THE AUSTRALIAN DEMAND FUNCTION FOR MONEY: ANOTHER LOOK AT STABILITY

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ABSTRACT

Opinion on the stability or otherwise of the demand for money in Australia can be characterised as divided. In this paper, several conventional single-equation models representing the demand for money are re-estimated with extended and revised data sets, and subjected to a range of stability tests. Some attention is paid to the possibility of heteroskedasticity in the residuals, which is important in the context of stability tests. Apart from testing for stability in a general sense, particular emphasis is given to the first half of the 1980's, where wide-ranging financing deregulation might be expected to affect relationships between the money stock, income and interest rates.

The conclusion is that it is difficult to accept the proposition that the conventional equations have not been subject to instability. This is particularly so for M3; the evidence is more mixed in the case of M1.

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PREFACE

This paper is part of a larger stream of research on monetary issues being conducted at the Reserve Bank. In that stream, it fits between two other papers. Earlier work by John Veale, Lindsay Boulton and Warren Tease re-estimated some standard demand for money equations, and looked at their performance, with particular interest in 1985. This was in order to focus on what was a particularly difficult policy problem at the time, namely the appropriateness of M3, and of monetary aggregates more generally, as monetary indicators. Stability of the equations was not tested in a formal sense.

A forthcoming paper by Adrian Blundell-Wignall and Susan Thorp will address the question of stability for broad money in a formal manner, in the context of a more general treatment of own-interest rate effects on money demand. It is some time since a study formally addressed the stability of existing demand functions for the narrower aggregates in Australia. This paper is aimed at filling that gap.

Glenn Stevens
February 1987

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1. Introduction

Milton Friedman's assertion that the demand for money is "a stable function of a few arguments" has arguably been one of the more influential statements made in macroeconomics. By the late 1970s, there were not too many industrial countries that did not adopt some sort of target or projection for growth in the money stock.

Yet at the very time this was taking place, the stability of "the" demand function for money went from being an accepted (and apparently empirically-documented) article of faith in many circles, to being seriously questioned. This was particularly so in the United States in the wake of the "missing money" episode beginning in 1974, but was not exclusive to that country. (See for example, Judd and Scadding (1982), Boughton (1980), and Atkinson _et_. _al_. (1984).)

In Australia, evidence on the stability or otherwise of the demand for money has been mixed. For M3,[1] Juttner and Tuckwell (1973) concluded in favour of stability, but Sharpe and Volker (1977), using essentially the same model but different techniques for testing stability, found that the equation was only stable when institutional changes were appropriately treated. The assessment of Davis and Lewis (1978), on the other hand, was that the need to incorporate extra variables to improve goodness of fit, the existence of large prediction errors from around 1972, and variation in the estimated co-efficient on the lagged dependent variable as new observations were added, constituted evidence that the instability that characterised demand functions for money overseas also operated in Australia.

In the case of M1[2] there has been a difference of opinion as well, with Adams and Porter (1976) arguing that the demand for money is unstable, while Pagan and Volker (1980, 1981), respecifying the Adams and Porter model, concluded that there was no convincing evidence of instability.

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1. Defined as currency and all deposits at banks held by the non-bank public.

2. Defined as currency and current accounts at banks held by the non-bank public.

It is now some years since those studies were completed. Given the far-reaching change in the Australian economy generally and the financial system in particular in the last five to ten years, it is natural to ask what results still hold.

Recently, work by Drane, Marzouk and Valentine (1984), and Freeland (1984) has concluded, the latter somewhat tentatively, in favour of stability. This paper attempts to provide systematic evidence on this question. It does so by updating some existing studies of the demand for money and then subjecting them to accepted tests for stability, with particular attention paid to the early 1980's and to an important technical issue for the test procedures. In so doing, it seeks to go further than earlier work of Veale _et_. _al_. (1985), where stability was not formally tested.

The models considered are those of Sharpe and Volker (1977), Pagan and Volker (1981), Porter (1979) and Freeland (1984). The predominant monetary aggregate of interest in the paper is M3, although M1 is the subject of the Pagan and Volker work. This is defensible since M3 was arguably the central indicator of monetary policy for many years, at least in public debate. For example, from early 1976 until early 1985, the Australian Government maintained a conditional projection for M3 on an annual basis.

There are couple of important omissions in this approach. Firstly, the debate about stability of the demand for money might usefully be expanded to consider broad money,[3] which is now accorded considerable attention in the assessment of financial conditions and monetary policy. To date this has been done only to a limited extent (see Drane, Marzouk and Valentine (1985), and Veale _et_. _al_. (1985)). This question is not addressed formally here; forthcoming work involving one of the authors will take up the stability of broad money further.

Secondly, it is noteworthy that the studies of concern here, in following a conventional pattern of single-equation estimation, diverge from another modelling tradition in the Australian literature, and one which has been particularly important in previous work at the Reserve Bank. The role of money as a buffer stock, and the explicit modelling of the effects of monetary disequilibrium on the course of other macroeconomic variables was discussed theoretically by Jonson (1976), and developed empirically in several generations of the simultaneously-estimated system first described by Jonson,

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3. Defined as deposits of the public with bank and non-bank institutions and public holdings of currency.

Moses and Wymer (1976). This latter approach potentially allows for a richer expression of the interaction between the observed money stock, interest rates and income than can be captured in a single equation.

The scope of this study is therefore necessarily limited. But it is of interest to systematically address the question of stability using single equations, if only because claims about stability or instability have been made based on such equations.

The procedure adopted is to reproduce, as closely as possible, the estimation results of the original study in the original sample period.[4] Then the equation in question is tested for stability, both within the original sample period and over a longer sample which is extended in most cases up to the end of 1985.

2. The Models

The models of interest here are fairly conventional. In common with much of the overseas literature, they are developed in something like the following way.

Let the desired stock of money be denoted by

$$(1) \qquad (m_t - p_t)^* = \beta_0 + \beta_1 y_t + \beta_2 r_t$$

where y_t is real income, r_t is the rate of interest, all variables are in logs,[5] and the expected signs on parameters are $\beta_1 > 0$, $\beta_2 < 0$.
Then let the actual stock of real balances held adjust towards the desired stock according to

$$(2) \qquad (m_t - p_t) - (m_{t-1} - p_{t-1}) = \gamma[(m_t - p_t)^* - (m_{t-1} - p_{t-1})].$$

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4. It has been pointed out to us that an alternative approach might be to use the equation with the "best fit". However, our objective was to test equations which had already been put forward as models of the demand for money. It seemed no less aribtrary to try to reproduce the original result and then test that than to search the data for some "best" alternative, which could not really be attributed to the original authors.

5. It is not uncommon for the interest rate to enter in actual rather than logarithmic form.

Straightforward substitution of (1) into (2) gives (3), the so-called "Koyck-lag" specification:

$$(3) \qquad m_t - p_t = \alpha_0 + \alpha_1 y_t + \alpha_2 r_t + \alpha_3(m_{t-1} - p_{t-1})$$

where $\quad \alpha_i = \gamma\beta_i \;$ for $i = 0, 1, 2$

and $\quad \alpha_3 = 1-\gamma.$

The lagged-adjustment hypothesis is a convenient justification for using equation (3) as an estimating equation, especially since a specification such as (3) normally fits the data much more closely than (1). Two studies considered here - Sharpe and Volker (1977) and Porter (1979) - used models of this type.

Yet equation (3), or at least the empirical versions of it, has not been without its problems in the literature, such as the tendency for the estimated value of γ to approach zero, implying very long lags in adjustment process. Results such as $\hat{\alpha}_3 = 0.9$ (which are not uncommon), imply in a quarterly model that only half of the adjustment towards the desired stock of money has taken place after a year and a half.

An alternative approach recognises the fact that the Koyck specification constrains the speed of adjustment of money demand to changes in different variables on the right hand side to be at the same rate, without actually testing whether this restriction is supported by the data.

A response to this is to propose a more general adjustment process, like that in (4):

$$(4) \qquad (m_t - p_t) - (m_{t-1} - p_{t-1}) = \theta_1(y_t - y_{t-1}) + \theta_2(r_t - r_{t-1}) + \theta_3[(m_{t-1} - p_{t-1})^* - (m_{t-1} - p_{t-1})]$$

This approach - Hendry and Mizon's (1978) "error-correction mechanism" - was adopted for M1 with some success by Pagan and Volker (1980, 1981), with the specification being narrowed down to something like (3), but with a lagged interest rate term added. Of course, this is only one of any number of more general lag specifications which might be employed. Sharpe and Volker (1977) also investigated distributed lag formulations, using the Almon technique.

