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Discrete Breaks in US Savings: Evidence and Permanent Income Implications.

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ABSTRACT: The main purpose of this paper is to investigate whether permanent, discrete breaks in U.S. savings have occurred. Breaks are hypothesized to occur in both a constant (intercept) and a time-trend term. To test for these breaks, I draw upon the recent methods applied to gross national product. Evidence in this paper suggests that permanent breaks in saving occurred during both the early 1970s the middle 1980s. As a related issue, the stationarity of savings is also discussed. Evidence presented within favors stationarity when breaks are included but not when breaks are omitted. Implications of breaks and stationarity for the expected long-run value of assets are examined.

An additional related issue that is also addressed in this paper regards test of the PIH. The PIH suggests that savings act as a buffer-stock to smooth consumption. One framework which captures this aspect of the PIH is due to Campbell (1987) and Campbell and Deaton (1989). In this paper, I modify their framework to include discrete breaks in savings. Evidence presented within suggest that, when breaks are added to their framework, the "rainy day" finding is strengthened.

Discrete Breaks in US Savings:
Evidence and Permanent Income Implications

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During the past two decades, savings rates have fluctuated considerably in the United States. These fluctuations interest both policy makers and economists. For example, the decline in savings during the 1980s has caused great concern in the policy community. If this decline is permanent, it will adversely affect capital accumulation in the long run. As well, large fluctuations in saving may have implications for tests of the permanent income hypothesis (PIH) or other theories of consumption. For example, Viard (1993) suggests that the savings decline associated with the 1973-74 oil price shock is inconsistent with the PIH.

The main purpose of this paper is to investigate whether permanent, discrete breaks in U.S. savings have occurred. Breaks are hypothesized to occur in both a constant (intercept) and a time-trend term. To test for these breaks, I draw upon the recent methods applied to gross national product. To choose candidate break dates, both prior information (following Perron (1989)) and pre-test information (following Christiano (1992)) are used. Evidence in this paper suggests that permanent breaks in saving occurred during both the early 1970s and the middle 1980s.

As a related issue, the stationarity of savings is also discussed. Stationarity is important for two reasons. First, critical values for discrete breaks depend on whether the underlying series is stationary or not. Second, the stationarity of savings suggests that the expected long-run value of wealth is bounded and may be estimated. [1] Evidence presented within favors stationarity when breaks are included but not when breaks are omitted. Implications of breaks and stationarity for the expected long-run value of assets are examined.

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[1] The stationarity of saving has other economic implications as well. For example, a presumption of the PIH is that income and consumption should trend together in the long run, or equivalently that savings are stationary. Campbell (1987) presents evidence that savings are non-stationary. Rather, income and consumption appear to be cointegrated, but not one-to-one. King, Plosser, Stock and Watson (1991) present evidence supporting the one-to-one cointegration of the <u>logarithms</u> of consumption and income.

An additional related issue that is also addressed in this paper regards tests of the PIH. The PIH suggests that savings act as a buffer-stock to smooth consumption. Tests of such consumption smoothing behavior should incorporate long-run factors such as a change in the desired level of wealth. One framework which captures this aspect of the PIH is due to Campbell (1987) and Campbell and Deaton (1989). In their formulation, the PIH implies that (correctly anticipated) falls in the present discounted value of income should be preceded by increases in saving, indicating that people "save for a rainy day". In this paper, I modify their framework to include discrete breaks in savings. Evidence presented within suggests that, when breaks are added to their framework, the "rainy day" finding is strengthened.

The paper is organized as follows. In Part 1, I develop a framework for savings and asset accumulation based on Hansen and Sargent (1981). Discrete, permanent breaks are incorporated into this framework and examined. In Part 2, I develop and present the test for breaks in several measures of U.S. saving, as well as stationarity. The savings measures are deflated both by disposable income and by population. Break dates and significance levels depend on both the measure used and its deflator. Nonetheless, the evidence suggests that discrete breaks in both the constant component and the trend component of saving occurred during 1972-74 and again during 1985-87. As well, breaks in the constant component (but not the trend component) occurred during the period 1972-74, the late 1970s, and the mid- to late 1980s. In Part 3, I evaluate the implications of breaks in saving for tests of the PIH due to Campbell (1987) and Campbell and Deaton (1989). In Part 4, some conclusions are presented.

1. Breaks in Savings and Capital Accumulation

An economy's stock of wealth is the accumulation of its savings flows over time. The purpose of this section is examine the empirical linkage between these two variables. To do so, we first develop a general expression for discounted target wealth. Based on Hansen and Sargent's (1981) formulation, this expression yields an expression for the expected present value of wealth as a function of current savings. [2] This expression includes both constant and trend terms which have economic interpretations. Next, discrete breaks in the constant and trend terms are incorporated into the model.

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[2] Other papers using this framework include Flavin (1981), Quah (1991), Galí (1990), Campbell and Deaton (1989) and Diebold and Rudebusch (1991).

1.1. Linking Current Savings to Expected Wealth

To model the linkage between savings and expected wealth, the first step is to write down the one-period budget constraint of a representative consumer:

(1) $$Y_t + rA_{t-1} - C_t = A_t - A_{t-1}$$

where r is the constant real interest rate, Y is labor income, A is net asset holdings and C is consumption. Progressive substitution of (1) over an infinite horizon yields the standard budget constraint:

(2) $$\sum_{j=0}^{\infty}(Y_{t+j} - C_{t+j})/(1+r)^j + (1+r)A_{t-1} = \lim_{t\to\infty} A_t/(1+r)^t$$

The terminal value of wealth for the consumer, A^*, is the limit term: [3]

(3) $$A^* = \lim_{t\to\infty} A_t/(1+r)^t$$

Since future values of Y and C are unknown, we must take expectations. A autoregressive moving average (ARMA) form with linear trend assumed for both variables:

(4a) $$Y_t = \mu + \theta t + \rho Y_{t-1} + \epsilon_t + \lambda_1\epsilon_{t-1} + \lambda_2\epsilon_{t-2} + \lambda_3\epsilon_{t-3} + \ldots$$

(4b) $$C_t = \phi + \omega t + \alpha C_{t-1} + \eta_t + \beta_1\eta_{t-1} + \beta_2\eta_{t-2} + \beta_3\eta_{t-3} + \ldots$$

[3] For a one-consumer closed economy, this corresponds to domestic capital stock. For an open economy, this corresponds to both domestic physical capital and claims on foreign assets.

Hansen and Sargent (1981) show that expressions such (4a) and (4b) yield an expression for the expected present discounted value of a variable.[4] Using their method and substituting expressions (4a) and (4b) into budget constraint (2) yields:

(5)

$$(1+r)\,A_{t-1} + (1+r/(1+r-\rho))\{Y_t + \mu/r + t\theta/r + \theta(1+r)/r^2 + \epsilon_t \sum_{j=1}^{\infty} \lambda_j/(1+r)^{j-1} + \epsilon_{t-1} \sum_{j=2}^{\infty} \lambda_j/(1+r)^{j-2} + \ldots\} -$$

$$(1+r/(1+r-\alpha))\{C_t + \phi/r + t\omega/r + \omega(1+r)/r^2 + \eta_t \sum_{j=1}^{\infty} \beta_j/(1+r)^{j-1} + \eta_{t-1} \sum_{j=2}^{\infty} \beta_j/(1+r)^{j-2} + \ldots\} = \lim_{t\to\infty} A_{t+k}/(1+r)^k$$

Rearranging equation (5) shows that the current estimate of terminal wealth A^* may be expressed as the sum of (i) wealth held over from last period (A_{t-1}), (ii) a constant term, (iii) a trend term, (iv) a function of current Y and C, and (iv) an error term:

(6)
$$A^* = A_{t-1} + \gamma_1 Y_t - \gamma_2 C_t + [\gamma_1(\mu + t\theta + \theta(1+r)/r) - \gamma_2(\phi + t\omega + \omega(1+r)/r)]/r +$$

$$\gamma_1 \sum_{t=1}^{\infty} \epsilon_t \sum_{j=1}^{\infty} \lambda_j/(1+r)^j + \gamma_2 \sum_{t=1}^{\infty} \eta_t \sum_{j=1}^{\infty} \beta_j/(1+r)^j$$

where $\gamma_1 = 1/(1+r-\rho)$ and $\gamma_2 = 1/(1+r-\alpha)$.

Several assumptions make the relationship between A^* and current total savings $S = Y_t + rA_{t-1} - C_t$ more simple and precise. For example, if $\rho=\alpha$, then $\gamma_1=\gamma_2=\gamma$, and the relationship between rA^* and the current excess of labor income over consumption, Y_t-C_t is written:

(7)
$$rA_{t-1} + r\gamma[Y_t - C_t] = +k_0 + k_1 t + \text{error}_t = rA^*$$

where $k_0 = -\gamma[(\mu-\phi) + [(\theta-\omega)(1+r)/r]$ and $k_1=-\gamma(\theta-\omega)$.

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[4] Their formulation, however, does not include a linear trend. As well, trend terms are not normally included in empirical investigations of savings rates. However, in this paper, the approach will be to include the trends and test for their significance.

The relationship between A^* and S even further simplified if consumption and income are assumed to be level non-stationary and difference stationary ($\rho=\alpha=\gamma=1$).[5] In this case, rA^* may be expressed as a precise function of current savings:

$$(8) \qquad S_t = k_0 + k_1 t + error_t = rA^*$$

where $k_0 = -[(\mu-\phi) + [(\theta-\omega)(1+r)/r]$ and $k_1=-(\theta-\omega)$. Here, rA^* is the sum of an intercept term plus a trend term plus an error term. In this case, if savings are stationary, the expected value of target wealth is a is $(k_0 + k_1 t)/r$.

The simplest case occurs when no trend appears in the expression (8) (k_1=0). In this case, if savings is stationary, target wealth is a bounded value with expectation is k_0/r.

1.2. Incorporating Discrete Breaks

Discrete breaks may occur in the intercept and trend terms of equations (5) through (8). As well, recent literature on GNP suggests that such breaks may be important for stationarity tests and must be accounted for.

Following recent work on real business cycles, one explanation for such breaks is productivity shocks. For example, a shock to the marginal product of capital or marginal tax rate may cause a shift in the target level of wealth A^*. This may cause shifts in the coefficients k_0 and k_1 resulting from either changes of parameters in the numerator $(\mu-\phi)$ and $(\theta-\omega)$ or a change in the mean interest rate.[6] Also, in an open economy, a shift in the mean (exogenous) real interest rate will shift the coefficients k_0 and k_1.

