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Meta Taylor Rules for the UK and Australia; Accommodating Regime Uncertainty in Monetary Policy Analysis using Model Averaging Methods *

by

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Abstract

This paper provides a characterisation of UK and Australian monetary policy within a Taylor rule framework, accommodating uncertainties about the nature and duration of policy regimes in a flexible but easy-to-implement analysis. Our approach involves estimation and inference based on a set of Taylor rules obtained through linear regression methods, but combined into a 'meta' rule using model averaging techniques. Using data that were available in real time, the estimated version of the meta Taylor rule provides a useful and detailed characterisation of monetary policies in the UK and Australia over the last thirty years.

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JEL Classification: C32, D84, E32.

1 Introduction

Monetary policy decisions generate considerable public and academic debate reflecting the uncertainty that exists around monetary policy prescription at any one time and a recognition of the changing nature of monetary policy implementation over the years. Commentators discuss almost continuously the detail of the current policy, judging the size and timing of recent and forthcoming interest rate movements in the context of the macroeconomic situation. Over a longer time frame, the academic literature on monetary policy has frequently discussed the purpose of macroeconomic demand management and the design of optimal monetary policy, developing over the years as economists' understanding of how the macroeconomy works changes, as institutions and market structures change, and as the emphasis on different policy objectives change. The treatment of structural instability is fundamental to the empirical analysis of monetary policy, then, both because of the shifting focus on the different drivers of decision-making within any given regime and because the nature of the policy regime itself changes over time, sometimes abruptly with the election of a new government or the introduction of a new policy framework, say, and sometimes more smoothly as opinions and attitudes evolve.

The pervasiveness and the diverse nature of changes in monetary policy means that it may be difficult to characterise and accommodate these changes in applied econometric analysis. However, despite the structural instabilities inherent in monetary policy, including frequent changes in the instruments through which monetary policy is conducted, Orphanides (2003) provides a compelling argument that, in the US at least, a coherent analysis of policy over many years can be conducted using the Taylor rule as an organising device. The Taylor rule, as originally reported in Taylor (1993), related the federal funds rate at time t to the rate of change of the implicit output deflator over the previous four quarters and a measure of the output gap at t. Taylor showed that a linear rule, with coefficients of 1.5 and 0.5 on inflation and the output gap respectively, accurately described recent US policy at the time of writing (i.e. covering the period 1987q1-1992q4). Orphanides (2003) argues that the principle that is built into the Taylor rule, of implementing monetary policy to lean against inflationary and excessive growth conditions, also serves as a useful vehicle for characterising monetary policy over much longer periods, concluding that US policy since the early 1950's and before can be readily interpreted within this framework.

Lee, Morley and Shields (2011) [LMS] develop this idea, providing a detailed characterisation of US monetary policy from the mid-1970s to today through the estimation of a 'meta' Taylor rule. In this, inference is drawn on US monetary policy based on a set of estimated Taylor rules obtained through linear regression methods, but combined into a 'meta' rule using model averaging techniques. In this approach, a set of separate Taylor rules are estimated with each distinguished by the policy horizon over which inflation or the gap is measured; i.e. focusing alternatively on experiences in the recent past or on expected future experiences. An analysis that incorporates these separate Taylor rule estimates acknowledge the '*specification uncertainty*' surrounding the drivers of decision-making at any time. Perhaps more importantly, the set of Taylor rules that are estimated can also be distinguished by the sample period over which they are estimated. This acknowledges the '*instability uncertainty*' that surrounds monetary policy subject to the types of structural changes discussed above. LMS describe a method for combining Taylor rules, each estimated over alternative sample windows and using alternative measures of inflationary and business cycle conditions, based on Bayesian model averaging techniques. The weights employed in combining the individual Taylor rules derive from the ability of the individual rules to explain past interest rate movements. The weights can change over time so that the approach is very flexible, even compared to more computationally-demanding time-varying parameter models of Taylor rules (see, for example, Kim and Nelson, 2006, and Alcidi, Flamini, and Fracasso, 2011, and the references therein). The resultant 'meta' Taylor rule in LMS then describes the changing nature of US monetary policy since the mid-1970's, describing and quantifying the changing roles of inflation and the gap in the conduct of monetary policy under the various Federal Reserve Chairmen and at times of expansion and periods of recession.

In this paper, we undertake a similar modelling exercise for monetary policy in the UK and in Australia. There is a sizeable literature investigating monetary policy through the estimation of Taylor rules in both countries. For the UK, Clarida et al. (1998), Nelson (2003), Cukierman and Muscatelli (2003), Martin and Milas (2004), Adam et al (2005), Srinivasan et al (2006), Mihailov (2006) and Kharel et al. (2010) provide evidence of a continuing interest in the estimation of Taylor-rule-like relationships, focusing on the nature of monetary policy regime change and the role of other influences, beyond inflation and gap measures, to explain interest rate movements over a prolonged period. In Australia, a significant proportion of the available research has derived from the Reserve Bank itself; de Brouwer and O'Regan (1997), Ball (1998), de Brouwer and Ellis (1998), and de Brouwer and Gilbert (2005). These papers explore specifications of the monetary policy rule that best meet policy objectives including the minimisation of output gap and inflation variability. Other researchers have considered the robustness of Taylor Rule relations in the Australian context, considering for example the time series properties of the data (Österholm, 2005) and whether information additional to inflation and the output gap might condition monetary policy (Sergi and Hsing, 2010).

As we shall see, the meta Taylor rule modelling approach provides a detailed and compelling characterisation of UK and Australian monetary policy over the last thirty years grounded within the simple Taylor rule framework and using reasonably straightforward and easy-to-calculate modelling methods. In what follows, Section 2 provides a brief review of the issues raised in the literature presenting estimated Taylor rules in the UK and Australia and explains how the meta modelling approach accommodates these. Section 3 introduces the UK and Australian data and Section 4 presents the estimates of the UK and Australian meta Taylor rules over the periods $1983q1 - 2009q3$ and $1987q1 - 2010q2$, respectively, highlighting the power of the approach to characterise policies over different phases of policy in a country and across countries. Section 5 concludes.

2 Regime Uncertainty and the Taylor Rule

The empirical analyses of monetary policy, and estimated interest rate reaction functions in particular, in UK and Australia are dominated by the discussion of regime change. Empirical work typically focuses on the interest rate behaviour in the countries since the flotation of sterling and of the Australian dollar in July 1972 and December 1983 respectively. These sample periods are reasonably short by the standards of much time series analysis but the intense interest in the conduct of monetary policy, and the recognition of the changing approaches to policy, means that it has been standard practice to break the data into separate regimes.

Nelson (2003) provides a good example of the approach for the UK, identifying six separate phases of monetary policy over the period 1972-1997 and estimating separate Taylor rules for each, sometimes using quarterly data and, when the sample period was very short, sometimes using monthly data. The six phases can be summarised briefly as follows:

1. 1973q2 - 1976q2: the Heath/Wilson period in which monetary policy was con-

sidered relevant for demand management but incomes policies were implemented to help control inflation;

2. 1976q3 - 1979q2: the Callaghan years in which monetary targeting for £M3 was introduced;

3. 1979q3 - 1987q1: the Thatcher years associated with the £M3 targeting of the Medium Term Financial Strategy (1980-1985) and monetary control of inflation thereafter;

4. 1987q2 - 1990q3: the late-Thatcher years concerned with the informal shadowing of the DM;

5. 1990q4 - 1992q3: membership of the Exchange Rate Mechanism (ERM);

6. 1992q4 - 1997q2: inflation targeting.

