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Structural Changes in Australia's Monetary Aggregates and Interest Rates

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This paper employs all quarterly time series currently available to determine endogenously the time of structural breaks for three monetary aggregates—the long- and short-term interest rates as well as the consumer price index—in Australia using the ZA (Zivot and Andrews, 1992) test and the LP (Lumsdaine and Papell, 1997) test. After accounting for the single most significant structural break, the results from the ZA test (model C) provide no evidence against the unit root null hypothesis for all series examined. However, when two structural breaks are incorporated in the testing procedure within the framework proposed by LP (i.e., model CC) the test results indicate that the unit root hypothesis is indeed rejected for four out of six of the variables under investigation at the 5% level. The estimated two structural breaks were found to be statistically significant in five out of six variables. The dates of structural breaks in most of the cases point to: (a) The 1973 oil shock; (b) The culmination of financial deregulation and innovation in the late 1980s; (c) The 1990-91 recession; and (d) The launch of the 1996 Wallis Inquiry into financial system.

Introduction

The issue of structural change is of considerable importance in the analysis of macroeconomic time series. Structural change may occur in a time series for any number of reasons, including economic crises, changes in institutional arrangements, policy changes and regime shifts. It is, thus, of paramount importance to test the null hypothesis of structural stability against the alternative of a one-time structural break. If such structural changes do, in fact, exist in the data generating process, but are not allowed for in the specification of an econometric model, results may be biased towards the erroneous non-rejection of the non-stationarity hypothesis (Perron, 1989; Perron, 1997; Leybourne and Newbold, 2003).

Earlier, dating of the potential break was assumed to be known *a priori* in accordance with the underlying asymptotic distribution theory. Test statistics were then constructed by

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adding dummy variables representing different intercepts and slopes, thereby extending the standard Dickey-Fuller procedure (Perron 1989). However, this standard approach has been criticized by Christiano (1992), who has argued that this invalidates the distribution theory underlying conventional testing.

A number of studies have proposed different methodologies for endogenising dates, including ZA (Zivot and Andrews, 1992), Perron (1997), LP (Lumsdaine and Papell, 1997) and Bai and Perron (2003). These studies have shown that by determining the time of structural breaks endogenously, bias in the usual unit root tests can be lessened. Perron (1997, p. 356) asserts that "...if one can still reject the unit-root hypothesis under such a scenario it must be the case that it would be rejected under a less stringent assumption". He (1994, 1997) has put forward a class of test statistics which allows for two different forms of a structural break—the Additive Outlier (AO) model, which is more relevant for series exhibiting a sudden change in the mean (the crash model), and the Innovational Outlier (IO) model, which are designed to capture changes in a more gradual manner through time.

The objective of this paper is to employ the ZA and LP models to examine structural breaks in Australia's monetary aggregates and interest rates using all available quarterly data. The monetary aggregates and interest rate series examined are the natural logs of quarterly observations for the longest period available. The monetary measures are the Monetary Base (MB), M3 and Broad Money (BM) measured in AUD billions and expressed in constant prices using the consumer price index (1989/90 = 100). The interest rate variables are RS (a short-term interest rate) proxied by the yield on 90-day bank accepted bills) and RL (the long-run rate of return on 10-year treasury bonds). The study also includes the Consumer Price Index (CPI) in this analysis. The data have been collected from the Reserve Bank of Australia (2005), and Australian Bureau of Statistics (2005a,b).

Zivot-Andrews and Lumsdaine-Papell Models

Zivot and Andrews (ZA, 1992) propose a variation of Perron's (1989) original test in which the time of the break is estimated, rather than known as an exogenous phenomenon. The null hypothesis in their method is that the variable under investigation contains a unit-root with a drift that excludes any structural break, while the alternative hypothesis is that the series is a trend stationary process with a one-time break occurring at an unknown point in time. By endogenously determining the time of structural breaks, Zivot and Andrews argue that the results of the unit root hypothesis previously suggested by conventional tests such as the ADF test may change.