It should also be noted that changes in the trend term $(\theta-\omega)$ imply changes to the average (constant component) in equation (8), $k_0= [\gamma_1(\mu+\theta(1+r)/r) - \gamma_2(\phi+\omega(1+r)/r)]/r$. To test for breaks, it is correct to consider a break in the constant terms μ and ϕ without a break in the trend. However, if the trend terms θ and ω change, the constant term *must* change as well, since k_0 includes trend terms θ and ω. Thus, it is not correct to consider a change in a trend term k_1 without a considering a break in k_0 as well. Finally, it should be noted that, in the work presented below, I

[5] Recent research such as Campbell (1987) suggests this assumption to be valid.

[6] Hakkio and Rush (1991) examine the implications of a variables interest rate with fixed mean for the government's intertemporal budget constraint. Tanner and Liu (1994, forthcoming) extend their analysis to the case of a discrete shift in the mean interest rate.

test only for breaks in the reduced-form parameters k_0 and k_1, rather than the underlying structural parameters θ, ω, μ, or ϕ.

2. Testing for Breaks in the U.S. Savings Process

2.1. The Basic Estimating Equations

Since there is a close relationship between non-stationarity and discrete breaks in variables it is common practice to combine break and stationarity tests into one equation.[7] This is achieved by introducing a dummy variable into a stationarity test (Perron (1989), Christiano (1992), and Zivot and Andrews (1992)). I follow this methodolgy. The basic equation to be estimated is an Augmented Dickey Fuller test with discrete breaks in the constant and trend terms:

(9) $$\Delta S_t = a_0 + a_0^D D_t^K + a_1 t + a_1^D D_t^K t + b_0 S_{t-1} + \sum_{i=1}^{I} b_i \Delta S_{t-i} + \text{error}_t$$

where D_t^K is a dummy which equals 0 for dates t = 1 to K and 1 for dates t greater than K. To test for the break, the restriction $a_0^D = a_1^D = 0$ is imposed and an F-Statistic is computed. Stationarity, a related issue, is tested for by comparing the t-statistic of b_0 to the Augmented Dickey Fuller critical values.

In addition, equation (9) is also estimated without the trend term:

(10) $$\Delta S_t = a_0 + a_0^D D_t^K + b_0 S_{t-1} + \sum_{i=1}^{I} b_i \Delta S_{t-i} + \text{error}_t$$

In this case, to test for the break, the restriction $a_0^D=0$ is imposed and an F-Statistic is computed. This additional test, without a trend, is presented for two reasons. First, the some tests presented below suggest that the trend terms are close to zero. Second, doing so permits the isolation of shifts in the constant term.

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[7] Beginning with Nelson and Plosser (1981), several researchers concluded that GNP is non-stationary. Perron (1989) re-examined the question. He incorporated discrete breaks in GNP. Based on prior information, he included breaks in the 1930s (corresponding to the Great Depression) and the early 1970s (corresponding to the oil-price shocks). His evidence suggests that when breaks are included, GNP is trend stationary

Of course, the dependent variable in equations (9) and (10) is the first difference of saving, rather than the level of saving in equation (8). For this reason, the coefficients a_0, a_0^D, a_1, and a_1^D are not the theoretical constant and trend terms discussed in the previous section, k_0 and k_1. Rather, the two sets of parameters are related are related to by a factor of $-b_0$. That is $a_0 = -b_0k_0$, $a_0^D = b_0k_0^D$, and so on.[8]

2.2. Critical Values and the Choice of Break Date

In order to test for the significance of breaks, it is important to determine the correct critical values used to test for the break date. Critical values for these depend on whether the underlying process is a random walk or a stationary autoregressive process. As well, as critical values for both break and stationarity tests depend on whether the trend and break terms are included and the location in the data set relative to the beginning of the dataset. Critical values for both break and stationarity tests that incorporate these factors are presented in Table 14.

An additional consideration in determining the correct critical value is how the break date is chosen. One way to do so is with prior information. In this case, recent research has shown that critical values should reflect the location of the break in the data set relative to its end points. Thus, when critical values are *location adjusted*, each date has its own set of critical values. Table 14 reports location adjusted critical values at the 90% and 95% levels for the random-walk (LR90, LR95) and the autoregressive process (LA90, LA95), for select periods. These values are calculated by a Monte Carlo procedure.

As an alternative to choosing a break date with prior information, it may be preferable to use a formal procedure to choose a break date. Christiano (1992) develops such a procedure. According to this method, regressions

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[8] To see this, think of an equivalent stationarity test on savings net of its mean, $S_t - k_0$, where k_0 is computed in standard fashion. The ADF test would be:

$$\Delta(S_t-k_0) = b_0(S_{t-1} - k_0) + \sum_{i=1}^{I} b_i\Delta(S_{t-i} - k_0) + \text{error}_t$$

In the above regression, the constant $a_0 = -b_0k_0$.

(9) and (10) are estimated and F-statistics are computed for all dates K from the first 15% to the last 15% of the dataset.[9] The break date is that date where the F-statistic is maximized.

Critically, if such a procedure is used, critical values should incorporate pre-test information. Thus, *pre-test adjusted* critical values are generated by a Monte Carlo procedure described in Christiano (1992) and Tanner and Liu (1994, forthcoming). Initial bootstrap values come from actual data. To adjust for pre-test information, draws over all datasets on a maximized F-statistic are generated. Unlike location-adjusted values, these values are the same for all dates in the series. [10] Like the location adjusted critical values, these critical values depend upon whether or not the underlying process is stationary.

Pre-test adjusted critical values are also presented in Table 14. To test for both a break in both the trend- and constant terms (equation (9)), in the random-walk case, simulations reveal the 90% and 95% pre-test adjusted critical values of the F-statistic for the significance of the break (PR90, PR95) to be 12.7 and 14.2, respectively. For the non-random-walk case these values (PA90, PA95) were 7.98 and 7.01 respectively. To test for a break in the constant term only (equation (10)), in the random-walk case, simulations reveal the 90% and 95% pre-test adjusted critical values (PR90, PR95) to be 15.4 and 17.8, respectively. For the non-random-walk case these values (PA90, PA95) were 7.5 and 9.1 respectively.

2.3. A Note on The Measurement of Savings

Savings are difficult to measure. Therefore, several measures are used in this paper. Some results depend on what measure is used.[11] Perhaps the most commonly used measure is *personal* or household saving, S^h. While this is a popular concept, it is criticized by several authors, including Poterba (1991), because it excludes retained earnings of corporations. Therefore, *private* savings S^p, which adds retained earnings to personal savings, is also used. Data from both the National Income and Product Accounts (NIPA) and the Federal Reserve Board's Flow of Funds (FOF)

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[9] Elimination of the first and last 15 percent of the data series is a commonly-used procedure (see, for example, Hansen (1992)).

[10] For the Monte-Carlo experiments, 5000 draws were used. The Monte-Carlo simulations were performed in the RATS (Regression Analysis of Time Series Package). All results reported in this paper exceed both Christiano's (1990) critical values and my own.

[11] For recent reviews of these measurement issues, see Bradford (1990), Poterba (1991), and Auerbach and Hasset (1991).

database are used.[12] [13] Thus, four measures of saving will be used: (i) S^{hn} personal NIPA, (ii) S^{pn} private NIPA, (iii) S^{hf} personal FOF, and (iv) S^{pn} private FOF.

The data are deflated both by GNP and population. In some cases, it will be also appropriate to report resutlts using the logarithm of per-capita savings. While the model in Part I applies to levels, a log trend coefficient yields a growth *rate* of savings. All data are quarterly, from 1952:1 to 1993:1. Per-capita data are converted to constant (1982) dollars with the GNP deflator. Following much of the literature on savings policy, the measure of income used is disposable income in 1982 dollars. [14]

2.4. Are Savings Stationary? Preliminary Tests

The main focus of this paper is discrete breaks in saving. However, as a statistical issue, the stationarity of savings is an important issue. Break tests and stationarity tests are closely related. Specifically, the appropriate critical values for break tests depend on the whether savings are stationary. [15]

Thus, as a preliminary step, savings are tested for stationarity. The tests used here are the Augmented Dickey Fuller (ADF) test, and the $Z\alpha$ and Zt tests developed by Phillips (1988) and Phillips and Perron (1989). Table 1a

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[12] As Bradford (1990) points out, the FOF measures income in a more inclusive way. For this reason, he prefers the FOF data to the NIPA data.

[13] Data from the FOF database are not to be confused with the FOF *concept* of savings that includes consumer durables.

[14] Similar results were obtained using total GNP. These results are available from the author.

[15] The stationarity of savings is also related to some important economic issues. From traditional models of consumption, (i.e. the permanent income hypothesis) there is a strong presumption that income and consumption should trend together dollar-for-dollar. Some evidence suggests that ρ and α are not statistically different from one. Thus, with non-stationary income and consumption, it is appropriate to test for their cointegration. One-to-one cointegration of income an savings is, of course, equivalent to the stationarity of savings. However, evidence regarding the stationarity of saving is mixed. For example, Campbell (1987) provides evidence that income and consumption are cointegrated, but not one-to-one.

A related proposition is that the *logarithms* of income and consumption are cointegrated one-to-one. King, Plosser, Stock and Watson (1991) note that traditional macroeconomic growth models imply such a cointegration. They cite the implication from growth models that certain "great ratios", such as the ratio of consumption to income, are stable over time. They are unable to reject the hypothesis While the cointegration of the logarithms of consumption and income is not the same as the cointegration of levels, the two are related. For example, most Ramsey-style growth models (Blanchard and Fischer (1989, Chapter 2)) suggest that the *per-capita* capital stock converges to a steady-state bound.

presents stationarity tests without trends, and Table 1b presents the tests with trends. For the with-trend tests, both the trend coefficients and their standard errors are presented.

The results are mixed. Of the four measures, only S^{hf} is revealed to be stationary from all tests. For the remaining 3 measures, the ADF tests suggest non-stationarity. However, the other tests are more favorable for stationarity. Only S^{pn} appears to be non-stationary from the Zt and $Z\alpha$ tests. The ADF results are close to but not identical to those Campbell (1987), who found that income and consumption cointegrate, but not one-to-one. [16]

Table 1b presents the test results when a trend is included. While these results are more favorable towards stationarity, the results are still mixed. Moreover, the trend terms in most cases appear to be small. In most cases, the standard errors indicate trend terms are not different from zero.

2.5. Candidate Break Dates Based on Prior Information

In the literature on U.S. GNP, researchers have related prior information on several "big events" to discrete breaks in GNP. Perhaps the events receiving the most attention are the oil-price shocks of 1973-74 and 1979-80. However, Christiano (1992) mentions several others, including the tax cut of 1964, and the financial deregulation of the early 1980s.