Adam et al. (2005) consider a similar sub-sample analysis using data over 1995-2003, splitting this into two periods up to exit from ERM, and then distinguishing the inflation targeting period 1992-1997 from

7. 1997q3 - today : inflation targeting with instrument-independence following the devolution of policy to the Monetary Policy Committee (MPC) of the Bank of England.[1]

Nelson's hypothesised regimes were identified according to explicit statements on the conduct of monetary policy made at the time, and the distinction between the operation of inflation targeting with and without central bank independence is also a

[1]Mihailov (2006) makes a similar distinction between the pre- and post-MPC inflation targeting years.

natural distinction to be drawn based on clear and distinct monetary policy arrangements. The approach is appealing in that the policy regimes can be neatly associated with specific individuals and episodes and, if the sample sizes are long enough, the differences between the periods of policy can be tested. The disadvantage of the approach is that the separate regimes are identified through announcements on the ways in which policy is implemented and the procedures through which policy is conducted. However, our interest is not in modelling the conduct or implementation of policy since it is understood that no policy-maker has actually used a Taylor rule to determine interest rate policy. Rather we are interested in characterising the monetary policy stance at different times and it is not necessarily the case that changes in policy stance will always coincide with changes in the way policy is implemented. Moreover, and perhaps even more importantly, the identification of distinct regimes on the basis of statements on the conduct of policy implies and assumes that policy change takes place in abrupt shifts, denying the possibility of any gradual change within the hypothesised regimes.

For Australia, Macfarlane (1997) provides an overview of the evolving nature of monetary policy. It is, perhaps, a simpler chronology than for the UK:

1. 1976q1 - 1985q1: monetary targeting;
2. 1985q2 - 1992q4: a checklist approach in which a broad range of variables were used to determine the stance of monetary policy (Stemp, 1991);
3. 1993q1 - today: inflation targeting.

Although there have been some nuances with regard to the inflation target, including debate about when an official announcement of the target was first made (Stevens, 2003), Australian monetary policy has been consistently interpreted to have been directed at securing an average inflation rate between 2 and 3 per cent since 1993. Even so, there is some ambiguity in this chronology. For example, in the years preceding the introduction of the inflation target, there is little doubt that low inflation was nonetheless an important target for monetary policy (Hughes, 1997).

One approach to accommodating changing policy reactions to inflation and the gap over time is to include in the interest rate reaction function a larger set of explanatory variables in addition to inflation and the gap (and the lagged dependent variable usually included to capture smoothing behaviour). Hence, Clarida et al. (1998), Adam et al. (2005) and Kharel et al (2011) all experiment with measures of foreign interest rates and exchange rates as additional explanatory variables to help explain UK interest rate movements, especially prior to the inflation targeting regimes from 1992, while Srinivasen et al (2006) incorporate squared and cubic terms in the inflation and gap measures in addition to the usual level terms. Similarly, Sergi and Hsing (2010) consider the influence the real exchange rate may have had on Australian monetary policy. These studies highlight the importance of the various influences on interest rates during different episodes. But they obscure the (reduced form) effects of inflation and the gap on the monetary policy stance that we hope to characterise through the Taylor rule. And again, they do not take into account the possibility that the reaction function might change within the sample period.

Cukierman and Muscatelli (2008) and Martin and Milas (2004) address the possibility of regime change while still working within the Taylor rule framework by the estimation of smooth transition models. Here, the responsiveness of the interest rate to inflation and to the gap changes over time depending on the level of inflation and the gap. In particular, the models allow asymmetries in the reaction to positive and negative values of inflation relative to target and of the gap, and they can distinguish between policies that pursue point targets or that react to values of the drivers within a specified range. These approaches allow for greater flexibility in the way that the policy response is characterised at different points in time, but the estimated relationship remain relatively restrictive in the form of the time variation that is considered, constraining the changes in regime to be relatively smooth, for example.

2.1 The Meta Taylor Rule Approach

2.1.1 The candidate models

LMS introduce the 'meta Taylor rule' as a means of addressing the difficulties in estimating an interest rate reaction function when there is regime uncertainty of the type discussed above. The meta Taylor rule accommodates the uncertainty that surrounds the choice of the drivers of interest rate decisions at any one time and also acknowledges the variety of ways in which regimes might change over time. The meta rule is based on a set of Taylor rule models M_{ijT} each distinguished according to the policy horizon, i, and the sample period for which the model is relevant $(T-j,...,T)$. Hence, the set of models characterising interest rate determination over the period $T_1,...,T_n$ is given by

$$\begin{aligned} M_{ijT} \quad &: \quad r_t = \rho_{ijT}\, r_{t-1} + (1-\rho_{ijT})\left(\gamma_{0ijT} + \gamma_{\pi ijT}\; {}_t\pi_{t+i} + \gamma_{xijT}\; {}_tx_{t+i}\right) + \varepsilon_{ijT,t} \quad (2.1) \\ &: \quad \text{where } i=-1,...,4,, \;\; j=16,...,40, \\ &: \quad t=T-j,...,T, \text{ and } T=T_1,..,T_n. \end{aligned}$$

Here, r_t is the interest rate at time t, π_t is inflation at time t, and x_t is the output gap in time t. The notation in ${}_tx_{t+i}$, for example, is used to denote the measure of the output gap at time $t+i$ as observed at time t and introduces the idea that, in the analysis of interest rate decisions, it is the relationship between the data available in *real time* that is relevant. In both the UK and Australia, data on quarterly inflation and output levels are available only with a one quarter lag and are then subject to subsequent revision, so the measures available in real time can differ markedly from those available using post-revision, final-vintage data.[2] Orphanides (2001), Orphanides and van Norden (2002), Garratt et al. (2008) showed that, in the case of the U.S., estimates of the output gap and of interest rate reactions functions obtained using real time data are very different to those obtained if the final-vintage data are used; and Garratt et al (2009) established that the same is true for UK output gap measures. The individual Taylor rule specifications given in (2.1) make it clear that it is the time-t data that should be used in estimating the real-time interest rate reaction functions at t.

There are $6 \times 25 \times n = 150n$ individual models in the set underlying the meta Taylor rule in (2.1) and the associated parameters are denoted ρ_{ijT}, γ_{0ijT} ,$\gamma_{\pi ijT}$, and γ_{xijT} , with $i = -1,..,4$, $j = 16,...,40$, $T = T_1,...,T_n$, while the associated $\varepsilon_{ijT,t}$ are i.i.d. innovations with mean zero and standard deviation σ_{ijT}. All of the models take the Taylor rule form in which interest rates are set with reference to inflation and the gap, allowing also for interest rate smoothing. In the individual models, the policy horizon considered by the decision-maker is assumed to look back one quarter or to look forwards for up to one year ($i = -1,...,4$). Hence, the meta rule allows for the possibility that, at different times, decision-makers might use the existing published data for the last period, or they might form expectations of the contemporaneous value of inflation and the gap (published with a lag next quarter), or they might use expectations of values of the variables over the near future. It is important that the set of models in (2.1) are able to capture this important aspect of specification uncertainty: Orphanides (2003) showed that the choice of policy horizon has a considerable impact on the estimation of Taylor rules in the US, and LMS

[2] In the event, we find that revisions in inflation data are unimportant and so only real-time data for output are used in the empirical work.

confirmed that this is true and that the policy horizon is different in different policy regimes. The models in (2.1) are also distinguished by the time span over which a rule is assumed to have operated, considered here to be in operation for j periods ending in period T. In an empirical exercise, we need enough observations for estimation purposes and so we assume that the minimum sample relevant for a regime is four years (16 quarters) and we do not consider any regime to last for longer than ten years (40 quarters). The models are each estimated recursively at each point in time, estimating 150 models on data ending in T_1, then 150 models ending in $T_1 + 1$, and repeated up to T_n.[3]

