetual Inventory Method

Our approach to estimate regional net capital stock differs from the traditional perpetual inventory method applied by BEA, BLS, and others (e.g., Hulten and Schwab). Instead of building up the capital stock estimates from a gross investment series, we begin by estimating 1982 regional net capital stock and then use the perpetual inventory method in reverse to calculate the 1955-1981 estimates and forward to calculate the 1983 and 1984 values. The reason that we took a slightly different approach is that it overcomes some of the estimation problems of the standard perpetual inventory method. Firstly, our approach does not require a regional gross investment series that extends back to the early 1900s and thus is not hampered by regional data limitations. Unlike Hulten and Schwab who had to use two different data sources for regional gross investment (ASM/CM data for the years 1951-1978 and their own estimates for 1920-1950), we were able to use one consistent regional gross investment series. Secondly, any estimation errors in our methodology will accumulate over a relatively shorter period of time and will be compounded for earlier years. In contrast, with the perpetual inventory technique, any estimation errors will be magnified over a relatively long time period and will be compounded for most recent years.

Our reversed version of the perpetual inventory formula is presented in Exhibit 1. Although the most significant difference between our formula and others is that we use the perpetual inventory method in reverse, there are some additional differences that exist in terms of the data, depreciation pattern, and price deflators used. These items are discussed in their respective section.

**Exhibit 1**

**The Model—Regional Real Net Capital Stock**

Notes:

1. Net capital stock series are calculated separately for plant and equipment using the same equations and are then summed.
2. All "estimated" variables are described in detail in the appropriate sections that follow.
3. Real denotes constant 1972 dollars.

4. Regional values are aggregates of state values. The regions mirror the nine Census divisions.

Formula:

$RNK_{i,82-t}$ = real net capital stock in i in region r for the year 1982-t.

For years 1955 to 1982[6] :

$$RNK^r_{i,82-t} = RNK^r_{i,82} - \sum_{t=1}^{27} [RGI^r_{i,82-t+1} - (d_i * RBV^r_{i,82-t})]$$

For years 1983 and beyond:

$$RNK^r_{i,82-t} = RNK^r_{i,82} + \sum_{t=-1}^{-2} [RGI^r_{i,82-t} - (d_i * RBV^r_{i,82-t-1})];$$

where i = type of capital good (e = equipment and p = plant).
r = region.
t = −2 (1984) to 27 (1955), $t \neq 0$.

$RNK^r_{i,82}$ = 1982 estimated net capital stock of i in region r.

$RGI^r_i = HGI^r_i / PGI^r_i$ real gross investment of i in r (for years 82-t+1 or 82-t).

$HGI^r_i$ = ASM/CM historical dollar gross investment of i in r.

$PGI^r_i$ = estimated regional gross investment price deflator.

$d_i$ = estimated depreciation rate for i.

$RBV^r_i$ = estimated real gross book value of i in r (for years 82-t or 82-t-1).

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To begin, we needed to estimate 1982 regional net capital stock for plant and equipment (i.e., $RNK_i$; see Exhibit 2 for the estimation procedure). Because no government data on real net capital stock are available at the regional level, we needed to devise a method by which we could allocate real national net capital stock data across regions. To calculate estimates of regional shares of national net capital stock, we used regional and national ASM/CM data on gross book value of depreciable assets. The implicit assumption is that the regional share of national gross book value and net capital stock are commensurate. In support of this assumption's credibility is the fact that net capital stock is a derivative of gross capital stock which, when valued in historical dollars, is the same as gross book value. In addition, the depreciation rate used to calculate the difference between gross and net capital stock should not vary greatly across regions.

**Exhibit 2**

**The Formulas For Estimating RNK In 1982 And The RBV Time Series**

$$RNK^{r}_{i,82} = RNK^{us}_{i,82} * (RBV^{r}_{i,82}/RBV^{us}_{i,82})$$

(1) (2) (3)

(1) $RNK^{us}_{i,82} = \sum_{j=20}^{39} [w^{r}_{j,82} * RNK^{us}_{ij,82}]$, or 1982 real net capital stock of i in the U.S. adjusted for region r's industry mix,

where $w^{r}_{j,82} = (EMP^{r}_{j,82})/EMP^{r}_{82})/(EMP^{us}_{j,82}/EMP^{us}_{82})$.

j = two-digit SIC code industry (20-39).

$EMP_{j,82}$ = 1982 BLS production worker employment in industry j (in r or in the U.S.).