These events may also be candidates for breakpoints in savings. For example, Viard (1993) suggests that a drop in savings followed a slowdown in productivity occurring after 1973. As a fraction of disposable income, savings were lower in the post-73 period relative to the pre-73 period. Personal savings drops from 8.5% to 7.5% while private savings drops from 13% to 11% of disposable income. However, average real *per-capita* saving was greater in the post-1973 period than in the pre-1973 period. The mean value of yearly personal NIPA S^{hn} rises from $626 dollars per person in the pre-1973 period to $784 per person after. Similar figures for private savings were $970 versus $1162.

Breaks in savings need not be limited to those discussed in the GNP literature. Breaks in private savings may coincide with breaks in public savings (i.e. the government budget surplus). Also, movements in real interest rates may be related to changes in savings. Most observers agree that real interest rates fell during the late 1960s or 70s and remained at historically low levels until the early 1980s.

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[16] Some of the differences between Campbell's (1987) results and my own may be due to the different measures and time periods used.

Finally, a break may have occurred during the mid-to-late 1980s. By most measures, savings rates declined to historically low levels during this period. Private savings dropped from approximately 8.5% of disposable income in the pre-1986 period to about 6% in the post-1986 period. Other measures of saving / income drop by similar amounts. This decline has attracted attention of policy makers. However, there is little consensus as to its either the cause of the decline or its permanence. Summers (1990) suggests that some elements of 1986 tax reform were responsible. In particular, many tax advantages of individual retirement accounts (IRAs) were repealed at this time.

2.6 Results of Break Tests

Equations (9) and (10) are estimated for the four measures of saving. [17] All measures are deflated by personal disposable income and population. Also, equation (9) is estimated for the logarithm of per-capita savings. The F-Statistics for the exclusion of the breaks are shown in Charts 1 to 5. Charts 1 to 3 present the F-Statistics for equation (9) for savings as a fraction of disposable income, savings per capita, and log savings per capita, respectively. Charts 4 and 5 present F-Statistics from equation (10) for savings / income and per-capita savings, respectively.

Ocular inspection of the charts suggest that F-Statistics peak during six main periods: (i) 1962-64, (ii) 1969-70, (iii) 1972-74, (iv) 1979-80, (v) 1982-84, and (vi) 1985-87. As discussed below, most of these periods coincide with breaks suggested by prior information. For this reason, it is legitimate to apply the location-adjusted critical values, as well as the pre-test adjusted ones.

Equations (9) and (10) are thus estimated with breaks in selected periods. Tables 2 -4 present summaries of the estimates for these equations. Each Table presents (i) F-Statistics for selected break dates within a range, (ii) the greatest critical value satisfied by the F-Statistic (i.e. PR, PA, LR, LA), (iii) a discussion of the coefficient estimates for a given break and (iv) a discussion of corresponding events. Table 2 applies to equation (9). Table 3 reports per-capita estimates of equation (10). Table 4 discusses estimates of equation (10) for savings / disposable income. Detailed estimates of (9) and (10) are presented in Tables 5 through 12. These tables provide coefficient values for trend and constant terms, and stationarity tests.

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[17] In addition to the reported results, the author ran all equations with the logarithm of per capita savings. The results are identical to those for level per-capita savings. As well, following King, Plosser, Stock and Watson (1991), equations (9) and (10) were estimated for the logarithm of Y/C. Like their results, mine favored stationarity. However, statistically significant permanent breaks occurred at dates close to those reported in this paper.

In each of the above periods, there are statistically significant breaks in savings. The location and significance of breaks depend on what measure and deflator is used and what equation is estimated. In most cases, the F-statistics exceed the least-stringent location adjusted critical values for the autoregressive null at the 90% level or greater (LA90). In several cases, F-Statistics exceed the more stringent pre-test adjusted values at the 90% or 95% level (PR90, PR95). In most cases, the significance of trend terms increases when breaks are included.

2.6.1. With-Trend Estimations (Equation (9)).

F-Statistics for the with-trend equation (9) are presented in Charts 1-3. Estimates of equation (9) without breaks are presented in Table 5. Peaks in F-Statistics appear during two periods: 1972-74 and 1985-87. The earlier period corresponds to the first oil price shock, while the later period corresponds to the tax reform act of 1986. Summaries of breaks during these periods are presented in Table 2. Tables 6 and 7 present detailed estimates for the 1972-74 and 1985-87 periods, respectively.

For both periods, the evidence suggests that savings are stationary when the break is included. Note, from Tables 6 and 7, that the ADF t-ratios exceed the location adjusted critical 95% level (from Table 16) for rejecting the null of non-stationarity. [18]

For the 1972-74 period, several conclusions emerge. The F-Test is greatest for private saving NIPA (S^{hn}). It exceeds the pre-test adjusted 95% critical level (PR95). However, F-Statistics private savings from both NIPA and FOF data (S^{pn} and S^{pf}) and personal FOF data (S^{hf}) exceed the LA95 critical value.

Qualitatively, all measures and deflators yield similar results. Trend terms, insignificant without the break, are significant when the break is included. Trends are positive before the break date and negative after. [19] On a dollar per-capita basis, the trend growth is positive before the break but is offset dollar-for-dollar by a trend decline after the break date.

Including the break also affects the constant term. For all equations, the constant term for all periods a_0 rises. For example, in the per-capita S^{hn} equation, the constant term rises from 367 when the break is not included to 467 when

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[18]Results for ADF(8) as well as the Zt and Zα tests, also indicate stationarity. They are not reported but available from the author on request.

[19]According an unreported log per capita equation, yearly growth of per-capita savings before the break date is offset by an equal percentage decline after the break.

the break is included. Also, the post-break constant term exceeds the pre-break constant. For the S^{hn} equation, the estimate for a^D_0 is 568. Similar results obtain for savings / disposable income, as the constant term rises after the break while the trend term falls.

Thus, trend terms and constant terms appear to move in opposite directions. Trend growth appears to be positive before the 1972-74 break dates, but negative thereafter, indicating a decline in wealth accumulation. However, this effect is offset by an increase in the constant term (representing the annuity value of average savings in every period).

For the 1985-87 break date, results are less conclusive. The F-Statistics are greatest for the personal NIPA savings S^{hn}. This F-statistics exceeds the location adjusted, random walk critical value at the 90% level (LA90%) for both per-capita savings and the savings / income ratio. Additionally, per-capita S^{pn} satisfies the pre-test adjusted critical 90% level for the random walk (PR90). F-statistics for per-capita S^{pn} and S^{hf} meet the LR90 and LA95 criteria, respectively. Estimates of constants and trends are similar in magnitude to previous estimates. However, in both cases, the dummy terms for both the constant (a^D_0) and trend (a^D_1) terms have t-statistics less than (absolute) 2.0. This suggests that, while the joint restriction $a^D_0 = a^D_1 = 0$ is rejected, the trend-break and constant-break terms by themselves are not statistically different from zero.

2.6.2 Without-Trend Estimations (Equation (10))

There are several important differences between the with-trend and without-trend estimates. First, as shown in Charts 4 and 5, some peaks in F-Statistics occur only for the without-trend estimates. Peak dates depend on the measure of savings and the deflator. Summary discussions of the breaks are presented in Tables 3 and 4 for the six periods mentioned above. Detailed estimates of equation (10) without the break are presented in Table 8. With-break estimates for four of the six periods, 1972-74, 1979-80, 1982-84, and 1985-87 are presented in Tables 9 - 12. [20]

[20] Space limitations prevent full reporting of all estimates. For per capita savings only, peaks in F-Statistic occur between 1962 and 1964. This peak does not occur in the with trend-equations. The F-statistic is greatest for personal FOF savings (S^{hf}). This period does not correspond to any of the candidate *a priori* break dates. However, some tests conducted by the author and available on request suggests that a break in trend population growth occurred around this time. Breaks were included at 1963:3 and 1963:4. Note that the F-statistic for per-capita S^{hn} equals 17.49, which satisfies the PR95 confidence level. For S^{hf}, the F-statistic of 9.17 satisfies the PA95 confidence level. The NIPA-based measures S^{hn} and S^{pn} satisfy the LA95 and LA90 confidence levels, respectively. Results available from the author show that, for all measures of saving, this break implies an increase in the constant component of savings of approximately 50%.

Like the with-trend equations, peaks in the F-Statistic occur during 1972-74, but only for savings as a fraction of disposable income. Overall, the results are weaker than those for the with-trend equation. Three measures, S^{pn}, S^{hf}, and S^{pf}, satisfy the LA95 criteria. Unlike the with-trend case, the estimates in Table 9 reveal a decline in the constant term of about 50%. For all cases except S^{hn}, savings are stationary when the break is included.

For all series, peak in F-statistics appear between 1979 and 1980, and between 1982 and 1985. Neither peak is apparent in the with-trend estimate. The 1979-1980 period corresponds to the second oil price shock. The break is most apparent in the S^{pn} and S^{pf} measures, at 1979:4 and 1980:3 respectively. The F-statistics, 12.11, and 9.10, both satisfy the LR95 criteria. For the S^{hf} measure, the break occurs 1980:4; its F-statistic, 6.8, satisfies the LA95 criteria. In all cases, savings are stationary when the break is included.

The period 1982-84 corresponds with a break in the U.S. Federal budget deficit (Tanner and Liu (1994, forthcoming)). Results for this period are strong. The break is most apparent in S^{hf}. The F-statistic for the break at 1985:02 is 16.258, which satisfies the PR90 criteria. However, breaks are apparent in other measures as well. For S^{hn}, S^{pn}, and S^{pf}, the F-statistics of 14.65 (at 1985:3), 14.49 (at 1984:4) and 8.656 (at 1984:3) all satisfy the LR95 criteria. Table 11 shows that, in all cases, savings are stationary when the break is included. Also, for all measures of saving, this break implies an decrease in the constant component of per-capita savings ranging from 33% to 50%.

Finally, like the with-trend equation, peaks in the F-Statistics appear around 1986-87 for most measures of savings. Like the with-trend estimates, ADF t- ratios in Tables 11 suggest rejection the null hypothesis of non-stationarity. In the case of private FOF savings S^{hf}, the F-statistic for a break at 1987:02 takes a value of 16.7, indicating that the break is significant at the pre-test adjusted random-walk 95% level (PR95). For the S^{hn} measure, the break which occurs at 1986:04, attains a value of 12.65. This statistic indicates significance at the LR95 level. Like the 1972-74 breaks, the estimates from Table 14 reveal declines in the constant term ranging from 33% to 50%.

