HOUSING AND THE BUSINESS CYCLE:
DATA APPENDIX

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Abstract

This paper serves as an empirical companion piece for "Housing and the Business Cycle" by Davis and Heathcote (2000).

A large part of the paper is devoted to documenting the growth, variability, and co-movement of major macroeconomic variables. We pay particular attention to the business cycle facts relating to residential investment and house prices.

We describe a method for using the NIPA Input-Output tables to allocate value added in final goods across three intermediate goods sectors: construction, manufacturing, and services. We apply this method to estimate the 1992 shares of the three intermediate sector inputs in consumption, residential investment, business investment, and GDP.

We construct time series for Solow residuals in our three intermediate sectors using sector-specific estimates of capital's share and annual data on sector outputs, capital stocks, and hours. Finally, we use a GMM approach to consistently estimate quarterly AR(1) productivity processes given these annual residuals.

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[1] The opinions expressed here are those of the authors and do not necessarily reflect the views of the Federal Reserve System of its staff.

I Final Goods Output

To show the trends in the composition of GDP by broad category of final demand (private consumption, total fixed investment, and government consumption), in figure 1 we graph the shares of nominal GDP of these categories since 1955.[2,3] The top two panels of this figure show that the private consumption share of GDP has been rising and the government consumption share of GDP has been declining. It appears these movements largely offset; no obvious upward or downward trend is apparent in the total fixed investment to GDP ratio, shown in the bottom panel.

In table 1, we report the cyclical volatility of quarterly real GDP and its components; we also report the cross-correlation of GDP with five leads and lags of the components of GDP. Even though the NIPA data have been revised a number of times

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[2] In what follows, "total fixed investment" refers to gross fixed private and government investment including residential investment and excluding government defense investment; "government consumption" refers to government consumption and defense investment expenditures; and "private consumption" refers to NIPA "personal consumption expenditures."

[3] Nominal and Real Gross Domestic Product by Final Demand are available in Tables 1.1 and 1.2 respectively of "Selected NIPA Tables," published by the US Department of Commerce in the *Survey of Current Business*. Nominal and real personal consumption expenditures, by "Major Type of Product," are available in NIPA tables 2.2 and 2.3. Nominal and real government consumption expenditures and gross investment "by type" are available in NIPA tables 3.7 and 3.8. Nominal and real gross private fixed investment by type are available in NIPA tables 5.4 and 5.5. The "Chain-Type Quantity" indexes used to convert nominal quantities to real $1996 quantities are available in Tables 7.4 – 7.11; these tables also contain "Chain-Type" Price Indexes we use to compute relative price movements of the components of GDP.

since Cooley and Prescott (1995) and more data are at our disposal, the (comparable) numbers in this table are quite close to those in their Table 1.1.

I.1 Consumption

NIPA consumption includes spending on nondurables goods and services as well as spending on durable goods and the (largely imputed) consumption of housing services.[4] As shown in figure 2, durable goods purchases account for approximately 12 percent of NIPA consumption expenditures; the consumption of housing services accounts for another 15 percent.

Durable goods purchases are a small fraction of total consumption expenditures, so their inclusion does not substantially change the consumption price index (shown in the top panel of figure 3) even though the price of durable goods relative to other consumption goods has been falling. The inclusion of durable goods increases the business cycle volatility of consumption (it increases the percent standard deviation from 0.87 to 1.33), but does not affect cyclical consumption movements; see table 1 and the bottom panel of figure 3 for details.

I.2 Total Fixed Investment

We divide total fixed investment into residential fixed investment, government investment (excluding defense investment), and business fixed investment. Shown in the top panel of figure 4, the residential and government shares of total fixed investment have

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[4] In calculating the both the rental value of tenant-occupied and owner-occupied dwellings, NIPA consumption of housing services is set equal to the product of a "typical" rent per dwelling, imputed in the case of owner-occupied dwellings, times the number of dwellings. See pp. 21 and 60 – 62 of *Personal Consumption Expenditures* (1990), published by the US Department of Commerce, for details.

remained relatively stable at approximately 25 and 15 percent, respectively, implying the business fixed investment share of investment has also remained stable. The nonresidential structures share of investment has fallen quite a bit since the early 1980s (bottom panel of figure 4), indicating that the equipment and software investment share (the other component of business fixed investment) has risen.

The business-cycle properties and trend prices of the different fixed investment series are quite different. Table 1 shows that residential investment is more than twice as volatile as total nonresidential fixed investment, defined as the sum of business fixed investment and government non-defense investment; residential investment also clearly leads GDP while total nonresidential fixed investment lags GDP. As for prices, the top panel of figure 5 confirms that total nonresidential fixed investment prices have risen less rapidly than residential fixed investment prices; shown in the bottom panel, the difference is accounted for by the price index of equipment and software (the dot line): the nonresidential structures (dash line) and government non-defense investment (solid line) price indexes are nearly identical.

I.3 Government

Government consumption (as we have defined it) is slightly more volatile than GDP (table 1), does not appear to be cyclically correlated with GDP (table 1), and has approximately the same rate of price inflation as private consumption expenditures (figure 6).

II Final Goods Prices: Housing

In the model, private consumption, total investment, and government consumption share a common price and the price of housing is expressed relative to the price of this composite good. As we have seen, the government consumption and private consumption price indexes are nearly identical, but figure 7 shows that total nonresidential fixed investment prices (dot line) have been falling relative to consumption (and thus government) prices, the solid line. Total nonresidential fixed investment accounts for less than 15 percent of nominal GDP excluding residential investment, so the appropriately calculated price index for GDP excluding residential investment (dash line) has almost the same time-series path as the price index for consumption, also shown in figure 7. Because these two prices indexes are nearly identical, in the work that follows we use the price index for consumption to compute all real relative prices.

To construct the real relative price of housing, we need to identify a price index for one unit of undepreciated housing stock. We know of two such price indexes: the price index for new residential investment, which comes directly from NIPA table 7.6, and the "Chain-Type Annual-Weighted Price Index (Fisher Ideal) of New One-Family Houses Sold Including Value of Lot," a series that is published by the Bureau of the Census.[5] The two price indexes differ along a number of dimensions. First, the NIPA price index tracks increases to the cost of inputs while the Census directly measures

[5] See table 7 of the April 2000 issue of the *Current Construction Reports*, published by the US Department of Commerce. Note that a similar Laspeyres index is available as table 7a.

changes to new house prices after controlling for movements in house prices caused by changes to house attributes.[6] Second, the NIPA price index measures changes to the price of inputs used to build all residential structures (single family, multi-family, and "other") while the Census price index only applies to new one family houses. In 2000:Q1, residential investment in single family homes constituted approximately 55 percent of total residential investment. Finally, changes to the Census price index include changes to the price of land, while the BEA measure does not.

Over the available range of data (the Census price series starts in 1979:Q1), the two house price indexes have very similar trends, as shown in the top panel of figure 8. The bottom panel of figure 8 shows the real relative price of new houses for both series. The relative price series are calculated by dividing the housing price indexes by the price index for consumption. The resulting ratio is itself a price index; this index does not yield the relative price of housing at a given time (in the graph, the relative price of housing is normalized to 1.0 in 1979:Q1 for both series), but changes to the index are reflective of changes to the relative price of housing. This graph shows that the real price of a new house has increased about 15 percent since 1955. If old houses are good substitutes for new, it appears that houses do not appreciate quickly, if at all.

Table 2 reports the business cycle relationship of real relative house prices measured using the NIPA series, GDP, and housing investment while table 3 shows these

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[6] In the Census price index, characteristics of houses such as the square-footage, location, number of bedrooms and bathrooms, etc. are held constant based on the "kinds" of houses sold in 1992. For a description of the hedonic regression methodology used to construct this price index, see Appendix A of the March 1997 issue of *Current Construction Reports*.

business cycle relationships with the Census real relative house price series. The bottom row of table 3 shows that the two price series are highly correlated (the contemporaneous correlation coefficient equals 0.85), but the Census series is 1.4 times more volatile than the NIPA series.[7] These tables also yield four business-cycle facts that are robust to the choice of the real house price series. First, real house prices are mildly procyclical. Second, residential investment and real house prices are mildly contemporaneously correlated at cyclical frequencies. Third, residential investment leads house prices but house prices negatively lead housing investment, shown in the RES row of both tables. Finally, new house prices measured by the NIPA series are less volatile than GDP; according to the Census series, they are equally as volatile as GDP.

This last point is important because it is often stated that house prices at business cycle frequencies are much more volatile than GDP. We believe such claims must be related to the business-cycle volatility of the average or median sale price of existing homes. The average price series has the advantage in that it represents the typical sale price of existing homes and not just the price of new residential investment. The disadvantage is that it does account for any year-to-year differences in the typical quality of homes that are sold; high year-to-year variability may be due to measurement of both price and quality variation.[8]

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[7] The contemporaneous correlation matrix of output, consumption, investment, government consumption, and the Census new house price series is available in table 4.

[8] When we say "quality" variation we are referring to variation in house attributes. One such attribute is house size, so in this sense quality variation is identical to quantity variation.

To attempt to uncover the variation in the real average sale price series due to quality variation, we compare the "Average sales price of kinds of houses sold in 1992 (estimated from price index)" with the "Average sales price of houses actually sold;" both data series are available from table 8 of April 2000 issue of *Current Construction Reports*. The first series ("Adjusted") reports the average selling price of a new house if house characteristics were held constant at the typical house built in 1992 whereas the second series ("Unadjusted") simply reports the average selling price of a new house.[9] The top panel of figure 9 plots the time-series of the two price series over their available range of data.[10] This panel indicates that house quality has been rising over time. The bottom panel shows the cyclical variation in the two price series after both have been deflated using the consumption price index. New house quality appears to vary over the business cycle. When measured from 1982:Q1 to 1997:Q4, the percent standard deviation of unadjusted new house prices is 3.4%, nearly double that of the adjusted series (1.8%).

[9] The adjusted series is constructed using the Laspeyres (not Fisher) price index. See the March 1997 issue of *Current Construction Reports*, page A-4.

[10] The unadjusted series starts in 1963:Q1 while the adjusted series starts in 1977:Q1.

III Aggregate Stocks of Capital and Housing

To calibrate the total "productive" capital stock of the model (the model variable k) we add NIPA estimates of the nonresidential fixed private capital stock to the NIPA estimates of the federal government non-defense and the state and local government capital stocks. For the housing stock h we use NIPA estimates of residential fixed private capital.[11] We exclude the value of the stock of durable goods owned by consumers from the productive capital stock and housing stock.

NIPA estimates year-end capital stock valuations, i.e. the reported 1994 stock of private business capital refers to the estimated stock of this capital on December 31, 1994. In contrast, the NIPA output, investment, and consumption data refer to the flow of these variables over a given time period. For calibration, we define the year t capital stock as the geometric mean of the NIPA reported capital stock in year t and $t-1$. This "middle-of-year" capital stock measure more closely aligns output (in a given year) with the capital stock used to produce that output; it more closely aligns the arguments of household utility in a given year (consumption during the year, hours worked during the year, and the housing stock); and, it allows us for more accurate calculation of depreciation rates, shown later in this section.

The top panel of figure 10 plots the ratio of the nominal stock of productive capital to the nominal housing stock. Since 1955, the total productive stock has been on average 1.53 times larger than the housing stock. As figure 11 shows, government non-defense capital accounts for slightly more than thirty percent of total productive capital

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[11] See *Fixed Reproducible Tangible Wealth in the United States, 1925 – 94* (1999), published by the US Department of Commerce, for details.

(top panel) and state and local capital accounts for almost ninety percent of this non-defense government capital (bottom panel).

Figure 12 plots the ratio of the annual nominal productive stock of capital to annual nominal GDP. From 1955 through 1998, the average ratio has been 1.53, shown by the dotted line. The fact that the ratio of the capital stock to the housing stock has averaged the same as the ratio of the housing stock to GDP implies, on average, the size of the housing stock equals annual GDP.

The two panels of figure 13 graph our estimated annual depreciation rates (in percent) of the productive stock of capital and the housing stock. We calculate annual depreciation rates for year *t* by dividing the NIPA estimate of the value of nominal depreciation[12] in year *t* by our middle-of-year measure of the year *t* nominal stock. The top panel of figure 13 shows that the housing stock depreciates at approximately 1.6 percent per year. This is much lower than the depreciation rate of productive capital, 5.3 percent per year, shown in the bottom panel. This difference is attributable to the high depreciation rate (6.6 percent per year) of business fixed capital, shown in the top panel of figure 14; at 2.3 percent per year, the depreciation rate on government capital (bottom panel) is not much higher than that of the housing stock.

[12] Nominal depreciation tables are included as part of the NIPA supplementary capital stock tables, available on the web at http://www.bea.doc.gov/

IV Intermediate Goods

To decompose output into value added by intermediate industry, we use the annual NIPA "Gross Product by Industry" (GPO) tables.[13] These tables parse Gross Domestic Income (GDI), equal to GDP minus the statistical discrepancy, into value added originating from 10 different industries. These NIPA industries are Agriculture, forestry, and fishing (AFF); Mining; Construction; Manufacturing; Transportation and public utilities; Wholesale trade; Retail trade; Finance, insurance, and real estate (FIRE); Services; and Government.[14]

Figure 15 shows the fraction of nominal private value added, defined as GDI excluding government value added, attributed by NIPA to the various "goods-producing industries" (top panel) and "services-producing industries" (bottom panel) as classified in table 3 of Lum and Yuskavage (1997). The top panel shows that from 1947-1998, the share of nominal value-added from manufacturing has steadily declined while the bottom shows the shares of value added from services (dot-dot-dash line) and FIRE (dot-dash line) have increased. In 1947, goods-producing industries accounted for 50 percent of private value added; in 1998, these industries accounted for only 26-1/2 percent. We omit government value added from our calculations (approximately 14 percent of GDP)[15] because we do not want to arbitrarily assign government value added to goods- or services- producing industries.