$EMP_{82}$ = 1982 BLS total production worker employment (in r or in the U.S.).

$RNK^{us}_{ij,82}$ = 1982 OBA real national net capital stock of i in industry j.

(2) $RBV^{r}_{i,82}$ = 1982 estimated real gross book value of i in region r.

Years

1957+: $RBV^{r}_{i,57+t} = RBV^{r}_{i,57} + \sum_{t=1}^{27}[(\%NETD_{i,57+t} * RGI^{r}_{i,57+t})]$

1955-56: No separate plant and equipment gross book value data available. In order to allocate total gross book value for the years 1955 and 1956, plant and equipment shares of total gross investment were used.

$$RBV^{r}_{i,57+t} = RBV_{i,57} - \sum_{t=1}^{-2}[(\%NETD_{i,57+t+1} + RGI_{i,57+t+1})] ;$$

where t = -2 (1955) to 27 (1984), $t \neq 0$.

$RBV^r_{i,57} = HBV^r_{i,57} \,/\, PBV^r_{ij,57}$

$HBV^r_{i,57} = ave[HGI^r_i / HGI^r] * HBV^r_{57}$, or estimated 1957 historical gross book value for i in r.

ave = average ratio between 1958-1960.

$HGI^r_i$ = ASM/CM historical dollar gross investment of i in r.

$HGI^r$ = ASM/CM total historical dollar gross investment in r.

$HBV^r_{57}$ = 1957 CM total historical dollar book value in r.

$PBV^r_{i,57}$ = 1957 estimated regional book value price deflator.

$\% \, NETD_i = (RGI^{us}_i - RDISC^{us}_i)/RGI^{us}$, or average percent of real national gross investment in i remaining after discards (for years 57+t or 57+t+1).

$RGI^{us}_i$ = OBA real national gross investment in i.

$RDISC^{us}_i$ = OBA real value of discards in i.

$RGI^r_i$ = HGI sup r sub i / $PGI^r_i$, or real gross investment in i in r (for years 57+t and 57+t+1).

$HGI^r_i$ = ASM/CM historical dollar gross investment in i in r.

$PGI^r_i$ = estimated regional gross investment price deflator for i.

(3) $RBV^{us}_{i,82} = \sum_{j=20}^{39} [w^r_{j,82} * RBV^{us}_{ij,82}]$, or 1982 estimated real book value of i in the U.S. adjusted for r's industry mix.

where $w^r_{j,82}$ = same as above.

$RBV^{us}_{ij,82} = RBV^{us}_{ij,57} + \sum_{t=1}^{25} [(\% NETD_{i,57+t} * RGI_{ij,57+t})]$, or 1982 estimated real national gross book value of i in industry j.

$RBV^{us}_{ij,57} = HBV^{us}_{ij,57}/PBV^{us}_{ij,57}$

$HBV^{us}_{ij,57}$ = 1957 estimated historical dollar national gross book value for i in industry j.

$PBV^{us}_{ij,57}$ = estimated national book-value price deflator for i in industry j.

$\%NETD_{i,57+t}$ = same as above.

$RGI^{us}_{ij,57+t}$ = OBA real national gross investment of i in industry j.

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An elaboration of the methodology used to estimate the regional gross book value time series ($RBV_r$) is useful. The regional $RBV_r$ time series was derived using the perpetual inventory method, beginning with 1957 gross book values and building up with gross investment net discards data to arrive at the 1982 values. The reason that ASM/CM 1982 regional gross book values were not used is that they are in historical dollars and converting them to real dollars would not have been as accurate as the method we have chosen to use. We felt that more accurate deflators could be estimated for gross investment than for gross book value.[7] With our method, we have to estimate only one book value deflator, 1957, whose importance to the 1982 estimate is very small.

The regional book values calculated from this formula were summed for each year and the totals were compared to OBA's real national gross capital stock time series. Theoretically, the aggregate of our book values should be commensurate with national gross capital stock values because the latter are equal to cumulative gross investment net discards. For our diagnostic checks, we calculated the correlation between the two series and ran simple regressions (regressing our book values on OBA's gross capital stocks). For both plants and equipment, the correlation was nearly one (.999) while the regression coefficients were .95 for plants and 1.02 for equipment.

# II. Data

In our model, we have used two key sources of data (excluding BLS employment data). For national data except book values, we have used OBA's capital stock database.[8] The OBA variables used were: national gross investment, discards, gross capital stock, and net capital stock. Price deflators were calculated from the historical and constant 1972 dollar series of these variables (see price deflator section). For regional data and book values, we have used ASM/CM data, which include data on expenditures for plant and equipment by state and gross book values of depreciable assets.