Another peak occurs between 1969 and 1970, for all measures and both deflators. This peak does not occur in the with-trend equations. A rise in inflation and a drop in real interest rates occurred around this time. The effect of this break is similar to that of 1962-64. However, the evidence favoring a break is weaker. Breaks were included at 1969:2 and 1969:3. Note that the F-statistic for per-capita S^{hf} equals 11.85, which satisfies the LR95 confidence level. Results for S^{hn} and and S^{pf} satisfy the LA95 and LA90 criteria, respectively. Results available from the author show that, As Table 10 shows, for all measures of saving, this break implies an increase in the constant component of per-capita savings ranging from 33% to 50%.

2.6.3. Conclusions and Long-Run Implications of Breaks in Savings

The main question of this section was whether discrete, permanent breaks in U.S. savings have occurred. The answer is 'yes'. Where the breaks occur and their significance levels depend on the measure of savings used and how it is deflated. However, the evidence regarding breaks is strongest for two time periods: 1972-74 and the mid-to-late 1980s (approximately 1984 to 1987).

For the 1972-74 period, breaks occurred in both the trend and as well as the constant term. For all measures of saving, estimates reveal positive (but small) trend before the break and an negative (but small) trend after the break. However, the level effect works in the opposite direction. For all measures of saving the constant approximately doubles at the break date. For this reason, the net effect of this break on long-run asset accumulation is ambiguous.

The results for the mid-to-late 1980s yield different results. During this period, the estimated constant term drops by 33-50%. As well, there is little evidence of a break in the trend. Some evidence supports Summers' (1990) suggestion that the change in IRA regulations was a key factor in the savings decline. For personal savings as a fraction of disposable income, there is also some evidence of a break during 1986. However, according to the F-statistics, the strongest evidence for breaks occurs around the end of 1984 or the beginning of 1985. This suggests that other factors may have also been important. [21]

3. Breaks and The Anticipation of Savings to Changes in Income

The preceding discussion of saving relates to long-run asset accumulation. However, economic theory predicts that movements in saving should play a key role in consumption smoothing. Campbell (1987) and Campbell and Deaton (1989) derive implications regarding the comovements of savings and income from the permanent income hypothesis (PIH). One such implication is that current changes in income should be negatively related to past movements in

[21] However, the results must be interpreted cautiously. For example, some measurement issues remain unaddressed. Bradford (1990) notes that if changes in asset values are properly accounted for the savings rate declined by much smaller magnitudes than otherwise. Unfortunately, the data used in this study do not capture all changes in asset valuation. A logical extension of this work would be to search for breaks in his dataset.

savings. Consumers anticipate falls in future income and thus "save for a rainy day". [22] Thus, in their model, increases in the savings ratio should precede (or Granger-cause) reductions in the growth of income if if the "rainy day" hypothesis is correct. To test for this implication, they develop a two-variable vector autoregression (VAR) system.

The breaks in saving discussed in the previous section represent additional information about long-run asset accumulation. Such information should be accounted for in tests of the PIH. This section presents an extension of Campbell (1987) and Campbell and Deaton (1989) which incorporates discrete breaks.

The analysis below extends Cambpell's (1987) and Campbell and Deaton's (1989) framework to include discrete breaks. Two questions are addressed. First, what is the relationship between breaks and the "rainy-day" response. If discrete breaks are incorporated into Campbell and Deaton's VAR, do conclusions regarding the "rainy-day" response change? Second, do changes in income account for the breaks in savings? If lagged income growth is included in a savings equation, do the breaks become insignificant? [23]

Evidence presented below suggests that, when discrete breaks are included, the "rainy-day" response rises dramatically. In both 1-lag and 4-lag VARs, the savings - income growth response approximately doubles when the

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[22] Recent research on the PIH assumes a representative consumer that maximizes utility over time, subject to an intertemporal budget constraint such as (2). The representative consumer who is free to borrow or lend at the market rate of interest, is assumed to be forward looking, uses all relevant information, and has rational expectations. In much PIH research, consumers expectations of future income are characterized by ***univariate*** forecasts such as equation (5).

In this vein, Flavin (1981) noted that consumption is sensitive to changes in temporary income (as estimated from univariate forecasts). Put differently, consumption is found to be too volatile to be consistent with the PIH.

Others, principally Deaton (1989), suggest that estimates of permanent income from univariate estimates exceed the variance of temporary income. In this case, consumption is too ***smooth*** relative to current income to be consistent with the PIH.

Whether consumption is too volatile or too smooth is for the PIH depends on how income is decomposed into temporary and permanent parts. An important issue is what information consumers use for their decomposition. It is likely that consumers use more information than univariate forecasting techniques such as (5).

A solution to the issue of information would be to simply "add more variables" to an expression such as (4a). Campbell (1987) and Campbell and Deaton (1989) suggest a more parsimonious approach. Their approach is followed below. It is assumed that consumers' own behavior reveals their expectations. In their model, consumer's behavior and expectations are incorporated in a two-variable vector autoregression (VAR) of the savings ratio (S/Y) and the log growth of income (Δ log Y).

[23] The idea that consumption is "too smooth" for the PIH to be true is known as the 'Deaton paradox'. As Diebold and Rudebusch (1991) note, investigations related to the Deaton paradox may either introduce alternative ***economic*** assumptions (such as liquidity constraints or precautionary savings) or alternative ***statistical*** assumptions. This research falls into the latter category.

break is included. Moreover, the inclusion of income growth in a savings equation does not "explain away" the breaks in savings.

To start, the PIH is restated in general form (see Flavin (1981)). In any period, consumption equals the expectation of permanent income:

$$(11) \qquad C_t = r/(1+r)\,[(1+r)A_{t-1} + \sum_{t=0}^{\infty} EY_{t+i}/(1+r)^i\,]$$

It is possible to express the *equivalent* of equation (11) in terms of savings. Specifically, using the one-period budget constraint (2), Campbell (1987) and Campbell and Deaton (1989) show that, according to the PIH, increases in saving correspond dollar-for-dollar with decreases in the expected present discounted value *labor* income. Equivalently, this condition may be expressed as a function of changes *total* income $Y^{TOT} = Y + rA$ minus the present value accumulated savings rA^*, as $r\Delta A_t = r(A_t - A_{t-1}) = r(S_t)$. [24] Thus, equation (11) may be equivalently rewritten as:

$$(12) \qquad S_t = -\sum_{t=0}^{\infty} E\Delta Y_{t+i}/(1+r)^i \equiv -\sum_{t=0}^{\infty} E\Delta Y^{TOT}{}_{t+i}/(1+r)^i + \sum_{t=0}^{\infty} rE(\Delta A_t)/(1+r)^t \equiv -\sum_{t=0}^{\infty} E\Delta Y^{TOT}{}_{t+i}/(1+r)^i + rA^*$$

Equation (12) shows that, according to the PIH, increases in saving correspond dollar-for-dollar with decreases in the expected present discounted value total income, net of target asset accumulation term rA^*. One way to test the PIH would be to use a univariate estimate of the present discounted value of income, similar to that found in (5):

$$(12') \qquad S_t = -(1+r)(1+r-\rho))[\Delta Y_t + \theta/r + \theta(1+r)/r^2 + \Delta\epsilon_t \sum_{j=1}^{\infty} \lambda_j/(1+r)^{j-1} + \Delta\epsilon_{t-1} \sum_{j=2}^{\infty} \lambda_j/(1+r)^{j-2} + \ldots] -$$

However, an alternative procedure is chosen here. First, equation (12) is re-cast in terms of the savings ratio (S/Y) and the growth rate of income $\Delta \log Y$. Campbell and Deaton (1989) show that (12) may be approximated as:

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[24] In the following discussion, Y^{TOT} refers to total (labor plus capital) personal disposable income.

(12) $$(S/Y)_t \approx -\sum_{t=0}^{\infty} E\Delta \log Y^{TOT}_{t+i}/\delta^i + \text{constant}$$

where the modified discount factor $\delta = [(1+r)/(1+\theta)]$, θ = the growth rate of income. The constant term is a function of rA^*.

We do not know the information set used by consumers to obtain the expected present value of Δ log Y. Campbell and Deaton (1989) suggest that, in the absence of such knowledge, we may use a vector autoregression (VAR) to infer consumers expectations from their own behavior. Their VAR contains S/Y and Δ log Y minus their respective means. No constants are included in their model. Their model is thus written:

(13) $$\mathbf{X}_t = \mathbf{a}_1\mathbf{X}_{t-1} + \mathbf{a}_2\mathbf{X}_{t-2} + \mathbf{a}_3\mathbf{X}_{t-3} + \ldots + \mathbf{a}_k\,\mathbf{X}_{t-k} + \mathbf{e}_t$$

where the $\mathbf{a}_i$ are 2x2 coefficient matrices and the vector $\mathbf{X}_t = [(S/Y)_t - \text{mean}(S/Y),\ \Delta \log Y_t - \text{mean}(\Delta \log Y_t)]$. The coefficients in the matrices a_i capture the lagged relationships between the variables. The "rainy day" effect is captured in the lagged effects of S/Y on Δ log Y, $\mathbf{a}_{SYi}$.

By itself, equation (13) does not provide a full test of the PIH. However, the PIH has certain precise, testable implications for restrictions on the coefficients in $\mathbf{a}_i$. In particular, Campbell and Deaton (1989) show that, for the 1-lag case, the PIH implies $(c_2 - c_1)\mathbf{a}_1 - c_2/\delta\,\mathbf{e}_t = 0$, where c_1 and c_2 are vectors, $c_1 = (1,0)$ and $c_2 = (0, 1)$. [25] This logic applies to the multi-lag case.

This research modifies Campbell and Deaton's (1989) model. Means are not subtracted off of the variables, and constant terms are included. Thus, the basic VAR system is now:

(13') $$\mathbf{X}_t = \mathbf{a}_0 + \mathbf{a}_1\mathbf{X}_{t-1} + \mathbf{a}_2\mathbf{X}_{t-2} + \mathbf{a}_3\mathbf{X}_{t-3} + \ldots + \mathbf{a}_k\,\mathbf{X}_{t-k} + \mathbf{e}_t$$

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[25] This restriction is easily shown to be equivalent to testing that neither lagged S/Y nor Δ log Y cause the current change in consumption scaled by lagged income, $\Delta C/Y_{t-1}$. Thus, it is similar to Hall's (1978) random walk test.

where a_0 is a 2x1 vector, the a_i are 2x2 coefficient matrices, and the vector $\mathbf{X}_t = [(S/Y)_t \; \Delta \log Y^{TOT}_t]$. As before, the "rainy day" effect is captured in the lagged effects of S/Y on Δ log Y^{TOT}, $\mathbf{a}_{SYi}$.