2.1.2 The model weights

The meta Taylor rule can be denoted by

$$\overline{M}_{T_1,..,T_n} = \{M_{i,j,T},\ \ w_{ijT},\ i = -1, .., 4,\ \ j = 16, ..40,\ \ T = T_1, .., T_n\}$$

and is defined not only by the set of models estimated in (2.1) but also by a set of weights assigned to the models, w_{ijT} where $\sum_{i,\, j} w_{ijT} = 1$. The approach is motivated by the Bayesian Modelling Average (BMA) formula (see Draper, 1995):

$$\Pr(\boldsymbol{\theta}_T \mid \mathbf{Z}_T) = \sum_{i=-1}^{4} \sum_{j=16}^{40} \Pr(\boldsymbol{\theta}_T \mid M_{ijT}, \mathbf{Z}_T) \times \Pr(M_{ijT} \mid \mathbf{Z}_T) \qquad (2.2)$$

where $\boldsymbol{\theta}_T$ represents the unknown responsiveness of interest rates in time T to inflation and the output gap, reflected by the parameters $(\rho, \gamma_0, \gamma_\pi, \gamma_x)$ in the Taylor rule form; where $\mathbf{Z}_T = (\mathbf{z}_1, ...\mathbf{z}_T)$ represents the data available at T with $\mathbf{z}_t = (\ r_t,\ {}_t\pi_{t+i},\ {}_tx_{t+i}\ \forall\ i)$; and where $\Pr(\boldsymbol{\theta}_T \mid \mathbf{Z}_T)$ is the inferential distribution that describes our understanding

[3] Obviously, the value of n is determined by the relevant data and differs from country to country. For example, limiting attention to the post-float period, T_1 is 40 quarters after 1973q3 in the UK and 40 quarters after 1983q4 in Australia so $n = 110$ and 69 respectively.

of the parameters of interest. The BMA formula deals with the structural uncertainty accommodated within $\Pr(\boldsymbol{\theta}_T \mid \mathbf{Z}_T)$ by decomposing it into a weighted average of the conditional distributions (i.e. conditional on a specific model), $\Pr(\boldsymbol{\theta}_T \mid M_{ijT}, \mathbf{Z}_T)$, using as weights the posterior model probabilities $\Pr(M_{ijT} \mid \mathbf{Z}_T)$.

As discussed in more detail in LMS, in practice, the conditional inferential distribution in (2.2) can be approximated using the maximum likelihood estimator of the parameters in M_{ijT}. Specifically, noting that $\left(\widehat{\boldsymbol{\theta}_{ijT}} - \boldsymbol{\theta}_{ijT} \mid M_{ijT}, \mathbf{Z}_T\right) \sim N(\mathbf{0}, \widehat{\mathbf{V}_{ijT}})$ where $\widehat{\boldsymbol{\theta}_{ijT}}$ and $\widehat{\mathbf{V}_{ijT}}$ denote the ML estimator and its estimation variance respectively, we can approximate $\Pr(\boldsymbol{\theta}_{ijT} \mid M_{ijT}, \mathbf{Z}_T)$ by $N(\widehat{\boldsymbol{\theta}_{ijT}}, \widehat{\mathbf{V}_{ijT}})$. In effect, this approach assumes that the sample information dominates any choice on priors, allowing us to adopt a classical stance within a Bayesian framework and to carry out inference in a standard way based on the separate 150 Taylor rules estimated at each point in time.

As for the weights $w_{ijT} = \Pr(M_{ijT} \mid \mathbf{Z}_T)$, LMS note that the probability can be decomposed as

$$\begin{aligned}
\Pr(M_{ijT} \mid \mathbf{Z}_T) &= \Pr(M_{ijT} \mid \mathbf{Z}_{T-1}, \mathbf{z}_T) \\
&= \Pr(\mathbf{z}_T \mid M_{ijT}, \mathbf{Z}_{T-1}) * \Pr(M_{ijT} \mid \mathbf{Z}_{T-1}) \qquad (2.3) \\
&= \Pr(\mathbf{z}_T \mid M_{ijT}, \mathbf{Z}_{T-1}) * \Pr(M_{ijT-1} \mid \mathbf{Z}_{T-1}) * \Pr(M_{ijT-1}, M_{ijT} \mid \mathbf{Z}_{T-1})
\end{aligned}$$

so that a model's weight depends on the probability of observing the final observation for the model, on the corresponding model's weight in the previous period, and on a transition probability $\Pr(M_{ijT-1}, M_{ijT} \mid \mathbf{Z}_{T-1})$. LMS suggest the assumptions that (i) irrespective of the policy regime so far, there is a constant probability of a break in regime in each period, ρ; and that (ii) if there is a break, the new regime is equally likely to focus on any of the alternative policy horizons; i.e.

$$\begin{aligned}
&\text{no break:} && \Pr(M_{i,j,T-1}, M_{i,j+1,T} \mid \mathbf{Z}_{T-1}) = 1 - \rho, && (2.4) \\
&\text{break to policy horizon i:} && \Pr(M_{i,j,T-1}, M_{k,1,T} \mid \mathbf{Z}_{T-1}) = \rho/6 \quad \text{for } k = -1, ..., 4. &&
\end{aligned}$$

These assumptions provide a set of weights which allow new regimes to be 'born' in each period and which recursively update the weights on existing regimes to reflect the probability of observing the most recent value of the interest rate given the model $\Pr(\mathbf{z}_T \mid M_{ijT}, \mathbf{Z}_{T-1})$. These weights can then be used to combine the models of (2.1). The fact that they can evolve over time, depending on the ability of the candidate models to explain the data, provides the meta model with considerable flexibility, accommodating the possibility of both gradual and more abrupt changes.

3 Meta Taylor Rules for the UK and Australia

This section describes the meta Taylor rules obtained as a weighted average of the various models described in (2.1) and using weights as in (2.3), estimated for the UK using data for the period $1972q1 - 2010q2$ and estimated for Australia using data for $1976q2 - 2011q2$. The variables employed in the UK include the 3-month Treasury Bill rate, the first-release data on real GDP measured in real time, and the annual inflation rate expressed as the percentage change in the Retail Price Index over the previous four quarters. The Australian analysis relates to the interbank target cash rate and employs the first-release data on real GDP released in real time and annual growth in the Consumer Price Index. More complete definitions and sources are described in the Data Appendix.

The output gap measures employed in the work are defined in a straightforward way, broadly based on the gap measure used in Taylor's original exercise and constructed using real-time data only. Here, at each time T, the output trend is defined by considering the output series over the previous 40 quarters as measured in the most recent data vintage - i.e. ${}_T y_{T-40}$, ${}_T y_{T-39}$, ...,${}_T y_{T-1}$ - and regressing this on an intercept, a linear and quadratic time trend (following Clarida, Gali and Gertler, 1998, and Nelson, 2003). The difference between the most recent output observation

${}_{T}y_{T-1}$ and the trend provides a measure of the gap ${}_{T}x_{T-1}$. As the estimation period moves on, the modelling exercise is repeated so that the gap measures employed in each estimated model are based on the most recent 10 years' output data as was available in real-time. While we recognise the potential limitations of this measure of the gap (and explore alternatives in Garratt et al., 2008, 2009), this measure closely corresponds with that used by Taylor himself and the use of a single simple measure of the gap allows us to focus on the insights on interest rate setting provided by the meta Taylor rule method.

In LMS, direct measures of expected contemporaneous and future values of inflation and output are available from surveys. In the absence of such measures for the UK and Australia, in what follows, the estimation of the individual Taylor rules with policy horizon $i = 0, 1, .., 4$ uses the Instrumental Variables (IV) method to take into account the timing issues arising from the presence of the contemporaneous and forward-looking measures of inflation and output in the real-time Taylor rules. In practice, this means the actual values of π_{t+i} and x_{t+i} in the Taylor rules are instrumented out using up to three lagged values of interest rates, output and inflation as available at time t.

