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ABSTRACT

This paper investigates the long-run demand for M1 in the postwar United States. Previous studies, based on data ending in the late 1980's, are inconclusive about the parameters of postwar money demand. This paper obtains precise estimates of these parameters by extending the data through 1996. The income elasticity of money demand is approximately 0.5, and the interest semi-elasticity is approximately -0.05. These parameters are significantly smaller in absolute value than the corresponding parameters for the prewar period.

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I. INTRODUCTION

This paper investigates the long-run demand for M1 in the postwar United States. Previous researchers, such as Lucas (1988) and Stock and Watson (1993), find that postwar data are inconclusive about the parameters of money demand. In contrast, this study yields fairly precise estimates. The long-run income elasticity of money demand is approximately 0.5, and the interest semi-elasticity is approximately -0.05.

The econometric methods in this paper are similar to the ones in previous studies. The results are different for a simple reason: the data extend longer. While previous work examines data ending in the late 1980s, this study uses data through 1996. It turns out that the data since the late 80s are very informative about money demand.[1]

Figure 1 shows why the recent data are important. The Figure plots the log of real output and a smoothed series for the interest rate on commercial paper produced with the Kalman filter. Through the early 1980s, output and the interest rate follow similar upward trends, and so it is difficult to separate their effects on money demand. In other words, there is a collinearity problem. The problem diminishes after the early 80s, because output continues to

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[1] Like this paper, Baba, Hendry, and Starr (1992) report an income elasticity near 0.5. Their estimate is based on a sample ending in 1988, only a year after Stock and Watson's sample. Baba et al.'s results differ from Lucas's and Stock and Watson's because of differences in econometric methodology. For a critique of Baba et al., see Hess, Jones, and Porter (1994).

trend up but the interest-rate trend shifts down. The data through 1996 cover more experience with independent movements in output and interest rates than do the data in previous studies, which include only a few years since the early 80s.

In addition to examining the postwar period, this paper considers the behavior of money demand over the entire 20th century. A number of authors argue that long-run money demand is stable over this period (Lucas; Poole, 1988; Stock and Watson; Christ, 1993). For example, Stock and Watson conclude that "the evidence [for 1900-1987] is consistent with there being a single stable long-run demand for money, with an income elasticity near one and an interest semi-elasticity near -0.10." This conclusion is valid given the data used in previous work: the prewar data suggest such a function, and the imprecision of postwar estimates means the function cannot be rejected for that period. When the data are extended through 1996, however, the postwar estimates become precise, and both the income and interest-rate coefficients are smaller than the prewar estimates. Thus the data reject stability across the two periods.

Section II of this paper presents estimates of long-run money demand. I replicate Stock and Watson's study and examine the effects of extending the sample. Following Lucas (1988), Section III examines the data informally to provide intuition for the results. Section IV concludes.

II. MONEY-DEMAND ESTIMATES

A. The Approach

This section estimates the parameters of a canonical money-demand function:

$$(1) \qquad m - p = \theta_y y + \theta_r r + \varepsilon ,$$

where m, p, and y are the logs of the money stock, the price level, and real output and r is the level of the nominal interest rate. Following Stock and Watson, money is defined as M1, output is NNP, the price level is the NNP deflator, and the interest rate is the commercial paper rate. Most of the analysis uses annual data on these variables.[2]

The appropriate estimation technique depends on the time-series behavior of real balances, output, and the interest rate. Previous researchers find that these variables are individually integrated of order one and cointegrated, based on standard tests such as the Dickey-Fuller and Johansen tests (e.g. Hoffman and Rasche, 1991; Stock and Watson). Extending the data through 1996 does not change the results of these tests. I therefore assume cointegration throughout this paper.

There are many estimators of cointegrating relations, and Stock and Watson find that postwar money-demand estimates vary widely across them. I therefore examine all eight of the

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[2] Data on money and interest rates for 1947-1996 are from the Federal Reserve Board and Data Resources, Inc. These data are spliced to Stock and Watson's data for 1900-1946. Data on income and prices for 1959-1996 are from the Bureau of Economic Analysis, and are spliced to Stock and Watson's data for 1900-1958.

techniques used by Stock and Watson. These techniques are ordinary least squares, the non-linear least squares estimator of Baba, Hendry, and Starr (1992), Stock and Watson's dynamic OLS and dynamic GLS estimators, the estimators of Phillips (1991) and Phillips and Hansen (1990), and Johansen's (1988) estimator with two and three lags. In addition, I use two versions of the commercial-paper rate: the raw series, and the series smoothed with the Kalman filter. All details of the procedures, such as the choices of various lag lengths, follow Stock and Watson.

B. Estimates for Alternative Postwar Periods

Table I presents money-demand estimates for Stock and Watson's postwar period, which is 1946-1987, and for extensions of this period. The extended period is 1946-1996 for some estimators and 1946-94 for others, which require two leads of the data. The table reports coefficients and asymptotic standard errors for the eight estimators (except for OLS and NLLS, for which standard errors are unknown).