In this methodology, *TB* (the Time of Break) is chosen to minimize the one-sided *t*-statistic of $\alpha = 1$. In other words, a break point is selected which is the least favorable to the null hypothesis. The ZA model endogenises one structural break in a series (such as y_t) as follows:

$$H0:\ y_t = \mu + y_{t-1} + e_t \qquad \text{...(1)}$$

$$H1:\ \Delta y_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \qquad \text{...(2)}$$

Equation (2), which is referred to as model C by ZA, accommodates the possibility of a change in the intercept as well as a trend break. They also consider two other alternatives where a structural break impacts on the intercept only (model A) or trend only (model B). Model C is the least restrictive compared to the other two models. In equation (2) $DU1_t$ is a sustained dummy variable capturing a shift in the intercept, and $DT1_t$ is another dummy variable representing a shift in the trend occurring at time *TB1*. The alternative hypothesis is that the series, y_t, is I(0) with one structural break. *TB* is the break date, and the dummy variables are defined as follows:

$$DU1_t = \begin{cases} 1 \text{ if } t > TB1 \\ 0 \text{ if } t \le TB1 \end{cases} \quad \text{and} \quad DT1_t = \begin{cases} t-TB1 \text{ if } t > TB1 \\ 0 \text{ if } t \le TB1 \end{cases}$$

The null is rejected if the α coefficient is statistically significant. The optimal lag length is determined on the basis of the t-test. The "trimming region" where we search for the minimum t-ratio is assumed to be within 0.05T-0.95T or $0.05T \le TB1 \le 0.95T$.

The approach used by Zivot and Andrews (1992) and Perron (1994, 1997) captures only one (the most significant) structural break in each variable. What if there have been multiple structural breaks in a series? Considering only one endogenous break may not be adequate and under these circumstances it could lead to a loss of information (Lumsdaine and Papell, 1997). As Ben-David *et al.* (2003) argued, "just as failure to allow one break can cause non-rejection of the unit root null by the Augmented Dickey-Fuller test, failure to allow for two breaks, if they exist, can cause non-rejection of the unit root null by the tests which only incorporate one break" (2003: 304). Computationally the determination of more than one structural break (even two) is very cumbersome. However, LP introduced a new procedure to capture two structural breaks and argued that unit root tests that account for two structural breaks (if significant) are more powerful than those which only allow for a single break.

As an extension of the Zivot and Andrews (1992) (model C as discussed in equation 2), LP modified the ADF test by taking into account two potential structural breaks as follows:

$$\Delta y_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t \qquad \text{...(3)}$$

where,

$$DU1_t = \begin{cases} 1 \text{ if } t > TB1 \\ 0 \text{ if } t \le TB1 \end{cases} \quad \text{and} \quad DU2_t = \begin{cases} 1 \text{ if } t > TB2 \\ 0 \text{ if } t \le TB2 \end{cases}$$

$$DT1_t = \begin{cases} t-TB1 \text{ if } t > TB1 \\ 0 \text{ if } t \le TB1 \end{cases} \quad \text{and} \quad DT2_t = \begin{cases} t-TB2 \text{ if } t > TB2 \\ 0 \text{ if } t \le TB2 \end{cases}$$

The two indicator dummy variables (*i.e.*, $DU1_t$ and $DU2_t$) capture structural changes in the intercept at time *TB*1 and *TB*2, respectively. The other two dummy variables (i.e., $DT1_t$ and $DT2_t$) capture shifts in the trend variable at time *TB*1 and *TB*2, respectively. The optimal lag length (*k*) is determined based on the general to specific approach (the *t* test) suggested by Ng and Perron (1995). The study selected the break points (*TB*1 and *TB*2) based on the minimum value of the *t* statistic for α. Following LP (1997) and Ben-David *et al.* (2003) the study assumed the lag length (*k*) to vary up to $K_{max} = 8$. The "trimming region" where the minimum t-ratio is searched for, starts from the second observation and ends at the penultimate observation where $TB1 \neq TB2$.

