

REGIME-SHIFTS & POST-FLOAT INFLATION DYNAMICS

OF

AUSTRALIA

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Abstract

Australia's inflation rate and inflation uncertainty during the post-float period 1983Q3-2006Q4 has acted as an important barometer of Australia's macroeconomic performance. The mainstream Friedman paradigm predicts that increase in the average rate of inflation increases inflation uncertainty distorting the price and interest rate mechanisms resulting in temporal and intertemporal allocative inefficiency retarding growth of GDP. The Markov Regime-Switching Heteroscedastic (MRSH) model captures the effects of inflation uncertainty that is generated by regime-shifts, which are ignored by historical volatility measures and the standard ARCH-GARCH approach. The empirical validation of the MRSH model for post-float Australia 1983Q4-2006Q2 revealed that the failure to take account of regime-shifts led to a heated debate between policymakers and academics on monetary policy mistakes due to the adoption of policy models that had become obsolete due to regime-shifts. The Australian MRSH empirics showed that significant departures from the predictions of the nexus between inflation and inflation uncertainty dynamics as conjectured by the Friedman paradigm and also from the MRSH empirics for G7 countries. The paper critically reviews the Australian empirics derived for the post-float period against the received wisdom of the rival paradigms: Keynesian-Mundell-Fleming, Friedman-Ball, Cuikerman-Meltzer and Holland. The critical reviews presented in the paper provide valuable insights to policymakers grappling with the challenge of designing monetary policy to combat the adverse effects of inflation and inflation uncertainty for Australia emerging out of the global financial crisis.

Key-words: Markov Regime-Switching Heteroscedasticity (MRSH), ARCH-GARCH, Inflation Uncertainty, Friedman paradigm, Keynesian-Mundell-Fleming Model, Intertemporal Optimisation, Australia.

JEL Classification: C5, C22, C51, C50, E0, E3.

1. Introduction

In this paper, we investigate the nexus between inflation and inflation uncertainty in the post-float period, 1983Q4-2006Q3 in the Australian economy that was subject to regime-shifts. Although most industrial economies floated their currency after the collapse of the Bretton Woods fixed exchange rate system in 1973, the Australian dollar was floated in 1983Q4. During the post-float period monetary policy was directed at controlling inflation by targeting the reduction of the current account deficit, based on the ‘twin-deficits’ hypothesis aimed at achieving internal and external balance premised on the tenets of the Keynesian-Mundell-Fleming paradigm under a fixed exchange rate regime. A band of leading academics contended that since Australia had achieved fiscal balance and the exchange rate was floating, targeting the reduction of the current account deficit was misconceived. The academics led by Pitchford (1990) argued that the current account deficit was the residual outcome of rational optimizing decision of private agents and therefore there was no justification to target the reduction of the current account deficit when there was fiscal balance and no perceived market failures. The Pitchford thesis was based on the intertemporal optimization model and its advocacy to avoid the targeting the current account deficit was consistent with overcoming the “open economy trilemma”(Krugman, 2009) or the “impossible trinity” of trying to achieve simultaneously a pegged exchange rate, cross-border capital mobility and independent monetary policy. Floating the dollar in 1983Q4 overcame the “open economy trilemma” and underscored the futility of targeting the reduction of the current account deficit drawing on the tenets of the Keynesian- Mundell-Fleming paradigm. Australian monetary policy evolved from targeting the current account deficit to the adoption of a “check-list approach” and then to inflation targeting with Central Bank Independence leading to the dumping of the policy of current account targeting and enthroning inflation targeting with Central Bank Independence as the key lever of monetary policy (Stevens 2000). The global financial crisis (2007) and the massive “fiscal stimulus” that was implemented to avoid the development of a full-blown recession has knocked the wheels off the Pitchford thesis and the Pitchford thesis no longer rules the monetary policy roost (Karunaratne, 2010). The fiscal stimulus has racked up public debt to unsustainable levels

threatening to unleash the inflation genie by raising interest payments on public debt and the inflation rate beyond the inflation target “comfort zone of 2 to 3%). This has led to the resurrection of Keynesian type interventionist policies in the form of 40 percent Resource Super Profit Tax (RSPT) tax to rein in the massive public debt and undertake infrastructure investments to remove bottlenecks to long-term growth. Critics of the RSPT proposal contend that this mining-tax is counterproductive as it will ‘kill the goose that lay the golden eggs’, that is by driving away potential investment of multinational companies to greener pastures elsewhere .A heated political debate on this issue is raging on.

The analysis undertaken in this paper reveals that the nexus between inflation uncertainty and inflation rate is much more complex than subsumed in the populist one-liners of politicians. The policymakers’ phobia with inflation has its roots in the welfare costs and benefits generated by inflation. Macroeconomic theory identifies five major costs of inflation: (1) Shoe leather Costs. (2) Tax distortions. (3) Money illusion. (4) Inflation variability. (5) Redistribution costs from creditors to debtors. Macroeconomic theory also identifies three major benefits of inflation: (1) Seigniorage. (2) Option of negative real interest rates, (3) Money illusion and real wage adjustment. This paper covers new ground in the following areas: First, it provides an explanation for the acrimonious monetary policy debate that occurred during the post-float period in Australia, due to the failure of policy makers’ to abandon a policy of targeting the reduction of the current account deficit based on the Keynesian-Mundell-Fleming model that had been rendered obsolete by regime-shift that occurred due to the floating of the exchange rate. Second, it reports the empirical results due to the validation of the Markov Regime-Switching Heteroscedasticity (MRSH) model for Australia during the post-float period shedding light on the dynamic nexus between inflation and inflation uncertainty, thereby complementing the MRSH model empirics for G7 countries reported by (and Third, it critically reviews the Australian empirics on the nexus between inflation and inflation uncertainty through the perspective of received wisdom in the shape of rival paradigms formulated by Ball-Friedman (Ball, 1992), Cuikerman-Meltzer (1986) and Holland (1993). These rival paradigms explain why the Australian empirics on post-float inflation dynamics deviate in a significant manner from the predictions of the mainstream Friedman (1977) paradigm. The mainstream Friedman paradigm predicted that increase in the average inflation rate increases inflation uncertainty both in the short-run and the long-run resulting distortion of temporal allocative efficiency (by undermining the price mechanism)

and intertemporal allocative efficiency (by distorting the interest rate) causing a loss of welfare due to the retardation of GDP growth. Fourth, the empirical findings based on the validation of the MRSH model for post-float Australia provide useful guidelines to design monetary policy to combat inflation in the aftermath of the global financial crisis (2007).