My results for 1946-87 are similar to Stock and Watson's results for that period. (Small differences are explained by data revisions.) As discussed by Stock and Watson, and also by Hoffman, Rasche, and Tieslau (1995), the income and interest-rate coefficients vary widely across estimators. In addition, the standard errors are usually large. (The standard errors are small for the Phillips and Phillips-Hansen estimators, but Stock and Watson show that these numbers greatly understate the finite-sample uncertainty.) Overall, we learn little from the data; for example, an income coefficient of one is accepted for several estimators, but so is a coefficient of zero. Figure 2A illustrates the uncertainty by plotting 95% confidence ellipses for various estimators.

The results are quite different when the sample is extended to 1994 or 1996. In these cases, the point estimates are clustered near 0.5 for the income coefficient and -0.05 for the interest-rate coefficient. As shown in Figure 2B, the estimates are fairly precise, and confidence ellipses bound the coefficients far from 1.0 and -0.1, the values suggested by Stock and Watson for the twentieth century. For the DOLS estimator, for example, the income coefficient is about eight standard errors below one and the interest-rate coefficient is about six standard errors above -0.1. The χ^2 statistic for the joint hypothesis that the coefficients are 1.0 and -0.1 is 66.8 (p-value $< 10^{-14}$).

C. Monte Carlo Results

Asymptotic confidence ellipses can greatly overstate the precision of estimates in finite samples. I perform Monte Carlo experiments to see how serious this problem is in my application. I focus on the question of how confidently one can reject money-demand coefficients of 1.0 and -0.1. The basic strategy is to determine how often tests of true hypotheses produce t and χ^2 statistics of the sizes reported above -- in other words, to calculate correct p-values for these statistics.

Following Stock and Watson's Monte Carlo experiments, I generate pseudo-data that mimic the dynamics of the true data for

1946-1994. Specifically, I set the long-run money demand coefficients equal to the DOLS estimates; after imposing these coefficients, I estimate the short-run dynamics of real balances, output, and the interest rate with a VECM(2). I generate 49 observations of pseudo-data by feeding Gaussian errors into the estimated VECM(2). For these observations, I calculate t and χ^2 statistics for the hypotheses that the long-run coefficients equal the values used to generate the data, using each of the estimation techniques in Table I. I replicate this procedure 10,000 times to derive distributions of the t and χ^2 statistics.[3]

The results confirm the rejections of money-demand coefficients of 1.0 and -0.1. For the DOLS estimator, for example, the t-statistics reported above are 7.9 for θ_y=1.0 and 5.7 for θ_r=-0.1. The Monte Carlo p-values -- the fractions of simulated t-statistics that exceed 7.9 or 5.7 -- are 0.001 and 0.02. The χ^2 statistic of 66.8 for the joint hypothesis has a Monte Carlo p-value of 0.004. These p-values are orders of magnitude larger than the asymptotic p-values, but they are small enough to produce strong rejections. The Monte Carlo p-values are even smaller for most of the other estimators than for DOLS.

D. Pre-war vs. Post-war Estimates

As discussed in the introduction, several authors argue that long-run money demand is stable across broad parts of the twentieth

[3] I have also performed Monte Carlo experiments with pseudo-data based on the true data for 1900-1994 rather than 1946-1994. The results are similar to the ones reported in the text.

century. Lucas, for example, finds stability across 1900-57 and 1958-85, and Stock and Watson find stability across 1903-45 and 1946-87. Like the postwar parameter estimates, these results are sensitive to the endpoint of the data. I document this using the stability test that Stock and Watson construct from their DOLS estimator. This procedure tests for the stability of the cointegrating relation under the assumption of constant short-run dynamics. I also consider a variation in which the parameters describing these dynamics are allowed to shift, which seems appropriate given the well-documented instability of short-run money demand.[4]

The first three columns of Table II contain DOLS estimates of money demand for 1903-45, 1946-87, and 1903-87, and the associated stability tests. The coefficients on output and the interest rate are close to 1.0 and -0.1 for the first subsample and the combined sample. The estimates for the second subsample are smaller in absolute value, but they are imprecise, as discussed above. Consequently, there is little evidence that the coefficients shift: none of the stability tests rejects at the ten percent level.

Once again, the results are very different when the sample is extended to 1994. The parameter estimates for the full sample change only moderately. However, the small and precise estimates for the postwar period produce strong evidence against stability.

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[4] Lucas argues that one should not assume stable short-run dynamics in testing for stability of long-run money demand. In his words, "one needs a maintained hypothesis in which one has more, not less, confidence than one has in the hypothesis being tested" (1988, p. 162).

Under the assumption of constant short-run dynamics, stability is rejected at the five percent level when the unsmoothed interest rate is used. When the short-run assumption is relaxed, stability is rejected at the one percent level for both the smoothed and unsmoothed interest rates.