Table 1
Sharpe and Volker's Equation

	Constant	S1	S2	S3	ln(GDP/P)	lnR2	$\ln(M3/P)_{-1}$	$\bar{R}^2$	$\hat{\rho}$(a)	h
SV-1 Original 52(2)-72(3) ln(M3/P)	0.427 (2.60)	0.022 (2.37)	-0.004 (-0.37)	0.002 (0.40)	0.225 (5.13)	-0.056 (-3.12)	0.756 (13.95)	0.998	0.57	1.53
SV-2 Revised 52(3)-72(3) ln(M3/P)	0.205 (2.239)	-0.027 (-7.140)	-0.0501 (-13.417)	-0.019 (-5.440)	0.1787 (4.009)	-0.072 (-4.833)	0.8187 (15.410)	0.995	0.336	0.203
SV-3 Updated 52(3)-86(1) ln(M3/P)	0.332 (3.257)	-0.019 (-5.133)	-0.045 (-12.35)	-0.012 (-3.421)	0.219 (6.083)	-0.048 (-5.446)	0.76 (16.954)	0.996	0.317	1.002

(a) Sharpe and Volker corrected for first order serial correlation using the Cochrane-Orcutt iterative procedure and the ρ reported. Equations SV-2 and SV-3 were adjusted using a two-step Yule-Walker procedure.

GDP = gross domestic product, seasonally adjusted in current prices

R2 = Yield on two-year rebate Commonwealth Government bonds for equations SV-1 & SV-2. The yield on two-year non-rebate bonds was used from 69(3) for equation SV-3.

P = Consumer Price Index, with base year 1980-81.

Si = seasonal dummy, equal to 1 in quarter i and zero otherwise.

Table 2
Porter's Equation

	Constant	S1	S2	S3	ln(GDP)	lnR2	$\ln(M3/P)_{-1}$	$\bar{R}^2$	h
PO-1 Original 66(3)-79(2) ln(M3/P)	1.46 (2.17)	*	*	*	0.204 (3.70)	-0.073 (-4.40)	0.818 (10.38)	0.976	0.324
PO-2 Revised 66(3)-79(2) ln(M3/P)	0.636 (1.297)	0.004 (0.315)	-0.028 (-2.215)	-0.003 (-0.32)	0.218 (3.95)	-0.06 (-3.60)	0.747 (9.109)	0.959	-0.273
PO-3 Updated 69(3)-86(1) ln(M3/P)	-0.731 (-1.634)	0.002 (0.188)	-0.026 (-2.518)	-0.001 (-0.143)	0.205 (4.234)	-0.057 (-3.94)	0.886 (15.352)	0.958	0.276

GDP = GDP in current prices.

P = implicit deflator for GDP, base year 1974/75.

R2 = yield on two-year non-rebate Commonwealth Government bonds.

* Estimated values for seasonal dummies were not reported by Porter.

Table 3
Freeland's Equation

	Constant	lnGDP	$\ln RGS_{-1}$	$\ln RSSA_{-1}$	$\ln RFD_{-1}$	$\ln(M3/P)_{-1}$	$\bar{R}^2$	h
FR-1 Original 67(3)-83(2) ln(M3/P)	1.0294 (2.85)	0.2292 (4.95)	-0.1101 (-6.08)	0.0242 (2.48)	0.0648 (2.91)	0.6934 (11.46)	0.97	0.37
FR-2 Revised 67(3)-83(2) ln(M3/P)	1.07 (2.92)	0.229 (4.997)	-0.114 (-6.115)	0.025 (2.512)	0.0665 (2.892)	0.6899 (11.545)	0.977	-0.108
FR-3 Updated 67(3)-85(1) ln(M3/P)	0.964 (2.951)	0.226 (5.114)	-0.113 (-6.318)	0.028 (3.454)	0.063 (2.861)	0.703 (12.317)	0.982	0.105

GDP = GDP in current prices.

P = implicit deflator for GDP, base year 1979/80.

RGS = yield on 2 year government securities.

RSSA = interest rate on statement savings accounts

RFD = interest rate on trading bank fixed deposits

Table 4
Pagan and Volker's Equation

	Constant	S1	S2	S3	lnGDP/P	$\ln(M1/P)_{-1}$	RBILL	$RBILL_{-1}$	$\bar{R}^2$	h
PV-1 Original 67(4)-78(2) ln(M1/P)	0.42 (1.01)	0.008 (1.16)	-0.039 (-5.00)	0.44 (6.10)	0.113 (4.96)	0.845 (18.27)	-0.003 (-2.22)	-0.006 (-4.37)	0.94	0.894
PV-2 Revised 67(4)-78(2) ln(M1/P)	0.379 (0.759)	-0.013 (-1.48)	-0.067 (-6.55)	-0.048 (-5.24)	0.127 (4.27)	0.836 (14.74)	-0.003 (-1.71)	-0.007 (-3.54)	0.916	-0.445
PV-3 Updated 67(4)-85(4) ln(M1/P)	0.247 (0.511)	-0.0159 (-2.028)	-0.0682 (-7.87)	-0.094 (-5.81)	0.126 (5.31)	0.848 (16.84)	-0.002 (-0.68)	-0.006 (-3.38)	0.883	-0.34

GDP = GDP in current prices.

P = implicit deflator for GDP, base year 1974/75.

RBILL = yield on 90-day bank-accepted bills of exchange.

Si = seasonal dummy, equal to 1 in quarter i, zero elsewhere.

Attempts to reproduce the results of the studies in question met with varying degrees of success. Equation SV-1 in Table 1 is the equation originally reported in Sharpe and Volker (1977). SV-2 represents our best efforts to reproduce the original parameter estimates, using (as far as possible) the same data. SV-3 is the result of estimation over a revised and extended data set. Analogous notation is used in Tables 2, 3 and 4 for the Porter, Freeland and Pagan and Volker studies.

In most cases, data revisions presented difficulties. This was especially so in the case of equation SV-1 from Sharpe and Volker (1977), where despite considerable effort, a number of parameters in our estimations remained noticeably different to those reported by the original authors. In particular, the first-order autocorrelation parameter reported in the original paper proved quite elusive. Equation SV-2 reported in Table 1 utilises a two-step Yule-Walker procedure available in SAS for correcting for first-order serial correlation. Although Sharpe and Volker used an iterative Cochrane-Orcutt technique, we have reported (and used) equation SV-2 because the slope parameters were closer to those in the original paper than were those in our attempts to reproduce the Cochrane-Orcutt specification. (The biggest differences occur in the coefficients on the seasonal dummies.) Our specification is further defensible because it is not apparently troubled by auto-correlation after the Yule-Walker procedure is applied, whereas the equation reported by Sharpe and Volker is suspect in this regard, even after using the Cochrane-Orcutt procedure.[6]

In fact the latter problem was behind Sharpe and Volker's decision not to use this equation for stability tests, since auto-correlation would upset the tests based on cumulative sums of recursive residuals. They go on to estimate alternative models, with the preferred ones being distributed-lag formulations.

These equations, shown as equations SV-4 and SV-6 in Tables A.1 and A.2 in the Appendix, proved no easier to re-produce. For computational reasons, it was not possible to apply stability tests to them. The results reported in Section 4 below relate to equations SV-2 and SV-3.

6. An additional difference between Sharpe and Volker's equation and ours is our use of GDP as the income variable whereas their data appendix indicates that they used GNE. Again, our choice is generated by what gives the closest parameter estimates to those they originally reported.

Porter (1979) uses a similar specification to equation SV-1, although over a shorter and later sample period. The original results and our updates are shown in Table 2. The estimation period was originally 1966(3)-1979(2), and over this period our regressions provided parameter estimates fairly close to those in the the original paper. When updating the equation to 1986(1), consistent data could be used only back to 1969(3), due to the change in the base period for quarterly national accounts data introduced in 1982 - hence the different starting date for equation PO-2. The altered sample period has the effect of lowering slightly the short run income and interest elasticities, and slowing the implied speed of adjustment. The median lag is six quarters, compared to four quarters in the original results.