Empirical Results

Table 1 summarizes the results of the ZA test in the presence of one structural break allowing for a change in both the intercept and trend. The results obtained from the ZA model reveal that all six variables examined contain unit root despite capturing one endogenously determined break in the data. Conventional unit root tests are also applied (i.e., ADF) and similar results are obtained. The ADF and KPSS results are not reported here but they are available from the authors upon request.

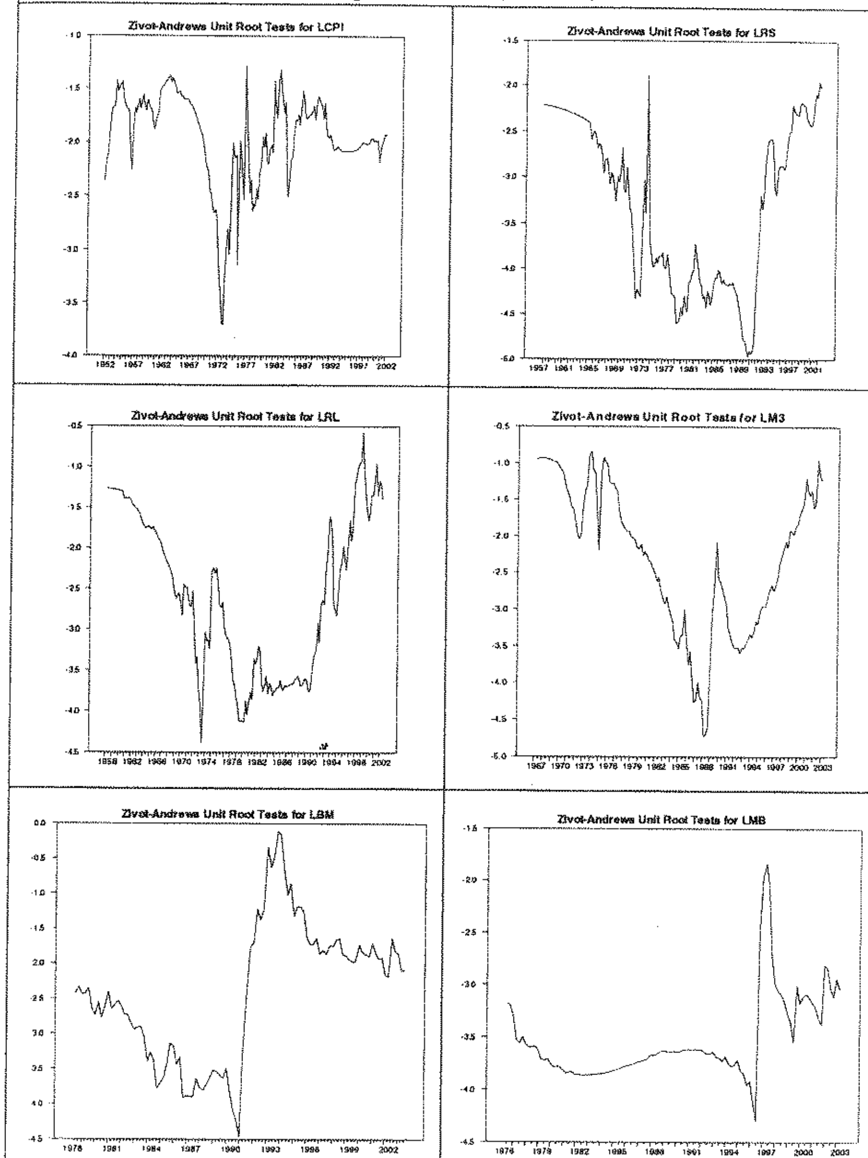
Table 1: The Zivot-Andrews Test Results: Break in Both Intercept and Trend (Model C)

$$\Delta y_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-1} + \varepsilon_t$$