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[13] Recent GPO data are available in the June 2000 issue of *Survey of Current Business*.

[14] GPO industry classifications follow the 1987 Standard Industrial Classification system.

[15] From 1955 through 1998, government value added has accounted for an average 13.8 percent of GDP (with a standard deviation of 0.77 percent).

IV.1 Capital Shares

Figure 16 graphs the capital share by NIPA industry for goods-producing (top panel) and services-producing (bottom panel) industries. For each industry, we calculate the capital share in year t, θ_t, as

$$\theta_t = 1.0 - \frac{COMP_t}{VA_t - IBT_t - PRO_t} \tag{A.1}$$

where $COMP_t$ is nominal compensation of the employees in the industry in year t, VA_t is the nominal value added of the industry in year t, IBT_t are the industry's nominal indirect business tax and nontax liabilities, and PRO_t is that industry's nominal proprietor's income in year t.[16] As in Cooley and Prescott (1995) p. 19, we derive equation (A.1) by assuming the share of IBT_t and PRO_t going to labor in year t is $(1-\theta_t)$. The top panel of Figure 16 demonstrates that the capital share of the construction industry (dash line) is the lowest of all goods-producing industries. The bottom panel shows that the capital shares of wholesale trade (dot line), retail trade (dash line), and services (dot-dot-dash line) are quite similar; in contrast, the capital share of transportation and public utilities (solid line) is a bit higher and rising over time, while the capital share of FIRE (dot-dash line) is much higher than all of the other capital shares.

Rent paid on housing is included in FIRE output, explaining why the capital share in FIRE is remarkably large. Line 58 of table 7 of the Gross Product by Industry tables (see footnote 16) lists the value added of "Nonfarm housing services," a subcategory of

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[16] These data are available in Lum, Moyer, and Yuskavage (2000) and "National Income and Product Accounts Tables," in the December 1999 issue of *Survey of Current Business*.

FIRE; these services approximately equal 80 percent of the nominal consumption of housing services (listed in Table 1.1 of the NIPA). From 1947 – 1998, the NIPA GPO tables attributed an average of 50 percent of FIRE value to nonfarm housing services.[17] When these services are purged from FIRE value added, the average FIRE capital share drops to 0.28, slightly higher than the average capital share of wholesale trade (0.24). The time-series variability of this modified FIRE capital share series is quite high, ranging from almost 0.45 in 1948 to 0.11 in 1968 and then 0.38 in 1986 and beyond; see figure 17.

As mentioned, the NIPA gross product by industry tables include data for nine private industries, but in the model we only have three intermediate goods sectors, "construction," "manufacturing," and "services." To calibrate the model's construction sector, we use data from the NIPA construction industry. For manufacturing, we group together all NIPA goods-producing industries except for construction: AFF, Mining, and Manufacturing. To calibrate the services sector of the model, we aggregate all of the NIPA services-producing industries excluding FIRE: transportation and public utilities, wholesale trade, retail trade, and services. We exclude the modified FIRE series because the variability of its capital share looks suspicious.[18]

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[17] The percentage has been steadily declining since 1963, when it was 63 percent. In 1998, the percentage was 42-1/2.

[18] This exclusion also eases the computation of the technology shocks to the model's service sector: Inclusion of the modified FIRE series requires excluding an arbitrary fraction of FIRE capital stock in order to calculate a Solow residual.

We calculate the capital share of the model's three intermediate goods sectors[19] $i \in \{b,m,s\}$ at date t ($\theta_{i,t}$) as

$$q_{i,t} = 1.0 - \frac{\sum_j COMP_{j,t}}{\sum_j \{VA_{j,t} - IBT_{j,t} - PRO_{j,t}\}} \qquad \text{(A.2)}$$

where j includes the AFF, mining, and manufacturing industries if $i=m$ and the transportation and public utilities, wholesale trade, retail trade, and services industries if $i=s$.[20] The three panels of figure 18 plot the time-series path of the capital share of the three intermediate goods sectors in the model, as we have defined them. The top panel shows the capital share of the construction industry; its average value from 1947 – 1998 is 0.13. The middle panel graphs the capital share for the manufacturing sector of the model ("Model Sector") along with the capital share of the NIPA manufacturing industry, "Manufacturing Only." The average capital shares over the 1947 – 1998 period are 0.31 and 0.26, respectively. The bottom panel shows the capital share for various service measures. The average capital share of the NIPA services industry in the post-1948 period is only 0.13, shown by the dashed line in the bottom panel. The inclusion of the wholesale and retail trade industries raises the average capital share to 0.18, the dotted line; the transportation and public utilities industries increases the average capital share to 0.24, the solid line in the bottom panel. For calibration and the computation of technology shocks by intermediate industry, we set

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[19] Consistent with the model section of the paper, "b" stands for the construction sector, "m" manufacturing, and "s" services.

[20] j equals the construction industry if $i=b$.

θ_b (construction)	θ_m (manufacturing)	θ_s (services)
.13	.31	.24

IV.2 Annual Technology Shocks

We assume that the three intermediate goods are produced using Cobb-Douglas technology with homogenous capital and labor inputs:

$$x_{i,t} = k_{i,t}^{q_i} \left(z_{i,t} n_{i,t}\right)^{1-q_i} \qquad i \in \{b, m, s\} \tag{A.3}$$

In this equation, $x_{i,t}$ is the real output of intermediate good sector i at year t, $k_{i,t}$ is the real capital stock of sector i at year t, $n_{i,t}$ is the supply of labor to sector i at year t, and $z_{i,t}$ is a labor-augmenting supply or "technology" shock to sector i at date t. Taking the natural logarithm of (A.3) and solving for the log of the sector specific technology shock yields

$$\log\left(z_{i,t}\right) = \frac{1}{1-q_i}\left[\log\left(x_{i,t}\right) - q_i \log\left(k_{i,t}\right) - \left(1-q_i\right)\log\left(n_{i,t}\right)\right] \tag{A.4}$$

for $i \in \{b,m,s\}$.

Calculation the time-series path of the log of the construction, manufacturing, and service sector technology shocks therefore requires data on real output, real capital stock, and hours worked by industry. Table 9 of the Gross Product by Industry tables (see footnote 16) lists the "Quantity Indexes for Gross Domestic Product by Industry." For each industry, multiplying this quantity index by 1996 nominal industry output yields real output in chain-weighted 1996 dollars. Although these calculations directly yield real output of the construction sector of the model, to construct real output in 1996 dollars for the manufacturing sector we need to "chain-weight" (correctly add) the real output of the AFF, mining, and manufacturing industries. Similarly, to construct real output of the service sector, we chain-weight real output of the transportation and public utilities, wholesale trade, retail trade, and services industries. To construct the real capital stock by model sector, we perform analogous calculations using tables 5 and 6 of the NIPA "Fixed Reproducible Tangible Wealth;"[21] we create our middle-of-period capital stock measure by calculating the geometric mean of the resulting year *t* and *t-1* chain-weighted real capital stock series. Annual hours worked in construction are directly observable from table 6.9c of the annual NIPA tables, "Hours Worked by Full-Time and Part-Time Employees by Industry Group."[22] To create annual hours worked in the manufacturing and service sectors, we add together the hours of the appropriate constituent industries, all of which are also located in this table.

Table 5 shows the business cycle volatility and cross-correlation with annual GDP of real annual output, hours worked, and real capital for the construction, manufacturing, and services sector for 1978 – 1997.[23] To show the influence of a different sample range and different filtering parameter on the reported business-cycle statistics of table 1, this table also reports the business cycle volatility and cross-correlation with GDP of the

[21] Table 5 of these tables reports the nominal value of industry-specific capital stocks and table 6 lists the quantity indexes. In these tables, industries are classified according to the 1987 Standard Industrial Classification system (SIC). See *Fixed Reproducible Tangible Wealth in the United States, 1925 – 94* (1999) for details.

[22] See "National Income and Product Accounts Tables" in the December 1999 issue of the *Survey of Current Business*.

[23] The real output by industry data is available from 1977 to the current. The BEA has no plans to release pre-1977 real output by industry data. For the contemporaneous correlation matrix of annual output, consumption, investment, government spending, house prices, and intermediate sector output, hours worked, and capital, see table 6.

components of final demand (consumption, total nonresidential investment, residential investment, and government consumption). A few facts emerge from this table. Construction output is more than twice as volatile as manufacturing output (which itself is nearly twice as volatile as services output). Construction and manufacturing hours and capital are more volatile than the respective services series. Also, the capital stocks of the three intermediate sectors are more volatile than aggregate capital, and, the hours worked of construction and manufacturing are more volatile than aggregate hours.

Given our estimates of the sector-specific capital shares, we calculate the time-series path of the annual logarithm of the technology shocks of the three sectors from 1977 (see footnote 23) through 1998. Figure 19 shows the time-series path of the log shocks, $\log(z_{i,t})$.[24] To estimate the rate of growth of the technology shock, we regress the log shocks on a constant and a time trend. As depicted in this figure, the technology shock has grown at 3.67 percent per year (0.91 percent per quarter) in the manufacturing sector, 1.19 percent per year (0.30 percent per quarter) in the service sector, and 0.0 percent per year in the construction industry.[25] In calibration of the model, we set

g_{zb} (construction)	g_{zm} (manufacturing)	g_{zs} (services)
.0000	.0091	.0030

[24] The 1977 value has been normalized to 1.0 in this figure.

[25] The growth rates shown in figure 19 are the focus of controversy among economists: some economists find it hard to believe that there has been no significant increase in construction multi-factor productivity, for example. See Jorgenson and Stiroh (2000), Gullickson and Harper (1999), Corrado and Slifman (1999), and Pieper (1990).

Figure 20 shows the linearly detrended logarithm of the annual sector specific technology shocks, denoted $\log(\tilde{z}_i)$ in the model section of the paper. The detrended log technology shock to services (dash line) is clearly less volatile than that to construction (sold line) and manufacturing (dot line). Statistics verify the intuition imparted by this graph: the standard deviation of the detrended logarithm of the services technology shock (0.017) is one-third the size of that of construction (0.054) and manufacturing (0.044).

IV.3 Quarterly Technology Shocks

The link between the *quarterly* logged detrended residuals (that we do not observe) and the logged detrended *annual* residuals (that we observe) is straightforward but algebraically complicated. For sector i of year t in quarter q, denote the Solow residual as $z_{i,t,q}$. The quarterly analog of (A.4) is

$$\log(z_{i,t,q}) = \frac{1}{1-q_i}\left[\log(x_{i,t,q}) - q_i \log(k_{i,t,q}) - (1-q_i)\log(n_{i,t,q})\right] \tag{A.5}$$

where $x_{i,t,q}$ is quarterly real output of sector i in quarter q of year t (expressed at an annual rate), $n_{i,t,q}$ are quarterly hours worked in sector i in quarter q of year t, also expressed at an annual rate, and $k_{i,t,q}$ is the capital stock of sector i in quarter q of year t. Averaging both sides of this equation over the quarters in a year and exploiting the properties of logarithms yields

$$\begin{aligned}&\log\left(\sqrt[4]{\prod_{q=1}^{4} z_{i,t,q}}\right)\\ &= \frac{1}{1-q_i}\left[\log\left(\sqrt[4]{\prod_{q=1}^{4} x_{i,t,q}}\right) - q_i \log\left(\sqrt[4]{\prod_{q=1}^{4} k_{i,t,q}}\right) - (1-q_i)\log\left(\sqrt[4]{\prod_{q=1}^{4} n_{i,t,q}}\right)\right]\end{aligned} \tag{A.6}$$

(A.6) shows that if annual output, capital, and hours were equal to the geometric mean of the quarterly numbers, then the annual logarithm of the Solow residual equals the logarithm of the geometric mean of the quarterly Solow residuals. Our middle-of-year capital stock measure (the geometric mean of the year-end annual capital stocks) should be fairly close to the geometric mean of quarterly capital stocks. In the NIPA, however, annual output and hours are the arithmetic average of quarterly output and hours (expressed at annual rates). Our intuition, however, is that the geometric means of quarterly output and hours approximately equal the arithmetic means.

We assume that the quarterly logged *detrended* residuals in each sector i follow a first-order autoregressive process with autoregressive coefficient a_i, i.e. for $q>1$

$$\log\left(\tilde{z}_{i,t,q}\right) = a_i \log\left(\tilde{z}_{i,t,q-1}\right) + e_{i,t,q} \tag{A.7}$$

and

$$\log\left(\tilde{z}_{i,t,1}\right) = a_i \log\left(\tilde{z}_{i,t-1,4}\right) + e_{i,t,1} \tag{A.8}$$

for the first quarter. Given this process, we know

$$\log\left(\tilde{z}_{i,t,q}\right) = a_i^4 \log\left(\tilde{z}_{i,t-1,q}\right) + \hat{e}_{i,t,q} \tag{A.9}$$

with

$$\begin{array}{ccccccccc} \hat{e}_{i,t,1} & = & a_i^3 e_{i,t-1,2} & + & a_i^2 e_{i,t-1,3} & + & a_i e_{i,t-1,4} & + & e_{i,t,1} \\ \hat{e}_{i,t,2} & = & a_i^3 e_{i,t-1,3} & + & a_i^2 e_{i,t-1,4} & + & a_i e_{i,t,1} & + & e_{i,t,2} \\ \hat{e}_{i,t,3} & = & a_i^3 e_{i,t-1,4} & + & a_i^2 e_{i,t,1} & + & a_i e_{i,t,2} & + & e_{i,t,3} \\ \hat{e}_{i,t,4} & = & a_i^3 e_{i,t,1} & + & a_i^2 e_{i,t,2} & + & a_i e_{i,t,3} & + & e_{i,t,4} \end{array} \tag{A.10}$$

Taking the average of both sides of equation (A.9) for $q=1,\ldots,4$ in each year t produces

$$\log\left(\sqrt[4]{\prod_{q=1}^{4} \tilde{z}_{i,t,q}}\right) = a_i^4 \log\left(\sqrt[4]{\prod_{q=1}^{4} \tilde{z}_{i,t-1,q}}\right) + \frac{1}{4}\sum_{q=1}^{4} \hat{e}_{i,t,q} \;. \tag{A.11}$$

The variable on the left-hand side of (A.11) is the logarithm of the annual detrended residual and the variables on the right hand side are the logarithm of the previous year's annual detrended residual and a mean zero error.[26] (A.11) reveals that if the quarterly logged detrended Solow residuals follow a first-order autoregressive process, then the annual residuals follow a first-order autoregressive process as well.