Freeland's (1984) preferred equation can best be seen as a distributed lag specification with the lag structure reduced through some (unspecified) procedure so as to include only the first lag of the three interest rates. It is shown as equation FR-1 in Table 3. Perhaps because of the recency of this study, it proved easier to reproduce, with the parameters altering only very slightly.

Pagan and Volker's (1981) preferred equation, using a more general lag formulation, is shown as equation PV-1 in Table 4. We were able to reproduce it satisfactorily. The income and interest elasticities are similar and the speed of adjustment is little changed, with the average lag remaining at four quarters.

3. Testing for Stability: Some Issues

Perhaps the most commonly-employed test for parameter variation within the sample is that originated by Chow (1960). This test has much to commend it - its simplicity, intuitive appeal, ease of computation and so on.

An objection to the Chow test in testing for parameter instability is that the point of change in parameter values must be arrived at in some fashion based on prior knowledge or arbitrary judgement. This problem can be handled by employing Quandt's (1960) likelihood-ratio technique to isolate the most likely point at which structural change may have occurred, and then applying the Chow test at that point.

A second difficulty with the Chow test, and with any test in which the alternative hypothesis embodies a discrete change in parameter values at some point, is that change may be gradual rather than discrete. While in principle multiple break points could be allowed for, it is preferable to employ techniques which cope with this possibility more effectively.

Accordingly, we supplement the Chow-type tests with the Cusum and Cusum of Squares techniques (hereafter called CUSUM and CUSUMSQ), outlined in Brown, Durbin and Evans (BDE, 1975). These tests, based on recursive residuals, are more suited to detecting gradual change. BDE's "homogeneity statistic", based on the residual sum of squares from moving regressions over non-overlapping sub-samples, is also reported.

In addition to the above, however, a further issue needs to be addressed. Discussion of instability of the demand for money invariably centres around the co-efficients on the interest rate and income terms, and on the implied adjustment speed (see, for example, Judd and Scadding (1982)).

An issue not given much attention in the literature is the possibility of heteroskedasticity in the residuals. This appears to be an important ommission. The increase in prediction errors of standard equations in the 1970's gained a good deal of attention. This may be due to changes in the slope parameters, but equally, it suggests that formal tests for non-uniformity of the error variance might be worth pursuing.

That said, it is of course worth noting that a change in the variance is itself a structural change, and an important one, particularly for policy purposes. For it means that a monetary policy based on even very good knowledge of the demand function for money must be conducted with less precision and certainty.

Table 5 presents evidence that heteroskedasticity cannot be ruled out. The equations are tested using Breusch and Pagan's (1979) test, which involves checking for any relationship between the squared estimation residuals, appropriately scaled, and some set of exogenous variables.

For most of the models, it seems to be inappropriate to assume that the error variance is uniform throughout the sample. The only exception may be Pagan and Volker's (1980) equation.

A problem then arises in some of the test procedures discussed above. The CUSUMSQ statistic, for example, would most likely be affected. BDE (1975) show that this statistic is equivalent to SSR_τ/SSR_T, where SSR_τ represents the sum of squared residuals from a regression on τ observations, and where the total sample length is T. This is just the ratio of the maximum likelihood variance estimators, for samples τ and T respectively, multiplied by the ratio τ/T. Where the error-variance is unchanging, therefore, the appropriate "centre-line" for the CUSUMSQ plot is the straight line defined by τ/T. Confidence intervals are developed for deviations of the CUSUMSQ statistic from this line. But where the error variance is changing, this centre-line and the associated confidence intervals will no longer be appropriate.

Table 5: Tests for Heteroskedasticity

Equation no:	Test * Statistic	Critical Value 1%	5%
SV-2	28.83	16.57	12.55
SV-3	10.78	16.87	12.59
PO-2	21.14	16.41	16.55
PO-3	12.67	16.21	12.55
FR-2	25.22	15.09	11.07
FR-3	26.80	15.09	11.07
PV-2	7.15	18.48	14.07
PV-3	9.06	18.48	14.07

* The test proceeds by considering a regression model $y_t = f(x_t, \beta) + \epsilon_t$ where ϵ_t has mean zero, but the variance property $\sigma_t^2 = h(z_t'\gamma)$, where the z_t are exogenous. If we take the z_t to be the x_t in the original regression, including a constant term, the null hypothesis is that $\gamma_2 = \gamma_3 = \ldots = \gamma_k = 0$, where k is the dimension of γ. The test is conducted by estimating the equation $\hat{\epsilon}_t^2/\hat{\sigma}^2 = z_t'\gamma + \mu_t$, where $\hat{\sigma}^2$ is the estimated sample variance. Denoting the regression sum of squares from this equation as RSS, under H_0, $RSS/2 \sim \chi^2_{k-1}$ (asymptotically).

Similarly, there will be difficulties with the Chow test, since in testing the hypothesis that the parameter vectors are identical between two subsamples, it assumes that the variance of the residuals is unchanging between the two subsamples.

There is a small literature indicating that the Chow test is inappropriate in conditions of heteroskedasticity. Toyoda (1974) and Schmidt and Sickles (1977) addressed this question. A general conclusion to emerge from this work was that the true significance level of the test differs from the nominal level, when the error variance is not uniform. Jayatissa (1977) developed a test statistic free from this problem, but it tends to be computationally demanding, as well as suffering some other disadvantages (see Honda (1982)). A Wald test proposed by Watt (1979) is computationally easier, and work by Honda (1982) allows reasonable confidence that the asymptotic properties of the Wald test are not inferior to those of the Jayatissa test for sample sizes of over 60 observations, provided the break point is not too close to one end of the sample.

With the above points in mind, the next section proceeds to give results of a range of tests discussed above.

4. Stability Tests: Some Results

Figures 1 through 3 show the results of the CUSUM and CUSUMSQ procedures, for estimated versions of the three models where these tests could be conducted, from both the forward and the backward recursions, over both the original and extended sample periods. Five per cent confidence intervals are plotted. Table 6 gives the results of the Quandt procedure to determine the most likely break point, and the results of the Chow test and Watt's Wald test conducted at those points, as well as the homogeneity statistic. Results for each model are discussed in turn.

(a) Sharp and Volker (1977)

Over the original sample period, equation SV-2 exhibited some tendency to instability. Both CUSUM and CUSUMSQ statistics remain well within the confidence intervals, for the forward recursions. But in the backward recursions, the CUSUMSQ test points to evidence of structural change some time in the mid 1960s.

Extending the sample period to 1986(1), in the forward recursions there is again evidence of instability, in the mid 1960s, from the CUSUMSQ. In addition, the CUSUM indicates the possibility of further structural change in the last year or two of the sample. The backward recursions point to the possibility of parameter changes in the first half of the 1970s, the mid 1960s and even the mid 1950s.