3.1 Evolving Monetary Policy in the U.K. and Australia

3.1.1 The UK results

Figures 1-5 summarise the results of estimating the meta Taylor rule for the UK. Figures 1 and 2 provide an indication of which models are best able to explain interest rates at each point over the sample by focusing on the weights assigned to the 150 alternative models considered in each period. Specifically, Figure 1 shows the probability-weighted average sample length employed in each of the 150 models at each point in time, $\bar{j}_T = \sum_{i=-1}^{4} \sum_{j=16}^{40} w_{ijT} \times j$. Figure 2 plots the probability-weighted average policy horizon, $\bar{i}_T = \sum_{i=-1}^{4} \sum_{j=16}^{40} w_{ijT} \times i$ to illustrate whether the policy horizon used in the most highly weighted models changes systematically over time. The corresponding confidence bands are plotted to indicate the precision of the estimated statistics and are obtained through stochastic simulation, where the estimated Taylor rules of (2.1) are used to provide 10000 alternative simulated "histories" and these are then used to obtain alternative meta Taylor rules and simulated distributions of $\bar{j}_T$ and $\bar{i}_T$.[4] The confidence intervals in the figures show the range covered by two standard deviations of the simulated distributions.

The average sample length plotted in Figure 1 starts at 25 quarters, the mid-point between 16 and 40, simply because all models are given equal weight at the start of the estimation procedure. However, the average sample length quickly drops to around 20 quarters in 1985, providing evidence that there was instability in the estimated rule in the late seventies and that the monetary policy regime in 1985 had been in place since around the early 1980's. This matches the view expressed in Nelson (2003), for example, that the Thatcher years represented a break with the past. Some stability in policy is established during 1985-1992, with the average sample rising slowly so that policy is closer to an eight year sample frame by the end of this sub-period,[5] but there is another clear break in 1992, coinciding with the UK's exit from ERM and the introduction of inflation targeting. A clearly rising average sample length between 1992 – 2002 and stability from there to 2008 provides evidence of some consistency in policy over this period which is brought to an end by the financial crisis. In short,

[4]See LMS for further details.

[5]Of course, an entirely stable policy would be reflected by an average sample length that rises one quarter in each quarter.

the meta Taylor rule method has identified precisely the phases in policy that are often cited in the literature, but has done so without imposing a prior restrictions or structural breaks and is based on the data alone.

In contrast to the plot of Figure 1, there is relatively little movement in the average policy horizon plotted in Figure 2. The plot is interesting though in establishing that policy-makers fairly consistently looked between one and two quarters ahead in forming their decisions, and the horizon is certainly significantly greater than zero (i.e. forward-looking) until the very end of the sample. An interesting feature of the corresponding plot for the US provided in LMS is that the policy horizon falls systematically during periods of recession or low output growth. Although this feature is not as clear cut in the U.K. figures, there is some (weak) evidence of a similar phenomenon with a fall in policy horizon apparent during the recession of the early nineties and following the crisis of 2008 and with an increasing policy horizon observed during the period of strong growth during the nineties.

Figures 3-5 provide more detail on the nature of the policies pursued by showing the probability-weighted averages of the coefficients on the lagged interest rate, inflation and the gap; namely, $\overline{\rho}_T$, $\overline{\gamma}_{\pi T}$ and $\overline{\gamma}_{xT}$ where, for example, $\overline{\rho}_T = \sum_{i,\,\mathrm{j}} w_{ijT}\ \rho_{ijT}$. The bands on these diagrams are 95% confidence intervals based on standard errors obtained analytically taking the weights as given and using the approach of Lee *et al* (1990, 1994). Figure 4 provides the most revealing insights, showing a positive but very weak (and statistically insignificant) feedback from inflation to interest rates through the eighties, but a very clear and dramatic increase in influence in 1992 at the onset of inflation targeting. The inflation coefficient then rises rapidly, to very high values in the early nineties, and stays above unity until the onset of the financial crisis in 2008. The plot provides good evidence that monetary policy has satisfied the Taylor principle (of leaning against inflation by raising interest rates by more than a rise in inflation) throughout the various incarnations of the inflation targeting regimes.

Figure 3 shows considerable volatility in interest rate decisions prior to the mid-1980s, with interest rate change becoming increasingly smooth through to the mid- to late 1990's. The weighted average of the smoothing parameter falls to less than 0.4 during 1999/2000, capturing the greater volatility at this time, but smoothed adjustment is reestablished (with $\overline{\rho}_T$ around 0.8) through the 2000's until the crisis. And, in contrast to the results for inflation in Figure 3, Figure 4 shows that there is little evidence of a straightforward feedback from the gap to interest rate decisions at any time during the period under investigation apart from the most recent period following the financial crisis.

3.1.2 The Australian results

Figures 6–10 provide the corresponding results derived from estimating the meta Taylor rule for Australia. Figure 6 suggests an initial fall in the average sample length, suggesting a degree of instability in policy during the eighties. Indeed the period from mid 1987 to December 1989 is often associated with a change in the stance of monetary policy (much tighter) and the simultaneous existence of an expanding economy, a growth cycle peak being reached in December 1989 (MIAESR 2009). Thereafter, macroeonomic performance deteriorated rapidly. In response, the cash rate was lowered in a series of steps until mid 1993 during a reasonably stable policy environment as suggested by the rising average sample length. By 1993, inflation had fallen significantly and the inflation target was brought in. Interestingly, the formal introduction of the inflation target seems to have had only a minor effect on the trend increase in sample length that began in late 1989. It would appear, at least in terms of the sample horizon, that the formal introduction of the inflation target did not signal a significant change in the conduct of monetary policy but merely formalised an approach that had begun a few years earlier. However instability emerges thereafter, the sample horizon falling from late 1999 until early 2001 which was a period in which the target cash rate was rapidly increased but then reduced almost as rapidly. The horizon subsequently increased until the unfolding Global Financial Crisis led to a renewed focus on contemporaneous events.

A broadly similar picture emerges from Figure 7 with monetary policy gradually becoming more forward looking until 1989, and then becoming more myopic during the recession, matching the pattern discussed above for the UK and US. The formal introduction of the inflation target, however, does seem to have had some effect on the policy horizon with a more forward looking orientation apparent after 1993. However, there is considerable instability from 1999 onwards with the forecast horizon collapsing, then increasing, only to collapse again in the wake of the Crisis.

In contrast to the UK, the smoothing parameter in Australia, shown in Figure 8, has been relatively unchanged, certainly since the introduction of the inflation target. The Crisis, however, was associated with a temporary abandonment of smoothing, the Reserve Bank having adopted an extremely aggressive monetary policy response in 2008/09. Figures 9 and 10 show the values of the underlying long-run coefficients on inflation and the gap. Neither of the coefficients are very well-determined during the early quarters up to 1992/1993, with the inflation response positive but insignificant and the output response actually negative for a large part of this time (although again insignificantly so). However, the inflation response then exceeds unity for a prolonged period, weakening only towards 2004/5 and then through the crisis period. The gap response was weak throughout although typically positive. In short, the coefficients show that the introduction of the inflation target was associated with the Reserve Bank adopting a reasonably clear leaning-against-the-wind approach to inflation but reacting only mildly, if at all, to the output gap.