The vector a_0 contains the constant terms (i.e. means) for the elements of **X**. According to the previous section, however, there are trends as well as breaks in both constant and trends in the process of at least one of the variables in **X**, S/Y. This information must be properly accounted for. One way to do so would be to include trends and breaks in the VAR. Thus, Campbell and Deaton 's (1989) approach is extended to include a trend term $\mathbf{a}_T$, a constant shift term $\mathbf{a}^D_0$, and a trend shift term $\mathbf{a}^D_T$:

$$(13'') \qquad \mathbf{X}_t = \mathbf{a}_0 + \mathbf{a}_0^0 D_t + \mathbf{a}_T t + \mathbf{a}^D_0 D_t t + \mathbf{a}_1 \mathbf{X}_{t-1} + \mathbf{a}_2 \mathbf{X}_{t-2} + \mathbf{a}_3 \mathbf{X}_{t-3} + \ldots + \mathbf{a}_k \mathbf{X}_{t-k} + \mathbf{e}_t$$

where t is a time trend and D_t is a scalar that equals 0 for dates before or equal to the break date and 1 otherwise. This procedure is similar to Blanchard and Quah (1989). The vectors $\mathbf{a}^D_0$, $\mathbf{a}^D_T$ and the scalar D_t represent breaks in the joint process of savings and income.

The presence of these breaks was **discussed** in previous section, as were break dates. Based on this discussion, there are several possible combinations of savings measures, break dates, lag lengths that might be applied to the estimation of (13') and (13"). A limited set of these estimations are presented in Tables 13a and 13b. The measure of saving used is NIPA personal, S^{hn}. [26] Breaks in both the trend and the constant terms are incorporated the VAR for two dates: 1972:3 and 1986:3. To test for the significance of the breaks in the system, a log-likelihood ratio test, distributed

[26] Similar results were obtained with S^{pn}. However, there were some differences in the results of the two NIPA measurements. One difference was the replication of Campbell's (1987) and Campbell and Deaton's (1989) results. Using the NIPA private measure S^{pn}, savings Granger-caused income only when breaks were included. Estimates with the FOF measures were less successful.

Chi-squared, is constructed.[27] Following Campbell (1987), both a 1-lag (Table 13a) and a 4-lag version (Table 13b) are estimated.

According to the log-likelihood ratio test, the hypothesis that the break terms are zero in the system is rejected. With the break terms incorporated, the "rainy-day" effect is strengthened in all estimates. Both the significance level (as measured by F-statistics to test for the exclusion of S/Y from the Δ log Y^{TOT} equation) and the magnitude of the coefficient values rise. Consider first , from the 1-lag regression (Table 13a) the estimation with no break and no trend. This version of the estimation essentially replicates previous results by Campbell and Deaton (1989). The lagged effect of saving on income (a_{SY1}) is about -16 cents on the dollar, and the F-statistic for the exclusion of lagged S/Y is 9.292, which is significant at greater than the 95% confidence level. However, when the break term is added, for either date, both the coefficient estimate and the F-statistic rise dramatically. For the 1972 date, the coefficient a_{SY1} approximately doubles to about -30 cents on the dollar. The associated F-statistic is 22.4. For the 1986 break date, the coefficient a_{SY1} rises to over -40 cents on the dollar. The associated F-statistic is 33.3. Similar results hold for the 4-lag estimates in Table 13b. It is also apparent that including income growth in the equations does not "explain away" the breaks in the savings equation. Rather, a comparison of Table 6 with Tables 13a and 13b reveal that signs and magnitudes of the coefficients for breaks are robust to the inclusion or exclusion of Δ log Y^{TOT}.

4. Conclusions

This paper tested for the presence of permanent breaks in U.S. savings. Evidence suggesting that permanent breaks in both the trend and constant components of savings occurred during the early 1970s and the mid-to-late 1980s. From a policy stand point, the permanent decline nature may have important implications for growth and capital accumulation. With regard to testing economic theories, evidence in this paper suggest that tests of the permanent income hypothesis depend upon the inclusion of permanent breaks in saving.

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[27] The test is computed as:

$$(R-c)\ [\ln H_r - \ln H_u]$$

where R is the number of restrictions, c is the multiplier correction factor (see Sims (1980)) and H_r and H_u are the determinants of the covariance matrices for the restricted and unrestricted cases, respectively. This test statistic is maximized at 1986:03.

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Table 1a: Stationarity Tests without Trend, Savings, Various Measures.

As a fraction of disposable income

	ADF(4)	ADF(8)	Zt(4)	Zt(8)	$Z\alpha$(4)	$Z\alpha$(8)
S^{hn}	-2.304	-1.298	-3.090**	-3.109**	-19.184*	-19.425*
S^{pn}	-1.581	-0.754	-1.904	-1.798	-8.372	-7.571
S^{hf}	-3.339**	-2.174	-12.694**	-12.882**	-170.277**	-196.390**
S^{pf}	-1.737	-1.264	-9.837**	-10.875**	-137.476**	-186.036**

Per Capita Savings

	ADF(4)	ADF(8)	Zt(4)	Zt(8)	$Z\alpha$(4)	$Z\alpha$(8)
S^{hn}	-2.377	-1.756	-2.908**	-2.897**	-15.099*	-14.971*
S^{pn}	-2.545	-1.849	-2.598*	-2.504	-12.149	-11.172
S^{hf}	-3.567**	-2.502	-11.948**	-12.424**	-169.648**	-205.453**
S^{pf}	-2.863*	-2.451	-10.309**	-11.254**	-148.391**	-195.370**

Table 1b: Stationarity Tests with Trend, Savings, Various Measures.

As a fraction of disposable income

	ADF(4)	ADF(8)	Zt(4)	Zt(8)	$Z\alpha$(4)	$Z\alpha$(8)	Trend Coeff	S.E. Trend
S^{hn}	-2.597	-1.597	-3.340*	-3.359**	-21.488**	-21.751**	-1.574e-05	1.306e-05
S^{pn}	-2.455	-1.665	-2.623	-2.526	-13.335	-12.329	-3.000e-05	1.684e-05
S^{hf}	-4.187**	-3.057	-13.386**	-13.371**	-170.910**	-185.378**	-0.655	0.161
S^{pf}	-3.026	-2.552	-11.230**	-11.978**	-163.550**	-207.850**	-2.730e-06	5.488e-05

Per Capita Savings

	ADF(4)	ADF(8)	Zt(4)	Zt(8)	$Z\alpha$(4)	$Z\alpha$(8)	Trend Coeff	S.E. Trend
S^{hn}	-2.376	-1.427	-3.348*	-3.430*	-21.726**	-22.844**	0.159	0.159
S^{pn}	-2.433	-1.415	-2.633	-2.554	-13.805	-12.986	0.095	0.167
S^{hf}	-4.174**	-2.925	-12.981**	-13.012**	-168.951**	-182.711**	1.243	0.491
S^{pf}	-2.812	-2.286	-10.901**	-11.681**	-158.258**	-201.541**	0.449	0.465

Legend:

ADF(x): Augmented-Dickey Fuller Test, null hypothesis of non- stationarity of variable, lag length x. Critical values: For without trend, 90 percent, -2.58, 95 percent -2.89; for with-trend tests, 90 percent, -3.15, 95 percent -3.45

Zt(x): Phillips-Perron (1988) Zt test, null hypothesis of non- stationarity of variable, lag length x. Critical values: same as for ADF(x) tests, above.

$Z\alpha$ (x):Phillips-Perron (1988) $Z\alpha$ Test, null-hypothesis of non-stationarity of variable, lag length x. Critical values: For without trend, 95 percent, -13.7, 99 percent -19.8; for with-trend tests, 90 percent, -17.5, 99 percent -20.7

Source of Critical Values for ADF, Zt, and $Z\alpha$ tests: Fuller (1976,pp. 371-73)

N.B. Trend Term in Table 1a, only

*, ** indicate rejection of null-hypothesis of non-stationarity at 90 percent and 95 percent levels, respectively.

Trend Coeff.: Coefficient Value on Time Trend

S.E. Trend: Standard Error of the time trend

Table 2
Summary
Breaks in Trend and Constant Terms, Equation (9)

(9) $$\Delta S_t = a_0 + a_0^D D_t^K + a_1 + a_1^D D_t^K t + b_0 S_{t-1} + \sum_{i=1}^{l} b_i \Delta S_{t-i} + error_t$$

Period of Breaks	**Maximal F-Statistic**				**Remarks**
	Deflator	**Meas**	**F-stat**	**Max CL**	
1972-74	**Per Capita**	S^{hn}	7.03	LA 95	Detailed estimates are in Table 6.
		S^{pn}	15.8	PR95	Period corresponds to oil price shock.
		S^{hf}	5.46	LA95	Most F-statistics are maximized at 1972:03.
		S^{pf}	7.22	LA95	In all cases, the trend term is positive before the break and negative after the break. Yearly growth rate is about 1% before the break and -1% after the break.
	Savings/Y^d	S^{hn}	7.55	LA95	
		S^{pn}	13.3	AR95	
		S^{hf}	5.13	LA95	In all cases, the constant term approximately triples after the break date. For per-capita private NIPA savings (S^{pn}), the constant rises from 249 (pre-break) to 822 (post break).
		S^{pf}	5.69	LA95	
1985-87	**Per Capita**	S^{hn}	13.5	PR90	Detailed estimates are in Table 7.
		S^{pn}	7.32	LR90	Period corresponds tax reform of 1986.
		S^{hf}	6.18	LA95	Most F-statistics are maximized at 1986:03.
		S^{pf}	3.3	-	In all cases, the trend term is positive before the break and zero after the break.
	Savings/Y^d	S^{hn}	11.8	LR95	
		S^{pn}	4.64	LA90	In all cases, the dummy constant term is negative but not significantly different from zero.
		S^{hf}	7.40	LR95	
		S^{pf}	2.88	-	

Notes:
1. The F-statistics in this table correspond to Figures 1-3.
2. F-Statistics on log per-capita regressions are omitted. The results are similar to level per capita results.
3. Definitions of savings: S^{hn}, personal NIPA; S^{pn}, private NIPA; S^{hf}, personal FOF data; S^{fi}, private FOF data.
4. **Max C.L.** indicate maximum critical level satisfied by F-statistic: P - pre-test adjusted; L - location adjusted; R - random - walk null hypothesis; A - autoregressive; 90, 95 indicate confidence levels. Example:"PR95" indicates pre-test adjusted, random-walk null, 95% confidence level. See Table 16.