Variables	Data Available	TB1	μ	β	θ	γ	α	k	Possible Causes for TBs
Ln(CPI)	1948:03-2003:01	1973q2	0.042 (4.12)	0.0001 (1.93)	0.016 (4.38)	0.001 (1.25)	–0.016 (–3.71)	3	The 1973 Oil Shock
Ln(RS)	1955:01-2004:03	1990q4	0.212 (4.75)	0.001 (4.21)	–0.128 (–4.01)	–0.002 (–2.23)	–0.143 (–4.97)	2	Recession and the property market collapse of 1990
Ln(RL)	1959:01-2004:03	1973q3	0.156 (4.03)	0.001 (0.23)	0.078 (3.73)	–0.001 (–2.52)	–0.083 (–4.38)	3	The 1973 Oil Shock
Ln(M3)	1965:01-2004:04	1988q2	0.194 (5.01)	0.0025 (4.83)	0.016 (3.01)	–0.001 (–4.98)	–0.086 (–4.73)	1	Setting the cash rate became the main objective of the RBA
Ln(BM)	1976:03-2003:04	1991q1	0.491 (4.64)	0.004 (4.34)	–0.026 (–4.85)	–0.001 (–3.62)	–0.123 (–4.47)	3	Recession and the property market collapse of 1990
Ln(MB)	1975:01-2004:03	1996q3	0.577 (2.58)	0.059 (4.26)	–0.077 (–3.47)	–0.013 (0.436)	–0.253 (–4.29)	1	Wallis Inquiry into financial system established.

Note: (a) Critical values at 1 and 5% levels are –5.57 and –5.08, respectively (Zivot and Andrews, 1992).
(b) All variables under investigation contain unit root.

Figure 1: Plots of the Estimated $\hat{t}_\alpha$ within the Trimming Region Using the ZA Test (Model C)



Note: The numbers on the vertical axis are $\hat{t}_\alpha$ ratios. The minimum t-ratio determines *TB*1.

Source: Authors' Calculations based on the ZA Procedure (Model C).

Pahlavani *et al.* (2005) employ the IO and AO models and the quarterly data on Australia's financial and monetary aggregates. Their empirical results do not provide any evidence against the null hypotheses of unit roots in all series. These results are consistent with the findings of this study based on the ZA model.

In ZA model, *TB*1 is endogenously determined by running the model sequentially allowing for *TB*1 to be any observation within the trimming region as defined earlier. The optimal lag length is determined on the basis of the t-test which is referred to as the 'general to specific' approach in the literature. Figure 1 shows the plots of the estimated $\hat{t}_{\alpha}$ within the trimming region using the ZA procedure. The lowest value for $\hat{t}_{\alpha}$ in each graph determines *TB*1. The estimated coefficients for equation (2) together with the corresponding *TB*1s for each of the six variables are presented in Table 1. As can be seen from the results, (a) The estimated coefficients for μ and θ are all statistically significant, supporting the view that at least one structural shift in the intercept has occurred during the sample period for all six variables; (b) The trend variable is significant in five out of six cases; indicating the series exhibit an upward or downward trend; (c) The estimated coefficients for γ are statistically significant for all variables (with the only two exceptions being *Ln(CPI)* and *Ln(MB)*, implying that at least one significant structural shift in the trend has occurred in the four of the variables under investigation.

The LP test results are presented in Table 2. Given that the estimated coefficients for θ, γ, ω and ψ are highly significant for *Ln(CPI)* and the three monetary aggregates, one can argue that these structural changes at time *TB*1 and *TB*2 have impacted on both slope and the intercept. In the case of *Ln(RS)*, while γ, ω and ψ are significant, θ is not. This suggests that the second structural break occurred at *TB*2 for this variable has affected both slope and the intercept but the first one exerted a significant change in trend only. Finally, based on the magnitude of t-ratios for θ, γ, ω and ψ, while the second structural break in *Ln(RL)* has shifted both trend and the intercept (because ω and ψ are highly significant), the first one has no significant effect (i.e., see the t-ratios for both θ and γ) whatsoever.