3.2 Incorporating a Time-Varying Inflation Target

The purpose of the modelling exercise is to characterise monetary policy in the UK and in Australia using the Taylor rule framework as a organising structure. For this reason, we restrict attention to estimated rules of the Taylor rule form in (2.1) and resist the temptation to include other explanatory variables in the search for an improved explanation of interest rate movements. However, we are also aware of the fact that both UK and Australia experienced very high rates of inflation at points during the seventies (much higher than in the US for example) so that, even retaining the Taylor rule formulation, it might be unrealistic to assume a constant target level of inflation throughout the sample. Specifically, we note that the intercept term γ_{0ijT} of the Taylor rule of (2.1) could be decomposed into its constituent elements - based on the target real interest rate ω^* and target inflation rate π^* - to write $\gamma_{0ijT} = \omega^* + \pi^* - \gamma_{\pi ijT}\ \pi^*$ and hence

$$\widetilde{M}_{ijT}: \quad r_t = \rho_{ijT}\ r_{t-1} + (1-\rho_{ijT})\,(\omega^* + \pi^* \ + \ \gamma_{\pi ijT}\ \ ({}_t\pi_{t+i}\ - \pi^*) + \ \gamma_{xijT}\ {}_tx_{t+i}) + \varepsilon_{ijT,t}\ . \tag{3.5}$$

A relatively minor generalisation of the rule which maintains the Taylor rule form but which accommodates the possibility that the inflation target changes over time would be achieved with using (3.5) in which the intercept provides a measure of the target real interest rate ω^* and a time-varying measure of target inflation π_t^* is included. We consider this extension to the analysis below.

To operationalise the extension in the case of the UK, a measure of the inflation target over the seventies can be obtained from the explicit inflation targets described in the successive incomes policies implemented up to 1979; see Ashenfelter and Layard (1983) for a description of these policies and the translation of the policies as expressed at the time into percentage inflation targets. It might be assumed that the inflation target then fell linearly until it matched German inflation levels from 1987q2, at which time policy explicitly aimed to shadow the DM. From 1992q4-1995q2, the target can be assumed to be the mid-point in the announced inflation targeting band (i.e. 2.5% as the mid-point between 1%-4%), staying at the explicit target of 2.5% between 1995q3-2003q4 and then falling to the new target of 2% thereafter.

In Australia, it is harder to validate an inflation target prior to 1993. Nevertheless, given the significant increase in the target cash rate that did occur around 1988, it does not seem unreasonable to assume that the RBA had begun to target aggressively a rate of inflation significantly below what had been the norm over the previous decade. One approach then is to take the midpoint of the average inflation rate over the period 1983 to 1988 (7%) and regard this an intermediate target that held over the period 1983 through to the end of 1987. From 1988 on, the target can reasonably be set at 2.5%, the midpoint of the target range (2% to 3%) eventually introduced in 1993.

Figures 11-20 illustrate the outcome of this extension of the modelling exercise in the case of the UK. In the event, the inclusion of the time-varying inflation target has relatively little effect on the results. The regime break suggested by the fall in the average sample length in 1993 is less pronounced in Figure 11 than it was in Figure 1, and the drop in the average policy horizon observed in the recession of the early nineties is a little more pronounced than in the previous figure. But the inflation and gap results are, broadly speaking, similar to those obtained in the absence of the time-varying inflation target.

Similar comments apply to the Australian results in Figures 15-20 as far as the average sample length, policy horizon and smoothing parameter are concerned. Where a significant difference does emerge, however, is the estimated average value of the inflation and gap coefficients through the recession of the early 1990s. The inflation coefficient is now positive (and statistically so) for most of the period up to inflation targeting and the gap coefficient is now also positive for most of the early period. This goes some way to validating our use of an estimated inflation target prior to 1993, capturing the idea that the target cash rate was lowered in line with the dramatic fall in inflation that accompanied the recession.

3.3 Conclusion

For some time now, the Taylor Rule has provided researchers and policy makers with a powerful analytical framework for thinking about monetary policy. Paradoxically, even as a rules-based approach has become the de facto standard for discussions regarding monetary policy, there remains a view about significant monetary policy changes through time - exemplified by those wishing to characterise US monetary policy as having distinct regimes associated with different Chairs of the Federal Reserve - which is the antithesis of a stable rules-based approach to policy making.

In previous research, Lee, Morley and Shields (2011) showed how the meta-Taylor approach, which can accommodate uncertainty about parameter estimates and disturbances to relations as well as uncertainties extending over the sample period in which a stable relation may hold, provides a means of modelling monetary policy in the United States, allowing the Taylor Rule to have traction in an environment of monetary policy instability. In this paper, we show a similar approach also provides insight into the monetary policies of two very different economies, the UK and Australia.

The results for both economies are consistent with the existence of monetary policy reacting structurally to changing circumstances: as in the UK, with the election of a committed inflation hawk (Mrs. Thatcher), the exit from the ERM and the adoption of the inflation target; and as in Australia with an aggressive anti-inflation policy introduced in the late 1980s followed by a move to inflation targeting. The results for both countries also demonstrate the establishment of reasonably stable policy-making, with interest rates reacting to inflation with a coefficient greater than unity following the Taylor principle, once inflation targeting was adopted. On the other hand, the analyses also reveal the impact of the recent crisis on both economies, a period in which monetary policy makers had to react very much to contemporaneous events, and shows that there were some interesting and sizeable shifts in policy even during the relatively stable inflation targeting regime. That the meta Taylor rule can accommodate these features of the data, points to the usefulness of adopting a flexible modelling approach to monetary policy even if what is being modelled is ostensibly grounded in the concept of a policy rule.

4 Data Appendix

Data for the UK

The variables used in estimating the Taylor Rule for the UK are the 3-month Treasury bill rate, real Gross Domestic Product (GDP) data and the annual inflation rate based on the retail price index (RPI).

- The 3-month Treasury bill rate is accessible via the Bank of England (BoE) website under the series entitled 'Wholesale interest and discount rates – Treasury bills (3 month) - Sterling'. In order to compare the analysis with Nelson (2003), the end-of-quarter series is used in this analysis although the end-of-quarter and quarterly average measures of the yield are very alike.

- The real GDP data is the first-release of the real GDP series as published in real-time and obtained from the Bank of England's 'Gross Domestic Product Real-Time Database' at http://www.bankofengland.co.uk/statistics/gdpdatabase/ supplemented by recent figures from the OECD's 'Original Release Data and Revisions Database'. This series is subject to one quarter lag in the release of the data.

- The inflation rate used in this analysis is the percentage change in the Retail Price Index (RPI) over 12 months as published by Office of National Statistics.

Data for Australia

The variables used in estimating the Taylor Rule for Australia are the interbank target cash rate, real Gross Domestic Product (GDP) data and the annual inflation rate.

- Monthly measures of the interbank target cash rate are reported in the table entitled 'Bank Accepted Bills – Interest Rates and Yields – Money Market' accessible via the Reserve Bank of Australia website. The series used in the paper is the average over the months of the quarter although the end-of-quarter series is very similar.

- The real GDP data were obtained from the Real-Time Macroeconomic Database for Australia currently maintained by the University of Melbourne (http://www.economics.unimelb.edu.au/RealTime_Macroeconomic_Database_for_Australia). The series collects the first-release of the real GDP series as published in real-time based on the Australian Bureau of Statistics' (ABS') publication Australian National Accounts: National Income, Expenditure and Product. There is a one quarter delay in release so that, for example, the last observation available in the 2011q1 vintage refers to the 2010 December reference quarter.

- The inflation rate used in this analysis is the annual inflation rate based on the headline quarterly consumer price index (CPI) published by the ABS. As the CPI data are typically not revised over time, the measure provided in the 2011q2 vintage is used in the paper. Annual inflation is defined as the log difference between the CPI for a quarter and the CPI for the same quarter in the previous year. The inflation rate series was adjusted for the introduction of the Goods and Services Tax (GST) for the 4 quarters from Sept 2000 - we deducted 3% off the series to allow for the one-off effects of the GST in that year.