Table 3
Summary
Breaks in Constant Terms, Equation (10)
Per Capita Savings

$$\Delta S_t = a_0 + a_0^D D_t^K + b_0 S_{t-1} + \sum_{i=1}^{I} b \Delta S_{t-i} + error_t \qquad (10)$$

Period of Break	**Maximal F-Statistic**			**Remarks**
	Meas	**F-stat**	**Max CL**	
1962-64	S^{hn}	6.34	LA90	Detailed estimates are in Table 9.
	S^{pn}	6.7	LA90	F-tests maximzed at 63:02 and 63:04. A break in trend population growth occured around this time.
	S^{hf}	17.49	PR95	
	S^{pf}	9.17	PA95	In all cases, the constant term increases after the break by one-third to one-half.
1969-70	S^{hn}	5.96	LA90	Detailed estimates are in Table 10.
	S^{pn}	2.61	-	F-tests maximzed at 69:02 and 69:03.
	S^{hf}	11.85	PA95	
	S^{pf}	3.13	-	In all cases, the constant term increases after the break by about to one-third.

Notes:
1. The F-Statistics in this table correspond to Figure 4.
2. F-Statistics on log per-capita regressions are omitted. The results are similar to level per capita results.
3. Definitions of savings: S^{hn}, personal NIPA; S^{pn}, private NIPA; S^{hf}, personal FOF data; S^{fh}, private FOF data.
4. **Max C.L.** indicate maximum critical level satisfied by F-statistic: P - pre-test adjusted; L - location adjusted; R - random - walk null hypothesis; A - autoregressive; 90, 95 indicate confidence levels. See Table 16.

Table 4
Summary
Breaks in Constant Terms, Equation (10)
Savings as a fraction of Disposable Income (S/Y^d)

(10) $$\Delta S_t = a_0 + a_0^D D_t^K + b_0 S_{t-1} + \sum_{i=1}^{I} b \Delta S_{t-i} + error_t$$

Period of Break	**Maximal F-Statistic**			**Remarks**
	Meas	**F-stat**	**Max CL**	
1972-74	S^{hn}	2.426	-	Detailed estimates are in Table 11.
	S^{pn}	5.689	LA95	F-tests maximzed at 74:01 and 74:02. This break corresponds to the oil price shock.
	S^{hf}	5.135	LA95	
	S^{pf}	6.247	LA95	In all cases, the constant term decreases after the break by about one-third
1979-80	S^{hn}	3.103	-	Detailed estimates are in Table 12.
	S^{pn}	9.102	LR95	F-tests maximzed at 79:04 and 80:04.
	S^{hf}	6.773	LA95	Corresponds to second oil price shock, Volcker disinflation, financial deregulation.
	S^{pf}	12.109	LR95	In all cases, the constant term decreases after the break by about one-third.
1982-85	S^{hn}	14.65	LR95	Detailed estimates are in Table 13.
	S^{pn}	14.496	LR95	F-tests maximzed in 1984 and 1985. Occurs after discrete break in Federal Deficit.
	S^{hf}	16.258	PR90	
	S^{pf}	8.656	LR95	The constant term decreases after the break from one-third to one-half.
1985-87	S^{hn}	12.647	LR95	Detailed estimates are in Table 14.
	S^{pn}	3.747	LA90	F-tests maximzed at 86:04 and 87:02.
	S^{hf}	16.791	PR95	
	S^{pf}	3.608	LA90	In all cases, the constant term decreases after the break from one-third to one-half.

Notes:
1. The F-Statistics in this table correspond to Figure 5.
2. Definitions of savings: S^{hn}, personal NIPA; S^{pn}, private NIPA; S^{hf}, personal FOF data; S^{fn}, private FOF data.
3. **Max C.L.** indicate maximum critical level satisfied by F-statistic: P - pre-test adjusted; L - location adjusted; R - random - walk null hypothesis; A - autoregressive; 90, 95 indicates confidence level. See Table 16.

Table 5
Estimates of Savings Equation (9), Breaks Excluded
Coefficient Estimates (Standard Errors in Parentheses)

	Savings / disposable income				Level Per Capita Saving			
Coefficient Estimates	S^{hn}	S^{pn}	S^{hf}	S^{pf}	S^{hn}	S^{pn}	S^{hf}	S^{pf}
a_0	0.009	0.012	0.061	0.043	57.031	78.203	367.673	272.750
	(0.004)	(0.005)	(0.016)	(0.017)	(24.022)	(32.228)	(94.793)	(104.609)
a_1	-1.574e-05	-3.000e-05	-9.731e-05	-2.000e-06	0.159	0.095	1.243	0.449
	(1.30e-05)	(1.68e-05)	(4.76e-05)	(5.48e-05)	(0.159)	(0.167)	(0.491)	(0.465)
b_0	-0.123	-0.084	-0.655**	-0.284	-0.117	-0.089	-0.675**	-0.289
	(0.048)	(0.036)	(0.161)	(0.109)	(0.049)	(0.038)	(0.161)	(0.109)
R^2**Adj.**	0.096	0.060	0.676	0.649	0.105	0.066	0.640	0.612

Note: Estimated equation is:

(9) $$\Delta S_t = a_0 + a_0^D D_t^K + a_1 + a_1^D D_t^K t + b_0 S_{t-1} + \sum_{i=1}^{I} b_i \Delta S_{t-i} + error_t$$

Double asterisk "**" indicates rejection of the null hypothesis of non-stationarity at the 95% level. ADF statistic is computed as b_0/ standard error. Critical value used is ADF(4) with trend, Critical values: 95 percent, -3.45, Source of Critical Values for ADF tests: Fuller (1976,pp. 371-73)

Table 6

Estimates of Savings Equation (9) Constant and Trend Breaks 1972-74

	Savings as fraction of disposable income				Level Per Capita Saving			
	S^{hn}	S^{pn}	S^{hf}	S^{pf}	S^{hn}	S^{pn}	S^{hf}	S^{pf}
Break Date	**72:03**	**72:04**	**72:04**	**72:04**	**72:03**	**72:04**	**72:04**	**72:04**
a_0	0.020	0.043	0.081	0.088	102.092	249.036	457.863	539.635
	(0.005)	(0.008)	(0.017)	(0.021)	(28.544)	(44.15)	(102.322)	(127.804)
a_0^d	0.026	0.054	0.057	0.079	239.422	573.339	568.698	877.796
	(0.007)	(0.010)	(0.018)	(0.024)	(64.069)	(101.984)	(172.570)	(232.268)
a_1	3.404e-05	8.699e-05	6.420e-05	9.217e-05	1.026	2.529	3.704	4.542
	(3.73e-05)	(4.29e-05)	(1.64e-05)	(2.42e-05)	(0.431)	(0.564)	(1.278)	(1.486)
a_1^d	-3.300e-05	-0.001	-0.001	-0.001	-2.128	-5.475	-5.526	-8.775
	(6.66e-05)	(5.80e-06)	(8.73e-05)	(4.85e-05)	(0.638)	(0.999)	(1.782)	(2.372)
b_0	-0.314**	-0.396**	-0.982**	-0.689**	-0.299**	-0.429**	-1.020**	-0.768**
	(0.067)	(0.069)	(0.187)	(0.160)	(0.068)	(0.070)	(0.188)	(0.164)
R^2Adj.	0.168	0.191	0.693	.669	0.171	0.218	0.660	0.642
Break F-Test	7.554	13.298	5.134	5.689	7.029	15.824	5.463	7.218

Table 7

Estimates of Savings Equation (9), Constant and Trend Breaks 1985-87

	Savings as fraction of disposable income				Level Per Capita Saving			
	S^{hn}	S^{pn}	S^{hf}	S^{pf}	S^{hn}	S^{pn}	S^{hf}	S^{pf}
Break Date	**86:04**	**87:03**	**87:03**	**85:03**	**86:03**	**84:04**	**85:02**	**85:02**
a_0	0.0255	0.023	0.0876	0.0621	142.516	151.146	483.534	379.556
	(0.0051)	(0.0065)	(0.0168)	(0.0194)	(28.852)	(38.618)	(99.077)	(115.147)
a_0^d	-0.026	-0.015	-0.192	-0.059	-258.36	57.916	69.774	-417.63
	(0.0282)	(0.0278)	(0.1099)	(0.0753)	(281.477)	(247.571)	(680.087)	(722.521)
a_1	4E-05	2E-06	-3E-05	-5E-05	1.582	1.200	3.447	1.985
	(2E-05)	(2E-05)	(5E-05)	(6E-05)	(0.334)	(0.351)	(0.800)	(0.809)
a_1^d	7E-05	3E-05	0.0011	0.0003	0.648	-1.241	-2.191	1.469
	(0.0002)	(0.0002)	(0.0007)	(0.0005)	(1.905)	(1.758)	(4.647)	(4.944)
b_0	-0.394**	-0.194**	-1.012**	-0.448**	-0.423**	-0.237**	-1.039**	-0.476**
	(0.0768)	(0.0548)	(0.185)	(0.1357)	(0.080)	(0.057)	(0.192)	(0.138)
R^2Adj.	0.2031	0.1033	0.7016	0.6569	0.231	0.138	0.663	0.624
F-Test	11.183	4.645	7.4031	2.7876	13.462	7.326	6.180	3.304

Note: In Tables 6 and 7, estimated equation is:

(9) $$\Delta S_t = a_0 + a_0^D D_t^K + a_1 + a_1^D D_t^K t + b_0 S_{t-1} + \sum_{i=1}^{I} b_i \Delta S_{t-i} + error_t$$

Double asterisk "**" indicates rejection of the null hypothesis of non-stationarity at the 95% level. ADF statistic is computed as b_0/ standard error. Critical value, as computed by author (see Table 16) are: For Table 6, 4.19, 95% level, 3.87, 90% level.; for Table 7 3.91, 95% level, 3.57, 90% level.