The use of both OBA and ASM/CM data did not present any inconsistency or comparability problems because OBA's 1949-1982 investment time series was supplied by the Bureau of the Census. The OBA, however, could not use the data directly and had to make two adjustments. Firstly, changes in industry definitions had to be considered. Secondly, some three and four-digit SIC code level detail were missing for earlier years and had to be approximated. As a sidenote, data differences do exist between OBA/BLS's and BEA's capital stock time series.[9]

The time series for the above variables were taken as given without any adjustments. However, data for some variables were not available for certain years. Firstly, as noted above, 1957 regional gross book value for plant and equipment were not available separately and had to be estimated from CM total gross book value. Secondly, ASM/CM gross investment data by state were missing for the years 1979, 1980, and 1981. In order to estimate these values, we used the Longitudinal Research Data file (LRD), which was developed by the Bureau of the Census and contains all the data in the 1972 and 1977 CM and the 1973-1976 and 1978-1981 ASM (see Exhibit 3).

**Exhibit 3**

**The Formula To Estimate Missing Data: 1979-1981**

$$HGI^{r}_{i,t1} = HGILRD^{r}_{i,t1} * lbracket(HGI^{us}_{t,t1}/HGILRD^{us}_{i,t1})/INDEX]$$

where i = plant or equipment.
t1 = 1979-1981.

$HGILRD_{it}$ = LRD historical gross investment in i (in r or the U.S.)

$HGI_{it}$ = ASM/CM historical gross investment in i (in r or the U.S.)

$$\text{INDEX} = [\sum_{t2=1972}^{1978} [(HGI^{us}_{i,t2}/HGILRD^{us}_{i,t2})*(HGI^{r}_{t,2} / HGILRD^{r}_{i,t2})]] / 7$$, or seven year (1972-1978) average value of the ratio of ASM/CM to LRD data

t2 = 1972 to 1978

Once all the necessary data for book values and gross investment were compiled, the next step was to estimate depreciation rates to derive net capital stock and to estimate price deflators to convert historical dollars to constant dollars.

# III. Depreciation

The depreciation pattern, which accounts for capital consumption, is a crucial element in calculating net capital stock estimates using the perpetual inventory method. In its most accurate form, called efficiency depreciation, it reflects the assets decline in productivity, which may or may not be commensurate with economic depreciation.[10] Because of the difficulty in measuring efficiency depreciation, economic depreciation is most commonly used.[11] It accounts for the decline in efficiency due to physical deterioration and the decline in remaining potential output that is affected by declining service life and obsolescence. Although economic depreciation is easier to measure, there is no consensus as to which depreciation pattern is the most accurate. Thus, the patterns used have varied widely and have triggered much debate. (See Exhibit 4 for a listing of alternative methods).

**Exhibit 4**

**Common Depreciation Patterns**

1. Straight-line depreciation (used by BEA, commonly used in company annual reports), which assumes that the physical deterioration of the capital good is linear, that is, equal dollar depreciation across the asset's service life. "Expected" obsolescence is accounted for in BEA's estimates of the asset service life.[12] "Unexpected" obsolescence is written off in the final year

2. NIPA depreciation (used in the National Income Product Account), which is similar to straight-line but allocates depreciation over the asset's service life in proportion to its estimated service in each period and charges obsolescence when the asset is retired.

3. Accelerated depreciation (e.g., double-declining balance, primarily used in income tax returns), which allocates the largest portion of the depreciation in the beginning years and accounts for obsolescence by assuming that it occurs at a constant percentage rate.

4. Discounted value (advocated by Faucett), which discounts the value of the asset's future services and results in a pattern opposite of the accelerated

depreciation pattern, that is, less depreciation in earlier years and more in later years.

5. Beta-decay function (used by BLS, see Bulletin 2034), which allows the pattern of efficiency depreciation to vary depending on asset type.

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We have chosen to use the straight-line depreciation pattern and are satisfied with our choice for several reasons. Although it is a simple pattern, studies have shown that overall straight-line depreciation is an accurate estimate of the actual depreciation pattern. BEA regards it as a close approximation and Hulten and Schwab (1984) were satisfied with its use in their net capital stock estimates. Young and Musgrave (1980), in their overview of the empirical results of studies of depreciation patterns conclude that "for broad aggregates, straight-line depreciation comes reasonably close to the measure called for by either definition [i.e., the NIPA definition and the discounted value definition]."[13] In response to Faucett's argument in favor of the discounted value model, Young and Musgrave wrote that Faucett's depreciation pattern did not differ significantly from the straight-line pattern.