For convenience, rewrite (A.11) in terms of the annual detrended residual as

$$\log\left(\tilde{z}_{i,t}\right) = \alpha_i \log\left(\tilde{z}_{i,t-1}\right) + \varepsilon_{i,t}\,, \tag{A.12}$$

where $\alpha_i = a_i^4$ and $\varepsilon_{i,t} = \frac{1}{4}\sum_{q=1}^{4}\hat{e}_{i,t,q}$. Ordinary least squares of equation (A.12) does not produce an unbiased estimate of α_i because the error term $\varepsilon_{i,t}$ is correlated with the regressor $\tilde{z}_{i,t-1}$.[27]

Using the annual logged detrended Solow residual data from 1979 – 1998, we estimate α_i of (A.12) for each of the three intermediate industries using GMM. We assume that $e_{i,t,q}$ is independently drawn over time, and with this assumption, any variable dated year t-2 or earlier is a valid instrument as long as the variable is correlated with both $\tilde{z}_{i,t}$ and $\tilde{z}_{i,t-1}$. This yields an infinite number of possible instruments. We have found that different instruments and sets of instruments yield different (unbiased and consistent) estimates of α_i for $i\in\{b,m,s\}$; our estimates of α_m and α_s are especially sensitive to the choice of instruments. For the construction and manufacturing industries ($i=b,m$), we use the year t-2 value of the annual log detrended construction residual as the

[26] We assume $E\left[e_{i,t,q}\right] = 0 \ \forall i, t, q$.

[27] $e_{i,t-1,q}$ is a component of the error term (see equation (A.10)) and $e_{i,t-1,q}$ is correlated with $z_{i,t-1,q}$ by (A.7).

instrument; for the services industry ($i=s$), we use the annual log detrended manufacturing residual as the instrument. We use this particular set instruments because they yield the largest estimates of α_i for each industry. Our estimates for α_i and (and thus $a_i = (\alpha_i)^{1/4}$) are[28]

	Construction	Manufacturing	Services
α_i (annual)	.420	.295	.612
a_i (quarterly)	.805	.737	.885

Given these estimates, we set the standard deviations and correlations of the annual innovations, $\varepsilon_{i,t}$, as

	Construction	Manufacturing	Services
Std. Dev. ($\varepsilon_{i,t}$)	.0325	.0345	.0156

Cor($\varepsilon_{b,t}$, $\varepsilon_{m,t}$)	Cor($\varepsilon_{b,t}$, $\varepsilon_{s,t}$)	Cor($\varepsilon_{s,t}$, $\varepsilon_{m,t}$)
.404	.394	.342

To compute the variance and covariances of the quarterly innovations given the above annual estimates, note that $\frac{1}{4}\sum_{q=1}^{4}\hat{e}_{i,t,q}$ equals $(1/4)\left[i_4\ A_i\ \tilde{e}_{i,t}\right]$, where ι_4 is a 1x4 vector of the element 1, $\tilde{e}'_{i,t} = \left[e_{i,t-1,2} \quad e_{i,t-1,3} \quad e_{i,t-1,4} \quad e_{i,t,1} \quad e_{i,t,2} \quad e_{i,t,3} \quad e_{i,t,4}\right]$, and

$$A_i = \begin{bmatrix} a_i^3 & a_i^2 & a_i & 1 & 0 & 0 & 0 \\ 0 & a_i^3 & a_i^2 & a_i & 1 & 0 & 0 \\ 0 & 0 & a_i^3 & a_i^2 & a_i & 1 & 0 \\ 0 & 0 & 0 & a_i^3 & a_i^2 & a_i & 1 \end{bmatrix}. \tag{A.13}$$

[28] The biased OLS estimates of α_b, α_m, and α_s are 0.686, 0.589, and 0.446, respectively.

As noted, we assume that the innovations to the quarterly log detrended residual, $\{e_{b,t,q}, e_{m,t,q}, e_{s,t,q}\}$, are independently distributed over time but may be contemporaneously correlated. Using the serial independence, we derive the following expression from (A.13),

$$E[e_{i,t}e_{j,t}] = \frac{1}{16}[i_4 A_i A_j' i_4'] E[e_{i,t,q} e_{j,t,q}]. \tag{A.14}$$

(A.14) relates the variances ($i = j$) and covariances ($i \neq j$) of the quarterly innovations, $e_{i,t,q}$, to the variances and correlations of the error in (A.12), $\varepsilon_{i,t}$. Based on this relationship, we calibrate

	Construction	Manufacturing	Services
Std. Dev. ($e_{i,t,q}$)	.0256	.0299	.0109

Cor($e_{b,t,q}$, $e_{m,t,q}$)	Cor($e_{b,t,q}$, $e_{s,t,q}$)	Cor($e_{m,t,q}$, $e_{s,t,q}$)
.404	.394	.344

V Final Good Technology

We assume that firms that produce final goods aggregate intermediate goods according to the following technology

$$y_j = b_j^{B_j} m_j^{M_j} s_j^{S_j} \,, \tag{A.15}$$

where S_j equals $1 - B_j - M_j$. In this equation, y_c is the output of the consumption-investment final good, y_h is the output of the residential investment final good, $\{b_c, m_c, s_c\}$ are the quantities of intermediate goods (construction, manufacturing, and services) used in production of the consumption-investment good, $\{B_c, M_c, S_c\}$ are the shares of construction, manufacturing, and services in production of the consumption-investment good, and $\{b_h, m_h, s_h, B_h, M_h, S_h\}$ are the quantities and shares of the intermediate goods in the production of residential investment.

Denote the price of intermediate goods in units of the consumption-investment good as p_i for $i \in \{b,m,s\}$. Derived in the model section of the paper, the first order conditions of the final goods firms imply that

$$B_c = \frac{p_b b_c}{y_c} \quad M_c = \frac{p_m m_c}{y_c} \quad S_c = \frac{p_s s_c}{y_c} \tag{A.16}$$

and

$$B_h = \frac{p_b b_h}{p_h y_h} \quad M_h = \frac{p_m m_h}{p_h y_h} \quad S_c = \frac{p_s s_h}{p_h y_h} \tag{A.17}$$

where p_h is the price of one unit of residential investment output expressed in units of the consumption-investment good. Profit maximization thus implies that the share parameters $\{B_c, M_c, S_c\}$ and $\{B_h, M_h, S_h\}$ equal the ratio of the value of purchased intermediate goods to the value of final goods that are produced.

To calculate the value added from the construction, manufacturing, and service sectors into PCE, business fixed investment, and residential investment, we use the "Use" table of the 1992 NIPA "Input-Output Accounts (IO) for the U.S. Economy." This IO Use table has two complementary sub-tables. In the first, the total sales of an industry (for all intermediate industries) are allocated to value-added of that industry, and, sales from other industries. In the second, final sales of each industry comprising the components of final demand (PCE, gross private fixed investment, etc.) are listed.[29] Taken together, these two tables allow a decomposition of PCE, private investment, etc. into value added by intermediate industry.[30]

In row 6 of box 1 on the next page, we list the 1992 final sales[31] of the construction, manufacturing, service and "other" (government) industries from this sub-table of the IO Use table.[32] Final sales consist of sales purchased from other industries, rows 1 through 4, and value added, row 5. For example, the 680 billion of sales originating from the construction industry (row 6 of column 1) consists of 212 billion of sales purchased from manufacturing industries (row 2, column 1), 153 billion of sales purchased from services industries (row 3, column 1), 772 million of sales purchased

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[29] For more details on the IO accounts, see Lawson (1997), and, *Benchmark Input-Output Accounts of the United States, 1992* (1998).

[30] Note that the IO tables do not use the 1987 SIC to classify intermediate industries, a point that to which we return later.

[31] These sales exclude the value of sales purchased from "non-comparable imports," accounting for less than one percent of total sales for all industries.

[32] We group together the AFF, Mining, and Manufacturing industries as the "Manufacturing" industry and the Transportation, Trade, Services, and FIRE industries as the "Services" industry.

Box 1: IO-Use Table (1992)
Decomposition of final sales (in millions of current dollars) by industry

		Final Sales from Industry			
		Construction (1)	Manufacturing (2)	Services (3)	Other (4)
(1)	Construction	594	23698	114174	21152
(2)	Manufacturing	212060	1369330	423470	15277
(3)	Services	153282	617704	1511859	27773
(4)	Other	772	12522	38769	1342
(5)	Value added	312622	1308901	3301666	853466
(6)	Total sales	679330	3332155	5389938	919010

from other (row 4, column 1), 594 million purchased from within the construction industry (row 1, column 1), and 313 billion of value added (row 5, column 1). In box 1, we subtract imputed rental income from housing from the total sales of the services industry (column 3, row 6), and, from the value added of services (column 3, row 5).[33]

The sum of the value added of the intermediate industries including the imputed rental income from housing equals nominal 1992 GDP. Interestingly enough, the I/O estimates of value added by intermediate industry, row 5, do not equal the 1992 GPO estimates of value added by industry (which sum to nominal 1992 GDI).[34] This discrepancy results because the NIPA GPO accounts and I/O accounts use different

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[33] We define the imputed rental income from housing as I/O code 710100 (FIRE industry); in 1992, this value was $457,250 million. We assume that NIPA allocates all imputed rental income to FIRE sales, imputed rental income is entirely FIRE value added, and, imputed rental income is not sold to any of the other industries.

[34] For example, the 1992 value added of the construction industry measured by the GPO accounts is 234 billion (current) dollars.

industry classifications and different data.[35] We do not correct for these differences in our calibration procedure.

From the information in box 1, we employ an infinite recursion to decompose sales attributed to one of the intermediate industries into value added from all four intermediate industries. To understand why we use an infinite recursion, consider column 1: final sales attributed to the construction industry include some value added from construction (row 5, column 1) and some sales purchased from the manufacturing industry (row 2, column 1). But, sales attributed to manufacturing industries include sales from purchased from the construction industry (row 1, column 2) and these sales, in turn, include construction value added. To help understand the recursion we employ, denote the sales attributed to the construction, manufacturing, services, and other industries as S_B, S_M, S_S, and S_O, respectively. Furthermore, denote the value added of the construction, manufacturing, services, and other industries as V_B, V_M, V_S, and V_O, respectively. We know from column 1 that $S_B = (.0009)S_B + (.3122)S_M + (.2256)S_S +(.0011)S_O +(.4602)V_B$, and we can write similar equations for the other three columns corresponding to the sales from the other three industries. Using these equations, we derive the following expression linking sales attributed to different intermediate industries to value added of the four intermediate industries.[36]

[35] See Parker (1997) for a discussion of this issue.

[36] The columns should sum to 1.0.

$$
\begin{bmatrix} V_B \\ V_M \\ V_S \\ V_O \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & .4602 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & .3928 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & .6126 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & .9287 \\ 0 & 0 & 0 & 0 & .0009 & .0071 & .0212 & .0230 \\ 0 & 0 & 0 & 0 & .3122 & .4109 & .0786 & .0166 \\ 0 & 0 & 0 & 0 & .2256 & .1854 & .2805 & .0302 \\ 0 & 0 & 0 & 0 & .0011 & .0038 & .0072 & .0015 \end{bmatrix}^{\infty} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ S_B \\ S_M \\ S_S \\ S_O \end{bmatrix} \tag{A.18}
$$

As noted, the second sub-table of the IO Use table lists components of demand by sales attributed to intermediate industries. Using the same industry classifications as before, in box 2 we report an abridged portion of this sub-table from the 1992 IO Use table. Columns 1 through 3 are directly copied from the I/O Use table. The I/O use table does not have a "residential investment" column, so in column 4 we assume that all 225.5 billion dollars of residential investment in 1992 are attributed to sales from the construction industry.[37] In addition, we subtract sales the imputed rental income from housing services from the sales of the services sector to PCE. Interpreting this table, in 1992 PCE excluding the imputed income from housing consisted of $0 of final sales from the construction industry, $869.3 billion of final sales from manufacturing industries,

[37] The I/O tables do list final sales attributed to I/O construction industries 110101 (New residential 1 unit structures, nonfarm), 110102 (New residential 2-4 unit structures, nonfarm), 110105 (New residential additions and alterations, nonfarm), 110108 (New residential garden and high-rise apartments construction), and 120101 (Maintenance and repair of farm and nonfarm residential structures). In 1992, the sum of sales attributed to these industries equaled $236,155 million, almost the same as the $225.5 billion recorded for residential investment. If these represent sales to consumers and not sales to other intermediate industries, our procedures are somewhat validated.