Table 8
Estimates of Savings Equation (10), No Trend, No Break

	Level per capita saving				Savings as fraction of disposable income			
	S^{hn}	S^{pn}	S^{hf}	S^{pf}	S^{hn}	S^{pn}	S^{hf}	S^{pf}
a_0	52.9708	76.5876	302.499	258.787	0.00721	0.00551	0.03873	0.01867
	(23.6789)	(32.0302)	(92.8355)	(103.582)	(0.00323)	(0.00364)	(0.01148)	(0.0110)
b_0	-0.0875	-0.0789	-0.4296**	-0.2396	-0.1087	-0.0523	-0.4869**	-0.1587
	(0.039)	(0.03289)	(0.13075)	(0.09615)	(0.04658)	(0.03209)	(0.13936)	(0.0865)
R^2Adj.	0.10496	0.07007	0.62676	0.61235	0.09365	0.04699	0.66973	0.643

Note: estimated equation is:

(10) $$\Delta S_t = a_0 + a_0^D D_t^K + b_0 S_{t-1} + \sum_{i=1}^{I} b \Delta S_{t-i} + error_t$$

Double asterisk "**" indicates rejection of the null hypothesis of non-stationarity at the 95% level. ADF statistic is computed as b_0/ standard error. Critical value used is ADF(4), critical values: 95 percent, -2.89, source of critical values for ADF tests: Fuller (1976,pp. 371-73)

Table 9
Estimates of savings as a fraction of disposable income
Equation (10), No Trend 1972-74

	S^{hn}	S^{pn}	S^{hf}	S^{pf}
Break Date	**74:01**	**74:02**	**74:02**	**74:02**
a_0	0.008	0.010	0.055	0.040
	(0.003)	(0.004)	(0.013)	(0.014)
a_0^d	-0.002	-0.003	-0.009	-0.012
	(0.001)	(0.001)	(0.004)	(0.005)
b_0	-0.114	-0.080	-0.629	-0.286
	(0.046)	(0.034)	(0.151)	(0.099)
R^2Adj.	0.102	0.075	0.678	0.655
Break F Test	2.426	5.689	5.135	6.247

Note: estimated equation is:

(10) $$\Delta S_t = a_0 + a_0^D D_t^K + b_0 S_{t-1} + \sum_{i=1}^{I} b \Delta S_{t-i} + error_t$$

Double asterisk "**" indicates rejection of the null hypothesis of non-stationarity at the 95% level. ADF statistic is computed as b_0/ standard error.

Table 10
Estimates of Savings / disposable income, Equation (10), No Trend 1979-80

	S^{hn}	S^{pn}	S^{hf}	S^{pf}
Break Date	**80:04**	**79:04**	**80:04**	**80:03**
a_0	0.010	0.017	0.061	0.071
	(0.004)	(0.005)	(0.014)	(0.018)
a_0^D	-0.002	-0.006	-0.012	-0.023
	(0.001)	(0.002)	(0.005)	(0.007)
b_0	-0.139	-0.137	-0.715	-0.524
	(0.049)	(0.042)	(0.162)	(0.134)
R^2Adj.	0.106	0.095	0.682	0.667
Break F-Test	3.103	9.102	6.773	12.108

Table 11
Estimates of Savings / disposable income Equation (10), No Trend 1982-85

	S^{hn}	S^{pn}	S^{hf}	S^{pf}
Break Date	**85:03**	**84:04**	**85:02**	**84:03**
a_0	0.020	0.024	0.085	0.058
	(0.005)	(0.006)	(0.016)	(0.017)
a_0^d	-0.008	-0.010	-0.025	-0.021
	(0.002)	(0.003)	(0.006)	(0.007)
b_0	-0.275	-0.197	-0.996	-0.441
	(0.062)	(0.049)	(0.183)	(0.128)
R^2Adj.	0.168	0.124	0.700	0.660
Break F-Test	14.650	14.496	16.258	8.656

Table 12
Estimates of Savings / disposable income, Equation (10), No Trend 1986-87

	S^{hn}	S^{pn}	S^{hf}	S^{pf}
Date	**86:04**	**86:04**	**87:02**	**86:04**
a_0	0.021	0.015	0.085	0.043
	(0.005)	(0.006)	(0.016)	(0.017)
a_0^d	-0.008	-0.006	-0.029	-0.015
	(0.002)	(0.003)	(0.007)	(0.008)
b_0	-0.297	-0.133	-1.003	-0.332
	(0.069)	(0.054)	(0.183)	(0.125)
R^2Adj.	0.158	0.062	0.701	0.649
FStat	12.647	3.474	16.791	3.608

In Tables 10, 11, 12, estimated equation is: I

(10) $$\Delta S_t = a_0 + a_0^D D_t^K + b_0 S_{t-1} + \sum_{i=1} b \Delta S_{t-i} + error_t$$

Note: Double asterisk "**" indicates rejection of the null hypothesis of non-stationarity at the 95% level. ADF statistic is computed as b_0/ standard error.

Table 13a

Vector Autoregression, Savings and Income 1-Lag

(13')
$$X_t = a_0 + a_0^D D_t + a_t t + a^D_0 D_t t + a_1 X_{t-1} + e_t$$

	Model without trend		Model with trend		Model with break in constant and trend			
	No Break		No Break		Break date 73:03		Break Date 86:03	
Dep. Variable:	**S/Y**	**Δ log Y**	**S/Y**	**Δ log Y**	**S/Y**	**Δ log Y**	**S/Y**	**Δ log Y**
Coefficient Estimate:								
a_{j0}	0.010	0.018	0.013	0.021	0.020	0.028	0.023	0.035
	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
a_{j0}^D					0.024	0.024	-0.030	-0.003
					(0.006)	(0.007)	(0.029)	(0.033)
a_{jT}			-1.752e-05	-2.355e-05	3.620e-05	5.833e-05	2.533e-05	3.660e-05
			(1.28e-05)	(1.50e-05)	(3.46e-05)	(4.12e-05)	(1.65e-05)	(1.91e-05)
a_{jT}^D					-2.600e-05	-4.400e-05	2.070e-05	-8.300e-05
					(6.17e-05)	(7.34e-05)	(8.68e-05)	(1.60e-05)
a_{jS1}	-0.130	-0.003	0.849	-0.169	0.698	-0.318	0.673	-0.410
	(0.066)	(0.077)	(0.043)	(0.051)	(0.057)	(0.067)	(0.061)	(0.070)
a_{jY1}	0.863	-0.150	-0.132	-0.006	-0.114	0.010	-0.131	-0.003
	(0.042)	(0.049)	(0.066)	(0.077)	(0.063)	(0.075)	(0.063)	(0.073)
R^2 Adj.	0.724	0.044	0.726	0.053	0.747	0.104	0.748	0.159
F-stat,S	427.025	9.292	389.852	11.248	152.332	22.311	123.882	34.302
F-stat,Y	3.927	0.001	4.089	0.006	3.267	0.016	4.352	0.002

Notes: Coefficient estimates a_{jS}, a_{jY} refer to the effect of the savings ratio (S/Y) and Δ log Y, respectively, by lagged S/Y, Δ log Y. Standard errors are in parentheses.

F-stat, S: F-statistic for the exclusion of first lag of S/Y

F-stat, Y: F-statistic for the exclusion of first lag of Δ log Y

Definition of saving used is S^{bn} (personal NIPA). Definition of Y used is disposable income.

Table 13b
Vector Autoregression, Savings and Income 4-Lag

(13')
$$X_t = a_0 + a_0^0 D_t + a_T t + a^D_0 D_t t + a_1 X_{t-1} + a_2 X_{t-2} + a_3 X_{t-3} + a_k X_{t-4} + e_t$$

	Model without trend		Model with trend		Model with break in constant and trend			
	No Break		No Break		Break date 73:03		Break Date 86:03	
Dep. Variable:	S/Y	Δ log Y	S/Y	Δ log Y	S/Y	Δ log Y	S/Y	Δ log Y
Coefficient Estimate:								
a_{j0}	0.008	0.011	0.011	0.014	0.022	0.022	0.029	0.034
	(0.003)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)
a_{j0}^D					0.027	0.022	-0.020	-0.002
					(0.007)	(0.008)	(0.028)	(0.034)
a_{jT}			-1.610e-05	-1.505e-05	4.283e-05	7.264e-05	3.845e-05	4.543e-05
			(1.300e-05)	(1.55e-05)	(3.638e-05)	(4.458e-05)	(1.762e-05)	(2.129e-05)
a_{jT}^D					-5.080e-05	-3.270e-05	3.316e-05	-9.491e-05
					(6.661e-05)	(8.164e-05)	(0.000016)	(0.000016)
$\sum a_{jSi}$, i = 1-4	0.880	-0.091	0.865	-0.105	0.667	-0.266	0.588	-0.413
$\sum a_{jYi}$, i = 1-4	-0.004	0.282	-0.022	0.265	-0.104	0.181	-0.206	0.051
R^2 Adj.	0.740	0.070	0.741	0.070	0.764	0.106	0.769	0.148
F-stat,S	114.582	4.256	104.761	4.454	42.537	6.366	35.796	8.711
F-stat,Y	1.098	1.271	1.121	1.167	1.810	0.665	2.671	0.286

Notes: Coefficient estimates $\sum a_{jS}$, $\sum a_{jY}$ refer to the effect of the savings ratio (S/Y) and Δ log Y, respectively, by the sum of lags 1-4 of, Δ log Y. .
F-stat, S: F-statistic for the exclusion of first lag of S/Y
F-stat, Y: F-statistic for the exclusion of first lag of Δ log Y
Definition of saving used is S^{hn} (personal NIPA). Definition of Y used is disposable income.

Table 14
Critical Values, Computed by Monte Carlo Procedure (see text)

Pre-Test Adjusted (PR,PA)Critical Values
F-Statistics for Break

	Trend, Constant Break		Constant Break Only	
	95% C.L.	90% C.L	95% C.L.	90% C.L.
Underlying Process:				
Random Walk (PR)	14.199	12.654	17.869	15.438
Autoregessive (PA)	7.987	7.017	9.089	7.497

Location Adjusted (LR,LA) Critical Values
F-Statistics for Break

		Trend, Constant Break		Constant Break Only	
Break Date	Process	95% C.L.	90% C.L	95% C.L.	90% C.L.
1963:04	LR	8.702	7.396	7.889	6.082
	LA	7.889	6.082	4.368	3.056
1969:03	LR	8.702	7.396	8.182	6.427
	LA	4.571	3.698	4.277	2.912
1973:01	LR	9.440	8.060	8.623	6.466
	LA	4.719	3.708	4.335	3.005
1979:04	LR	8.764	7.525	8.156	6.100
	LA	4.796	3.719	4.279	2.955
1984:04	LR	8.354	6.958	7.336	5.455
	LA	4.696	3.706	4.278	3.008
1986:03	LR	8.015	6.720	6.761	4.908
	LA	4.690	3.722	4.135	2.878

Location Adjusted (LR,LA) Critical Values
Augmented Dickey Fuller Tests

	Trend, Constant Break		Constant Break Only	
Break Date	95% C.L.	90% C.L	95% C.L.	90% C.L.
1963:04	-4.061	-3.761	-3.272	-2.950
1969:03	-4.061	-3.761	-3.352	-3.033
1973:01	-4.191	-3.879	-3.352	-3.038
1979:04	-4.075	-3.750	-3.326	-3.001
1984:04	-3.919	-3.578	-3.237	-2.899
1986:03	-3.795	-3.497	-3.151	-2.814

C.L.: Confidence level
PR,PA: Pre-adjusted, random-walk, autoregressive
LR, LA: Location adjusted, random-walk, autoregressive