The rest of the paper is organised as follows: Section 2 presents a literature review of the rival paradigms that purport to explain how regime-shifts affect the nexus between inflation and inflation uncertainty in a manner that either reinforces or deviates from the predictions of the mainstream Friedman paradigm. Section 3 discusses the theoretical framework of the Markov Regime-Switching Heteroscedasticity (MRSH) used in the paper for the empirical validation of Australia's post-float inflation dynamics. This section also comments on the methodological superiority of the MRSH model over the standard ARCH-GARCH models used in the past to analyse the nexus between inflation and inflation uncertainty. Section 4 critically reviews the results of the empirical validation of the MRSH for G7 countries and complements these results by validation of the MRSH model for Australia during the post-float period. This section also presents a critical review of the deviations of Australian inflation rate from inflation uncertainty in the short-run and long-run through the lens of rival paradigms proposed by the Keynesian-Mundell-Fleming, Friedman-Ball, Cuickerman-Meltzer and Holland stabilization theories. Section 5. Concludes the paper, presenting some guidelines for designing policies to combat inflation in Australia in the aftermath of the global financial crisis (2007).

2. Literature Survey

(Friedman, 1977) in his Nobel lecture put the intuition on the nexus between inflation and inflation uncertainty in the short-run and long-run a theoretical footing. The costs of high inflation was widely recognized and in “The Mirage of Steady Inflation” (Okun, 1971) compared the uncertainty due high inflation to a bumpy ride. Friedman (1977) contended that the nexus between inflation and inflation uncertainty is two-pronged. The first prong contends that increase in inflation may motivate policymakers to implement contractionary monetary policy creating more uncertainty and higher inflation in the future. “A burst of inflation produces strong pressures to counter it. Policy goes from one direction to another, encouraging wide variation in the actual and anticipated inflation rate. Everyone recognises that there is great uncertainty about what actual inflation will turn out to be over any specific future interval.” (Friedman, 1977, Ball, 1992)). In the second prong, Friedman's paradigm

predicts that inflation uncertainty would increase the observed rate of unanticipated inflation and the welfare losses associated with it due to the distortion of the price mechanism undermining temporal allocative efficiency and the interest rate undermining intertemporal allocative efficiency, both process contributing to welfare losses due to retardation of GDP growth.

The **Friedman-Ball** (Ball, 1992) paradigm provides a theoretical rationale for the mainstream Friedman paradigm based on a game theoretic framework using asymmetric information in which the public faces uncertainty about the policymaker's commitment to reduce inflation. The Ball-Friedman paradigm assumes that there are two types of policymakers, conservative (C) and liberal (L) that alternate in power in a stochastic manner, with the C-type policymaker being hawkish about fighting high inflation even if it results in a costly recession, while the L-type of policymaker is dovesh and prone to renege on the commitment to keep inflation low in order to achieve a temporary increase in employment for short-term political gain. Since the two types of policymakers alternate in a stochastic fashion the Ball-Friedman paradigm contends that higher current rate of inflation causes more inflation uncertainty about the future level of inflation than a lower current rate of inflation. The Friedman-Ball paradigm predicts that causality runs from high current inflation to increase in future inflation uncertainty.

The **Cukierman-Meltzer** (Cuikerman and Meltzer 1986) paradigm, develops a positive theory of credibility, ambiguity, and inflation under discretion and asymmetric information. In an environment of high inflation uncertainty, where the policymaker has an incentive to create "surprise" inflation in order to achieve temporary increase in employment as hypothesised in the (Barro, 1983) model. In the Cukierman-Meltzer paradigm, credibility is defined in terms of the speed with which the public recognises changes in the objectives of the policymaker. Credibility decreases as monetary control becomes noisier because the policymaker. looser monetary control over monetary policy increasing inflation uncertainty and causing higher average inflation in the future, reversing the direction of causality between inflation and inflation uncertainty predicted by the mainstream Friedman paradigm.

The (Holland, 1993) stabilisation paradigm contends that as inflation uncertainty increases due to rise in the inflation rate, the policymaker is motivated to implement contractionary monetary policy to counter the negative welfare costs associated with high inflation uncertainty. Holland argues that the pursuit of such stabilisation policies to counter

the adverse effects of inflation uncertainty reverses the direction of causality of higher inflation leading to higher inflation uncertainty as predicted by the Cukerman-Meltzer paradigm (Cukerman and Meltzer, 1986).

The rival paradigms lend support and refute the predictions of the mainstream Friedman paradigm that high average rate of inflation leads to increase inflation uncertainty both in the short and long-run. The association between inflation and inflation uncertainty differs depending on whether shocks are temporary or permanent and across countries. Empirical studies based on the ARCH-GARCH framework based on the conditional variance find that Granger causality tests indicate that inflation increases inflation uncertainty in all G7 countries (Grier, 1998)). The ARCH-GARCH methodology suffers from major limitations because it ignores inflation uncertainty due to regime-shifts. This omission is redressed by the superior econometric methodology of the Markov Regime-Switching Heteroscedastic (MRSH) model which has been applied by both Bhar and Hamori (2004) and Bredin and Fountas (2006) to analyse the interactions between the inflation rate and inflation uncertainty in the long and short-run. The Bhar-Hamori study examines inflation dynamics in the G7 countries (Canada, France, Germany, Italy, Japan, UK, USA) over the period 1961Q2-1994Q4. Bredin-Fountas study is based only on four European countries (Germany, Holland, Italy and UK) and uses a more recent data set covering the period 1966Q1-2005Q1. Both studies concur that relationship between inflation and inflation uncertainty varies: i. According to the type of shock buffeting the economy (i.e. whether it is temporary or permanent).ii. The time-horizon(i.e. whether it is short-term or long-term).iii. According to different countries. For example Bhar-Hamori find that high inflation uncertainty has resulted in a positive shift in the average level and variance of inflation in Germany and USA and negative shift in Canada. They support their empirical findings with a battery of diagnostics that also includes the Vuong test. Bredin-Fountas in their four country study find a positive or zero association for transitory shocks and a negative or zero association for permanent shocks. Therefore, Bredin-Fountas conclude that their empirics support the conjecture of the mainstream Friedman paradigm that inflation uncertainty causes high average and variance inflation only partially i.e. only in the short-run and not in the long-run.

The empirical validation of the MRSH for Australia during post-float period shows that both in the short-run and long run under temporary and permanent shocks the Australian inflation rate is out-of-step with the predictions of the mainstream Friedman paradigm and also with

the empirical findings for several G7 countries by Bhar and Hamori and Bredin and Fountas. In this paper, we provide a critical review of the rival paradigms that purport to explain the paradoxical deviation of Australian inflation dynamics from the predicted directions of the mainstream Friedman paradigm through the lens of received theory as encapsulated in the rival paradigms of Keynes-Mundell-Fleming, Friedman-Ball, Cukierman--Meltzer and Holland.