FIGURE 1

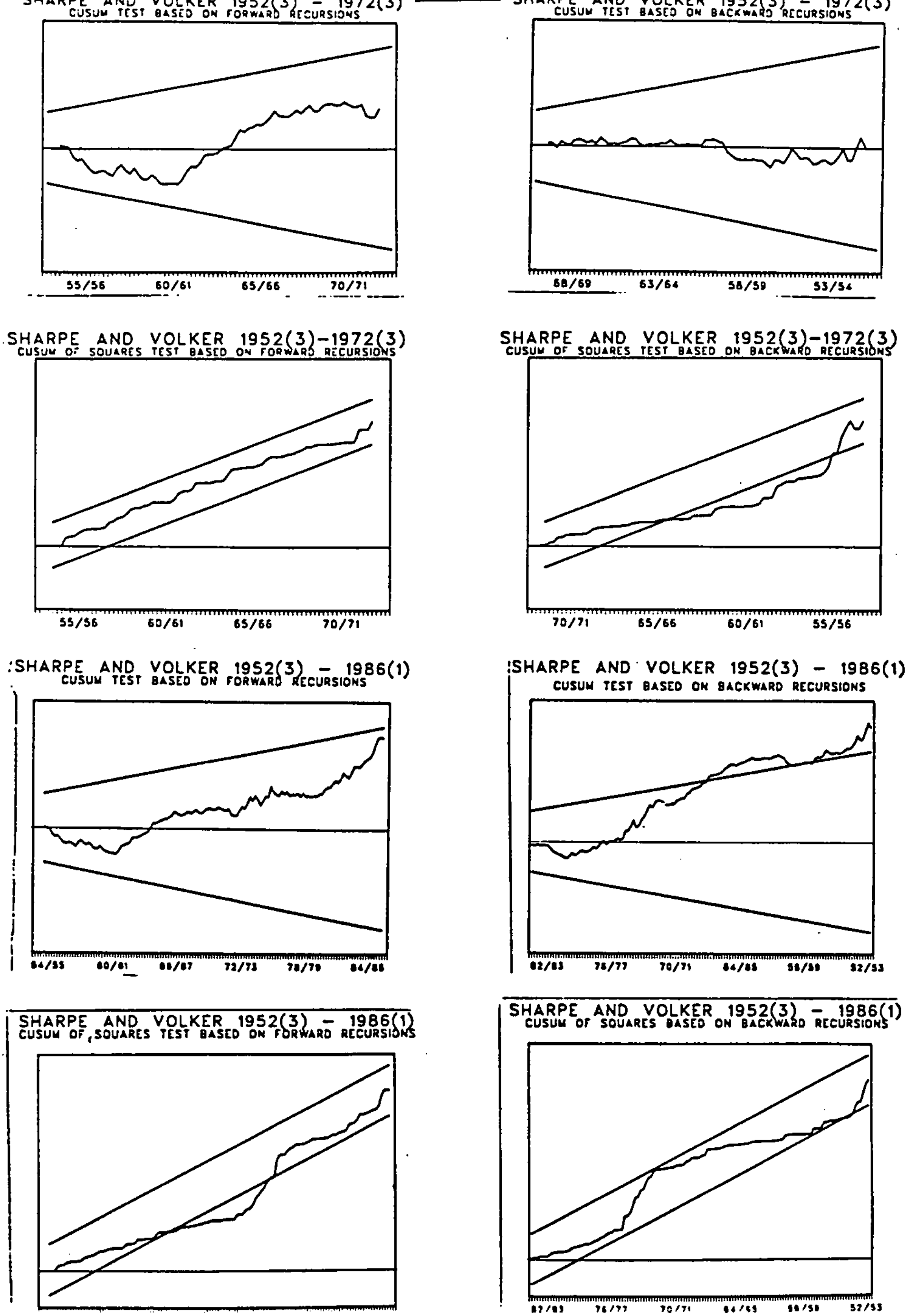
SHARPE AND VOLKER 1952(3) - 1972(3)
CUSUM TEST BASED ON FORWARD RECURSIONS
55/56
60/61
65/66
70/71
SHARPE AND VOLKER 1952(3) - 1972(3)
CUSUM TEST BASED ON BACKWARD RECURSIONS
68/69
63/64
58/59
53/54
SHARPE AND VOLKER 1952(3)-1972(3)
CUSUM OF SQUARES TEST BASED ON FORWARD RECURSIONS
55/56
60/61
65/66
70/71
SHARPE AND VOLKER 1952(3)-1972(3)
CUSUM OF SQUARES TEST BASED ON BACKWARD RECURSIONS
70/71
65/66
60/61
55/56
SHARPE AND VOLKER 1952(3) - 1986(1)
CUSUM TEST BASED ON FORWARD RECURSIONS
SHARPE AND VOLKER 1952(3) - 1986(1)
CUSUM TEST BASED ON BACKWARD RECURSIONS
SHARPE AND VOLKER 1952(3) - 1986(1)
CUSUM OF SQUARES TEST BASED ON FORWARD RECURSIONS
SHARPE AND VOLKER 1952(3) - 1986(1)
CUSUM OF SQUARES BASED ON BACKWARD RECURSIONS

FIGURE 2

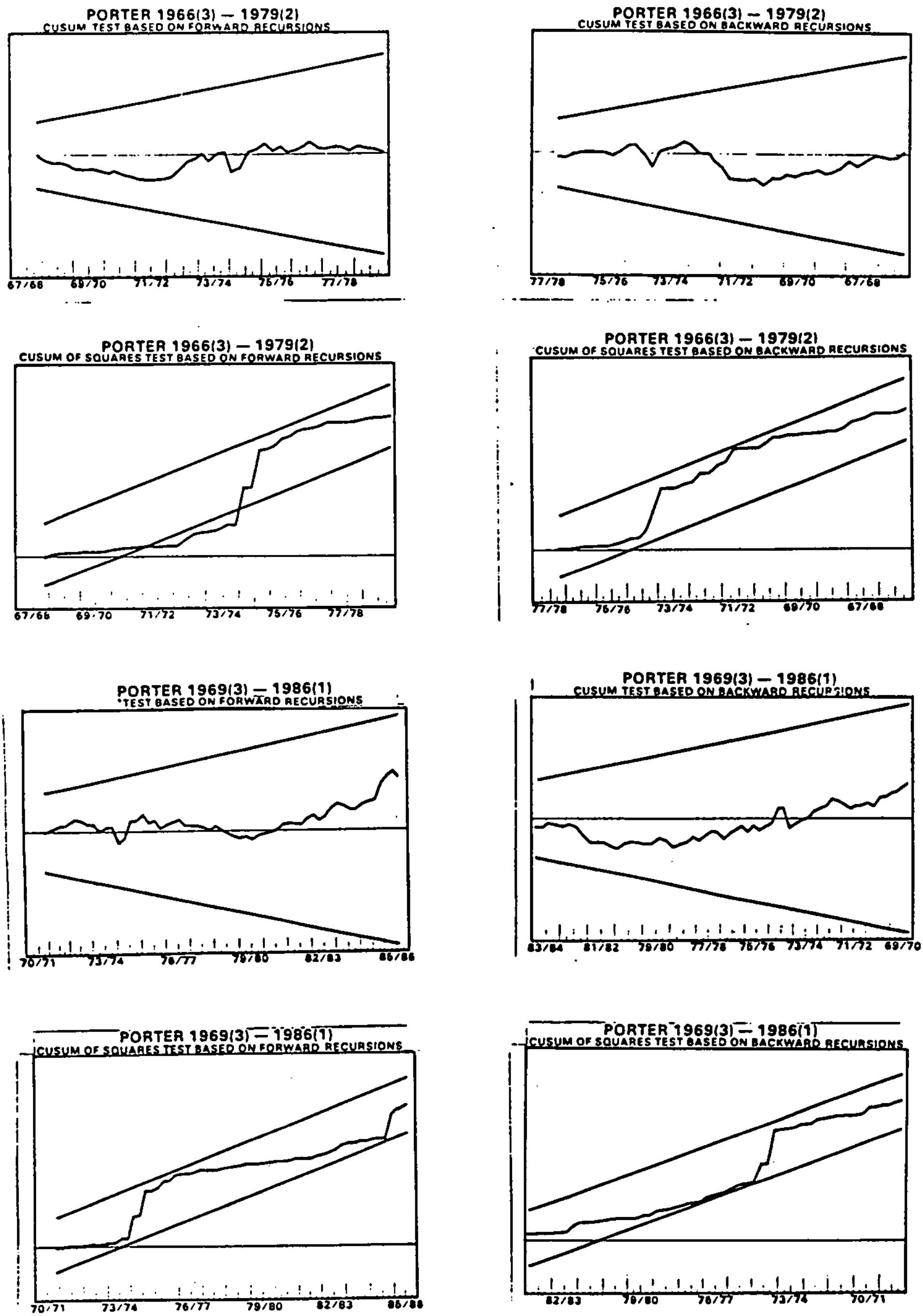
PORTER 1966(3) — 1979(2)
CUSUM TEST BASED ON FORWARD RECURSIONS
67/68 69/70 71/72 73/74 75/76 77/78
PORTER 1966(3) — 1979(2)
CUSUM TEST BASED ON BACKWARD RECURSIONS
77/78 75/76 73/74 71/72 69/70 67/68
PORTER 1966(3) — 1979(2)
CUSUM OF SQUARES TEST BASED ON FORWARD RECURSIONS
67/68 69/70 71/72 73/74 75/76 77/78
PORTER 1966(3) — 1979(2)
CUSUM OF SQUARES TEST BASED ON BACKWARD RECURSIONS
77/78 75/76 73/74 71/72 69/70 67/68
PORTER 1969(3) — 1986(1)
TEST BASED ON FORWARD RECURSIONS
70/71 73/74 76/77 79/80 82/83 85/86
PORTER 1969(3) — 1986(1)
CUSUM TEST BASED ON BACKWARD RECURSIONS
83/84 81/82 79/80 77/78 75/76 73/74 71/72 69/70
PORTER 1969(3) — 1986(1)
CUSUM OF SQUARES TEST BASED ON FORWARD RECURSIONS
70/71 73/74 76/77 79/80 82/83 85/86
PORTER 1969(3) — 1986(1)
CUSUM OF SQUARES TEST BASED ON BACKWARD RECURSIONS
82/83 79/80 76/77 73/74 70/71