E. Quarterly Data

As a final robustness check, I estimate the postwar money demand function using quarterly rather than annual data. Hoffman et al. examine quarterly data and, like Lucas and Stock-Watson, they cannot disentangle the effects of interest rates and output. Once again, this problem disappears when the data are extended. For example, DOLS for 1948:2-1995:4 produces an income coefficient of 0.430 (s.e.=0.060) and an interest-rate coefficient of -0.041 (s.e.=0.009). These results, and those for other estimators, are close to the results for annual data.[5]

III. INTERPRETATION

A. Examining the Data

If one has not seen the data, it might be surprising that money-demand estimates change dramatically when the sample is extended by nine years. However, Figure 1 in the introduction shows why the data since 1987 are so important. When these years are included, we can compare the pre-1982 period, when interest rates and output trended together, to a substantial post-82 period

[5] The quarterly DOLS regressions use four leads and lags of the data; an AR(4) error was used to compute the standard errors.

when they moved in opposite directions. This allows us to disentangle the effects of the two variables on money demand.

We can learn more from Figure 3, which shows the smoothed interest rate and the log of the income velocity of money. Through the early 1980s, velocity followed an upward trend, which means that money grew less quickly than income. By itself, this fact suggests that the income elasticity of money demand is less than one. Lucas, however, offers a different interpretation: velocity rose because interest rates have strong effects on money demand, and interest rates rose through the early 80s. If one imposes a unit income elasticity, an interest semi-elasticity near -0.1 can explain the velocity trend. Lucas acknowledges, however, that the data can also be explained by a combination of a smaller income coefficient and a smaller interest coefficient.

The data since the early 80s rule out Lucas's preferred story in favor of the one with lower coefficients. If the interest-rate coefficient were large, so rising interest rates caused the rise in velocity through 1981, the fall in interest rates after then should have caused a fall in velocity. In fact, velocity has been roughly trendless since the early 80s. By the mid-1990s, interest rates fell to the same level as in the late 1960s, but velocity was much higher than in that period. Since the rise in velocity since the 60s cannot be explained by interest rates, it implies an income elasticity below one.

Figure 4 makes these points a different way. Panel A is a scatterplot (similar to one in Lucas) of the log of velocity against the smoothed interest rate. Through 1987, there is a close linear relation, suggesting a stable money-demand function with a unit income elasticity. The relation breaks down after 1987, however. Note that 1987 is the last year in Stock and Watson's sample.

The breakdown in the velocity / interest rate relation does not imply that the money demand function shifted in 1987. It simply means that a stable function must have an income elasticity different from one. In general, the money demand function implies a linear relation between the interest rate and "quasi-velocity," defined as $\theta_y y-(m-p)$. Figure 4B plots the smoothed interest rate against quasi-velocity, with θ_y set at the DOLS estimate of 0.423. This relation is stable throughout the postwar period.

B. An Alternative Interpretation

The analysis so far, like the recent literature, rests on the assumption that equation (1) is the correct money-demand function -- and in particular, the implicit assumption that the function does not include a time trend. It is not clear that this restriction is reasonable. For given output and interest rates, money demand can change over time if there are changes in the economy's transaction technology. And the postwar era has seen a series of changes that allow individuals to reduce their holdings of M1, such as the creation of near-monies. It is therefore plausible that money demand has trended downward.[6]

This possibility suggests yet another interpretation of the velocity movements in Figure 3. The rise in velocity for given interest rates may reflect a downward trend in money demand rather than an income elasticity below one. In principle, one can test this idea by including a trend in the estimated money-demand function. But in practice, a trend is highly collinear with income, so one cannot disentangle their effects. A trend in the transaction technology and a low income elasticity are near-observationally-equivalent interpretations of the data.

Table III illustrates this problem with several DOLS regressions for 1946-94. In the first column of the table, a time trend is added to the basic money demand equation, with inconclusive results: neither income nor the trend is significant, because the standard errors are large. The second column repeats a regression from earlier in the paper: it imposes a zero trend to obtain a precise estimate of the income coefficient. The final column uses a different indentifying assumption: it restricts the income coefficient to one, and obtains a precisely estimated trend of -1.6% per year. In all specifications, the interest-rate coefficient is close to -0.04 or -0.05.

Is there any way to separate the effects of income and

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[6] If shifts in the transaction technology cause random-walk movements in money demand, then real balances are not cointegrated with output and interest rates. In principle, such shifts are ruled out by the common empirical finding of cointegration. This finding does not, however, rule out money-demand shifts that are well-approximated by a deterministic trend.

technological change? One possibility is to examine cross-sectional variation in money demand, such as variation across U.S. states or across firms and households (Mulligan and Sala-i-Martin, 1992; Mulligan, 1997). With cross-section data, one can estimate the income elasticity of money demand at a fixed level of technology. Then this estimate can be combined with the time-series trend in velocity to determine the trend in the money-demand function.