F Statistic, Break in Trend and Constant, Log Per Capita Savings

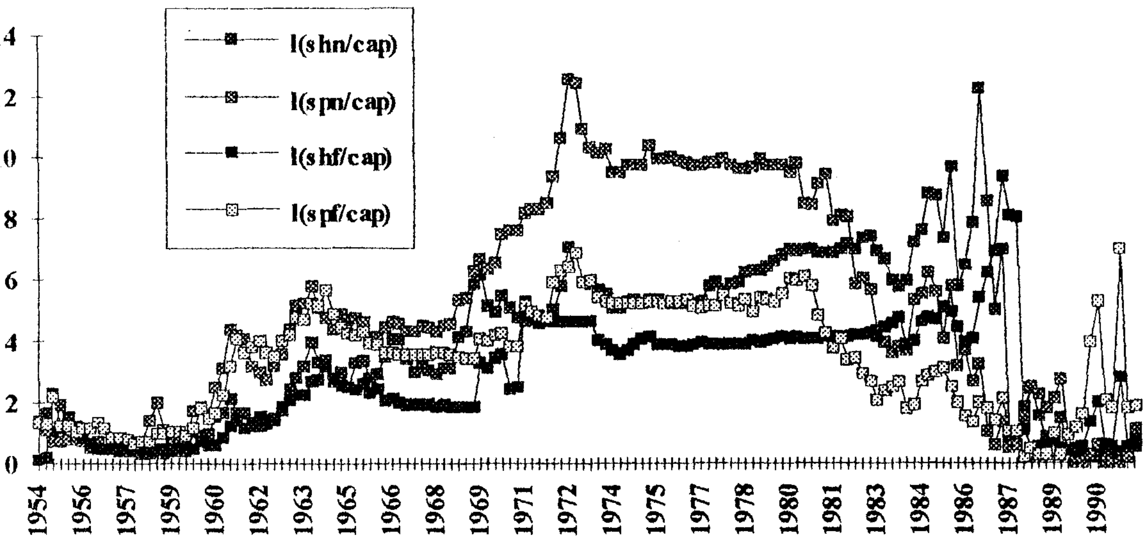

Figure 1

F-Statistics, Constant and Trend Break, Per Capita Savings

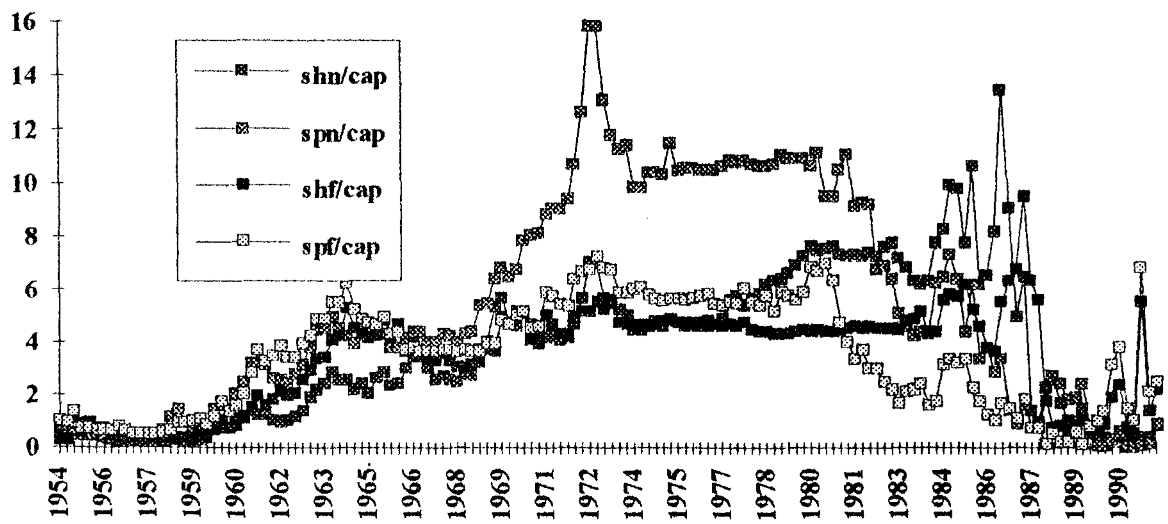

Figure 2

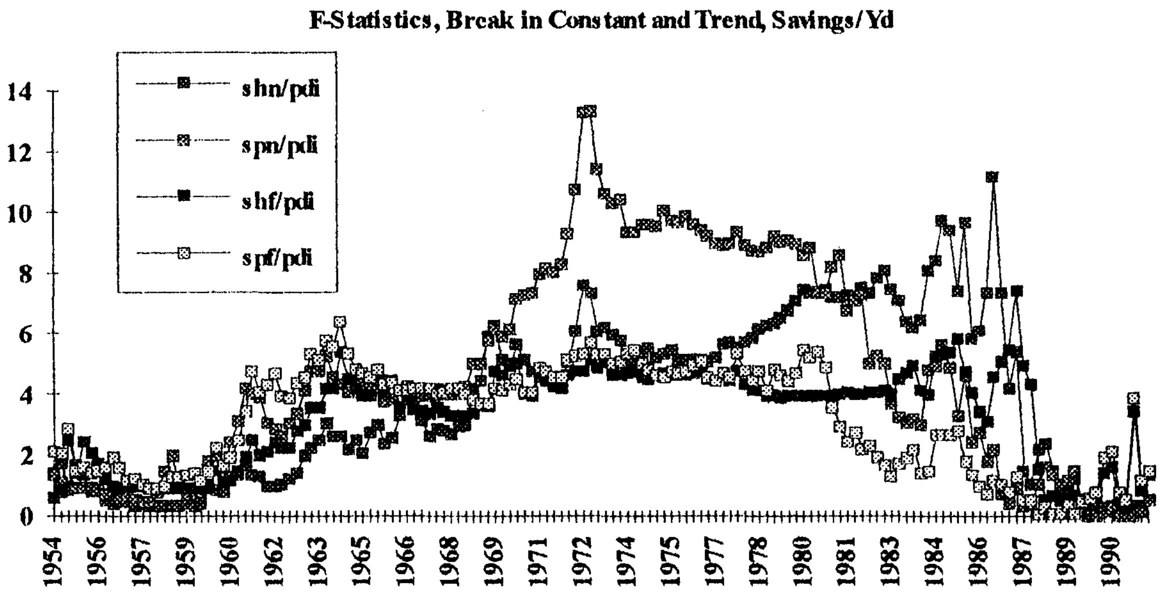

Figure 3

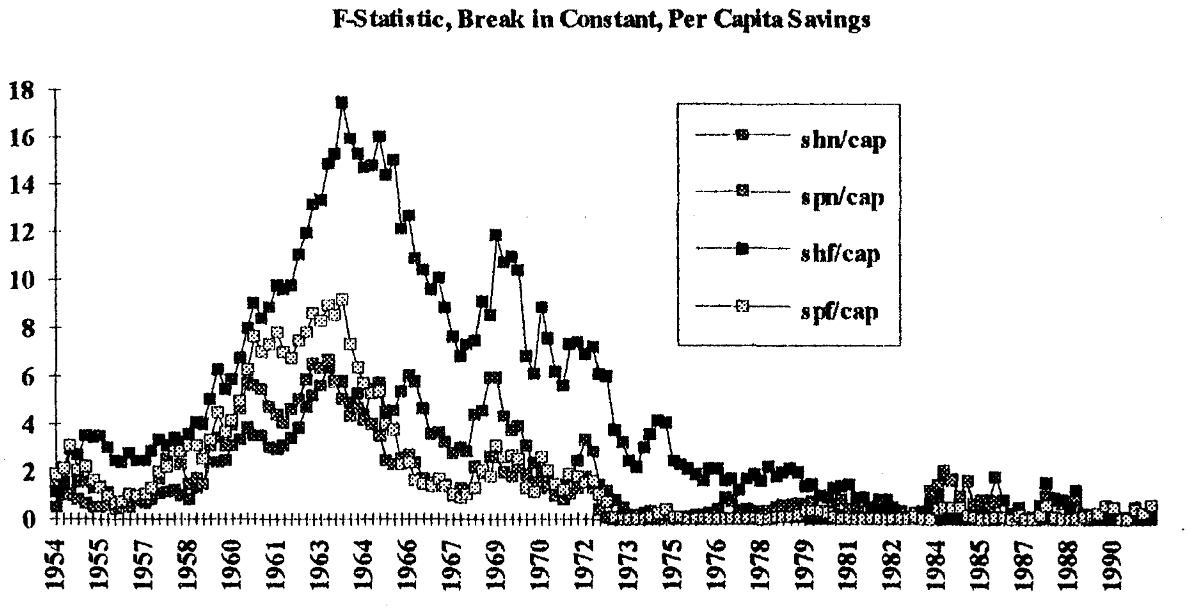

Figure 4

F-Statistic, Break in Constant, Savings/Yd

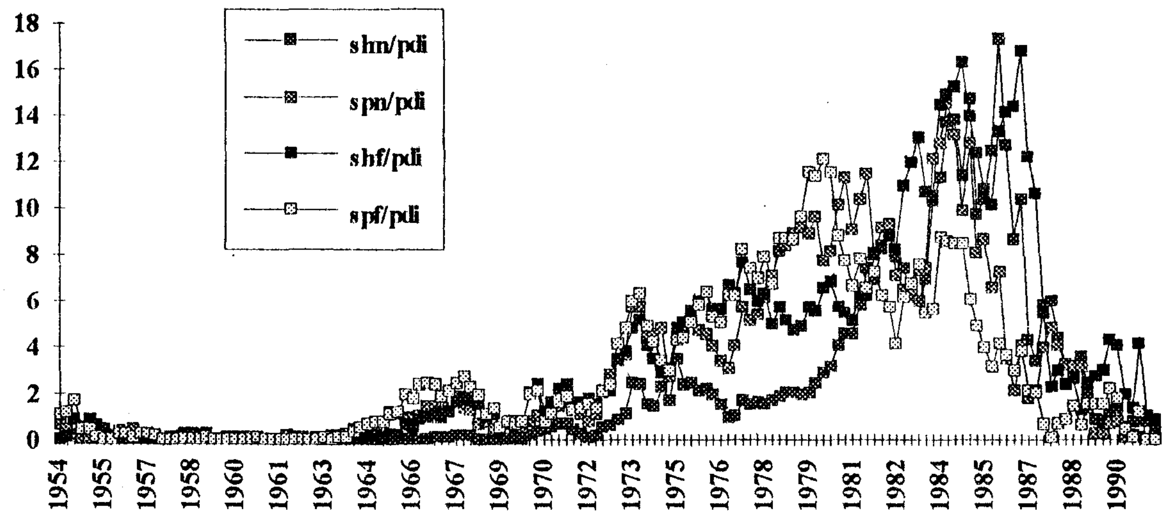

Figure 5