The reason that straight-line depreciation is comparable to the discounted value approach is that there are two offsetting errors. Firstly, for certain types of equipment, straight-line may provide too slow of a depreciation pattern. In contrast, for certain types of plants, it may overstate depreciation during the early years. Thus, when plant and equipment net capital stock are aggregated, the estimation errors counteract each other. Secondly, if straight-line depreciation is too low in early years and thus too high in later years (as some believe), these errors may be counteracted by straight-line depreciation's treatment of obsolescence. Our diagnostic checks compared our aggregated estimates of national net capital stock with OBA's. The findings showed that our use of the straight-line method did not cause any significant deviations in our series from OBA's series that are based on a more complex depreciation pattern.

The next step, after choosing a depreciation pattern, was to determine the asset service lives to be used. Similar to depreciation patterns, asset service lives vary by source. Lack of regional data on type of assets precluded us from disaggregating beyond the two broad categories of plant and equipment. We chose our service lives based on BEA estimates. For equipment, we chose an average service life of 18 years (a depreciation rate of .058), and for plants, we used an average service life of 30 years (a depreciation rate of .033). These estimations were compared to OBA's depreciation rates that we approximated from OBA's gross and net capital stock series summed across all industries. Our rates were close to our estimates of OBA's rates (1956-1982 averages, .062 for equipment and .026 for plants). Our rate for plants is close to that developed by Hulten and Schwab (1984) of .0361, but our rate for equipment was less than half of theirs of .1464. Their equipment rate, which reflects an asset service life of 6.83 years, appears to be underestimated given BEA service lives estimates.

# IV. Price Deflators

As highlighted in the methodology section, the selection of accurate price deflators poses some difficulties. The major problem that plagues national deflators is how to account for new assets and significant quality changes in existing assets. Our task of overcoming these problems was simplified because we used OBA's historical and constant dollar series which have already been adjusted for price differences among asset types and to the extent possible, quality changes. We did, however, have to make adjustments for regional differences in industry mix. It is important to account for varying regional industry mixes because deflators vary significantly across industries (e.g., substantially greater increases have occurred in the costs of the food and kindred product industry than in the costs of the electrical machinery industry). See Exhibit 5 for estimation procedures.

**Exhibit 5**

**The Formula Used To Estimate The Deflators**

**Gross Investment:**

For years 1955 to 1982:

$PGI^{r}_{i,82-t} = \sum_{j=20}^{39} [v^{r}_{j,82-t} * PGI^{us}_{ij,82-t}]$, or estimated regional gross investment price deflator for i;

where t = -2 (1984) to 27 (1955), $t \neq 0$.

$v^{r}_{j,82-t} = EMP^{r}_{82-t} / EMP^{r}_{82-t}$

j = same as above.

$EMP^{r}_{j,82-t}$ = BLS production worker employment in industry j in r.

$EMP^{r}_{82-t}$ = BLS total production worker employment in r.

$$PGI^{us}_{ij,82-t} = HGI^{us}_{ij,82-t} / RGI^{us}_{ij,82-t}$$

$HGI^{us}_{ij,82-t}$ = OBA historical dollar national gross investment of i in industry j.

$RGI^{us}_{ij,82-t}$ = OBA real national gross investment of i in industry j.

For years 1983 and beyond:

$$PGI^{r}_{i,82-t} = ave(PGI^{r} / PGI^{us}) * ave(PGI^{us} / DPGI^{us}) * DPGI^{us}_{i,82-t};$$

where ave = 3 year average of 1980-1982 ratios.

$PGI^{r}_{i,82-t}$ = same as above.

$PGI^{us}_{i,82-t} = HGI^{us}_{i,82-t} / RGI^{us}_{i,82-t}$ same as above.

$DPGI^{us}_{i,82-t}$ = BEA national industry implicit price deflator for nonresidential fixed investment of i.

**Gross Book Value**

$PBV^{r}_{i,57} = \sum_{j=20}^{39} [v^{r}_{j,57} * PBV^{us}_{ij,57}]$, or 1957 estimated regional gross book value price deflator for i;

where $v^{r}_{j,57}$ = same as above.