3. Econometric Methodology

In this section, we discuss the evolution of econometric techniques that aim to measure the pivotal concept inflation uncertainty that underpins the dynamic nexus between inflation and inflation uncertainty exposited in the mainstream Friedman paradigm. The early estimates of inflation uncertainty such as the survey measure based on individual forecasts and the moving standard deviation measure were both nonparametric measures based the historical volatility of the inflation rate. The survey based forecast measure was likely to underestimate and the moving standard deviation measure overestimate inflation uncertainty. These historical measures being non-parametric could not be subject to diagnostic testing. The ARCH-GARCH approach is designed to overcome the limitations of inflation uncertainty based on historical volatility of the inflation rate. The ARCH (Autoregressive Conditional Heteroscedasticity) approach advanced by (Engle, 1982) is a nonlinear structural model designed to capture phenomena such as leptokurtosis (fat tails), ‘volatility clustering’, ‘volatility pooling’ and ‘leverage effects’ that characterize financial and economic variables such as the inflation rate.

The structural model explains the dependent variable y in terms of x explanatory variables x and a stochastic error term u as specified below:

$$y = \beta_1 + \beta_2 x_t + \dots + \beta_T x_T + u_t \text{ or in matrix notation } y = X\beta + u$$

The error term u is assumed to distributed normal with constant variance (homoscedasticity) according to the classical linear regression model (CLRM) i.e. $u \sim N(0, \sigma^2)$. But non-linearities due to structural breaks and volatility bursts violate the homoscedasticity, the variance of the error term assumption of the CLRM. The heteroscedasticity is accounted by expressing conditional variance, $\text{Var}(u_t) = \sigma_t^2$, as an autoregressive conditional heteroscedastic (ARCH) effect, wherein the conditional variance depends only on the lagged value of the squared error term once as given by: $\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2$. This an ARCH(1) process aimed at

making the residuals white-noise (Engle 1983). If the lags of squared error required to whiten the error is generalized to q lags we have an ARCH(q) process. The selection of the appropriate number of lags in ARCH modeling can lead to over fitting and violation of the non-negativity constraints.

The generalized ARCH or the GARCH model was proposed independently by (Bollerslev, 1986) and (Taylor, 1986) to overcome the limitations of the ARCH model by formulating a more parsimonious GARCH (1,1) model, where the conditional variance of the error term depends on the squared error and the conditional variance lagged, both lagged once, as specified below:

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta \sigma_{t-1}^2$$

The above GARCH (1,1) model can be re-arranged as an ARMA (1,1) in defining the conditional variance as a composite of one AR and one MA term. The GARCH (1,1) model can be generalized to a GARCH (q,p) model with q lags of the squared error term and p lags of the conditional variance term. However, for most practical applications the GARCH (1,1) model captures nonlinearities and volatility phenomena adequately, making it unnecessary to use higher order GARCH processes. However, a major deficiency of the GARCH modeling occurs because inflation uncertainty is explained only by changing conditional variance, which is also notated $h_t = \text{Var}(u_t) = (\sigma_t^2)$, while assuming that the unconditional variance is constant. This leads to serious mis-measurement of inflation uncertainty because it ignores the volatility caused by structural breaks and regime-shifts (Evans, 1993). The conditional variance of the GARCH model is defined by $\text{var}(u_t) = \alpha_0 / [1 - (\alpha_1 + \beta)]$ only if $(\alpha_1 + \beta) < 1$ and it is a nonstationary or a unit process if $(\alpha_1 + \beta) = 1$ and remains undefined when $(\alpha_1 + \beta) > 1$ creating problems in forecasting inflation over long-term time horizons.

The Markov Regime Switching Heteroscedasticity (MRSH) econometric model is designed to overcome the major limitations of the ARCH-GARCH models that measure inflation uncertainty only in terms of the conditional variance. The measure of inflation uncertainty using the constant conditional variance fails to capture the notion of inflation uncertainty as conceptualized in the mainstream Friedman paradigm as it is only a measure of volatility. The MRSH model is superior to ARCH-GARCH model because of at least three reasons: First, it captures inflation uncertainty in terms of the time-varying unconditional

variance which captures the effects of uncertainty due to unanticipated shocks caused by regime-shifts. Second, the decomposition of shocks into a stochastic permanent component and temporary white-noise component providing insights on the dynamic nexus between inflation and inflation uncertainty in the short-run and long-run. This type of decomposition provides insight on how an increase in inflation uncertainty undermines allocative efficiency and retards long-term economic growth as conceptualized by the mainstream Friedman paradigm (Lastrapes, 1989). Third, it takes explicit account of inflation uncertainty generated by regime-shifts or structural breaks.

The MRSH model has been specified by (Kim, 1999) terms of equation (1) and equation (2) that postulate that the inflation rate (π_t) for any given country at time t can be decomposed into a stochastic trend (random-walk) component and a stationary (white-noise) component as suggested by the theoretical interpretation of the Friedman paradigm by (Ball, 1990). The temporary shock affecting equation (1) is distributed normally $e_t \sim N(0,1)$ and also the permanent shock affecting equation (2) is distributed normally: $v_t \sim N(0,1)$ normally. A permanent shock (v_t) differs from a temporary shock in that it can alter the trend money growth rate in the positive or negative direction depending on whether the policymaker is implementing expansionary or contractionary monetary policy, the latter could be aimed at disinflation resulting in a recession. A temporary shock (e_t), only causes temporary deviations from the trend money growth rate and does not alter the trend money growth rate. The two equations that decompose the inflation rate into stochastic permanent trend component and temporary stationary component are given by equation (1) and (2) below:

$$\pi_t = T_t + C_t + \mu_2 S_{1t} + \mu_3 S_{2t} + \mu_4 S_{1t} S_{2t} + (h_0 + h_1 S_{2,t}) e_t \quad (1)$$

$$T_t = T_{t-1} + (Q_0 + Q_1 S_{1t}) v_t, \quad (2)$$

The endogenous variable T_t : refers to the unobserved permanent trend component and C_t : refers to the cyclical component as hypothesised in structural time-series modelling ((Harvey, 1989). In the above specification of the MRSH model $S_{1,t}$ and $S_{2,t}$ define the two unobserved Markov processes or state variables or regime in which the economy is at any given point in time due to permanent trend component and the stationary temporary component, respectively. These two state variables evolve independently of each other according to their own transition probabilities given by the two-state Markov switching process, which takes

the value 0 if the economy is in a low variance state and the value 1 if the economy is in a high variance state. The two-state Markov switching process assumes the transition probabilities defined in equation (3) below:

$$\begin{aligned} \Pr[S_{1,t}=0 \mid S_{1,t-1}=0] &= p_{00}, \Pr[S_{1,t}=1 \mid S_{1,t-1}=0] = p_{11}, \\ \Pr[S_{2,t}=0 \mid S_{2,t-1}=0] &= q_{00}, \Pr[S_{2,t}=1 \mid S_{2,t-1}=0] = q_{11}, \end{aligned} \quad (3)$$