FIGURE 3

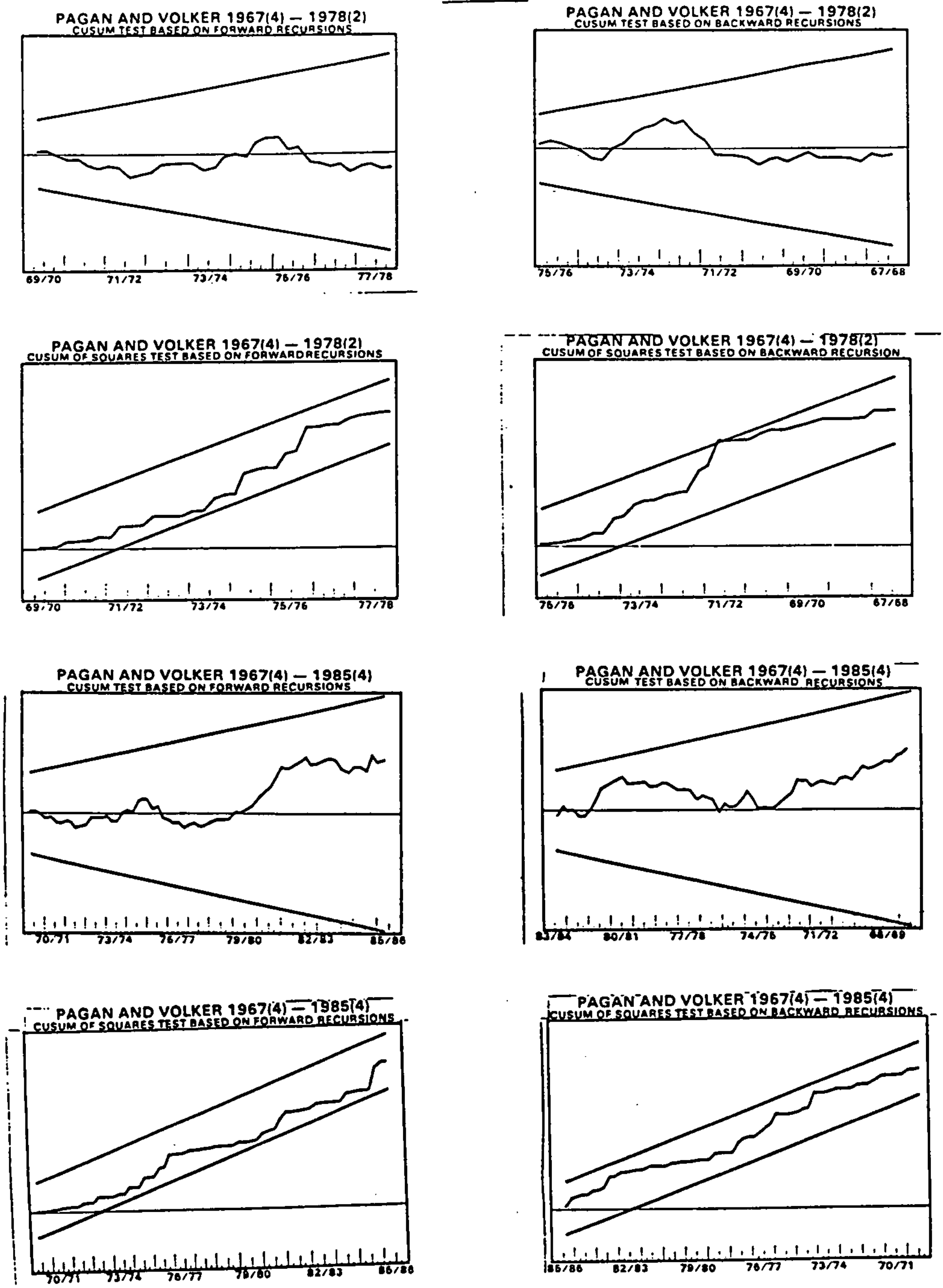
PAGAN AND VOLKER 1967(4) — 1978(2)
CUSUM TEST BASED ON FORWARD RECURSIONS
69/70 71/72 73/74 75/76 77/78
PAGAN AND VOLKER 1967(4) — 1978(2)
CUSUM TEST BASED ON BACKWARD RECURSIONS
75/76 73/74 71/72 69/70 67/68
PAGAN AND VOLKER 1967(4) — 1978(2)
CUSUM OF SQUARES TEST BASED ON FORWARD RECURSIONS
69/70 71/72 73/74 75/76 77/78
PAGAN AND VOLKER 1967(4) — 1978(2)
CUSUM OF SQUARES TEST BASED ON BACKWARD RECURSION
75/76 73/74 71/72 69/70 67/68
PAGAN AND VOLKER 1967(4) — 1985(4)
CUSUM TEST BASED ON FORWARD RECURSIONS
70/71 73/74 76/77 79/80 82/83 85/86
PAGAN AND VOLKER 1967(4) — 1985(4)
CUSUM TEST BASED ON BACKWARD RECURSIONS
83/84 80/81 77/78 74/75 71/72 68/69
PAGAN AND VOLKER 1967(4) — 1985(4)
CUSUM OF SQUARES TEST BASED ON FORWARD RECURSIONS
70/71 73/74 76/77 79/80 82/83 85/86
PAGAN AND VOLKER 1967(4) — 1985(4)
CUSUM OF SQUARES TEST BASED ON BACKWARD RECURSIONS
85/86 82/83 79/80 76/77 73/74 70/71

Table 6
Results of Stability Tests

Equation no:	Sample Period	Minimum Quandt[1]	Chow Test[2] Statistic	Critical Value 1%	Critical Value 5%	Wald Test[3] Statistic	Critical Value 1%	Critical Value 5%	Homogeneity Statistic[4]	Critical Value 1%	Critical Value 5%
SV-2	52(3)-72(3)	57(4)	7.91	3.07	2.18	39.09	18.48	14,07	42.99	1.77	2.24
SV-3	52(3)-86(1)	71(3)	4.32	1.82	1.53	28.21	18.48	14,07	119.05	1.79[5]	2.26[5]
PO-2	66(3)-79(2)	72(3)	3.23	2.91	2.11	26.77	20.10	15.51	19.75	2.26	3.15
PO-3	69(3)-86(1)	82(3)	2.95	2.50	1.91	26.44	20.10	15.51	10.95	1.91	2.6
FR-2	67(3)-83(2)	75(3)[6]	1.47	2.47	1.88	13.97	16.81	12.59	n.a.		
FR-3	67(3)-85(1)	75(3)[6]	1.27	2.38	1.84	12.69	16.81	12.59	n.a.		
PV-2	67(4)-78(2)	74(3)	3.53	3.13	2.23	33.61	20.1	15,51	0.70	2.32	3.29
PV-3	67(4)-85(4)	74(4)	2.43	2.63	1.96	22.49	20.1	15.51	1.49	2.11	2.85

1. Point at which Quandt's likelihood ratio statistic is minimised.
2. Under the null hypothesis, the distribution of the Chow statistic is $F_{k,T-2k}$, where k is the number of regressors, and T the sample size.
3. Under the null hypothesis, the asymptotic distribution of the Wald statistic is χ^2_k, where k is the number of regressors.
4. Non-overlapping sample size is 20 observations, unless otherwise stated.
5. Non-overlapping sample size is 40 observations.
6. The Quandt ratio technique could not be applied. 75(3) was arbitrarily chosen as the break point.