$PBV^{us}_{ij,57} = HGK^{us}_{ij,57} / RGK^{us}_{ij,57}$, or 1957 national book value price deflator of i in industry j.

$HGK^{us}_{ij,57}$ = 1957 OBA historical dollar national gross capital stock in i (i.e., cumulative investment net discards).

$RGK^{us}_{ij,57}$ = 1957 OBA real national gross capital stock in i.

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We do not account for regional cost variations for two reasons. Firstly, the market for equipment is national. Thus, the deflator should be similar across all regions. Secondly, while the market for plants may be regional and reflect differing construction costs, the size of our regions is probably large enough to make these differences negligible.

## V. Diagnostic Checks

To gauge the accuracy of our regional capital stock (RNK) series, we performed several diagnostic checks. Firstly, we compared the aggregate of our RNK series with OBA's national capital stock series. Secondly, we made comparisons between our RNK series and that of Hulten and Schwab (1984). The diagnostic tools that we used included graphs (absolute and indexed levels) and correlations.

*A priori,* we would expect the aggregate of our series to be close to OBA's series because our estimates are partially based on OBA estimates for real national gross investment, value of discards, and net capital stock. The results from the correlation check reveal a strong positive relationship between the two series for both plant and equipment (see Table 1). The strong correlation is demonstrated graphically in terms of absolute levels (see Graph 1). There is a slight divergency between the two series at the beginning of the period from 1956 to 1965. The probable reason for this gap is that any errors in our methodology are compounded for earlier years because we use the perpetual inventory equation in reverse (i.e., beginning with 1982 RNK). This divergency translates into a gradually increasing gap between the trend in our national aggregate and OBA's, which can best be seen by indexing both series to the base year of 1956 (see Graph 2).

**Table 1**

**Correlation Between Three Measures of National Real Net Capital Stock**

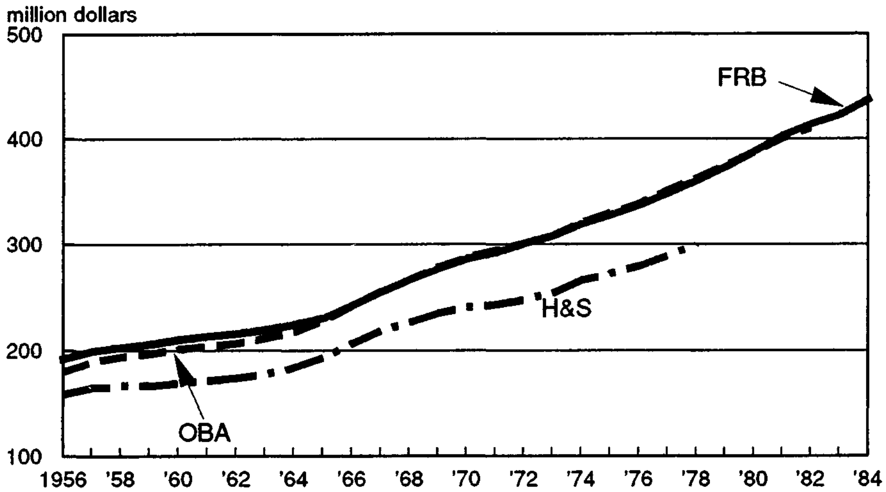
| RNK Series[a] | Correlations[b] | | |
|---|---|---|---|
| | OBA | FRB | H&S |
| OBA (n=28) | 1.0 | | |
| FRB (n=30) | .999 | 1.0 | |
| H&S (n=24) | .999 | .998 | 1.0 |

[a]OBA = Office of Business Analysis (U.S. Department of Commerce)
FRB = Federal Reserve Bank of Chicago
H&S = Hulten and Schwab

[b]All correlations are significant at the 1 percent level or less.