In equation (3) p_{00} denotes the probability that the trend component will remain in regime 0 given that the system was in regime 1 during the previous period, and p_{11} denotes the probability that the system is in regime 1, given that the system was in regime in the previous period. While $q_{00} = (1 - p_{00})$ defines the probability that y_t will change from state 0 in period $t-1$ to the state 1 in the period t , and $q_{11} = (1 - p_{11})$ denotes the probability of shift from state 1 to state 0 between times $t-1$ and t . It can also be shown that in the above specification, S_t evolves as and AR(1) process in period t . The transition probabilities given in equation (3) can be classified into four regime as indicated by equation (4) given below:

$$\begin{aligned} \text{Regime 1: low } Q_t \text{ and low } h_t (S_{1,t}=0, S_{2,t}=0) \\ \text{Regime 2: low } Q_t \text{ and high } h_t (S_{1,t}=0, S_{2,t}=1) \\ \text{Regime 3: high } Q_t \text{ and low } h_t (S_{1,t}=1, S_{2,t}=0) \\ \text{Regime 4: high } Q_t \text{ and high } h_t (S_{1,t}=1, S_{2,t}=1) \end{aligned} \quad (4)$$

The parameters of the MRSH model specified by equation (1) and (2) can be estimated using the computer algorithm supplied by (Kim, 1999). The parameters μ_2, μ_3, μ_4 provide estimates of the inflation rate depending on the state or regime. The estimate of μ_2 measures the effect of uncertainty associated with the high variance state of the trend or the long-run permanent component. While the parameter μ_3 measures the effect of inflation uncertainty associated with the high variance state of the temporary component in the short-run. The estimate of the parameter μ_4 measures the shift in the mean inflation rate due to the interaction of change in both the temporary and permanent uncertainty on the inflation rate. The increase in the inflation rate due to increase in the variance in the permanent or trend component during the high (low) variance state is given by Q_1 (Q_0) and the increase in variance of the temporary component during the high (low) variance state is given by h_1 (h_0).

The statistical reliability of the empirical validation of the MRSH model defined by equations (1) and (2) has been evaluated using a series of descriptive statistics relating to the inflation rate (mean, standard deviation, skewness, kurtosis) and by subjecting estimated model parameters to three diagnostic test: i. JB-test (Jarque, 1997) test the null-hypothesis of normality, which is not rejected at 5% (1%) level of significance if the p-value for the critical value of the test exceeds 0.05 (0.01).ii.. The BDS test for non-linearity that tests the null-hypothesis that the error term is i.i.d as proposed by (Brock, 1996). ii. The ARCH test for white-noisiness of residuals to test the null hypothesis of heterosceasticity as suggested by (Engle, 1982)) iii. The KS (Kolmogrov-Smirnov) test of the null hypothesis of normality of residuals . Besides, four additional tests were implemented to ensure that MRSH methodology captured the dynamic nexus between inflation uncertainty adequately : i. The modified von-Neumann ratio test to test the null of for serial correlation of residuals. ii. The Regime Classification Measure (RCM) proposed by Ang and Bekaert (2002) to determine whether the existence of regime shifts in the data. iii. Th(Rivers, 2002) Vuong-test to compare the superiority of the MRSH model against the variants of the GARCH models based non-nested AR(1)-GARCH(1,1) and MA(1)-GARCH(1,1) specifications. iv. The decomposition of the mean inflation rate into the long-run and short-run components to measure inflation uncertainty in the MRSH econometric methodology depends crucially on whether the inflation rate is non-stationary or integrated order one, I(1). A number of tests can be implemented to test the null hypothesis of non-stationarity and they include the ADF (Dickey, 1979)test , the Kwiatkowski et al. (KPSS) test or the Phillip-Perron PP-test. In this paper we have used the ADF test to test and the null of nonstationarity is not rejected satisfying the validity of decomposition of the inflation rate in the short-run and long-run components, as hypothesized in the MRSH model.

4. Empirical results

The empirical validation of the MRSH model for seven G7 countries by (Bhar, 2004) for the period 1961Q1-1999Q4 report the results based on the implementation of a battery of diagnostic tests and additional tests as described above. They report positive estimates for the parameter $\mu_2 > 0$ in the MRSH model, implying that high uncertainty in the inflation was associated with a significant positive shift of the inflation rate in the long-run for Canada, Germany and Japan as predicted by the Friedman paradigm. They report positive estimates

for the parameter $\mu_3 > 0$, implying that that high uncertainty in the inflation rate in the short-run inflation was associated with a significant positive shift of inflation rate in Germany and USA but a negative significant negative shift for Canada. The latter result for Canada runs counter to the predictions of the Friedman paradigm. The positive short-run shift in the inflation rate above the normal rate in Germany and USA can increase inflation uncertainty due to less monetary policy that prevailed in these countries. The estimates of the MRSH model parameter μ_4 was significant for Japan and UK, implying that uncertainty in both the long-run trend and short-run temporary component played a significant role in increasing inflation in these two countries. The Bhar-Hamori empirics for G7 also indicate the persistence of inflation in Italy and Japan as measured by the contribution to the conditional variance by the trend component ($p_{11}+p_{00}-1$) and the temporary component ($q_{11}+q_{00}-1$) were significant and differed from pattern of behavior observed for the other G7 countries. The Regime Classification Measure (RCM) due to (Ang, 2002) which takes the value 0 when there is perfect regime classification information and 100 when there is an absence of in the data yielded different results for G7 countries. For the trend component Japan with RCM =7.06 gave the highest indication of regime-switching and German with RCM= 55.35 gave the lowest support for regime-switching in the G7 countries in the long-run. The RCM indicating regime-switching in the short-run was shown to be highest for Japan with an RCM=11.12 and lowest for USA, with and RCM= 67.07. The Bhar-Hamori G7 study also reported that the Vounge-test demonstrated that MRSH model captured the regime-switching phenomenon in the data generation process better than the variants of the non-nested GARCH models Whilst conceding that the Bhar-Hamori empirics establish through a battery of diagnostic and other tests overwhelming support for validity of the MRSH model in shedding light on inflation uncertainty associated with regime shifts these findings have a major short-coming. This is mainly because Bhar-Hamori empirics fail to interpret the policy significance of their empirical results in the light of received wisdom as subsumed in the rival paradigms. In this paper we overcome this lapse when interpreting the Australian empirics of the MRSH model during the post-float period.