It should be noted that the LP test results presented in Table 2 indicate that the null hypothesis is rejected for four out of six variables at 5% significance level. These variables are *Ln(RS)*, *Ln(M3)*, *Ln(BM)* and *Ln(MB)*. The consumer price index and the long-term interest rate remain non-stationary despite the fact that two structural breaks have been captured in the data. LP (1997) and Ben-David *et al.* (2003) have found that some I(1) variables, according to the ADF test or the ZA test, can become I(0) after capturing two significant structural breaks in the data. Results of this study are also consistent with the results obtained by Narayan and Smyth (2004) as they also find that the use of LP test rejects the null hypothesis of unit root in 7 out of 16 Australia's macroeconomic variables. However, they have not reported the estimated coefficients for θ, γ, ω and ψ and as such one cannot say anything about the statistical significance of the resulting structural breaks (i.e., $DU1_t$, $DU2_t$, $DT1_t$ and $DT2_t$).

In order to ease the comparison between the resulting break dates from the ZA and LP methods, they are presented in columns 2 and 3 of Table 2, respectively. It is interesting to recognize that the estimated *TB*1s for most variables in the ZA model are quite close to their corresponding LP counterparts. The majority of the endogenously determined break dates coincide with the following events: (a) The 1973 oil shock; (b) The peak of financial reforms during the period 1987-88; (c) The profound effects of the very deep and prolonged 1990-1991 recessions on the Australian economy and a consequent property market collapse; and (d) The launch of the 1996 Wallis Inquiry into financial system.

According to the results presented in Table 2, the consumer price index has been subject to two significant structural breaks in 1973q2 and 1987q4. One may attribute these two breaks to the 1973 Oil shock and the 1987 stock market crash. First graph presented in Figure 2 clearly shows that the intercept and slope for the CPI visibly changed in *TB*1 = 1973q2 and *TB*2 = 1987q4 according to the LP test and in 1973q2 according to the ZA test. It is also observed that *Ln(RS)* was subject to two structural breaks in 1973q3 (trend only) and 1991q3 (both trend and the intercept). The long-run interest rate, however, was subject to one significant structural break in 1981 (both trend and the intercept) a year after the interest rate ceiling on bank deposit rates in Australia was lifted.

The structural breaks for M3 occurred in 1973q2 (*TB*1) and 1988q4 (*TB*2). The first structural break is clearly in accord with the 1973 oil/wages shock, while the second structural break is highly likely to stem from a drastic change in the approach taken by the Reserve Bank of Australia (RBA) to monetary policy in the late 1980s. It should be noted that from the mid-1970s until 1987, monetary policy was conducted in Australia by targeting the annual growth of M3. However, this policy was abandoned in 1988 because deregulation of the financial system had made M3 a misleading indicator of the stance of monetary policy (Grenville, 1990). It should be noted that since 1989 the RBA has decided to set the official cash rate in the money market rather than determining the quantity of money in circulation or pursuing the "check-list approach". Table 2 and Figure 2 indicate that this policy change caused a tangible structural break in M3 in 1988, which is the same year as the one revealed by the corresponding break date for *Ln(M3)* in both ZA and LP models (columns 2 and 3 of Table 2). In other words, both LP and ZA tests have successfully identified this important policy change in 1988.

The first break in monetary base (1988q4) and broad money (1987q4) can be attributed to the effects of the following policy changes which occurred a year before the above break dates: (1) The removal of ceiling rates on new home loans: (2) The abolition of statutory reserve deposits; and (3) Regulatory permission for non-bank financial institutions to issue payment orders (Juttner and Hawtrey, 1997). It is worth noting that M3 was also subject to a structural break around the same time. The second significant break that had an impact on both the trend and the intercept of the monetary base and broad money coincides with the 1996 Wallis Inquiry which restructured the Australian financial systems.