Box 2: IO-Use Table
Decomposition of Final Demand into Final Sales From Industries

	PCE (1)	Private Investment (2)	Government Expenditures[a] (3)	Residential Investment (4)
Construction	0	360278	159357	225500
Manufacturing	869311	339131	209393	0
Services	2858985	121875	105337	0
Other	-9837	-30293	771644	0
Total	3718459	790991	1245731	225500

a. Includes government consumption and government investment expenditures.

$2,859.0 billion of final sales from services industries, and -$9.8 billion dollars of sales from other (government),[38] adding to $3,718 billion dollars.[39]

Using equation (A.18) with the final sales by spending category given in box 2, we map final sales by industry into value added by industry for the four different industries for PCE, total private fixed investment, residential investment, business fixed investment, and the sum of PCE, BFI, and government non-defense investment (GOVI); see box 3. For example, to calculate the value added by intermediate industry for PCE, we set $S_B = 0$, S_M, $= 869{,}311$, $S_S = 2{,}858{,}985$ and $S_O = -9{,}837$ (taken from column 1 of box 2) and apply the formula given in (A.18).

To compute the construction, manufacturing, and services share of PCE, we simply divide the value added of those industries (given in the rows of column 1) by total

38 We unfortunately can not provide an interpretation for negative sales.

39 1992 nominal PCE equals $4,210 billion dollars; the consumption of housing services and sales attributed to non-comparable imports account for the difference.

Box 3: Decomposition of Final Demand into Value Added From Industries

	PCE (1)	Private Investment (2)	Residential Investment (3)	BFI (4)	PCE+BFI +GOVI (5)
Construction	50303	173218	105264	67954	135789
Manufacturing	846613	329539	53385	276154	1194015
Services	2792337	309819	65468	244351	3099731
Other	29205	-21585	1383	-22968	311
Total	3718459	790991	225500	565491	4429847

PCE minus value added from "other." This yields shares of 1.36, 22.95, and 75.69 percent of PCE for the construction, manufacturing, and services industries. For residential investment (column 3), we calculate construction, manufacturing, and services shares of 46.97, 23.82, and 29.21 percent, respectively. For Business Fixed Investment (column 4 = column 2 minus column 3), we calculate shares of 11.55, 46.93, and 41.52 percent.

In the model, the consumption-investment good is the sum of PCE, BFI, and government investment. We assume that the composition of government investment by intermediate industry value added is the same as business fixed investment. In 1992, nominal government investment was equal to 25.8 percent of business fixed investment. Multiplying the rows of the BFI column by 1.258 and then adding the rows of the PCE column yields the value added by industry of the model's consumption-investment good, the PCE+BFI+GOVI column. The value-added shares of this good are 3.07 percent for construction, 26.96 percent for manufacturing, and 69.98 percent for services. Therefore, for calibration of the model, we set

B_c	M_c	S_c	B_h	M_h	S_h
.0307	.2696	.6998	.4697	.2382	.2921

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TABLE 1
BUSINESS-CYCLE VOLATILITY OF GDP AND KEY COMPONENTS, 1955:Q1 – 1997:Q4

Variable	SD%	x(-5)	x(-4)	x(-3)	x(-2)	x(-1)	x	x(+1)	x(+2)	x(+3)	x(+4)	x(+5)
		Cross-Correlation of GDP with:										
GDP	1.65	-.04	.16	.39	.63	.85	1.0	.85	.63	.39	.16	-.04
Consumption expenditures												
CONS	1.33	.20	.38	.55	.72	.84	.88	.72	.51	.28	.04	-.14
CNDS	0.87	.15	.34	.52	.69	.81	.83	.72	.54	.33	.11	-.06
CD	5.02	.24	.38	.51	.66	.77	.81	.62	.40	.17	-.05	-.22
Total fixed investment												
INVT	4.46	.07	.24	.42	.64	.82	.92	.82	.63	.41	.17	-.03
Total nonresidential investment												
INVTXH	4.02	-.23	-.10	.07	.32	.57	.80	.86	.81	.68	.51	.31
GOVI	3.85	.02	.06	.13	.23	.29	.35	.31	.27	.27	.34	.36
BFI	4.75	-.25	-.13	.05	.29	.55	.79	.86	.81	.68	.48	.25
Residential investment												
RES	10.57	.39	.54	.65	.74	.76	.66	.42	.16	-.09	-.28	-.40
Government consumption and defense investment												
GOVC	2.05	-.12	-.12	-.10	-.11	-.09	-.04	-.03	-.03	-.01	.02	.07

Notes: All variables are real, chain-weighted 1996$ and have all been logged and HP filtered from 1947:Q1 to 2000:Q1 with $\lambda = 1600$. GDP stands for GDP; CONS – personal consumption expenditure; CNDS – consumption of nondurables and services; CD – consumption of durables; INVT – gross fixed investment; INVXH – gross fixed investment excluding residential investment; GOVI – government non-defense investment; BFI – gross business fixed investment; RES – gross residential fixed investment; GOVC – government consumption and defense investment purchases.

TABLE 2

BUSINESS-CYCLE VOLATILITY OF RELATIVE NEW HOUSE PRICES (NIPA) AND OTHER SERIES, 1955:Q1 – 1997:Q4

		Cross-Correlation of Relative New House Prices (NIPA) with:										
Variable	SD%	x(-5)	x(-4)	x(-3)	x(-2)	x(-1)	x	x(+1)	x(+2)	x(+3)	x(+4)	x(+5)
New House Prices (NIPA)	1.18	.19	.36	.47	.65	.77	1.0	.77	.65	.47	.36	.19
GDP	1.65	.36	.44	.54	.54	.52	.46	.40	.25	.16	.04	-.07
RES	10.57	.54	.55	.53	.44	.34	.18	.05	-.10	-.22	-.31	-.41

Notes: All variables have been logged and HP filtered from 1947:Q1 to 2000:Q1 with $\lambda = 1600$. The New House Prices (NIPA) series equals the chain-type price-index for NIPA residential investment divided by the chain-type price index for NIPA personal consumption expenditures. GDP stands for real, $1996 chain-weighted GDP and RES stands for real, chain-weighted $1996 gross residential fixed investment.

TABLE 3

BUSINESS-CYCLE VOLATILITY OF RELATVE NEW HOUSE PRICES (CENSUS) AND OTHER SERIES, 1982:Q1 – 1997:Q4

		Cross-Correlation of Relative New House Prices (Census) with:										
Variable	SD%	x(-5)	x(-4)	x(-3)	x(-2)	x(-1)	x	x(+1)	x(+2)	x(+3)	x(+4)	x(+5)
New House Prices (Census)	1.53	.26	.37	.45	.52	.71	1.0	.71	.52	.45	.37	.26
GDP	1.44	.23	.28	.34	.37	.37	.33	.30	.23	.21	.15	.12
RES	9.58	.48	.47	.48	.45	.37	.24	.12	.00	-.07	-.14	-.20
New House Prices (NIPA)	1.10	.24	.39	.52	.64	.75	.85	.81	.69	.58	.44	.32

Notes: All variables except for New House Prices (Census) have been logged and HP filtered from 1947:Q1 to 2000:Q1 with $\lambda = 1600$. The New House Prices (Census) series equals the "Chain-Type Annual-Weighted Price Index (Fisher Ideal) of New One-Family Houses Sold Including Value of Lot" divided by the chain-type price index for NIPA personal consumption expenditures; the resulting ratio is logged and HP filtered from 1979:Q1 to 2000:Q1. For other notes, see above.

TABLE 4

CONTEMPORANEOUS CORRELATIONS COMPUTED WITH QUARTERLY DATA

1982:1 – 1997:4

		1 GDP	2 CONS	3 INVTXH	4 RES	5 GOVC	6 P_H
1	GDP	1	.88	.82	.73	.01	.33
2	CONS		1	.64	.81	.10	.44
3	INVTXH			1	.35	-.06	.22
4	RES				1	-.04	.24
5	GOVC					1	-.04
6	P_H						1

Notes: All variables have all been logged and HP filtered with $\lambda = 1600$. All spending variables are in real, chain-weighted 1996$. GDP stands for GDP; CONS – personal consumption expenditure; INVTXH – gross fixed investment including government non-defense investment and excluding residential investment; RES – gross residential fixed investment; GOVC – government consumption and defense investment purchases; P_H is the Census new house chain-type price index divided by the chain-type price index for NIPA personal consumption expenditures.

TABLE 5

BUSINESS-CYCLE VOLATILITIES COMPUTED WITH ANNUAL DATA

1978 – 1997

		Cross-Correlation of Output with:		
Variable	SD%	x(-1)	x	x(+1)
GDP	2.2	.59	1.0	.59
Final Goods				
CONS	2.1	.77	.92	.48
INVTXH	4.84	.32	.75	.51
RES	13.8	.79	.78	.08
GOVC	2.1	.34	.40	.47
Intermediate Goods Output				
CONSTR	7.7	.65	.95	.58
MANUF	3.8	.53	.84	.41
SERVICES	2.0	.61	.94	.56
Hours				
ALL	2.2	.45	.92	.64
CONSTR	6.5	.56	.93	.67
MANUF	2.9	.26	.81	.51
SERVICES	1.7	.49	.88	.62
Private Fixed Capital				
ALL	.37	-.03	.16	.46
CONSTR	3.1	-.29	.08	.31
MANUF	1.3	-.14	-.31	-.29
SERVICES	.62	.30	.56	.66

Notes: All variables have been logged and HP filtered using all available data with $\lambda = 100$. GDP, CONS, INVTXH, RES, and GOVC are defined the same as in table 1. CONSTR, MANUF, and SERVICES stand for the construction, manufacturing, and services sector of the model; manufacturing incorporates agriculture, forestry, and fishing, mining, and manufacturing; services incorporates transportation and public utilities, wholesale trade, retail trade, and services. ALL private hours equals the sum of the hours worked in all industries except government; ALL private fixed capital equals the sum of the stocks of nonresidential private fixed capital and government non-defense capital.

TABLE 6

CONTEMPORANEOUS CORRELATIONS COMPUTED WITH ANNUAL DATA

1978 – 1997

		1 GDP	2 CONS	3 INVTXH	4 RES	5 GOVC	6 P_H	7 X_b	8 X_m	9 X_s	10 N_{all}	11 N_b	12 N_m	13 N_s	14 K_{all}	15 K_b	16 K_m	17 K_s
1	GDP	1	.92	.75	.78	.40	.64	.95	.84	.94	.92	.93	.81	.88	.16	.08	-.31	.56
2	CONS		1	.58	.86	.55	.64	.92	.77	.88	.78	.86	.57	.80	.13	-.20	-.31	.51
3	INVTXH			1	.48	.02	.52	.70	.73	.74	.84	.86	.81	.74	.30	.42	.27	.58
4	RES				1	.25	.45	.81	.65	.68	.62	.68	.51	.58	-.23	-.22	-.25	.18
5	GOVC					1	.24	.39	.22	.46	.16	.32	-.13	.25	.57	-.51	-.24	.54
6	P_H						1	.60	.70	.55	.72	.73	.56	.73	.37	.13	-.03	.71
7	X_b							1	.82	.90	.87	.93	.74	.82	.07	.00	-.36	.49
8	X_m								1	.81	.85	.86	.76	.83	.18	.02	-.12	.55
9	X_s									1	.86	.91	.73	.84	.33	.09	-.18	.65
10	N_{all}										1	.95	.93	.96	.16	.33	-.20	.57
11	N_b											1	.82	.92	.26	.20	-.13	.66
12	N_m												1	.81	.00	.51	-.19	.38
13	N_s													1	.19	.18	-.23	.57
14	K_{all}														1	.10	.45	.86
15	K_b															1	.25	.21
16	K_m																1	.26
17	K_s																	1

Notes: All variables have all been logged and HP filtered with $\lambda = 100$. All output and capital variables are in real, chain-weighted 1996$. All correlations of (x,P_H) are estimated from 1979 to 1997. The "manufacturing sector" includes the AFF, mining, and manufacturing industries. The "services sector" includes the transportation and public utilities, wholesale trade, retail trade, and services industries. GDP stands for GDP; CONS – personal consumption expenditure; INVTXH – gross fixed investment including government non-defense investment and excluding residential investment; RES – gross residential fixed investment; GOVC – government consumption and defense investment purchases; P_H is the Census new house chain-type price index divided by the chain-type price index for NIPA personal consumption expenditures; X_b is output of the construction sector; X_m is output of the manufacturing sector; X_s is output of the services sector; N_{all} are the hours worked in all private industries; N_b is the hours worked in the construction sector; N_m is the hours worked in the manufacturing sector; N_s is the hours worked in the services sector; K_{all} is the total productive capital stock in the economy (business fixed capital and government non-defense capital); K_b is the capital stock of the construction sector; K_m is the capital stock of the manufacturing sector; K_s is the capital stock of the services sector.