Australian MRSH empirics

The inflation rate (π_t for Australia has been estimated using the seasonally adjusted quarterly implicit price deflator (P_t) published by the OECD national accounts (DX-database). The inflation rate $\pi_t = 100 \times (P_t - P_{t-1})/P_t$, covers the post-float period 1983Q4 –

2006Q3 . A series of descriptive statistics for the Australian inflation rate: the mean, standard deviation (SD), skewness, kurtosis and the p-value of the Jarque-Bera (JB) test for the post-float period are reported (see Table 1) and they are relatively high compared to those for the seven G7 countries reported by Bhar- Hamori (2004) empirics. The JB-test fails to reject the null hypothesis of non-normality of 5%(1%) level of significance as the p-value exceeds 0.05(0.01), respectively. The results of the ADF test indicates that the Australian inflation rate for the post-float period fails to reject the unit-root or non-stationary at the 5% level but not at the 1% level of significance as the calculated ADF test-statistic -2.9435 is less than the critical value of 1% level has a p-value of 0.0444. The non-stationary of the inflation rate is a pre-requisite to make a valid decomposition of the inflation rate into short-run and long-run components for the empirical validation of the MRSH model for Australia for the post-float period (see Table 1).

The implementation of the battery of diagnostic tests for Australia for the post-float period reveals that the BDS non-linearity test fails to reject the null hypothesis that the disturbance is i.i.d. The implementation of the BDS required the assignment of a value of 2 for the embedding dimension and a value epsilon $\epsilon = 0.10$ for the distance measure.. The null that disturbance term is i.i.d is not rejected for Australia during the post-float period. The ARCH test of no serial correlation in the squared residuals up to lag 26 is not rejected. The Kolomgrov-Simornov (KS) test of the null of normality of the residuals is also not rejected as the calculated of the KS test statistic is less than the critical value of 0.113 at the 95% level of significance. The modified von-Neuman ratio (MNR) test (Harvey, 1990) that tests the null of no serial correlation in the recursive residuals is also not rejected as the calculated t-statistic is less than the critical value from the critical value from the Student's t-table at the 95% level of significance (See Table 2). Therefore, the diagnostic tests provide overwhelming support for the MRSH modeling framework that is used to shed light on the dynamics between inflation and inflation uncertainty in Australia during the post-float period.

This paper complements the MRSH empirics of Bhar-Hamori (2004) and Bredin-Fountas (2006) for G7 countries, being the first study to identify regime shifts in post-float Australia. It is noteworthy that regime-shift in post-float Australia sparked off a heated debate between academics about the validity of modeling approach that guided policymaking in Australia during the post float period as summarized in the '(Pitchford, 1990).

The maximum likelihood estimates (MLE) of the MRS model parameters for post-float period has been estimated using the quasi-optimization algorithm of (Kim, 1993) and (Kim, 1999). The numerical optimization of the of the MRS parameters was estimated using the Newton-Raphson algorithm which converged after 17 iteration was based on Gauss 8.0, converged after 17 iterations. These parameters are reported in Table 3.

The estimate of the parameter $\mu_2 = -0.0838^{**}$ is small and negative and highly significant and this implies that increase inflation uncertainty causes a decline in the long-run trend inflation rate. This result runs counter to the prediction of the mainstream Friedman paradigm that increase in inflation uncertainty leads to permanent or increase in the trend inflation rate according to the Ball-Friedman paradigm (Ball 1992). The estimated value of μ_2 was also significant and negative and much larger only for Italy according to the G7 empirics of Bhar and Hamori (2004) G7 for both Italy and UK according to findings of Bredin and Fountas (2006). The estimate of the parameter $\mu_3 = 0.6909^{**}$ for post-float Australia is positive and significant indicating that increase in short-run uncertainty increases the short-run transitory inflation rate as predicted by the mainstream Friedman (1977) paradigm. This type of finding implies that the inflation rate increases above the normal level, creating uncertainty among the public about the possible response of policymakers to accommodate inflation according to the Cuikerman and Metzler (1992) paradigm. Similar results were also observed for G7 countries, except for Canada and UK where μ_3 was negative implying that increase in inflation uncertainty decreases short-run transitory inflation rate contrary to the ==predictions of the mainstream Friedman paradigm. The estimate of $\mu_4 = 0.5164$ was not significantly different from 0 for the post-float period in Australia, implying that the interaction between the short and long run uncertainty had no effect on the trend inflation rate. This finding that implies that the interaction between short-run and long-run inflation uncertainty has no impact on the changes of the average inflation rate either in the short-run or in the long-run. If the inflation rate and the probability of high variance state for permanent shocks observed for G7 countries revealed three facts about the relationship between the inflation rate and the probability of the high variance state for permanent shocks implying that they were caused by a common international shocks such at the oil price shocks. In the Australian case such common international shocks appear to reduce inflation uncertainty rather than increase it. Secondly, the behavior of Australian inflation uncertainty appears to differ from that of many of the G7 countries which reported positive values for μ_2 , and

therefore consistent with the predictions of the mainstream Friedman-Ball paradigm. But Australian empirics do not support the predictions of the Friedman-Ball paradigm. Thirdly, the analysis recognizes that structural change could occur in the country that is analyzed. For example, in the case of Australia, the probability of high variance state of the permanent component is close to unity during the most of the post-float period. Therefore, the use of the MRSH model has allowed us to capture the possibility of structural change and therefore regime shifts. The failure to allow for regime-shifts leads can lead to a gross over overestimation of the persistence of variance of the inflation rate series (Lastrapes, 1989). The empirical results for the MRSH parameters for Australia run counter to predictions of the mainstream Friedman (1977) paradigm and we present a critical review of the flurry of explanations based on rival paradigms.