IV. CONCLUSION

This paper examines postwar money demand using the same methods as previous papers, but extends the sample through 1996. This extension has major effects on the results. Previous researchers express uncertainty about postwar money demand, but suggest an income elasticity near 1.0 and an interest semi-elasticity near -0.1. My estimates of these parameters are about 0.5 and -0.05. These estimates are significantly smaller in absolute value than the corresponding estimates for the prewar period.

A caveat is that my estimates depend on the questionable assumption that the money-demand function does not contain a trend. Future work should try to relax this assumption by combining cross-section and time-series data.

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Table I
Money Demand Estimates

	r=Commercial Paper Rate				r=Smoothed Commercial Paper Rate			
	1946-1987		1946-1996*		1946-1987		1946-1996*	
Estimator	θ_y	θ_r	θ_y	θ_r	θ_y	θ_r	θ_y	θ_r
SOLS	0.1796	-0.0144	0.3691	-0.0320	0.3913	-0.0452	0.5018	-0.0599
NLLS	-0.4463	0.0868	0.5911	-0.1484	0.3695	-0.0355	0.4120	-0.0460
DOLS	0.2732	-0.0277	0.4268	-0.0449	0.3972	-0.0465	0.4229	-0.0492
	(0.1894)	(0.0230)	(0.0722)	(0.0097)	(0.3150)	(0.0432)	(0.0803)	(0.0119)
DGLS	0.7757	-0.0179	0.4469	-0.0405	0.8609	-0.0915	0.5166	-0.0581
	(0.3177)	(0.0097)	(0.0628)	(0.0087)	(0.1147)	(0.0141)	(0.0658)	(0.0094)
Phillips	0.2092	-0.0192	0.4251	-0.0435	0.3584	-0.0417	0.4958	-0.0590
	(0.0834)	(0.0098)	(0.0492)	(0.0072)	(0.1460)	(0.0194)	(0.0442)	(0.0072)
Phillips-Hansen	0.1913	-0.0166	0.4041	-0.0401	0.3796	-0.0445	0.4888	-0.0593
	(0.0489)	(0.0055)	(0.0404)	(0.0056)	(0.0964)	(0.0132)	(0.0345)	(0.0058)
Joh.(2)	2.1575	-0.2954	0.4386	-0.0516	-2.6020	0.3856	0.4248	-0.0498
	(6.5800)	(0.9248)	(0.0666)	(0.0102)	(6.1784)	(0.8918)	(0.0631)	(0.0097)
Joh.(3)	-3.0986	0.4719	0.4435	-0.0492	-0.7227	0.1215	0.4639	-0.0545
	(13.754)	(2.0472)	(0.0508)	(0.0076)	(0.9170)	(0.1363)	(0.0578)	(0.0089)

* 1946-1994 for DOLS and DGLS.

Table II
Pre-war vs. Post-war Estimates
(DOLS)

r=Commercial Paper Rate

	1903-1945	1946-1987	1903-1987	1946-1994	1903-1994
θ_y	0.8871 (0.1966)	0.2732 (0.1894)	1.0514 (0.1604)	0.4268 (0.0722)	1.0531 (0.1383)
θ_r	-0.1060 (0.0391)	-0.0277 (0.0230)	-0.0916 (0.0344)	-0.0449 (0.0097)	-0.0910 (0.0297)
χ^2 for subsample stability (assumes constant SR dynamics)			1.894 (p=.39)		7.157 (p=.03)
χ^2 for subsample stability (allows different SR dynamics)			4.019 (p=.13)		9.1490 (p=.01)

r=Smoothed Commercial Paper Rate

	1903-1945	1946-1987	1903-1987	1946-1994	1903-1994
θ_y	0.8570 (0.0737)	0.3972 (0.3150)	0.9452 (0.1776)	0.4229 (0.0803)	0.9512 (0.1539)
θ_r	-0.1340 (0.0175)	-0.0465 (0.0432)	-0.1208 (0.0431)	-0.0492 (0.0119)	-0.1195 (0.0373)
χ^2 for subsample stability (assumes constant SR dynamics)			0.285 (p=.87)		1.637 (p=.44)
χ^2 for subsample stability (allows different SR dynamics)			3.489 (p=.18)		18.761 (p=.00)

Table III
Estimates with a Time Trend
(DOLS, 1946-1994)

Restriction:	None	No Trend	θ_y=1
θ_y	-0.0051 (0.4575)	0.4268 (0.0722)	1.0
θ_r	-0.0401 (0.0105)	-0.0449 (0.0097)	-0.0537 (0.0110)
Trend	0.0121 (0.0127)	0.0	-0.0157 (0.0023)