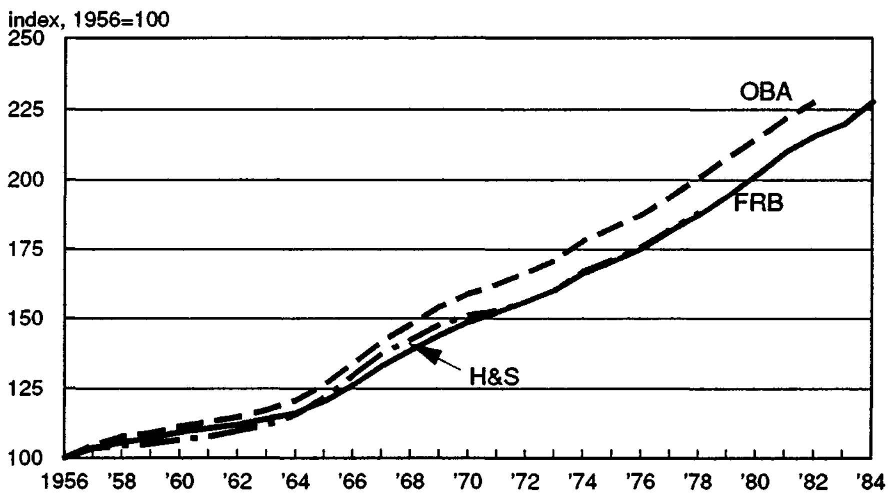
**Graph 1**

**Comparison Of Absolute Levels Of Real Net Capital StocK (RNK)-National Aggregates**




**Graph 2**

**Comparison Of Indexed Levels Of RNK - National Aggregates**



Before comparing our regional RNK series to that of Hulten and Schwab, we examined the aggregate of the Hulten and Schwab series. Similar to our series, their aggregated series was highly correlated with OBA's (see Table 1). In terms of absolute levels, however, Hulten and Schwab's series differed from OBA's. Hulten and Schwab's national aggregate ranged from 12 percent (1956) to 18 percent (1973) lower than OBA's (see Graph 1). As the gap widened, however, Hulten and Schwab's national aggregate showed a weaker upward trend than OBA's (see Graph 2). In fact, the indexed values of Hulten and Schwab's series matched more closely our pattern of growth than they did OBA's.

At the regional level, there were no startling divergencies between our series and Hulten and Schwab's. The region by region inter-series correlations were 0.99 for all but one region. The one exception was the East North Central region for which the correlation was 0.95.[14]

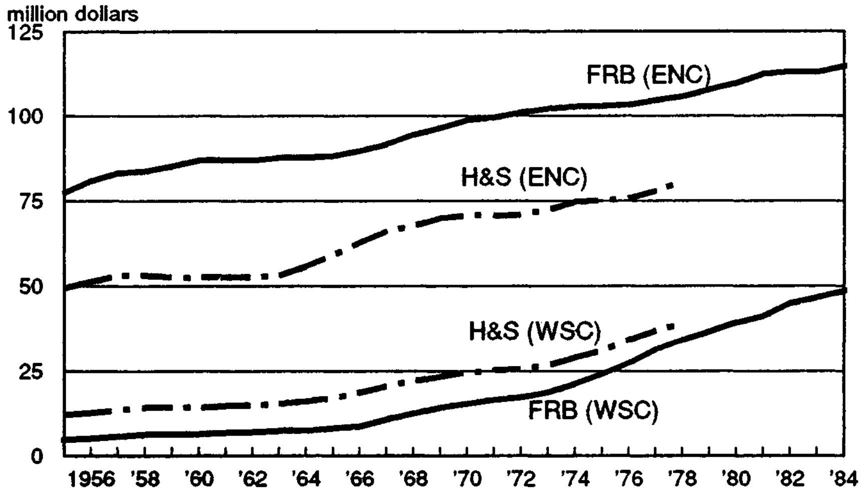
A comparative examination of regional shares of national RNK revealed a slightly different regional distribution of RNK in the Hulten and Schwab series. In our series, the industrial heartland (i.e., the New England, Mid-Atlantic, and East North Central regions) holds a greater share of national RNK (about 55 percent in 1978) than they do in the Hulten and Schwab's series (about 50 percent). The converse is true for the peripheral regions, that is, those regions whose manufacturing sector has developed relatively recently (e.g., East South Central, West South Central, and Mountain).

Differences between our series and Hulten and Schwab's were found, however, when regional levels of RNK were examined. As was visible in the aggregate comparisons, our series results in greater absolute levels than Hulten and Schwab's series. On a region by region basis, the absolute levels of our series exceed that of Hulten and Schwab for six out of the nine regions. The three regions for which this is not the case are the same three peripheral regions mentioned above. Graph 3 displays examples of the two contrasting cases: East North Central (our series is greater) and West South Central (Hulten and Schwab's is greater).