The estimates of the elements of the transition probability matrix give probabilities p_{11} and p_{00} for the switching variable $S_{1,t}$ and the elements q_{11} and q_{00} give the transition probabilities for the switching variable $S_{2,t}$. All the transition probabilities are highly significant.. The estimates of the contribution to the conditional variance by the permanent or trend component and the transitory or temporary component are given by $(p_{11} + p_{00} - 1) = 0.9338$ and $(q_{11} + q_{00} - 1) = 0.8797$ respectively (Kim, 1999):164). It is noteworthy that the size of the contributions of the transition probabilities to the conditional variance reported for post-float Australia above is similar to those observed for the G7 countries reported Bhar-Hamori G7 empirics.

A measure of Regime-Change Classification (RCM) due to (Ang, 2002) and Bekaret (2002) indicates whether the switching variable S_1 and S_2 yield information on the existence of regime-switching. The RCM measure ranges from 0 to 100, 0 implies a perfect regime classification and numbers near 100. The RCM measure was estimated for Australian during the post-float period using the formula:

$$RCM = 400 \times \frac{1}{T} \left[\sum_{t=1}^T p_{S_{1,t}} (1 - p_{S_{1,t}}) \right]$$

The results for the RCM measure are reported in Table 4 and indicates that $RCM=46.92$ for the permanent component and compares with similar results obtained for Canada, France, Germany and UK. While the $RCM= 55.69$ for the temporary component and compares with results observed for Germany and USA. We suspect that the regime-switching variables S_1 and S_2 have been obscured by the operation of 'noise' factors. The sharpest

regime switching effects for both the permanent and temporary components were reported for Japan in the Bhar-Hamori G7 empirics.

A visual inspection of the graphs which plot the inflation rate and the probability of being in the thigh variance state for the permanent and transitory shocks during the post-float period. are shown in Figure 1 and Figure 2, respectively. A closer inspection of Figure1 represents the inflation and the probability of high variance due to permanent shocks allow us to make the following three observations: First, the probability of a high variance state does not appear to vary during the post-float period as this probability is less than 0.5 until the 1990s. However, post-1990s the probability of high variance state approaches unity indicating that inflation uncertainty has begun to cause increases in the average long term inflation rate. Second, during most of the post-float period the probability of the high variance state is less than 0.5 indicating the existence of regime change during the post-float period 1983Q4-2001Q2. Third, the probability result of the high variance state that reveals the existence of a regime-shift justifies the use of the MRSH econometric methodology to validate the dynamics between inflation and inflation uncertainty in post-float Australia. A visual inspection of Figure 2 that plots the rate of inflation and the probability of the high variance state for transitory shocks lead to the following observations: First, the probability of high variance state for transitory shocks is quite low and below 0.5 during the post-float period until 2000Q2, when the probability starts approaching unity implies that inflation uncertainty started to increase average rate of inflation after 200Q2. Second, Figure 2, also provides evidence of structural change when the probability was low, less than 0.5 for most of the post-float period, and started approaching unity after 2000Q2.

Kim (1993) also found that the ratio of high to low variance of permanent shocks is larger than that for transitory shocks for US, which means $Q_1 > h_1$. Similar findings are reported for Australia during the post-float period (SeeTable 3). Kim also finds that when variance of permanent shocks when low as measured by Q_0 is close to zero for Australia during the post-float period. Similar findings for Q_0 reported for Germany and USA according to the Bhar-Hamori G7 empirics. This finding suggests that infrequent permanent shocks to the price level account for most of the persistence of the price level.

In Table 3, we also report the estimates for Q_1 and Q_0 for the increase in the variance of the trend component during high and low variance states, respectively. Furthermore, h_1 and h_1 provide estimates of the increase in the variance of the temporary component during the

high and low variance states, respectively. For Australia the ratio of high to low variances for permanent shocks is smaller than for transitory shocks $Q_1 < h_1$. This is consistent with similar findings for G7 countries such as Canada, France, Japan and UK but differed from the results for USA, and Italy. According to (Kim, 1993) if the variance of the permanent shock is low, revealed by an estimate of Q_0 that is not significantly different from 0 for Australia and for other G7 countries except Germany and the USA.

The variance of inflation forecasts for different pre-specified time horizons can be derived using the methodology suggested by (Evans, 1993). This methodology defines the two components of certainty equivalence, $\text{Var}(\text{CE})$, and the regime uncertainty component. Figure 3 and Figure 4 show that the two components of variance forecast for forecast horizons of two ($k=2$) and four quarters ($k=4$) for Australia during the post-float period. These Figures show that inflation uncertainty increases at all horizons with peaks after first oil shock in 1972Q4 and the second oil shock in 1981Q1 and returns to low levels only after 1990Q4. These results observed for Australia are similar to the results observed for G7 countries by (Bhar, 2004).

Rival paradigms

A number of rival paradigms purport to explain the significant departures of Australian inflation dynamics in the post-float period from the predictions of the mainstream (Friedman, 1977) paradigm. We present a brief review of the three main paradigms that have been used in this study to critically evaluate the dynamics of the inflation and inflation uncertainty nexus for post-float Australia. The Bhar-Hamori paper fails to critically review the G7 empirics from the perspective of received wisdom as contained in the rival paradigms and in this paper we remedy this above omission for the Australian empirics in the post-float period.

The Friedman-Ball paradigm

Friedman's two-pronged anti-inflation thesis was formalized in a game-theoretic framework. The Friedman-Ball paradigm (Ball, 1992) conjectures that inflation uncertainty would increase the average inflation rate as predicted by the mainstream paradigm as postulated by Friedman (1977). The Friedman-Ball paradigm underscores that because the conservative or opportunistic policymakers could alternate in office in a stochastic fashion—two types of policymakers with different degrees of commitment to reduce the economic

costs of disinflation. The conservative type of policymaker will implement contractionary monetary policy during periods of low inflation while the opportunistic type of policymakers will be tempted to engage in expansionary monetary policy, thereby increasing future inflation uncertainty. The Friedman-Ball paradigm predicts that an increase in inflation uncertainty will increase the average rate of inflation not only in the long-run but also in the short-run, thereby undermining allocative efficiency and retarding the growth in GDP as predicted by the mainstream Friedman paradigm. Empirical findings for Australia fail to support the predictions of the Friedman-Ball paradigm, but rather supports reverse causality as indicated by the Cukierman-Meltzer and Holland paradigms as discussed below.

The Cukierman-Meltzer paradigm

Cukierman and Meltzer paradigm (Cukierman and Meltzer 1986, Barro 1983) contends that contrary to the predictions of the Friedman-Ball paradigm an increase in inflation uncertainty increases the average rate of inflation. They use the logic underpinning the (Barro, 1983) model to explain that opportunistic policymakers may trade-off a reduction of unemployment at the cost of increasing long-term average rate of inflation for short-term political gain. Therefore, policymakers by implementing discretionary policies engage in time-inconsistent behavior increasing inflation uncertainty that causes an increase the long-run inflation rate both in the short-run and long-run. The opportunistic behaviour of policymakers that leads to increase inflation uncertainty is attributed to the lack of a commitment mechanism involving the institutional of Central Bank independence and inflation targeting.