Figure 1
Output and the Interest Rate

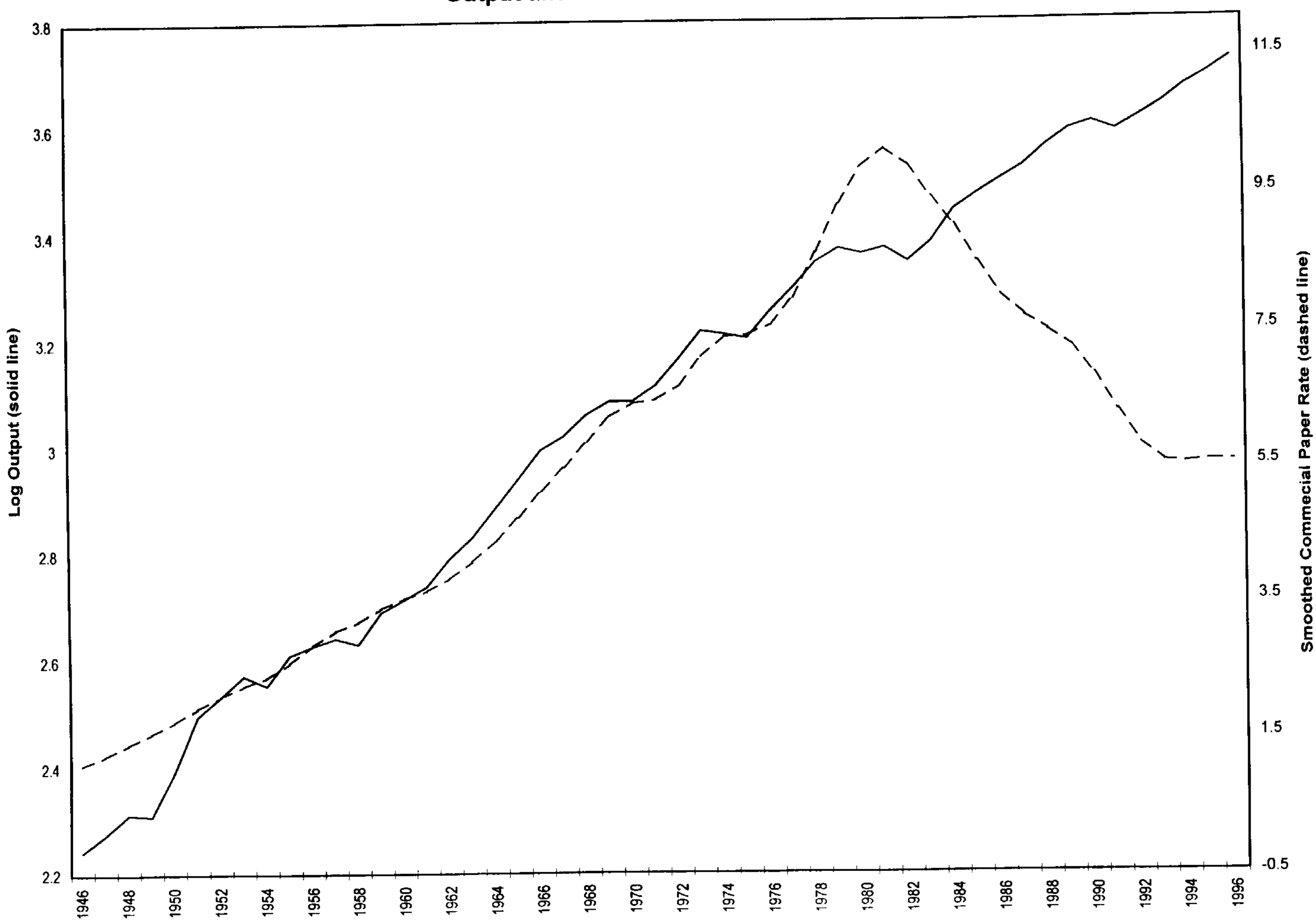