The Chow test applied at 1957(4) in the original sample rejects the null hypothesis of stability, as does the Wald test, quite convincingly. Both tests also reject stability in the extended sample.

The homogeneity statistic overwhelmingly rejects the null hypothesis of no instability at the 1 per cent level of significance, for a range of non-overlapping sample sizes, both in the original sample and the extended sample.

In the case of Sharpe and Volker's distributed lag models, we found that the large number of dummy variables tended to induce matrix singularity in the sub-samples, so most of the stability tests could not be conducted.

(b) Porter (1979)

Over the original sample period, the CUSUMSQ statistics point to possible instability in the early to mid 1970's. This is supported by the Chow and Wald tests conducted with the sample break at 1972(3), and the homogeneity test, in all of which the null hypothesis is convincingly rejected.

Over the sample 1969-86, there is again some evidence from the CUSUMSQ plots of instability in the first half of the 1970's. In addition to this, it also seems possible that there was some shift during the first half of the 1980's. The point at which Quandt's likelihood ratio is minimised is 1982(3). The Wald test conducted on this assumption rejects the null hypothesis, and although the Chow test statistic is not significant at the 5 per cent level, it is not really low enough to allow one to entertain the hypothesis of stability with great confidence. The homogeneity test over this extended sample also rejects stability.

(c) Freeland (1984)

The presence in the specification of two bank deposit interest rates suggests looking for some effects the deregulation of those rates in December 1980. Unfortunately, the three interest rates in the specification are highly collinear, making for difficulty in inverting the X'X matrix for a small number of observations. Consequently, the CUSUM, CUSUMSQ and homogeneity tests could not be conducted, and the Quandt likelihood ratio procedure could not be applied.

We are left then with the Chow and Wald tests. 1975(3) was arbitrarily chosen as the break point, for both the original and extended samples. Although the Chow test at this point cannot reject the null hypothesis, the Wald test rejects it at the 5 per cent level of significance.

(d) Pagan and Volker (1981)

The original authors contended, on the basis of the CUSUM plot, that "the evidence is not obviously indicative of instability". This appears reasonable on the basis of the plots reported in their paper. However, the differences between the data set they used and the one we used, even over the same period, appear to be such that confidence in that conclusion is diminished somewhat. Yet again, the mid 1970s appear as a problem period. Over the longer sample, the equation appears to perform a little better in the CUSUM and CUSUMSQ tests, staying inside the confidence intervals.

On the other hand, the Chow and Wald tests for a break at the minimum Quandt point in the second half of 1974 are not particularly supportive of stability. The most surprising outlier in this set of test results is the homogeneity statistic, which cannot reject the null.

So, while Pagan and Volker's conclusion against instability, cannot be held unswervingly, there is probably enough variation in the results that it cannot be dismissed out of hand.

(e) Summary

On balance, the conclusion we draw from the above results is that in the case of M3, it is difficult to accept the proposition that equations have not suffered from instability, as detected by the tests employed here. The verdict on M1 is perhaps less clear.

The recurrence of the period from the end of 1971 through to the middle of 1975 as the period in which structural change is most likely to have occurred is notable. But it is also likely that there has been instability at other times, including the 1980's. The next section looks more closely at this period, which is one of considerable recent interest for monetary theory and policy.

5. Stability in the 1980s: Results of Further Tests

In the first half of the 1980s, the Australian financial system has undergone substantial, and rapid, deregulation. Amongst the important changes have been:

- the lifting of restrictions on interest rates paid on most bank deposits in December 1980;
- the introduction of tender arrangements for marketing long-term government debt in August 1982;
- floating of the Australian dollar and the abolition of most exchange controls in December 1983;
- lifting of restrictions on terms and maturities on bank deposits in August 1984;
- the licensing of a number of new banks, from early 1985.

These events have had a profound influence on the financial system, and particularly on the monetary aggregates. The freeing-up of the banking system improved the banks' competitive position vis-a-vis non-bank financial intermediaries, and led to a shift of business between the two sectors. To the extent that the financial system generally became more competitive and efficient, there could also have been some shift from direct financing to intermediation.[7] Both of these factors could affect the relationship between observed levels of the money stock, interest rates and real activity. In addition, the floating of the exchange rate might be expected to affect the variability of domestic interest rates, and the nature of the money supply process. In a simple analytical framework assuming a fixed exchange rate and perfect capital markets, the quantity of money supplied is seen as adjusting to the quantity demanded. Under a floating regime, this is no longer so (in the absence of systematic central bank intervention). This may have implications for the estimated relationship between the money stock and other variables.

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7. These points are brought out more fully in a Research Report "Changing Patterns of Finance", published in the Reserve Bank <u>Bulletin</u>, May 1985.

For these reasons, an additional test is performed on equations SV-3, PO-3, FR-3 and PV-3, namely the post-sample predictive test developed by Davidson et. al. (1978). This consists of estimating the model up to some date T, which we have taken to be December 1980, and then using the model for (static) simulation past T (up to around the end of 1985 in this case). Davidson et. al. (1978) develop a formal test statistic for the forecast residuals, which is easy to compute.

Figure 5 shows plots of the simulation errors. The absolute size of the errors is large in several cases. The scale on the graph is calibrated in logs, so that the figures indicate proportionate errors - with peaks between 5 and 8 per cent. It is notable that a large error in mid 1985, the period immediately following the abandoning of the conditional projection for M3 (in January 1985), shows up clearly in all three equations in which the test is conducted that far out.

So much for the absolute errors. Table 7 gives the formal test statistics, based on the sums of squared residuals.

Table 7: Post-Sample Predictive Tests

Equation no:	Test * Statistic	Critical Value 1%	Critical Value 5%
SV-3	53.4	38.9	32.7
PO-3	44.3	38.9	32.7
FR-3	103.8	33.4	27.6
PV-3	56.2	37.6	31.4

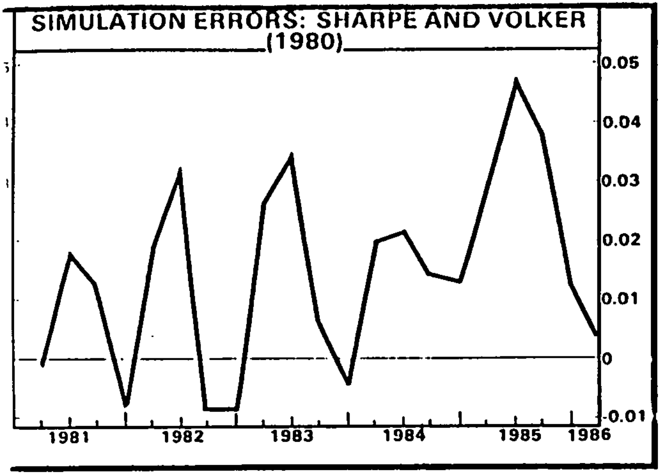
* In a model of the form $y_t = x_t'\beta + \epsilon_t$, $\epsilon_t \sim (0, \sigma^2)$, estimated using T observations, and simulated using actual values for the x_t for periods $t = T+1, \ldots T+\ell$, under the null hypothesis of no change in the β (and assuming σ^2 is unchanged) the test statistic is

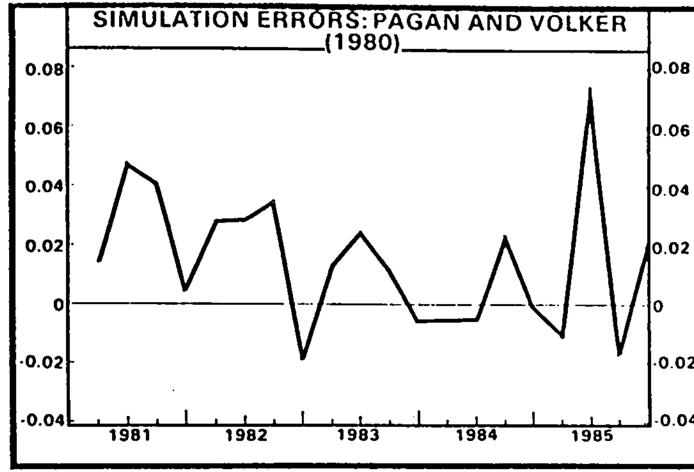
$$\left(\sum_{t=T+1}^{T+\ell} \hat{\epsilon}_t^2\right) / \hat{\sigma}^2 \sim \chi^2_\ell$$