FIGURE 1

PRIVATE CONSUMPTION, GOVERNMENT CONSUMTION, AND TOTAL FIXED INVESTMENT SHARE OF NOMINAL GDP

1955:Q1 – 2000:Q1

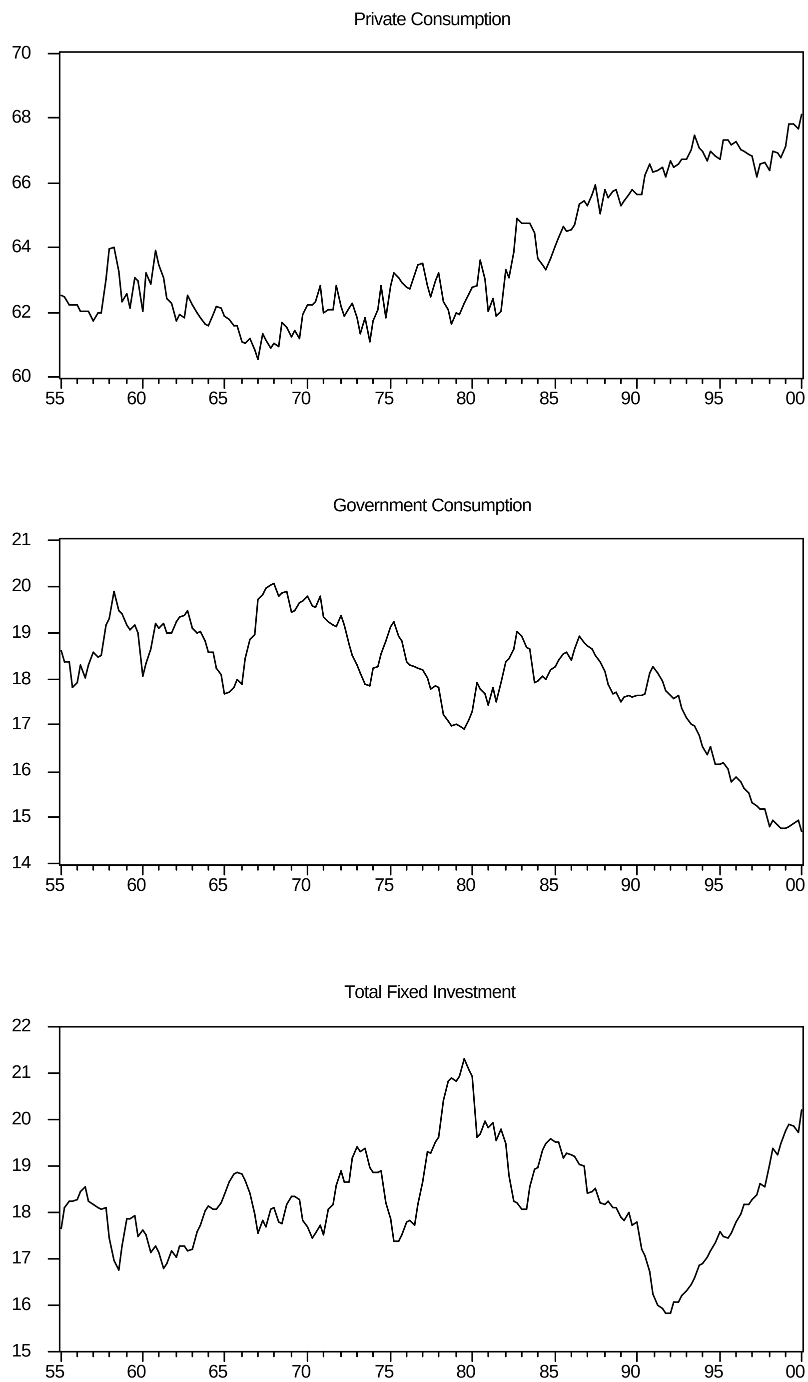


FIGURE 2

DURABLE GOODS AND HOUSING SERVICES SHARE OF NOMINAL NIPA CONSUMPTION, 1955:Q1 – 2000:Q1

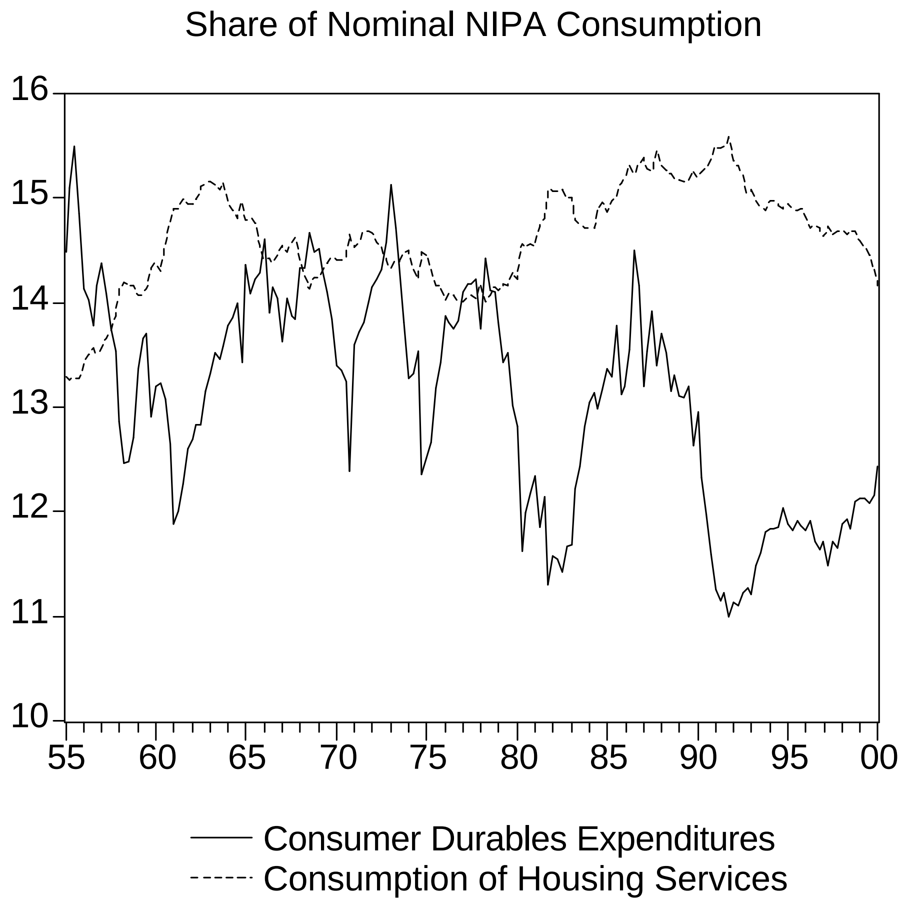
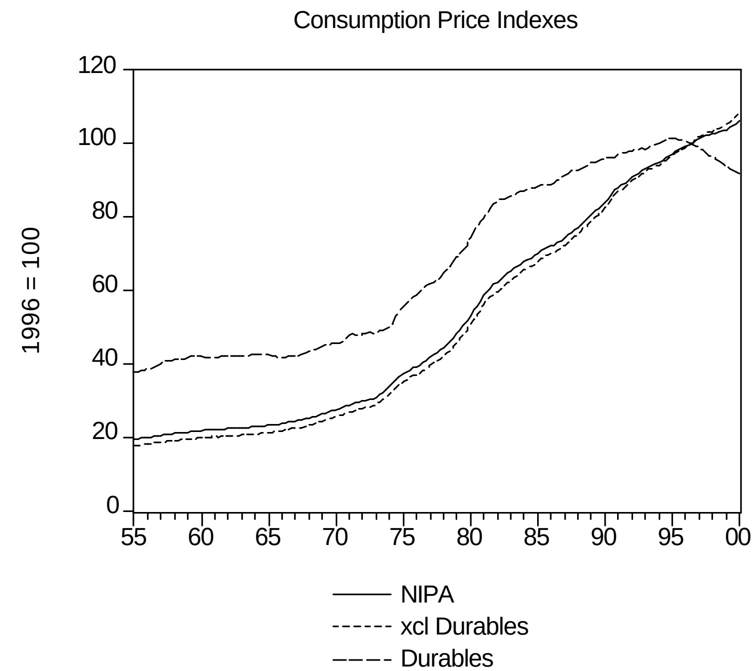


FIGURE 3

PRICE INDEX AND BUSINESS CYCLE DYNAMICS OF VARIOUS MEASURES OF CONSUMPTION, 1955:Q1 – 2000:Q1



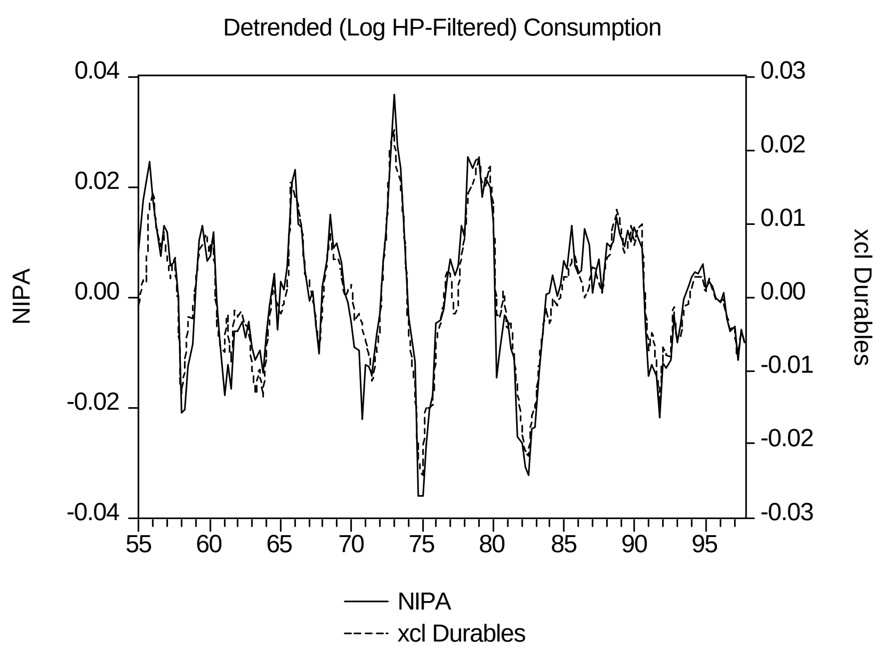


FIGURE 4

NOMINAL SHARES OF GROSS PRIVATE FIXED INVESTMENT

1955:Q1 TO 2000:Q1

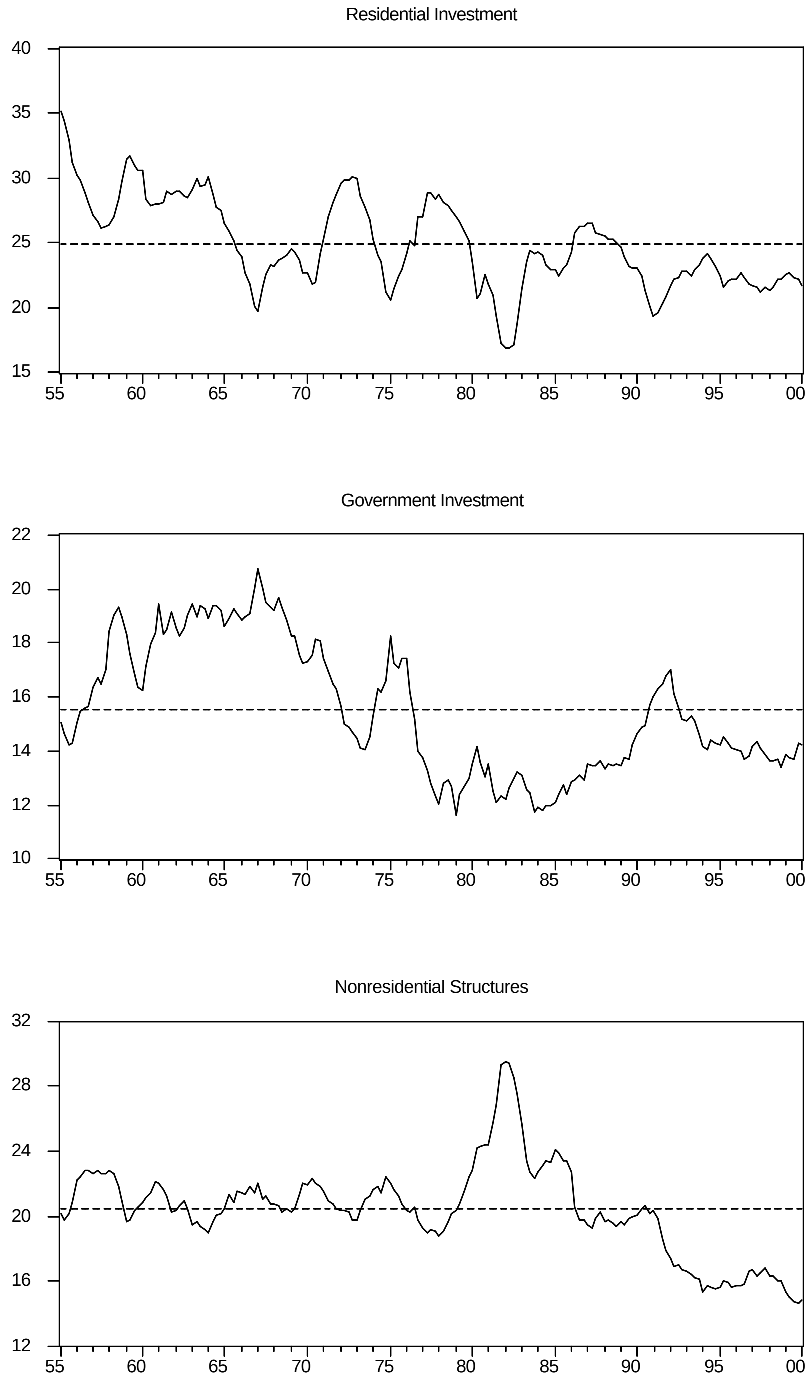
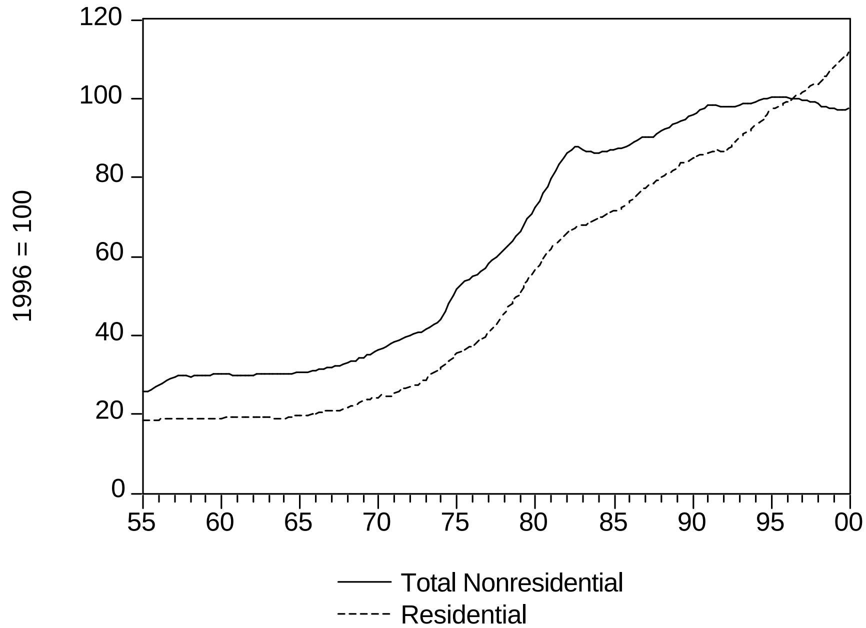