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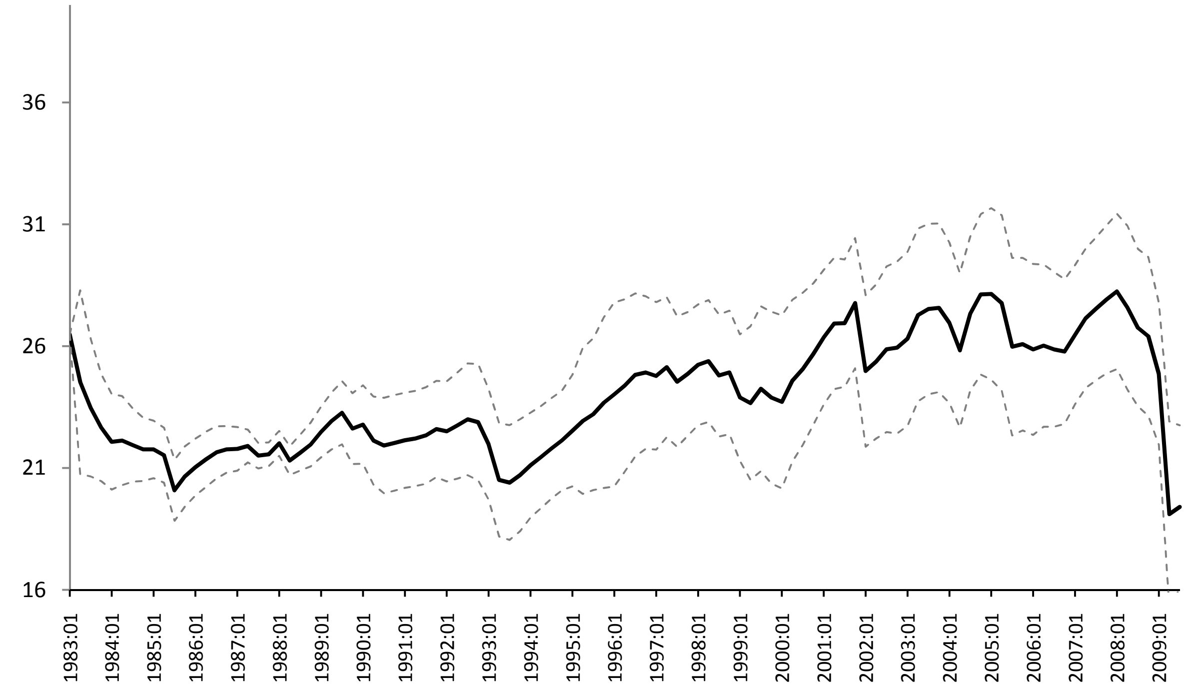