Figure 2 shows the log and the quarterly growth rate of each of the six variables employed as well as their corresponding two LP structural breaks—the solid line denotes *TB*1 and a

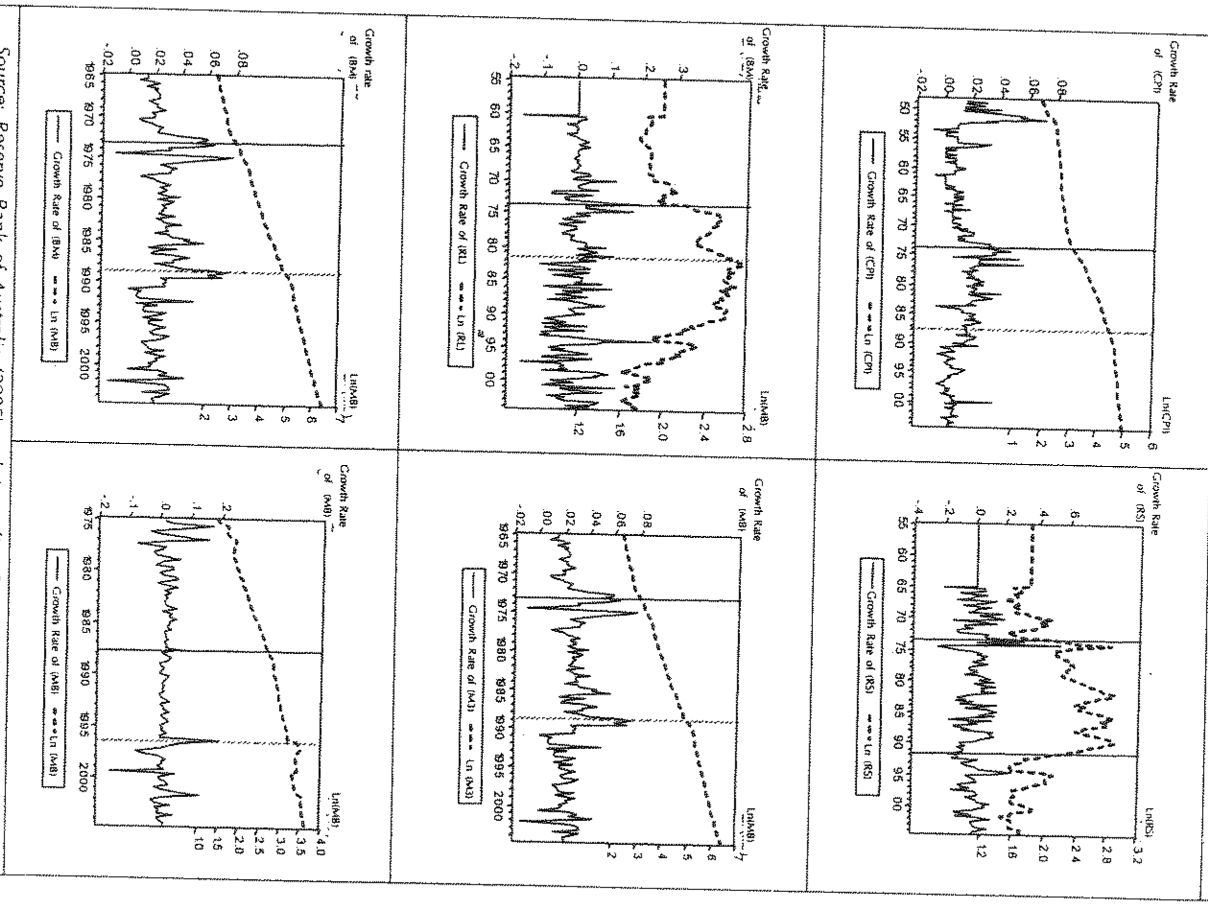
Table 2: The Lumasdaine-Papell Test Results: Break in Both Intercept and Trend (Model CC)

$$\Delta y_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \omega DU2_t + \psi DT2_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + \varepsilon_t$$