FIGURE 5

PRICE INDEXES FOR VARIOUS FIXED INVESTMENT SERIES,

1955:Q1 – 2000:Q1



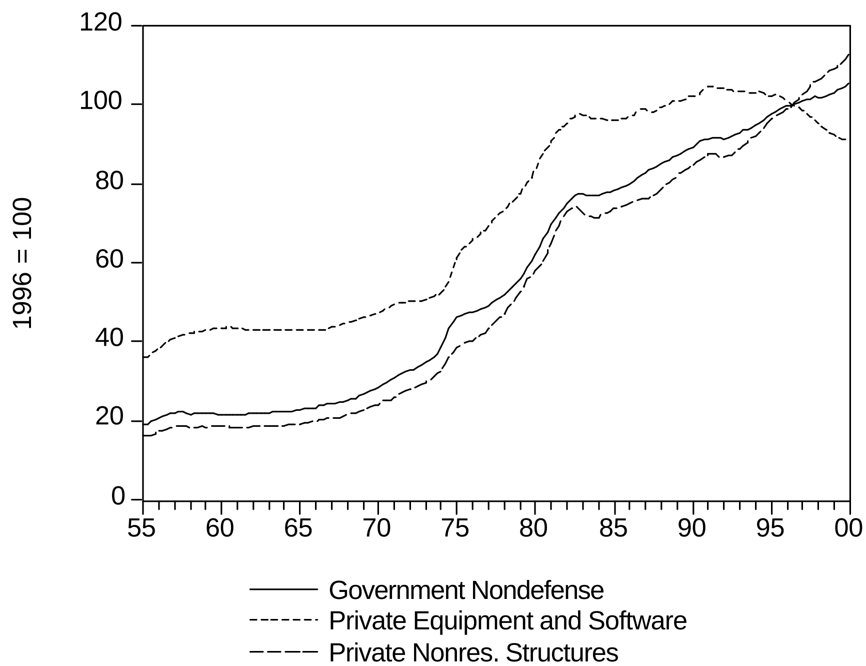


FIGURE 6

PRICE INDEXES FOR GOVERNMENT CONSUMPTION

AND PRIVATE CONSUMPTION EXPENDITURES,

1955:Q1 – 2000:Q1

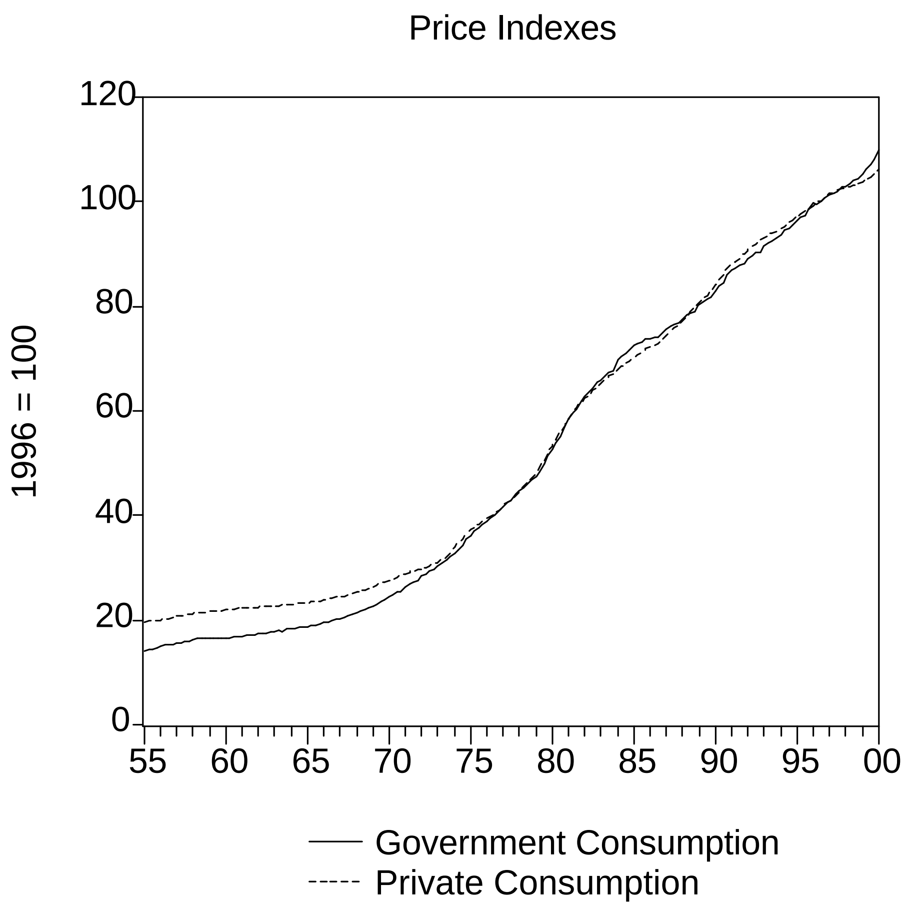


FIGURE 7

PRICE INDEXES FOR PRIVATE CONSUMPTION,

TOTAL FIXED INVESTMENT XCL RESIDENTIAL INVESTMENT,

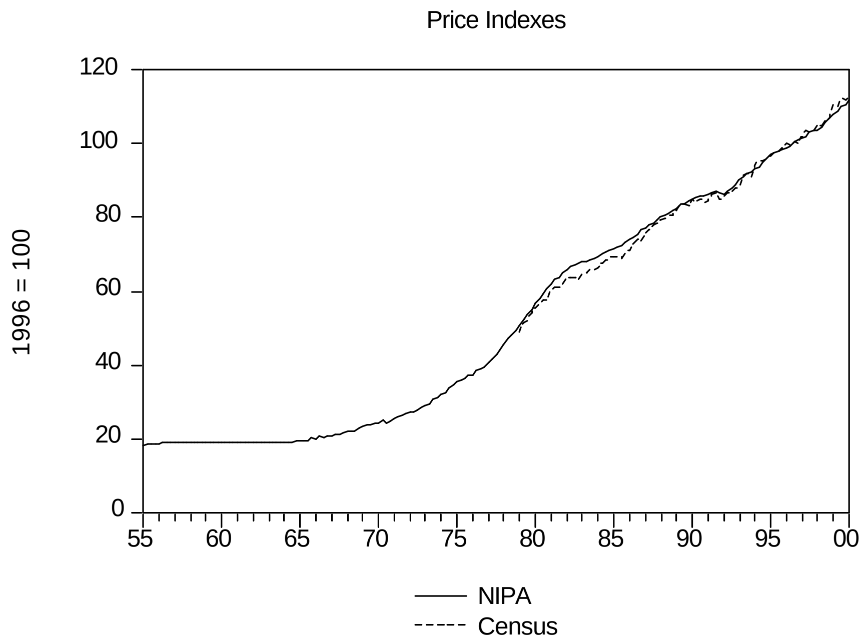
AND GDP XCL RESIDENTIAL INVESTMENT

1955:Q1 – 2000:Q1

FIGURE 8

QUALITY-ADJUSTED NEW HOUSES, PRICE INDEXES AND RELATIVE PRICES

1955:Q1 – 2000:Q1



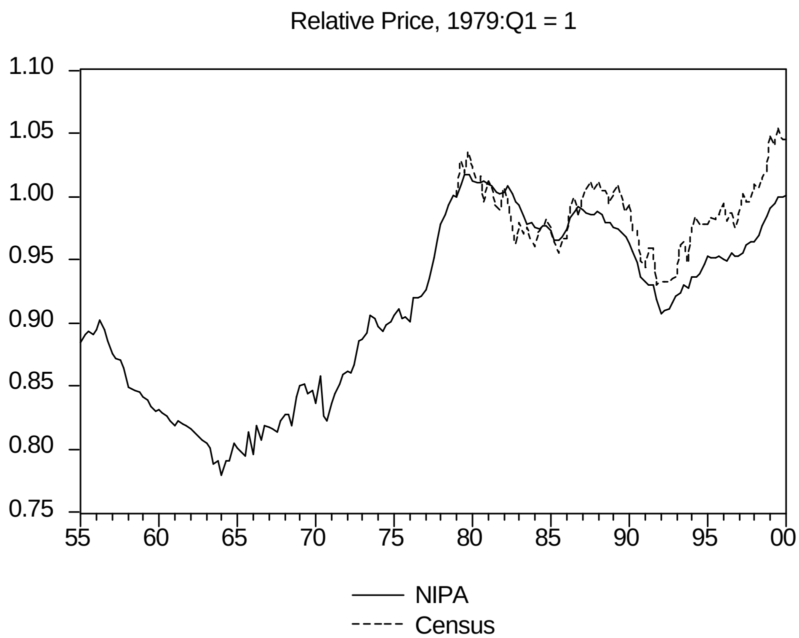
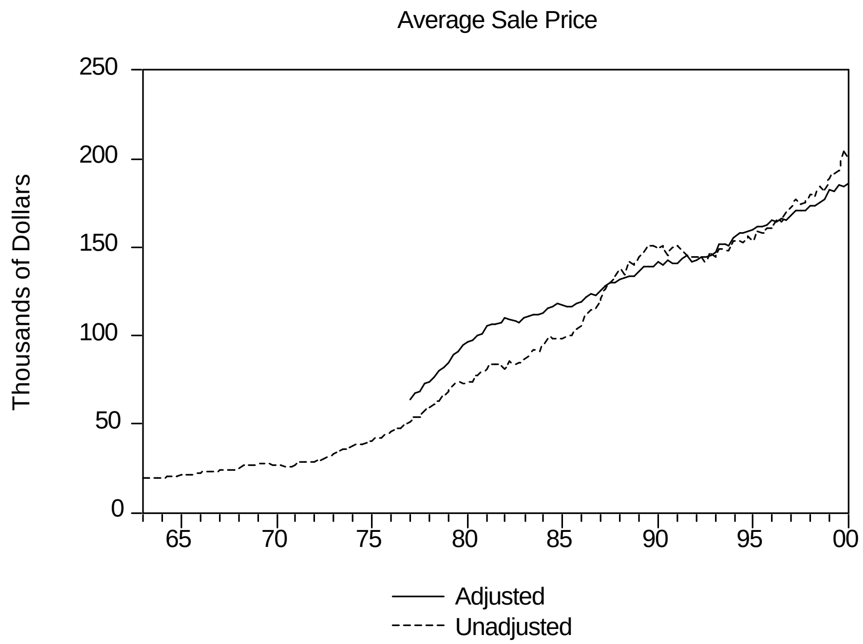