Figure 1: Recursive Estimation of the Sample Horzion for the UK

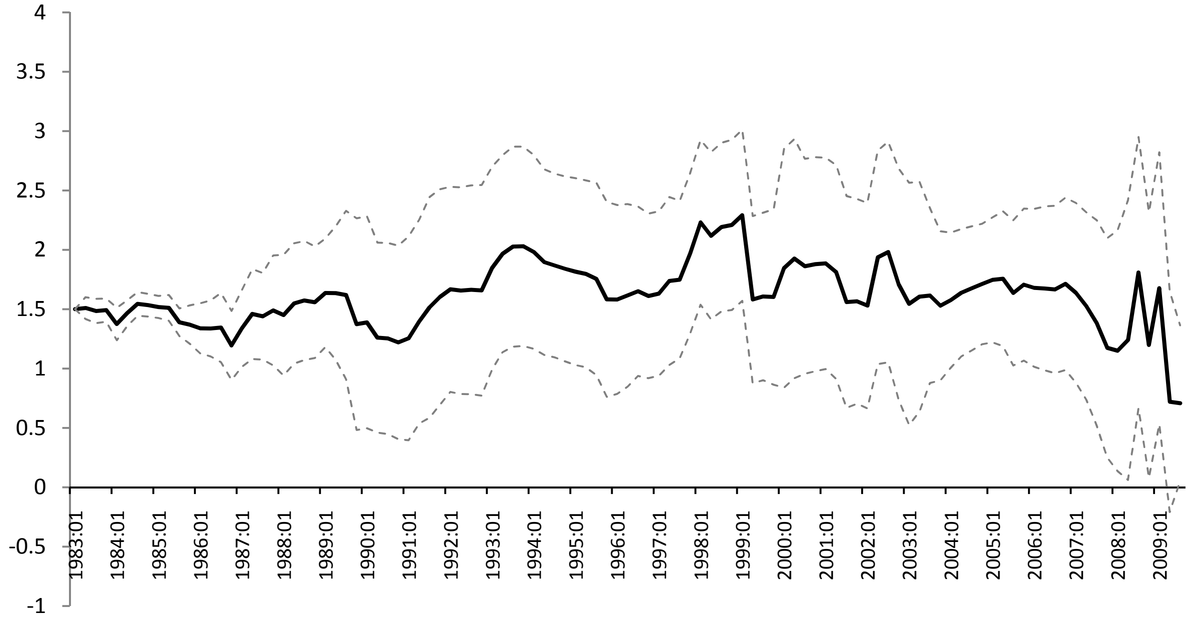

Figure 2: Recursive Estimation of the Policy Horizon for the UK

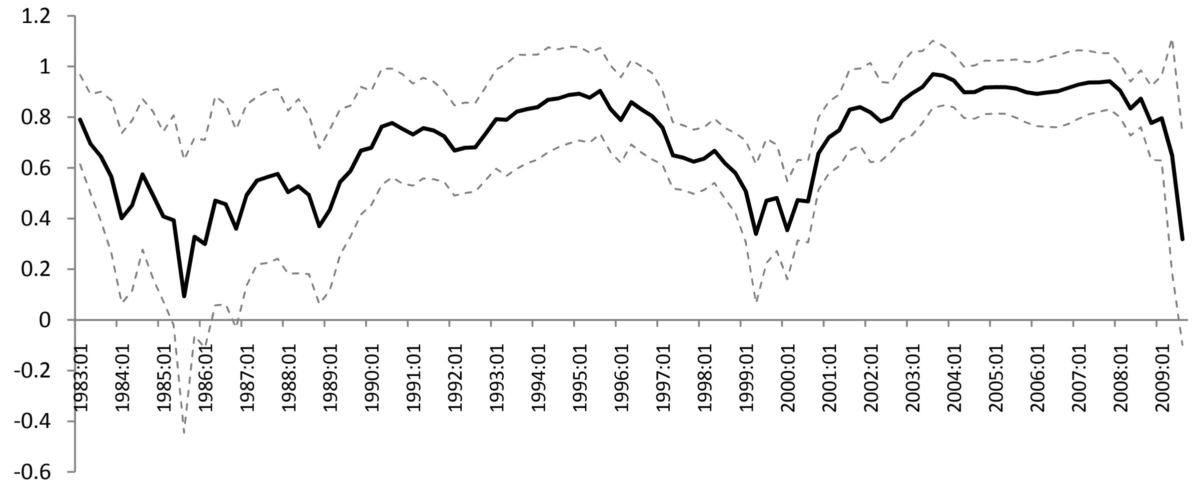

Figure 3: Recursive Estimation of the Partial Adjustment Coefficient for the UK

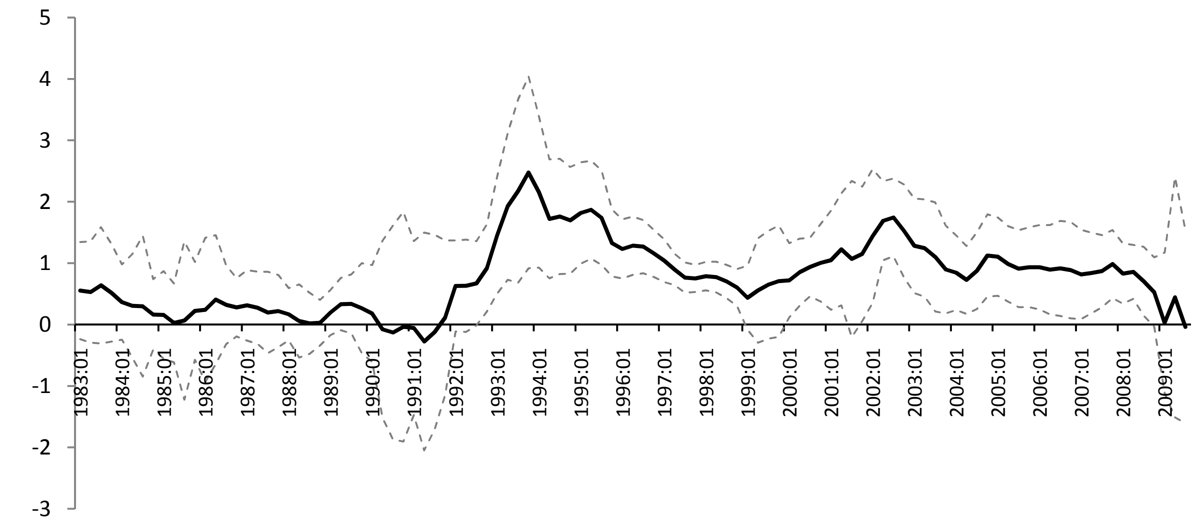

Figure 4: Recursive Estimation of the Medium Run Inflation Coefficient for the UK

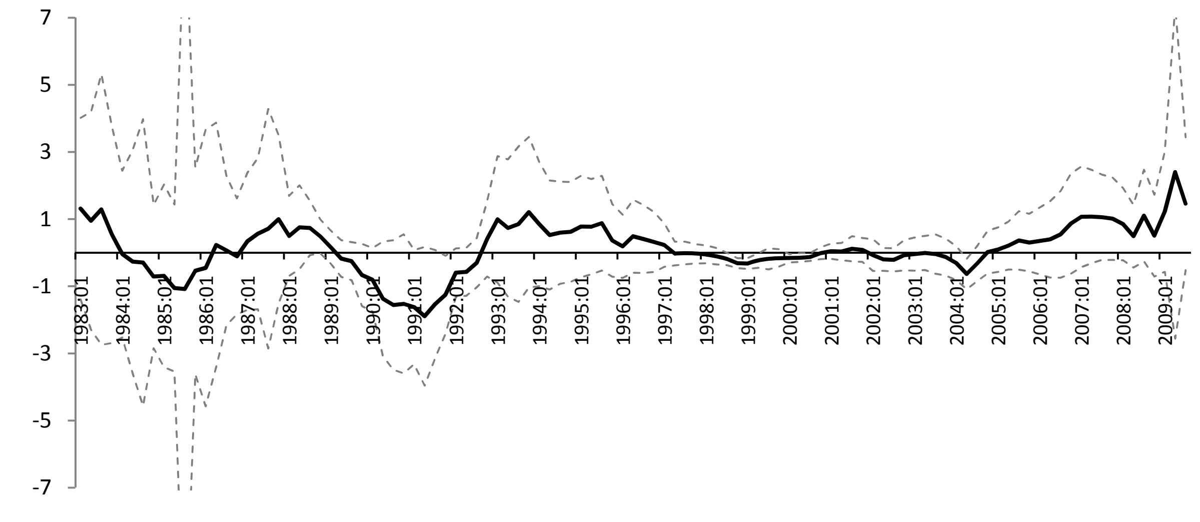

Figure 5: Recursive Estimation of the Medium Run Output Gap Coefficient for the UK