When transformed into indexed levels (1955 = 100), our series shows stronger growth than Hulten and Schwab's for all but two regions (East North Central and West North Central). The greatest divergency in trends across the two series occurred for three regions: East North Central, West South Central, and Mountain. For the East North Central region, Hulten and Schwab's series shows a stronger trend. For the latter two regions, Hulten and Schwab's series lags ours. The probable explanation for the

## Graph 3

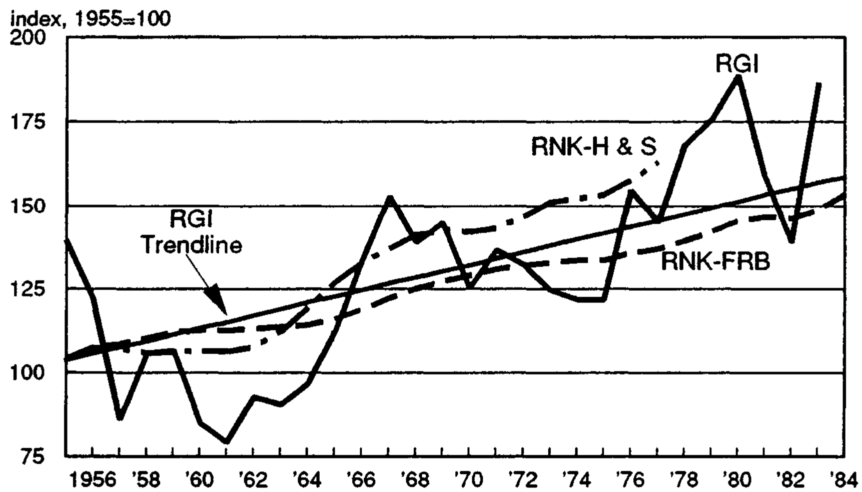
**Comparison Of Absolute Levels Of RNK - ENC And WSC Regions
East North Central Region**




Note: ENC = East North Central (Il, IN, MI, OH, and WI) and WSC = West South Central (AR, LA, OK, and TX).

## Graph 4

**Comparison Of Trends In Capital Stock And Investment -
East North Central Region**




Note: East North Central Region is IL, IN, MI, OH, WI.

divergency existing for the latter two peripheral regions is that the base value (1955) of these regions' RNK in our series is relatively small. As a result, when transformed into an index, our series shows a stronger growth trend (i.e., steeper slope).

In trying to interprete the differing inter-series patterns, the trend in regional real gross investment (RGI) was plotted along with the trends in RNK. For all but the two western regions (Mountain and Pacific), our series tended to track the trend in RGI better than Hulten and Schwab's series (a trendline was added because the gross investment series is relatively cyclical). For example, Graph 4 displays the trend of Hulten and Schwab's RNK, our RNK, and RGI for the East North Central region, plus RGI's trendline. For the period 1955-1964, our series shows slightly stronger RNK growth than Hulten and Schwab's and the RGI trendline. For the period 1964-1978, however, the trend in our series reflects closely that in RGI.

# VI. Conclusion

Our belief that we have found a feasible and accurate way to estimate regional capital stock (post-World War II) has been reinforced by our diagnostic checks. Our primary intent was to capture the pattern of capital stock growth with our reverse perpetual inventory model. To that extent, as evidenced by our comparisons with OBA's series, we have been very successful in terms of both absolute and indexed levels. At the regional level, we also seem to be capturing regional patterns of growth that are consistent with those displayed by the Hulten and Schwab's series, even though the levels tend to differ. An additional advantage to our approach is that it can easily be applied to any region and/or industry for which a gross investment time-series and gross book-value data (only one year needed) are available. In other words, our reverse inventory model can be generalized to provide a real net capital stock series required of most productivity models.

# Footnotes

[1] The model referred to allocates the growth of real value added by region across the growth rates of regional capital stock, regional labor, and regional total factor productivity. For an example see Charles Hulten and Robert Schwab, "Regional Productivity Growth in U.S. Manufacturing: 1951-1978," *The American Economic Review*, Vol. 74, No. 1, 1984, pps. 152-162.

[2] The nine Census divisions are:

New England = Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.

Middle Atlantic = New Jersey, New York, and Pennsylvania.

South Atlantic = Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia.

East North Central = Illinois, Indiana, Michigan, Ohio, and Wisconsin.

West North Central = Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.

East South Central = Alabama, Kentucky, Mississippi, and Tennessee.

West South Central = Arkansas, Louisiana, Oklahoma, and Texas.

Mountain = Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming.

Pacific = Alaska, California, Hawaii, Oregon, and Washington.

[3] BLS's gross investment series begins in 1921 for equipment and in 1890 for plants. The beginning of BEA's gross investment series varies within plant and equipment groupings. Most of the equipment gross investment data begin around 1900 while the plant data begin around 1830.