FIGURE 9

THE AVERAGE SALE PRICE OF NEW HOMES: QUALITY ADJUSTED AND UNADJUSTED

1963:Q1 – 2000:Q1



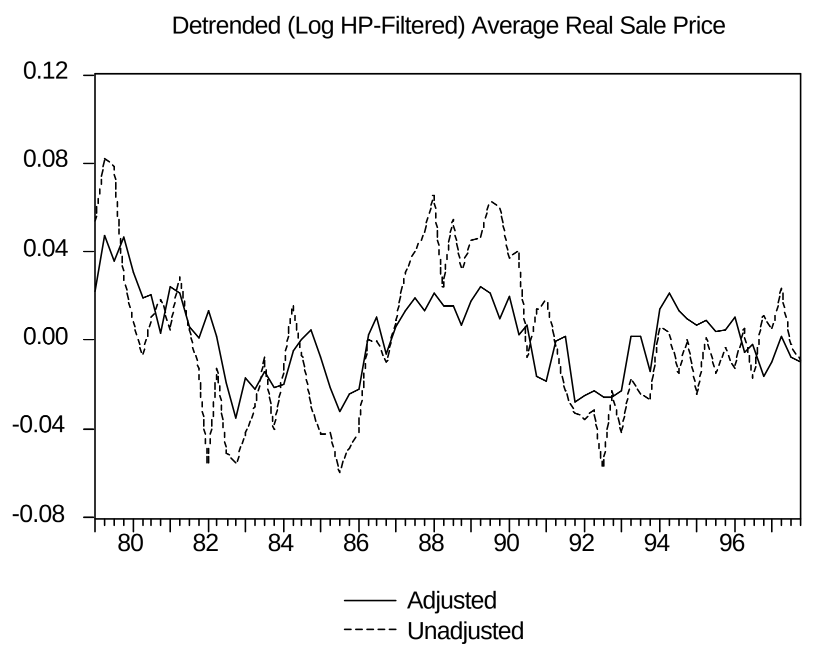


FIGURE 10

RATIO OF NOMINAL PRODUCTIVE STOCK TO NOMINAL HOUSING STOCK

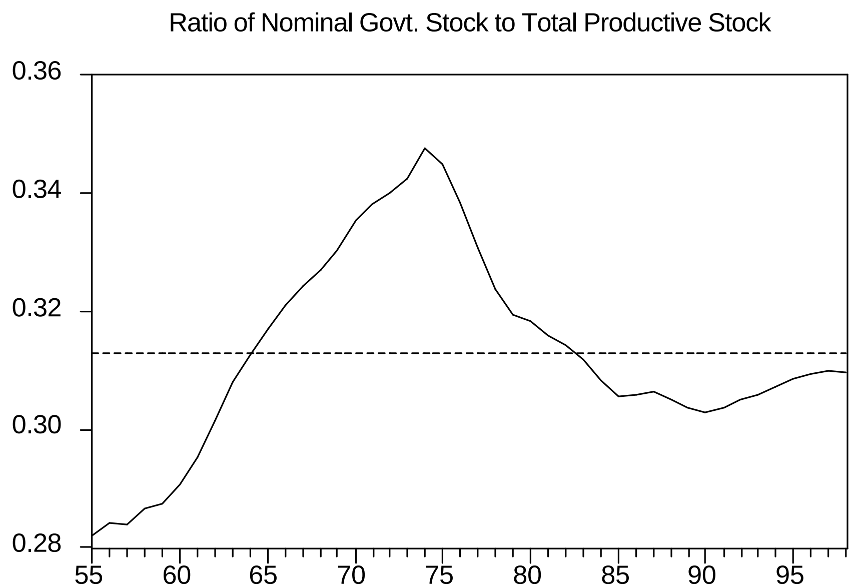
1955 – 1998

FIGURE 11

RATIO OF NOMINAL GOVERNMENT STOCK TO TOTAL PRODUCTIVE STOCK

AND FRACTION OF NOMINAL GOVT. STOCK FROM STATE AND LOCAL GOVT. STOCK

1955 – 1998



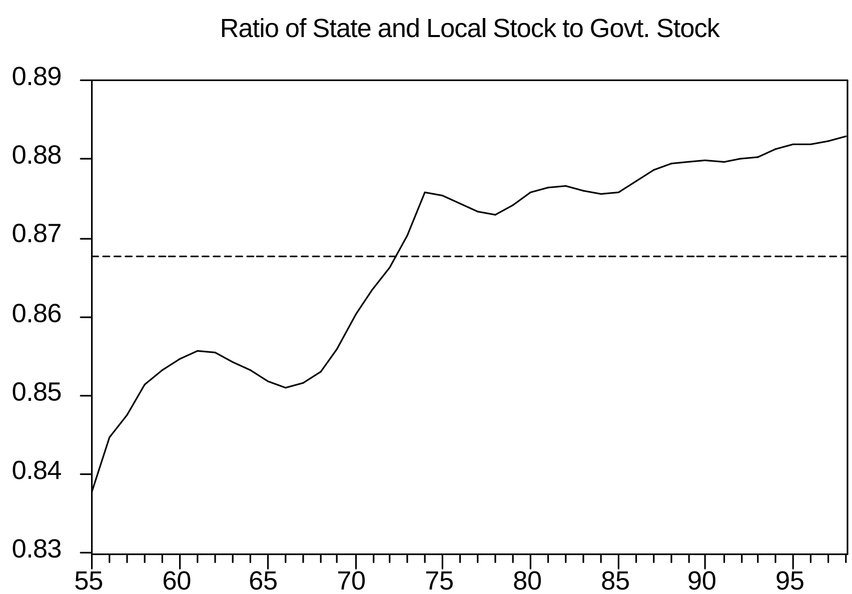


FIGURE 12

RATIO OF NOMINAL ANNUAL TOTAL PRODUCTIVE STOCK TO ANNUAL GDP

1955 – 1998

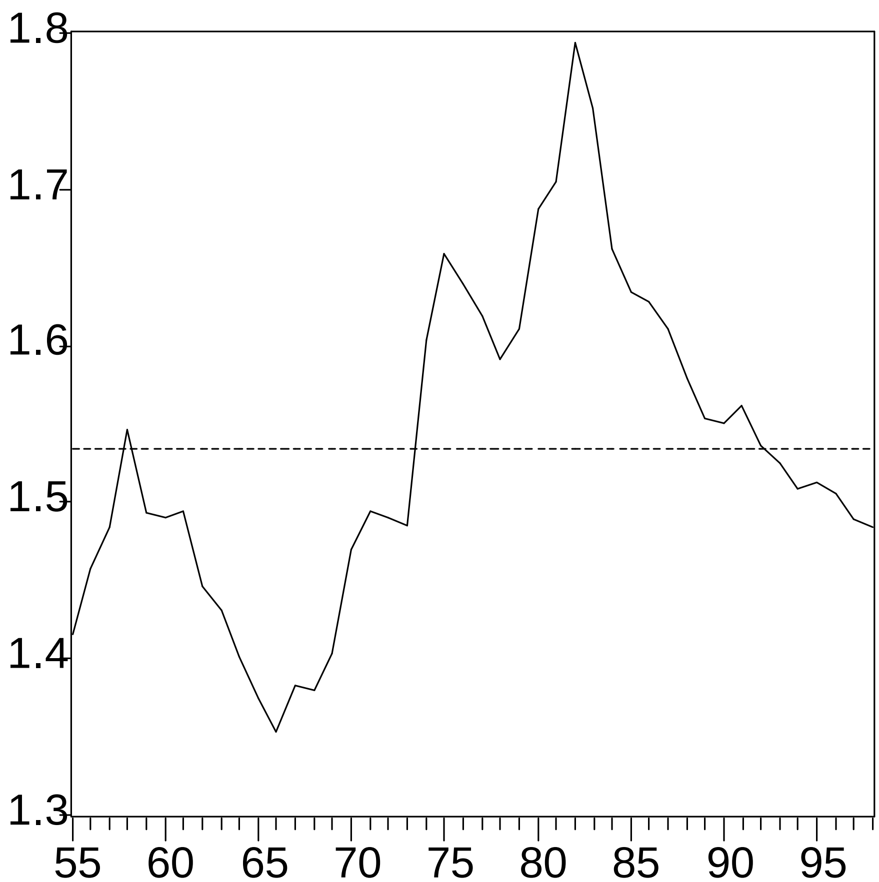
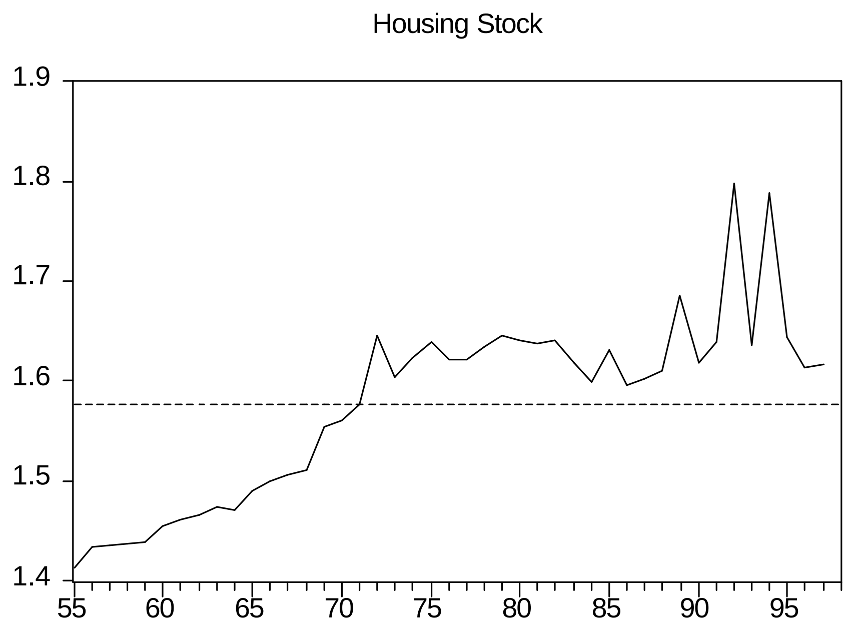


FIGURE 13

ANNUAL DEPRECIATION RATES (IN PERCENT) OF

THE HOUSING STOCK AND PRODUCTIVE STOCK

1955 – 1998



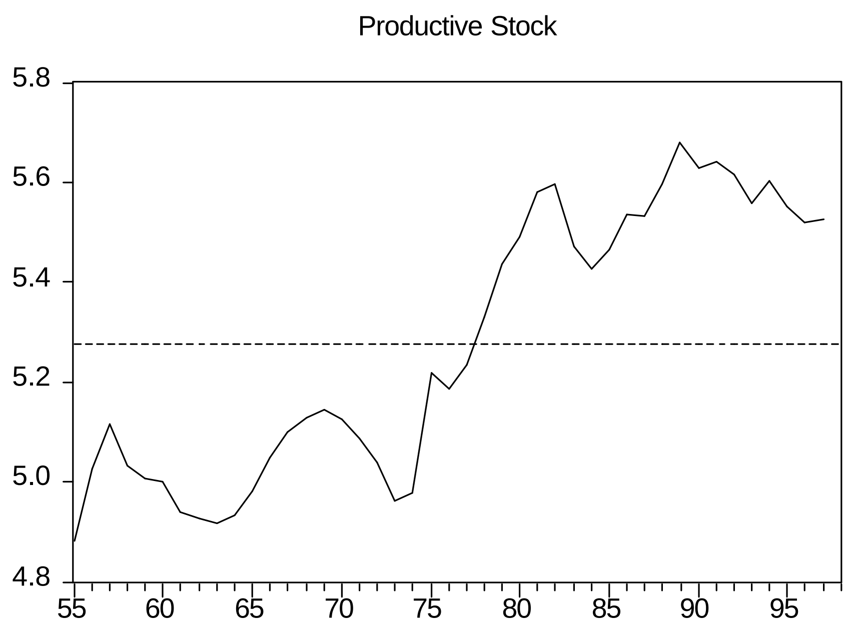
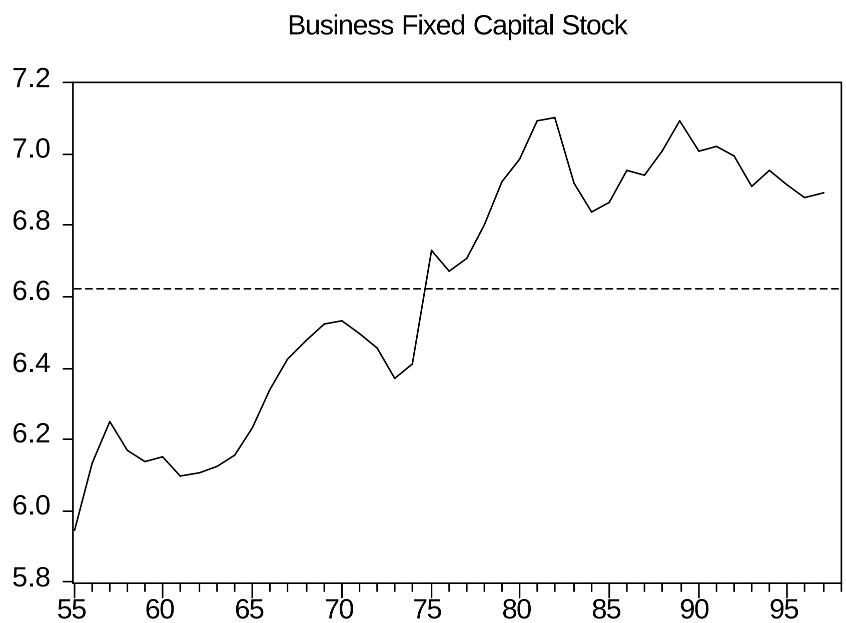


FIGURE 14

ANNUAL DEPRECIATION RATES OF BUSINESS FIXED CAPITAL AND GOVERNMENT CAPITAL

1955 – 1998



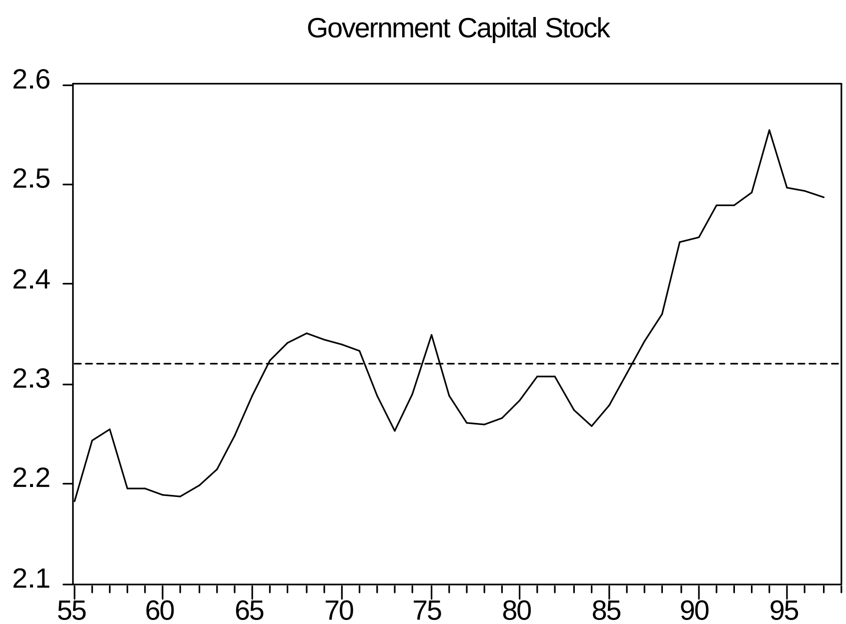
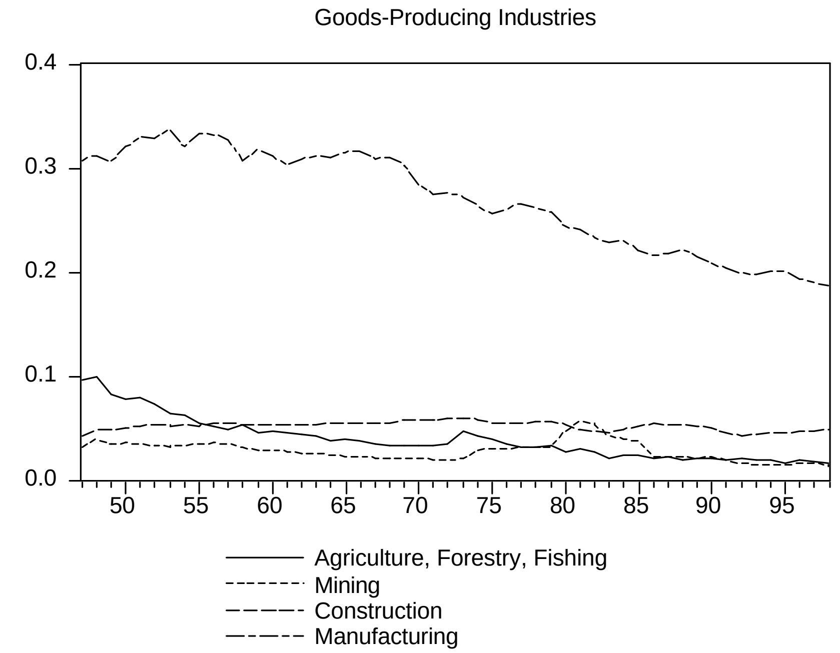