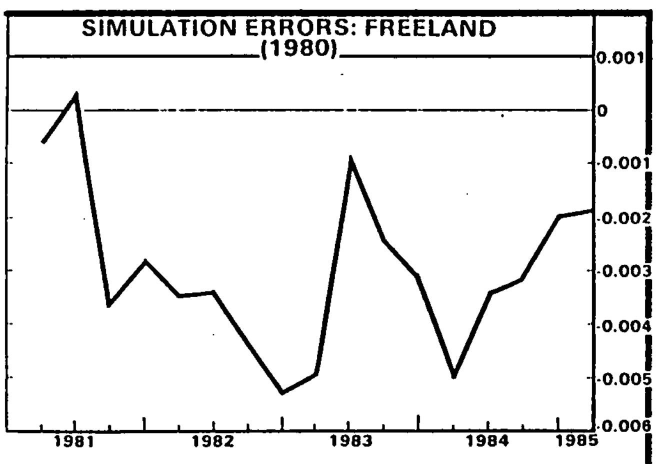
where $\hat{\sigma}_T^2$ is the estimate of the variance of the error within the sample

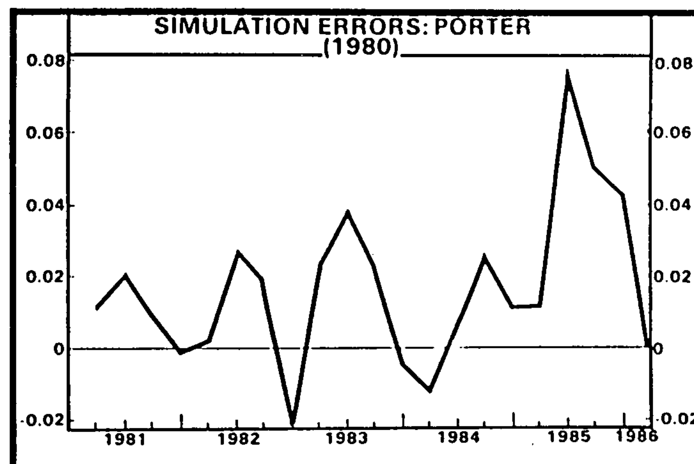
sample: $\hat{\sigma}_T^2 = \sum_{t=1}^{T} \hat{e}_t^2 \,/T-k$.

All of the test statistics reported here convincingly reject the null hypothesis of stability.


SIMULATION ERRORS: SHARPE AND VOLKER
(1980)
0.05
0.04
0.03
0.02
0.01
0
-0.01
1981
1982
1983
1984
1985
1986


SIMULATION ERRORS: PAGAN AND VOLKER
(1980)
0.08
0.06
0.04
0.02
0
-0.02
-0.04
1981
1982
1983
1984
1985


SIMULATION ERRORS: FREELAND
(1980)
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
1981
1982
1983
1984
1985


SIMULATION ERRORS: PORTER
(1980)
0.08
0.06
0.04
0.02
0
-0.02
1981
1982
1983
1984
1985
1986

Of course, this test is likely to be affected by the heteroskedasticity problem, just as were the tests in Section 4. If the variance is growing over time, it seems, intuitively at least, that the Davidson et. al. test would be biased against the null hypothesis. Even so, it seems likely that this problem would have to be severe in order to completely invalidate the conclusions, especially as they are consistent with the earlier results.

It might be argued that a five-year simulation period is an unreasonably long period over which to test a model. But allowing estimation up to June 1984, and simulating over only 7 quarters does not substantially change the results.

6. Concluding Comments

This paper has sought to address in a systematic way the question of stability of the demand for money, in several conventional models. Given the uncertainties over the performance of the test procedures discussed earlier, interpretation of the results is perhaps not straightforward.

Some of the tests applied - the CUSUMSQ and homogeneity tests for example - are quite demanding. But on the other hand, a number of tests have been employed - a conclusion of evident instability does not depend exclusively on these demanding tests.

For one model (Sharpe and Volker), the data period is quite long, so that complete stability over that entire period may be too stringent a standard. However, this model showed evidence of instability in even its original, shorter sample period. Indeed, on the Wald test in Table 6, each of the four models is shown to be unstable in its original sample period at the 5 per cent level of significance.

On balance, our conclusion from the results reported here is that the conventional models cannot easily be accepted as empirically stable. The mid 1970s still represent a problem period for estimated equations.

This conclusion is not new. Indeed, the 1970s caused difficulties for many empirical relationships that may previously have been considered quite dependable. It may be that money demand equations are not any more unstable over this period than most other equations.

Perhaps a newer result, though not necessarily a surprising one, is that the 1980's - a period not systematically addressed before in Australia - has also been a period in which conventional equations appear to break down.

It must be conceded that the stability or otherwise of broad money has not been considered. This is a shortcoming since broad money has attracted increasing attention in recent years, not least because of some of the changes to the financial system outlined in the previous section. One attraction of broad money is that shifts of business between banks and non-banks do not, in the first instance at least, affect it. In principle then, while shifts between direct and intermediated financing could still lead to instability in the demand for broad money, at least some of the potential sources of instability in the demand for narrow aggregates should not affect it. Empirically, this remains to be demonstrated.

What are we to make of these results?

Laidler (1986) gives a practical interpretation of the problem, noting that conventional money demand functions may remain useful as long-run descriptions but suffer periods in which errors are large. Such periods will show formal instability. Laidler argues that, despite this, the demand functions may be useful as a framework for thinking about money if properly interpreted.

Taking the more general view of the tests reported in this paper as being simply another set of diagnostics, it could be argued that what we have taken to be instability is in fact evidence that the equations were wrongly specified in the first place. Going one step further would take us back to a closer examination of the models themselves, both theoretically and empirically. In this context, the work of Milbourne (1985), is sobering. He found that, for Australian data, no one type of model was able to completely dominate all others in empirical performance, suggesting that the whole gamut of monetary models may need to be re-thought.

Alternatively, returning to an earlier theme, it may be inappropriate to model the demand for money as a single equation in isolation from the economic system. This could mean that the results here are ambiguous.[8]

A third alternative is to accept the results here as simply confirmation of what would be expected based on theory. The insights due to Lucas, which in the monetary sphere find their expression in what has become known as Goodhart's Law, suggest that the very attempt to depend on a stable demand for money for policy purposes may itself upset that stability.

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8. Against this point of view, Pagan and Volker (1980) utilised Sargan's Generalised Instrumental Variables Estimator to try to gauge the extent of any simultaneous equations bias in their single-equation model and found very little.

Evaluation of the results should probably give heed to all of the above. To return to the notions of mispecification and simultaneity, Gordon (1984) provides a timely reminder of a key point about identification. In the context of an orthodox, though more completely specified, model of the demand for and supply of money, changes in the money supply process, such as a move away from interest rates and towards financial quantities as proximate policy objectives, introduce ambiguities into the econometric procedure: it is no longer clear that the researcher is actually estimating a demand function at all. Observed changes in estimated co-efficients could simply reflect the changing institutional regime, rather than instability in the demand for money itself.

An analogous point is made by Laidler (1982), as a result of drawing the distinction between adjustment of real balances at an individual level, and adjustment at an aggregate level. It is at the individual level that the microeconomic notion of adjustment costs is invoked to explain lagged adjustment. At this level, real balances adjust by changes in the level of nominal balances. But it is the aggregate level we observe. At that level, under the assumption that the supply of nominal balances is given by the authorities, real balances must adjust by the price level changing. Thus Laidler's point is that the empirical demand for money equation may in fact be some sort of price adjustment equation in disguise. Shifts in those equations can then be interpreted as changes in pricing behaviour in the economy.

Other possible explanations for unsatisfactory econometric performance include measurement error. "Money" may not correspond closely to measured financial aggregates. Similarly, "income" may not be well represented by GDP. It is possible that alternative measures of money may provide different results to those above.

For example, monetary aggregates constructed on a functional basis, where deposits of the same type are combined across a range of institutions (including non-bank financial intermediaries), may have a more stable relationship with income and interest rates, since they would be less affected by re-intermediation. However, the data for such aggregates are not easily available in Australia.