[4] BEA attempts to account for quality changes by adjusting Producer Price Indexes (PPI). The theoretical basis of BEA's quality adjustments is explained in Edward Denison's "Theoretical Aspects of Quality Change, Capital Consumption, and Net Capital Formation," in Denison's *Problems of Capital Formation: Concepts, Measurement, and Controlling Factors,* Conference on Research in Income and Wealth: Studies in Income and Wealth, Vol. 19, Princeton: Princeton University Press for National Bureau of Economic Research, 1957. For an alternative method that attempts to measure equipment according to performance characteristics see Robert Gordon, *The Measurement of Durable Goods Prices*, 1989, forthcoming.

[5] For greater detail on these methods see Young and Musgrave, and Faucett's Comment in *The Measurement of Capital* (pps. 23-46 and p. 70, respectively); and BLS, *Capital Stock Estimates for Input-Output Industries: Methods and Data*, pps. 1-4.

[6] For the years 1955-1965, a different methodology was used for real net capital stock in equipment ($RNK_e$) for the West South Central and Mountain regions (WSC and MTN). The reason for this was that when the methodology described in the paper was used to calculate $RNK_e$ for these regions, their $RNK_e$ at the be-

ginning of the series turned negative. The probable reason is that these regions' $RNK_e$ is relatively small (around 6.0 percent of the nation's for WSC and 1.0 percent for MTN). Thus, when the perpetual inventory method was applied in reverse, the real gross investment subtractions eventually eroded these region's $RNK_e$ beyond zero.

In order to correct for this problem, WSC's and MTN's share of national OBA $RNK_e$ in 1966 was multiplied by 1955-1964 national OBA $RNK_e$ to derive an estimate of their 1955-1964 $RNK_e$ (assuming their share remained constant during this period).

To gauge the impact of the above adjustments, the change in the other regions' share of total national RNK and the change in the trend of total national RNK were examined. Regarding the results for both, there were negligible changes. As the last section demonstrates, the aggregate of the regional total RNK's tracks well OBA's national RNK.

[7] Because gross book-value data are valued at acquisition cost, the estimation of gross book-value deflators is nearly impossible. It would require regional data on the age distribution of the capital stock for each year which is unknown. In order to estimate our 1957 gross book-value deflator, we used OBA's historical and constant dollar national gross capital data (comparable to gross book-value) to calculate the ratio between historical and constant dollars (see section IV).

[8] For published information on the methodology used by OBA to construct their capital stock database, see BLS, *Capital Stock Estimates for Input-Output Industries: Methods and Data,* Bulletin 2034, 1979. There is one important difference between BLS and OBA calculations. BLS assumed that the pattern of assets purchased remained fixed across all years (i.e., assets were purchased in the same proportion) whereas OBA accounted for changes in the pattern of assets purchased by using NIPA data on types of assets purchased.

[9] The three major differences between BEA and OBA/BLS (and thus ASM/CM) gross investment data are that BEA totals unlike OBA totals include: first, purchases of government surplus assets; second, passenger automobiles owned by households used for business purposes; and third, capitalized trade margins on purchases of used equipment assets. In addition, as mentioned above, BEA's and BLS's investment series begin in different years. For more information see, BLS Bulletin 2034.

[10] For a detailed definition of these two types of depreciation, see BLS Bulletin 2034.

[11] There are other types of depreciation such as tax depreciation and change in market value which should not be confused with efficiency depreciation.

[12] 12For an explanation of BEA's methodology, see BEA, *Fixed Reproducible Tangible Wealth in the U.S., 1925-1985*, June, 1987.

[13] Allan Young and John Musgrave, "Estimation of Capital Stock in the U.S.," in Dan Usher, ed., *The Measurement of Capital,* Chicago: University of Chicago Press for National Bureau of Economic Research, 1980, p. 36.

[14] The slightly lower correlation for the East North Central (ENC) region stems from the relatively low correlation between the plant component of our series and Hulten and Schwab's (.85). In order to shed some light on why this occurred, we examined the share of total RNK and book value (1957) held by the plant component. Across all regions, Hulten and Schwab's plant component consistently held a higher share of the total than our plant component whose share was on average close to its share of total book value. For example, for the ENC region, plant's share using Hulten and Schwab's series went from 58 percent (1957) to 47 percent (1978), whereas its share according to our series was a relatively stable 34 percent (which was equal to its share of book value in 1957).

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