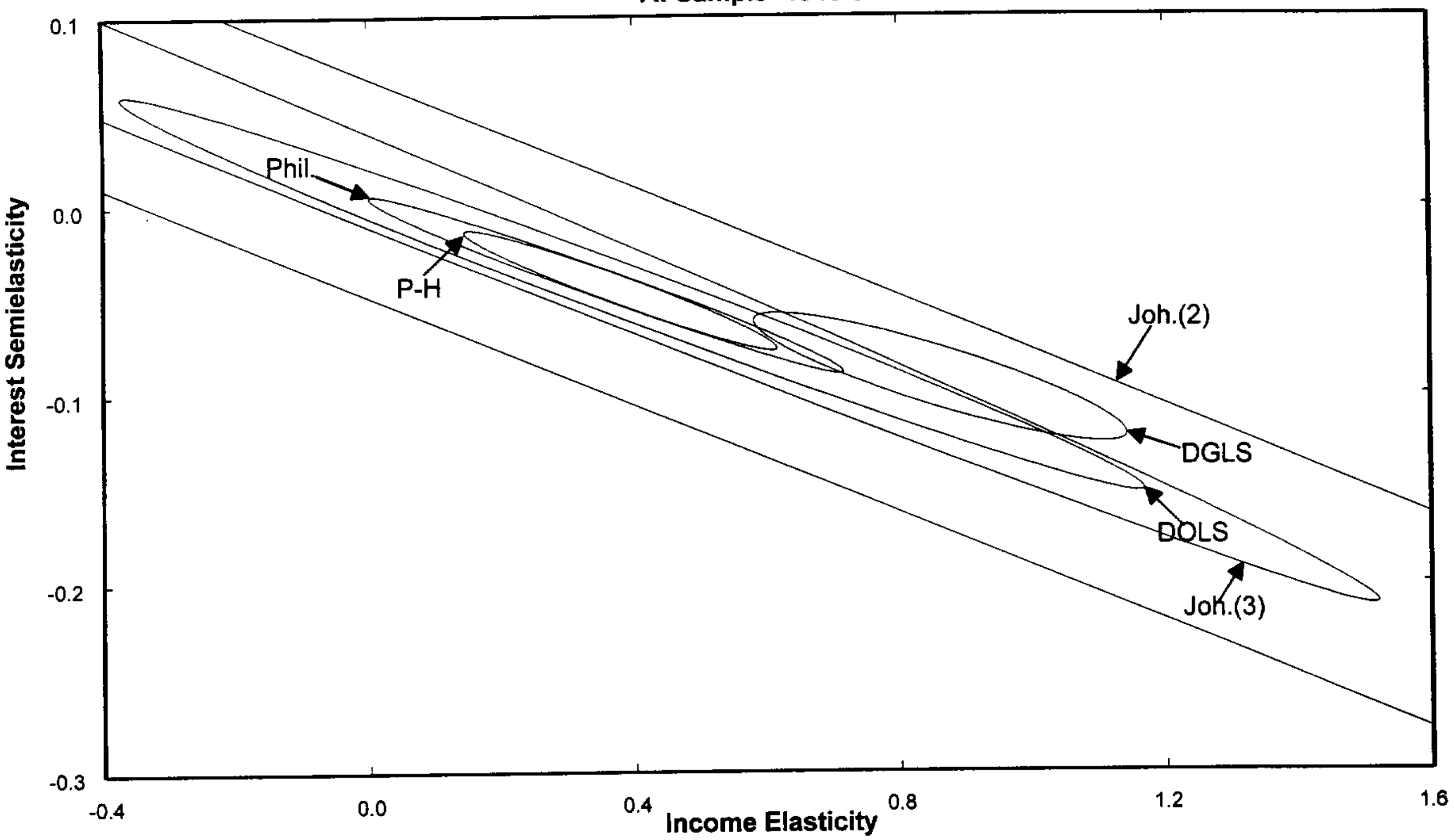