FIGURE 15

SHARE OF NOMINAL PRIVATE VALUE ADDED

1947 – 1998



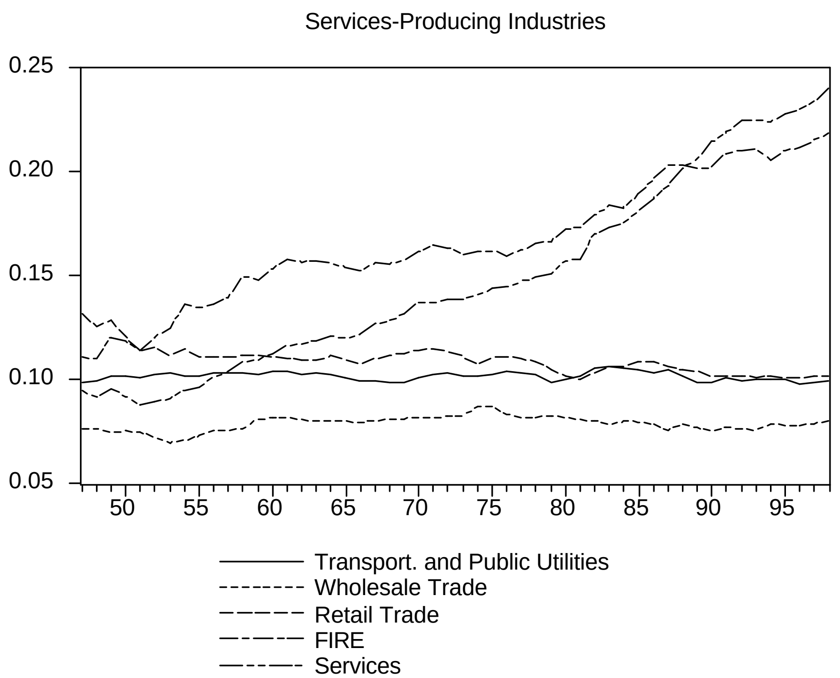
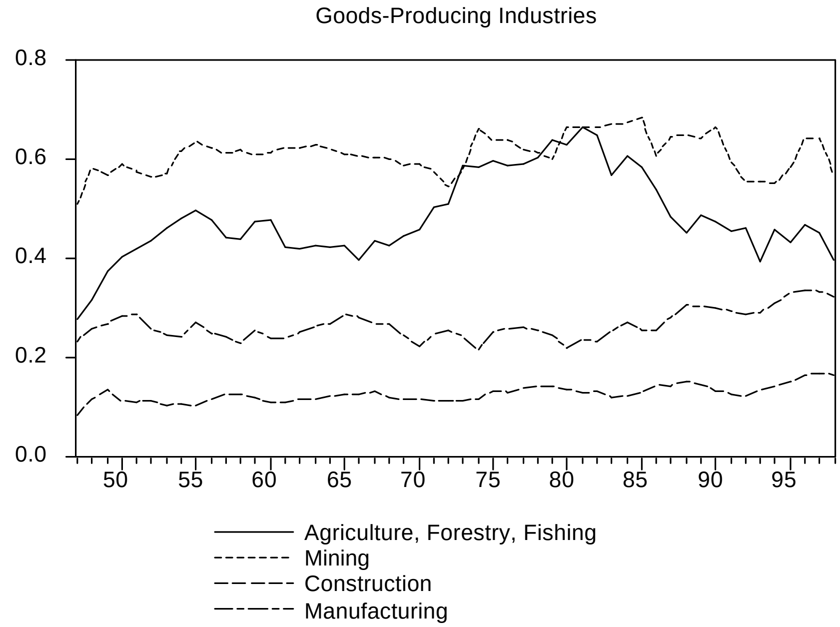


FIGURE 16

CAPITAL SHARE BY INDUSTRY

1947 – 1998



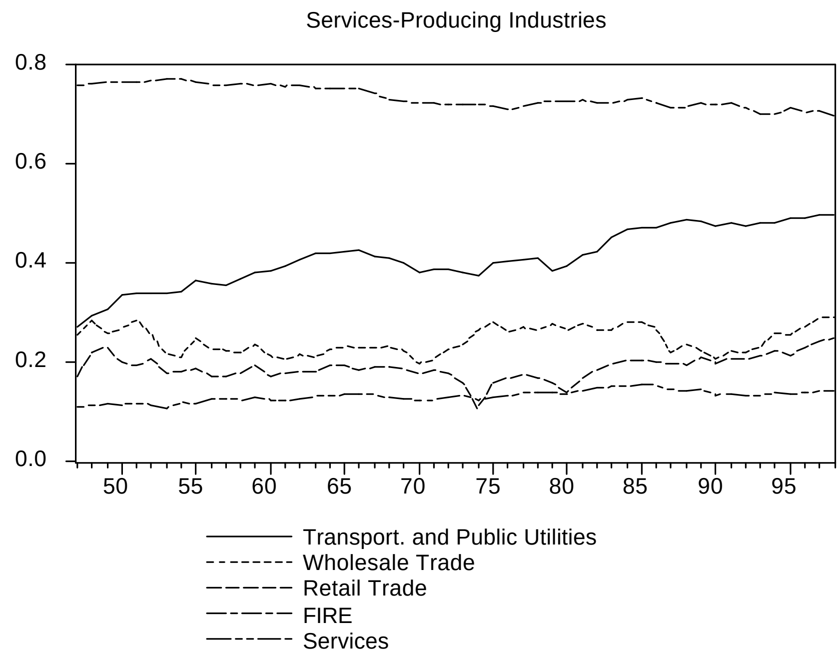


FIGURE 17

MODIFIED FIRE CAPITAL SHARE

1947 – 1998

FIGURE 18

CAPITAL SHARES: CONSTRUCTION, MANUFACTURING, SERVICES

1947 – 1998

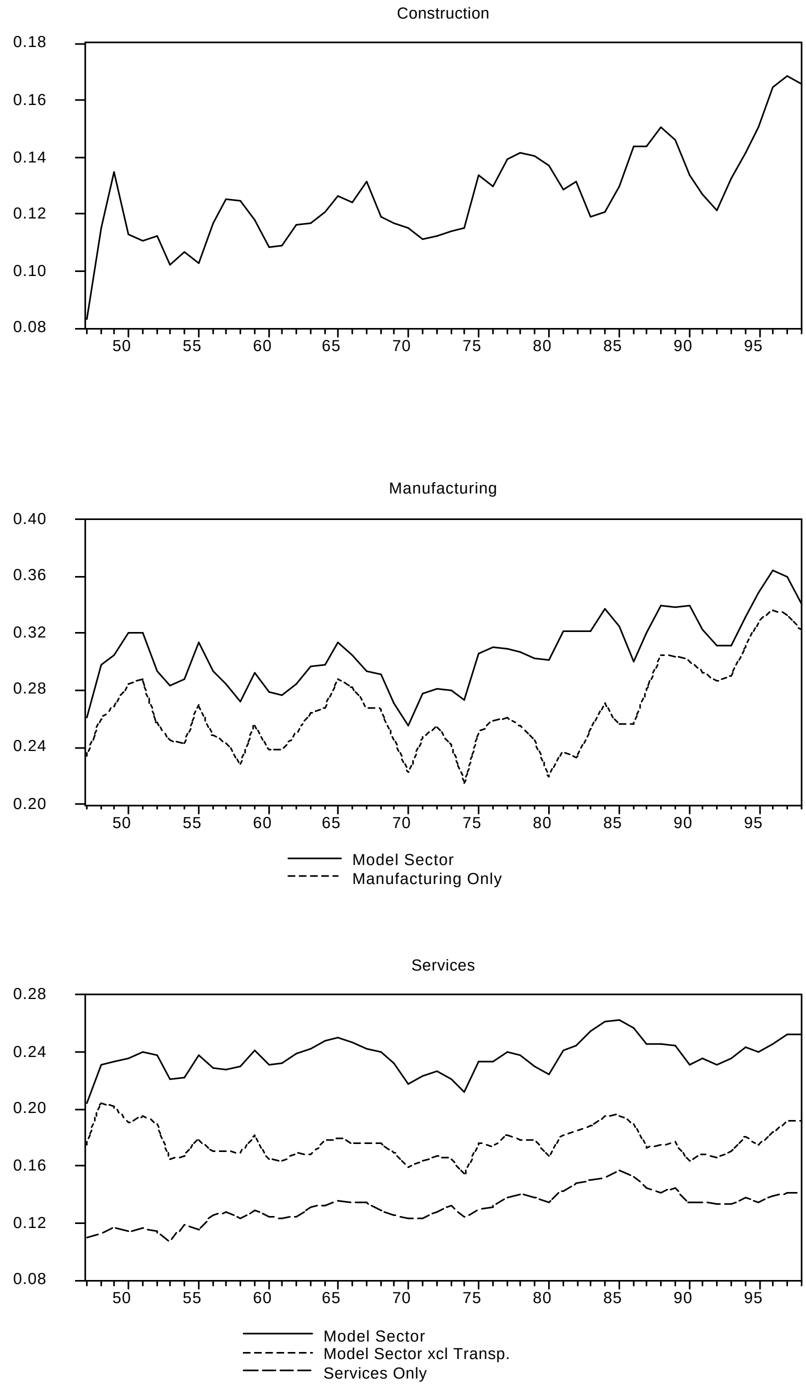


FIGURE 19

LOG OF SECTOR SPECIFIC TECHNOLOGY SHOCK

1977 – 1998

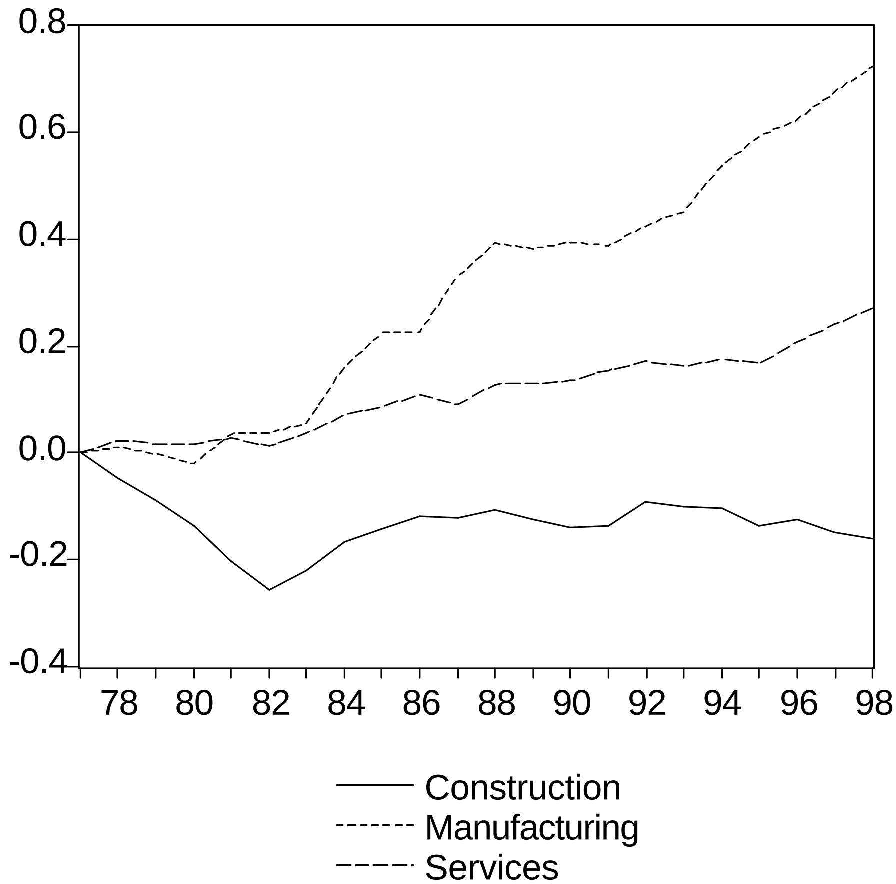


FIGURE 20

DETRENDED LOG OF SECTOR SPECIFIC TECHNOLOGY SHOCK

1977 – 1998