The Holland paradigm

The (Holland, 1993) 'Fed stabilization' paradigm contends that increase in inflation uncertainty will induce policymakers to implement contractionary monetary policy in order to disinflate and reduce inflation uncertainty and its negative welfare effects. Therefore, inflation uncertainty contrary to the predictions of the Cukierman-Meltzer paradigm will reduce future inflation rather increase it.

The rival paradigms that purport to explain the divergence in the nexus between inflation and inflation uncertainty in the long-run and in the short-run reviewed above require empirical analysis to resolve the conflicting predictions using time-series and panel

databases. In this paper we have attempted to empirically validate for the first time the MRSH model using an up-to-date Australian quarterly time-series dataset for inflation covering the sample period (1983Q3-2006Q4). The estimates of the parameters of the MRSH model shed light on the complex dynamics of nexus between inflation and inflation uncertainty in the Australia during the post-float period.

The critical review of the empirical results observed from the validation of the MRSH model for Australia during the post-float period overcomes a significant omission in the Bhar-Hamori empirics reported for G7 countries, as these results are presented bereft of a critical review in the light of received wisdom on the dynamics inflation and inflation uncertainty as revealed by the rival paradigms. The empirical results from the validation of the MRSH model for Australia reveal that the behaviour of short-run and long run dynamics of inflation and inflation uncertainty deviates in a significant manner from the predictions of mainstream Friedman paradigm as supported by the Friedman-Ball paradigm. The inflation uncertainty decreases in Australia in the short-run and long run in the face of temporary shocks and permanent shocks respectively, contrary to the predictions of the mainstream Friedman paradigm. However, the finding that the increase the average inflation rate decreases inflation uncertainty in the short-run and long-run lends support to the predictions of Cukierman-Meltzer paradigm that it is the outcome of the creation of “surprise” inflation due to discretionary policy in the absence of a commitment mechanism for the post-float period up to about 2000Q1. The reverse causality of increasing inflation uncertainty that decrease inflation contrary to the predictions of the Friedman paradigm in Australia lend support to the Holland (1993) stabilization paradigm which contends that increase in inflation uncertainty induces policymakers to implement stabilization policies to reduce the average inflation rate.

6. Concluding observations

The MRSH model has been empirically validated for Australia using quarterly time-series data for Australia during the post-float period (1983Q4- 2006Q3) to examine the nexus between inflation and inflation uncertainty. The MRSH modeling methodology overcomes some of the conceptual limitations in relation to the measurement of inflation uncertainty that

precluded the GARCH approach from identifying the occurrence of structural changes and regime shifts. The Markov-regime switching model applied to analyze Australia's inflation process in the 1960s includes an output gap term as a significant exogenous explanatory. It also endogenizes structural breaks and encompasses the non-constant variance ARCH process (Simon, 1996). However, the methodology of Markov-regime switching in the RBA discussion paper fails to incorporate heteroscedasticity as subsumed in the modeling of inflation dynamics and regime- shifts that we have borne out in our empirical analysis in this paper.

The MRSH approach allows for regime shifts in both the mean and variance of inflation providing insights on the nexus between inflation and inflation uncertainty over the short-run and long-run. The empirical results from the MRSH model reveal that the nexus differs: i, between transitory and permanent shocks to inflation and ii) and across countries. It is noteworthy that the nexus is negative for permanent shocks and positive for transitory shocks. Hence, the predictions of Friedman's paradigm that inflation uncertainty is positively related to the inflation rate is only partially supported by the model empirics. In the long-run inflation uncertainty leads to a reduction in the average inflation rate as $\mu_2 < 0$ and in the short-run inflation uncertainty increases the average rate of inflation.

We have also critically reviewed the paradoxical results observed for Australia during the post-float period against the backdrop of: I) Theoretical perspectives offered by rival paradigms on the nexus between inflation uncertainty and inflation. ii) Cross-country empirical evidence available from G7 countries. Iii) The evolution of the stance of monetary policy over the post-float period.

The insights offered by the theoretical paradigms and the complex dynamics linking inflation uncertainty and the inflation rate should dispel any doubts about the ability of controlling inflation as proclaimed in populist sound bytes or one liners relating to the slaying of the inflation dragon. In fact with the unraveling global financial crisis triggered by the U.S. sub-prime mortgage meltdown most economies in the world have plunged into recession and Keynesian fiscal stimulus packages involving the massive increase in government spending on infrastructure projects is advocated to boost sagging aggregate demand and arrest deflation. However, it should be noted that these infrastructure expenditure is stifled by long gestation lags and may only increase consumer spending after the lag of a decade triggering

another boom-bust cycle putting back into the policy centre stage the control of inflation uncertainty and the inflation rate.

(Note all the Tables in the revised version have been replaced by Tables in Excel format).

| Table 1 Descriptive Statistics | |
|---|----------------------------------|
| Australian Inflation Rate 1983Q4-2006Q3 | |
| Mean | 0.9122 |
| Median | 0.8249 |
| Maximum | 0.9641 |
| Minimum | 2.9697 |
| Standard Deviation | -0.8495 |
| Skewness | 0.4428 |
| Jarque-Bera(JB) test | 3.01067, p=0.2219 |
| ADF test statistic | $\hat{\alpha}$ -2.9435, p=0.0444 |
| Critical value 5% (1%) | -3.5142 (-2.8901) |

| Table 2 Diagnostic Tests on Model Adequacy Based on Recursive Residuals | | | |
|---|---------------------------------------|----------|-----------------------------------|
| Test | Test-Statisti. Value | Critical | Decision |
| 1. BDS | Dimension=2, $\hat{\epsilon} = 1.112$ | | Do not reject null of i.i.d |
| 2. ARCH | (5.803), d.f. 11, p-value= 0.886 | | Reject null of heteroscdasticity |
| 3. KS | (0.047), CV 95% = 0.142 | | Do not reject null of normality |
| 4. MNR | (2.153), CV 95% = 0.244 | | Reject no serial correlation null |
| 5. Recursive-T | -1.06, CV 95% = 0.288 | | Reject null of model inadequacy |

Table 3 Parameter estimates of the MRSH Model.