Variables	*TB1* ZA (Model C)	*TB1 TB2* LP (Model CC)	μ	β	θ	γ	ω	ψ	α	*K*	Possible Causes for *TB1* and *TB2*
Ln(CPI)	1973q2	1973q4 1987q4	0.149 (6.52)	0.001 (5.08)	−0.071 (−4.22)	0.001 (5.28)	0.155 (5.19)	−0.001 (−5.19)	−0.064 (−6.23)	5	- The 1973 Oil Shock - The 1987 Stock Market Crash
Ln(RS)	1990q4	1973q3 1991q3	0.548 (7.39)	−0.0001 (−0.39)	−0.0183 (-0.32)	0.00236 (3.13)	0.3904 (2.48)	0.004 (−3.84)	−0.307 (−7.71)*	3	- The 1973 Oil shock - Recession and the property market collapse of 1990
Ln(RL)	1973q3	1973q3 1981q3	0.360 (5.67)	0.0001 (0.21)	0.1203 (1.38)	−0.0002 (−0.21)	0.3237 (2.67)	−0.002 (−2.05)	−0.189 (−5.84)	3	- 1973 Oil Shock - Interest rate ceiling on bank deposits rates lifted
Ln(M3)	1988q2	1973q2 1988q4	0.491 (7.35)	0.004 (6.71)	-0.029 (-2.86)	0.002 (4.56)	0.214 (6.91)	−0.002 (−6.79)	−0.214 (−7.25)*	5	- The 1973 Oil shock - Setting the cash rate became the main objective of the RBA
Ln(BM)	1991q1	1988q4 1996q1	1.056 (7.24)	0.008 (7.06)	0.2453 (6.63)	−0.004 (−6.77)	−0.117 (−5.22)	0.001 (5.19)	−0.274 (−7.14)*	7	- Setting the cash rate became the main objective of the RBA - Wallis Inquiry into financial system established
Ln(MB)	1996q3	1987q4 1996q3	0.851 (7.56)	0.013 (7.92)	0.298 (6.14)	−0.004 (−6.36)	0.437 (5.48)	−0.004 (−4.95)	−0.604 (−7.61)*	8	- The share market crash of October 1987 - Wallis Inquiry into financial system established.

Note: (1) * Indicates that the corresponding null is rejected at the 5% level.
(2) The optimal lag length *(k)* is determined by the general to specific method (the *t* test) and $K_{max} = 8$.

Figure 2: Plots of the Actual Data Employed and the Two Endogenously Determined Structural Breaks (Model CC)



Source: Reserve Bank of Australia (2005) and Australian Bureau of Statistics (2005 a, b).

dashed line is used to point to *TB2*. Figure 1 also shows that the resulting break dates for the variables under investigation obviously coincide with major turning points in the intercept and/or the trend of the variables under investigation. Possible causes of the structural breaks for each series are briefly presented in the last columns of Tables 1 and 2.

Conclusion

This paper uses all available quarterly data to determine endogenously the time of the most important structural breaks in Australia's monetary aggregates and interest rates. The study applies both the ZA approach (which assumes the possible existence of a single break in both intercept and slope) and the LP approach (which captures the possible existence of two structural breaks in both intercept and trend). The empirical results based on the ZA model do not provide enough evidence against the null hypotheses of unit roots in all series. In other words, despite considering a single structural break in each series, all of the six variables examined are found to be I(1). This is also consistent with the results obtained by the ADF tests. However, by applying the LP test, the study finds mixed results concerning the stationarity or otherwise of the Australian monetary and interest rates data. Four out of the six variables under investigation became stationary.

The majority of the estimated structural breaks are more likely to result from—(a) The 1973 Oil shock; (b) The peak of financial reforms during the period 1987-88 when the RBA decided for the first time to implement monetary policy via changes in the official cash rate; (c) The profound effects of the very deep and prolonged 1990-91 recessions engulfing the Australian economy in the early 1990s and the consequent property market collapse; and (d) The launch of the 1996 Wallis Inquiry, which really updated the Australian financial systems. This study sheds some light on the issue of structural breaks in the data and as such, provides complementary evidence and useful results for future studies examining Australian monetary variables and interest rates.

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