Figure 2
95% Confidence Ellipses for θ_y and θ_r

A: Sample=1946-87



B: Sample=1946-96

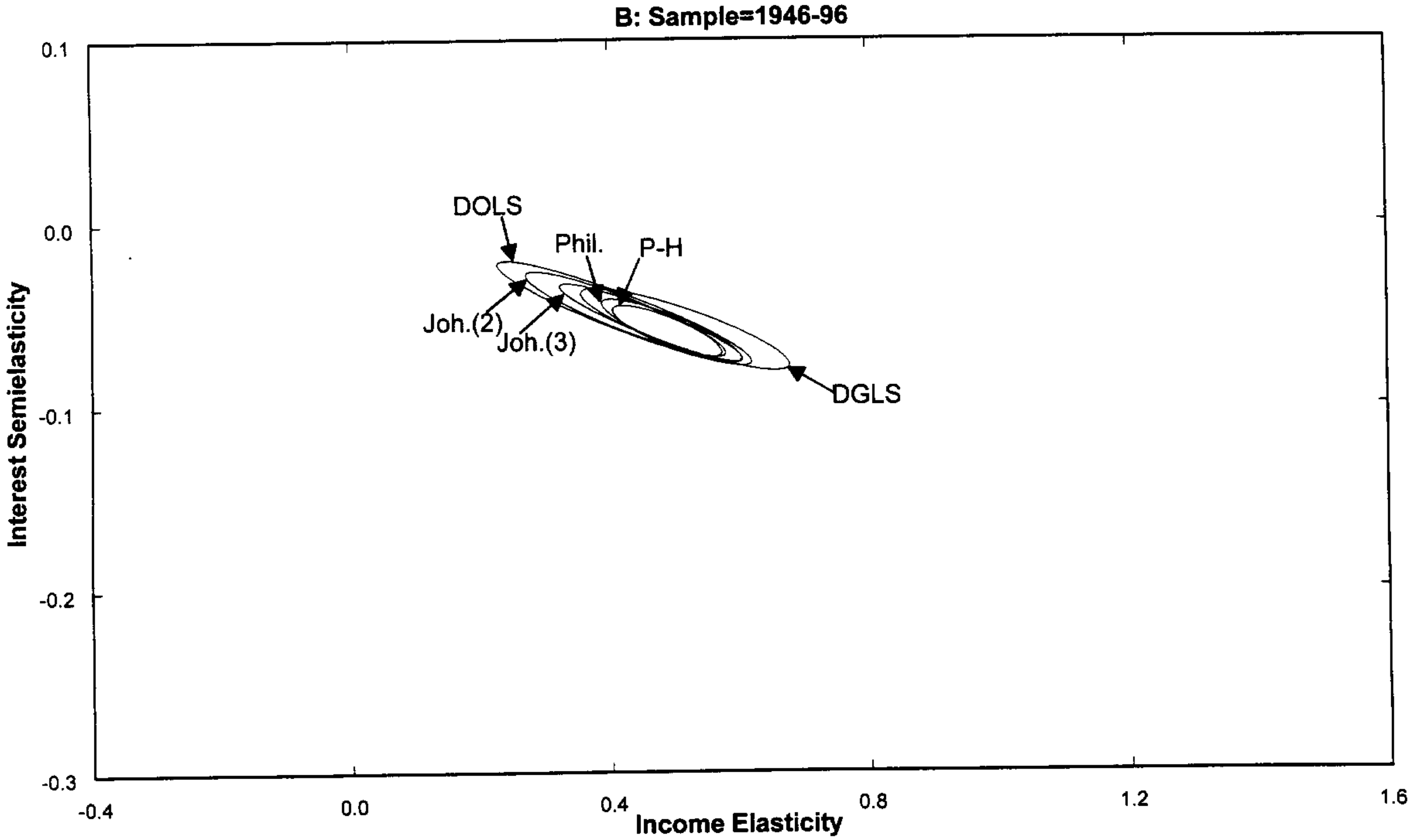


Figure 3
Velocity and the Interest Rate