Post-float Australia (1983Q4-2006Q3)

| Parameter | Estimate | Std. Error |
|-----------------------|-----------|--------------|
| p_{11} | 0.9820** | 0.02337 |
| p_{00} | 0.9518** | 0.04292 |
| q_{11} | 0.9431** | 0.04513 |
| q_{00} | 0.9366** | 0.04475 |
| Q_0 | 0.000001 | 0.04645 |
| h_0 | 0.2909** | 0.0422 |
| Q_1 | 0.0972* | 0.06036 |
| h_1 | 0.3246** | 0.09478 |
| μ_2 | -0.0838** | 0.02584 |
| μ_3 | 0.6909** | 0.19021 |
| μ_4 | 0.5164 | 0.34466 |
| Max. lik. Value | 76.3534** | Sample: n=92 |
| Level of significance | * 5% | ** 1% |

Table 4 Regime Classification Measures (RCM)

Australia

Permanent 49.62

Temporary 53.69

Source: Ang and Bekaert (2002)

Table 5

Young Statistic for Non-Nested Model Selection of MRSH Model

against the two different Variants of the GARCH models

| | AR(1)-GARCH(1,1) | MA(1) GARCH(1,1) Mean |
|---------------------|------------------|-----------------------|
| Australia | 2.82 | 1.81 |
| Critical Values(CV) | 1.64(2.56) | 1.64(2.56) |

Source: Rivers and Vuong (2002)

If entry in the Table is > Critical value (CV)

MRSH Model is superior GARCH

Figure 1

Inflation Rate and Probability of High Variance State (Permanent Shocks)

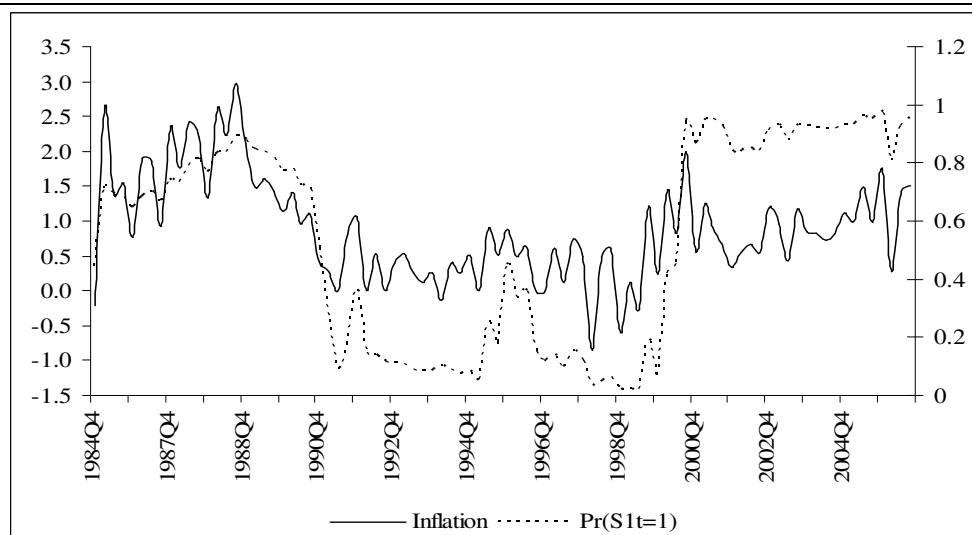


Figure 2

Inflation Rate and Probability of High Variance State (Temporary Shocks)

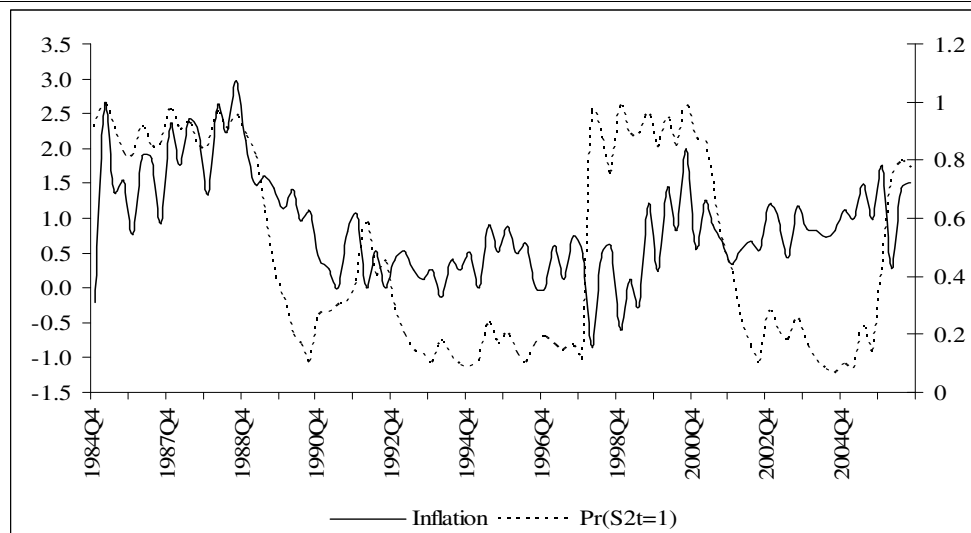
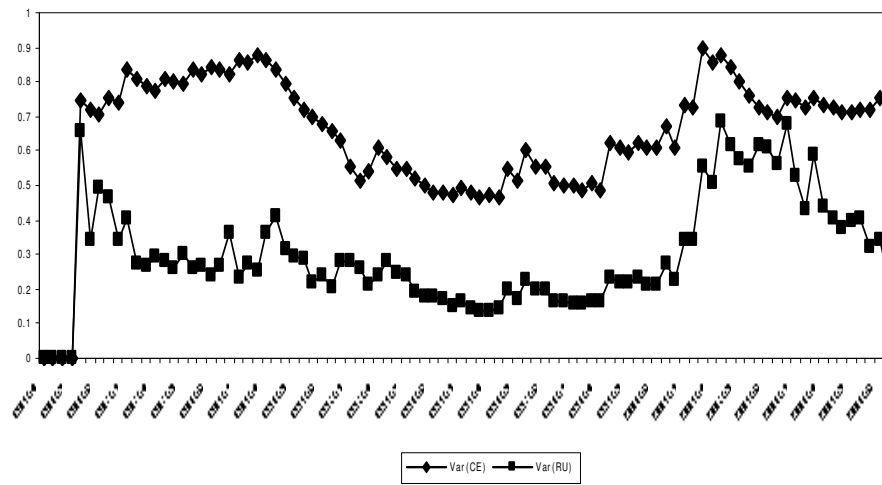


Fig. 3 Components of Forecast Variance at k=2:Australia



Fig. 4 Components of Forecast Variance at k=4:Australia



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