Clearly, these questions have not been satisfactorily resolved in this paper. But even if the results reported here are not taken to be indicative of instability in the demand for money so much as evidence of mis-specification - they do provide evidence that the conventional approach to the relationship between monetary aggregates, interest rates and economic activity has not yet yielded results which are sufficently robust for stability to be claimed.

APPENDIX

Table A.1
Sharpe and Volker's Equations (cont'd)

	Constant	ΔS1	ΔS2	ΔS3	R2-RFD	LENDP	ΔAB_{-1}	$\Delta \ln(\frac{Y}{P})_{-i}$	$\Delta \ln R2_{-i}$	$\Delta \ln(\frac{P}{P_{-1}})_{-i}$	$\bar{R}^2$	DW
								i=0, ...,6	i=0, ...,5	i=1, ...,4		
SV-4 Original 52(2)-72(3)	-0.001	-0.018	0.012	0.019	-0.005	-0.006	0.24	0.248	-0.029		0.992	1.87
Dependent = $\Delta \ln(\frac{M3}{P})$	(-0.64)	(-4.06)	(1.57)	(2.86)	(-3.18)	(-2.28)	(5.98)	(6.5)	(-2.07)			
								0.130	-0.025	-0.584		
								(4.08)	(-2.78)	(-4.28)		
								0.095	-0.016	-0.743		
								(2.97)	(-1.65)	(-4.17)		
								0.110	-0.005	-0.600		
								(4.41)	(-0.64)	(-3.56)		
								0.142	0.003	-0.303		
								(5.67)	(0.34)	(-2.20)		
								0.157	0.006			
								(4.92)	(0.69)			
								0.121				
								(4,30)				
								i=0, ...,6	i=0, ...,5	i=1, ...,4		
SV-5 Revised 52(3)-72(3)	0.011	0.000	-0.027	-0.024	-0.005	-0.008	0.168	0.088	-0.028		0.876	1.84
Dependent = $\Delta \ln(\frac{M3}{P})$	(2.754)	(0.169)	(-12.16)	(-12.43)	(-3.079)	(-2.782)	(1.658)	(1.602)	(-1.332)			
								0.086	-0.042	-0.31		
								(1.988)	(-2.103)	(-1.673)		
								0.084	-0.014	-0.239		
								(2.343)	(-0.843)	(-1.611)		
								0.082	-0.000	-0.167		
								(2.305)	(-0.024)	(-1.254)		
								0.079	-0.005	-0.096		
								(1.872)	(-0.27)	(-0.649)		
								0.077	0.017	-0.025		
								(1.428)	(0.789)	(-0.133)		
								0.075				
								(1.103)				

Table A.2
Sharpe and Volker's Equations (cont'd)

	Constant	$\Delta S1$	$\Delta S2$	$\Delta S3$	$\Delta DS2$	R2-RFD	LENDD	$\Delta\dot{AB}_{-1}$	$\Delta\ln\dot{DRFD}_{-i}$	$\Delta\ln DRTB_{-i}$	$\Delta\dot{AB72}_{-i}$	$\Delta\ln(\frac{Y}{P})_{-i}$	$\Delta\ln R2_{-i}$	$\Delta\ln(\frac{P}{P-1})_{-i}$	$\bar{R}^2$	DW
									i=0, ...,2	i=0,1	i=0,1	i=0, ...,6	i=0, ...,5	i=1, ...,4		
SV-6 Original																
52(3)-75(1)	-0.001	0.023	0.02	0.024	0.01	-0.0046	-0.005	0.225	0.189	0.10	0.77	0.291	-0.03		0.919	1.6
Dependent =																
$\Delta\ln(\frac{M3}{P})$	(-0.62)	(4.64)	(2.37)	(3.18)	(2.54)	(-2.77)	(-1.62)	(4.97)	(4.95)	(0.75)	(2.04)	(7.00)	(-1.9)			
									0.033	0.110	0.086	0.155	-0.022	-0.509		
									(1.25)	(4.81)	(2.16)	(4.38)	(-2.11)	(-3.36)		
									0.068			0.013	-0.018	-0.726		
									(2.41)			(2.86)	(-1.60)	(-3.67)		
												0.103	-0.016	-0.626		
												(3.70)	(-1.65)	(-3.28)		
												0.124	-0.013	-0.340		
												(4.39)	(-1.32)	(-2.17)		
												0.135	-0.008			
												(3.67)	(-0.91)			
												0.104				
												(3.19)				
SV-7 Revised																
52(3)-75(1)	0.015	0.001	-0.025	-0.023	0.008	-0.006	-0.004	-0.001	-0.01	-0.003	0.001	0.081	-0.032		0.856	1.66
Dependent =																
$\Delta\ln(\frac{M3}{P})$	(3.50)	(0.563)	(-10.433)	(-11.094)	(1.454)	(-3.120)	(-1.422)	(-0.602)	(-0.688)	(-0.242)	(1.761)	(1.462)	(-1.658)			
									-0.025	0.009	0.001	0.064	-0.055	0.46		
									(-1.513)	(0.687)	(2.296)	(1.456)	(-3.528)	(2.233)		
									-0.005			0.047	-0.013	0.325		
									(-0.679)			(1.309)	(-0.800)	(1.071)		
												0.031	-0.024	0.19		
												(0.898)	(-1.574)	(1.27)		
												0.141	-0.067	0.054		
												(0.362)	(-3.597)	(0.344)		
												-0.003	0.017	-0.001		
												(-0.052)	(0.884)	(-0.454)		
												-0.019				
												(-0.316)				

Table A.3
Sharpe and Volker's Equations (cont'd)

	Constant	ΔS1	ΔS2	ΔS3	ΔDS2	R2-RFD	LENDD	AB_{-1}	$\Delta DRFD_{-i}$	$\Delta DRTB_{-i}$	$\Delta AB72_{-i}$	$\Delta\ln(\frac{Y}{P})_{-i}$	$\Delta\ln R2_{-i}$	$\Delta\ln(\frac{P}{P_{-1}})_{-i}$	$\bar{R}^2$	DW
									i=0, ...,2	i=0,1	i=0,1	i=0, ...,6	i=0, ...,5	i=1, ...,4		
SV-8 Updated 52(3)-86(1)	0.004	0.004	-0.024	-0.021	0.007	-0.001	-0.004	0.000	0.012	-0.009	0.001	0.163	-0.022		0.757	1.74
Dependent = $\Delta\ln(\frac{M3}{P})$	(0.998)	(1.876)	(-10.39)	(-10.07)	(1.149)	(-0.729)	(-1.543)	(0.040)	(-0.807)	(-0.766)	(1.133)	(3.245)	(-1.204)			
									0.004	-0.014	0.001	0.140	-0.048	0.106		
									(0.274)	(-0.969)	(1.810)	(3.477)	(-3.121)	(1.284)		
									0.008			0.117	-0.021	0.080		
									(1.651)			(3.480)	(-1.622)	(0.703)		
												0.094	-0.025	-0.025		
												(2.905)	(-1.946)	(-0.258)		
												0.071	-0.045	-0.131		
												(1.921)	(-2.84)	(-1.255)		
												0.049	0.029	-0.237		
												(1.054)	(1.759)	(-1.831)		
												0.026				
												(3.448)				

R2, P
S_i = same as S_2 from 1952(1) to 1955(4)
RFD = interest rate on 12 month fixed deposits of less than $50,000 at trading banks
DRFD = RFD for 1971(4)-1976(1)
LENDD = synthetic variable for Central Bank Lending directives = 1 in 1952(1-3), 1955(3)-1957(1), 1960(1)-1961(2), 1964(4)-1966(2), 1967(2-3), 1968(4)-1969(1), 1970(2)-1971(4), 1973(3)-1974(3) = 0.5 in 1969(3)-1970(1).
AB = per cent growth in "liquidity augmented monetary base"* from 1952(1) to 1956(4).
DRTB = yield on 90-day Trade Bill for 1971(4)-1975(1).
AB72 = per cent growth in "liquidity-augmented monetary base" for 1972(1)-1975(1)
Y = GDP as defined in Table 1A.

* Liqudity-augmented monetary based defined as holdings of coin, bullion, and deposits of the Central Bank and Commonwealth Government Securities by trading banks, and holdings of currency by the public.

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