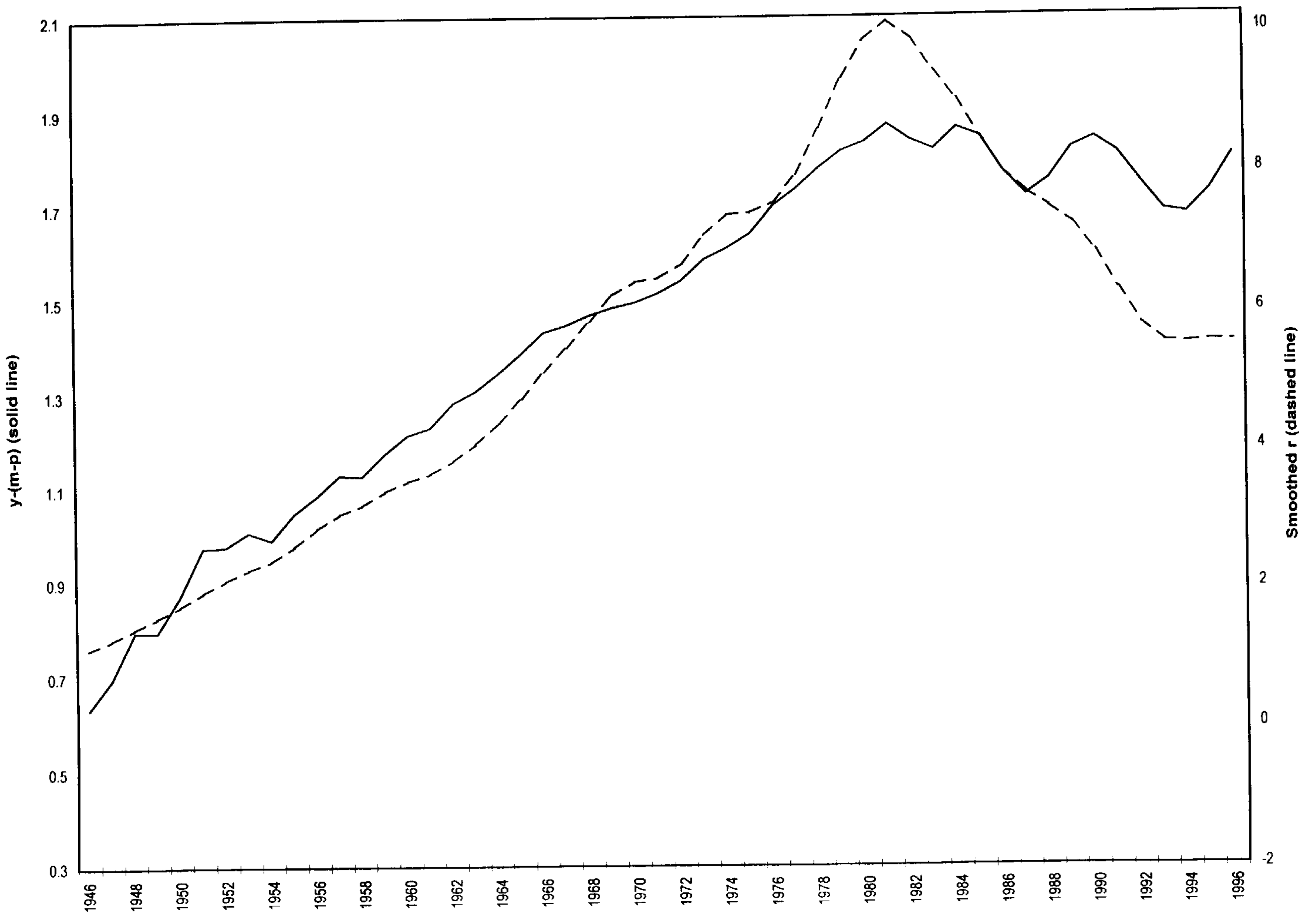


Figure 4A
Velocity and the Interest Rate

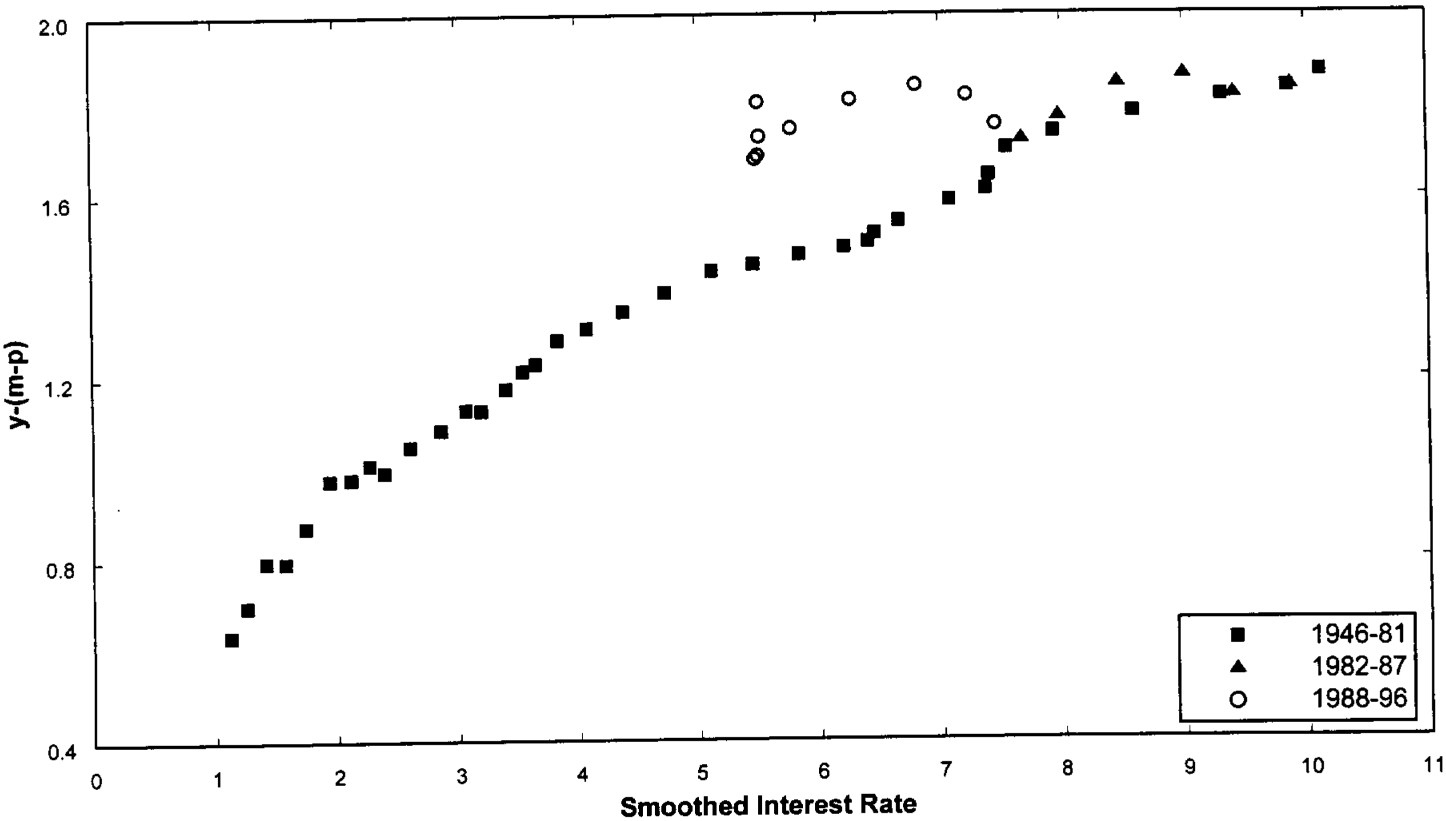


Figure 4B
Quasi-Velocity and the Interest Rate