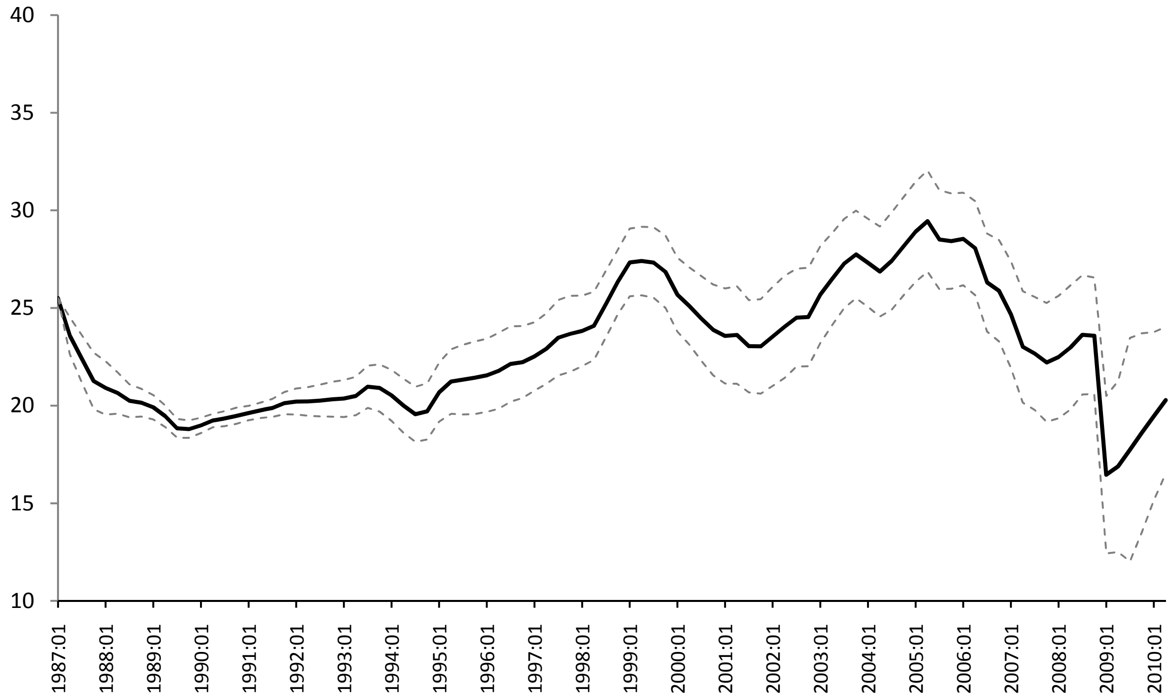

Figure 6: Recursive Estimation of the Sample Horzion for Australia

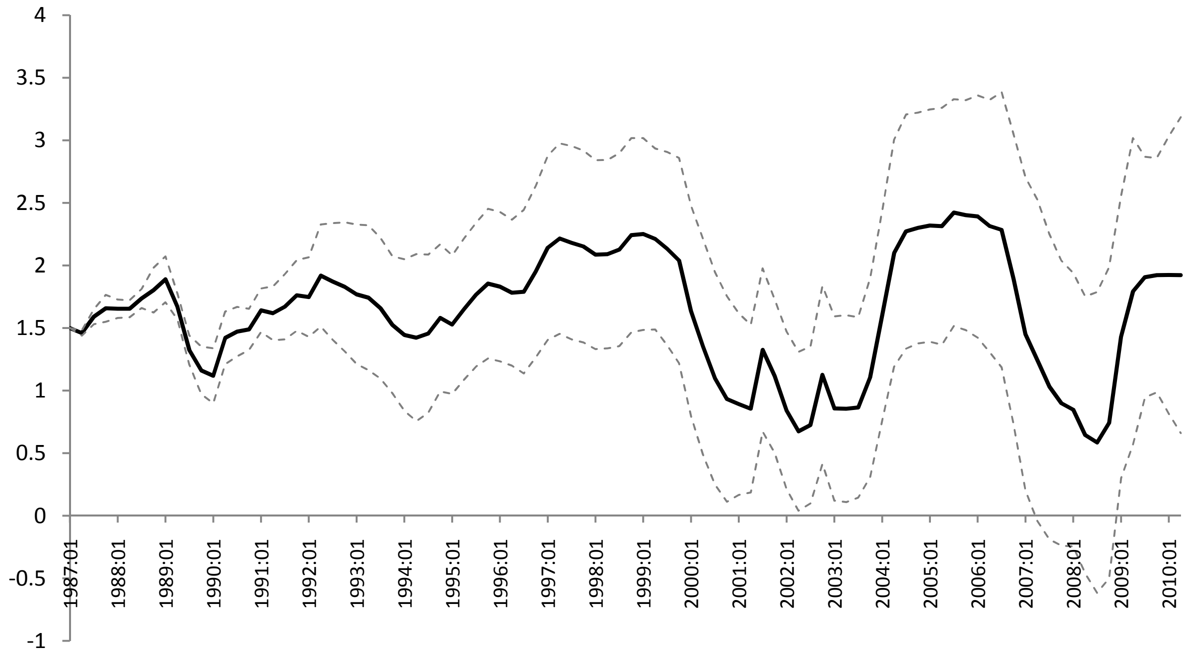

Figure 7: Recursive Estimation of the Policy Horizon for Australia

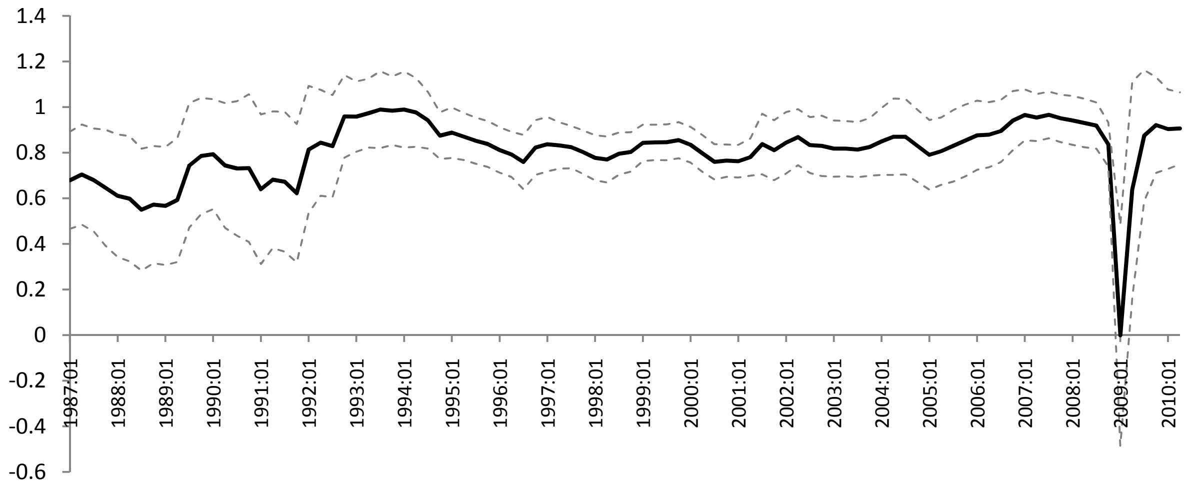

Figure 8: Recursive Estimation of the Partial Adjustment Coefficient for Australia

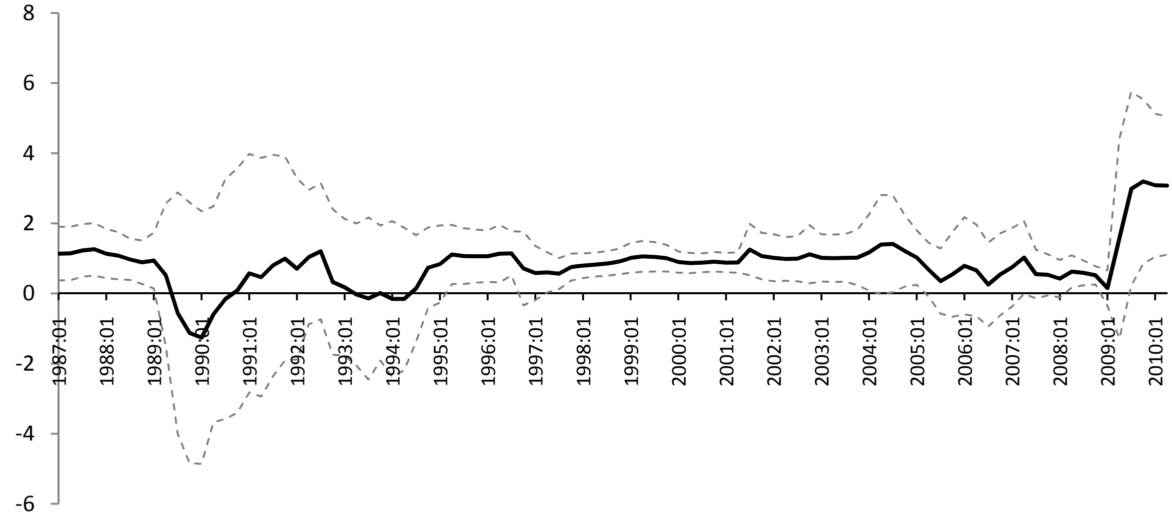

Figure 9: Recursive Estimation of the Medium Run Inflation Coefficient for Australia

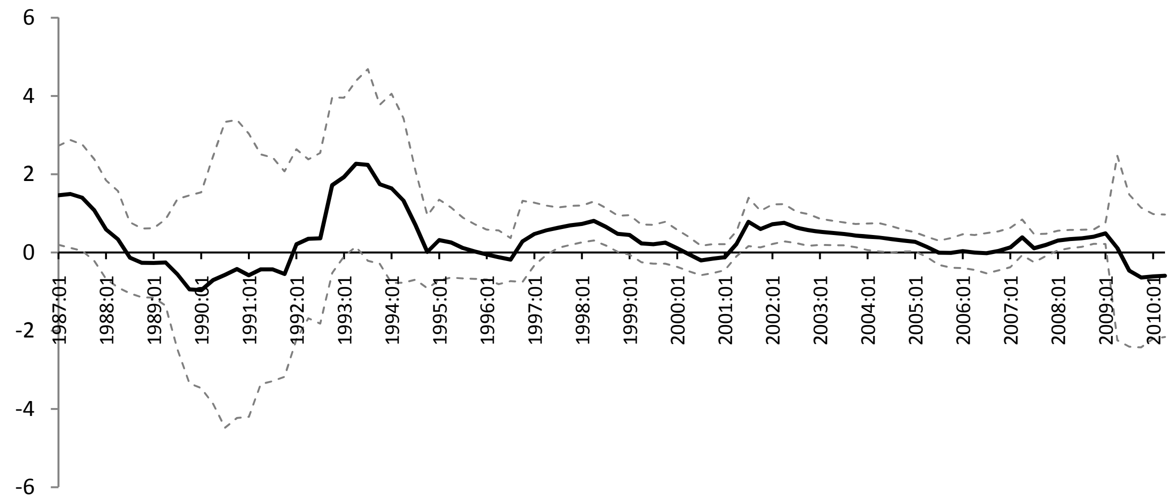

Figure 10: Recursive Estimation of the Medium Run Output Gap Coefficient for Australia

Figure 11: Recursive Estimation of the Sample Horzion for the UK
with a Time-Varying Inflation Target

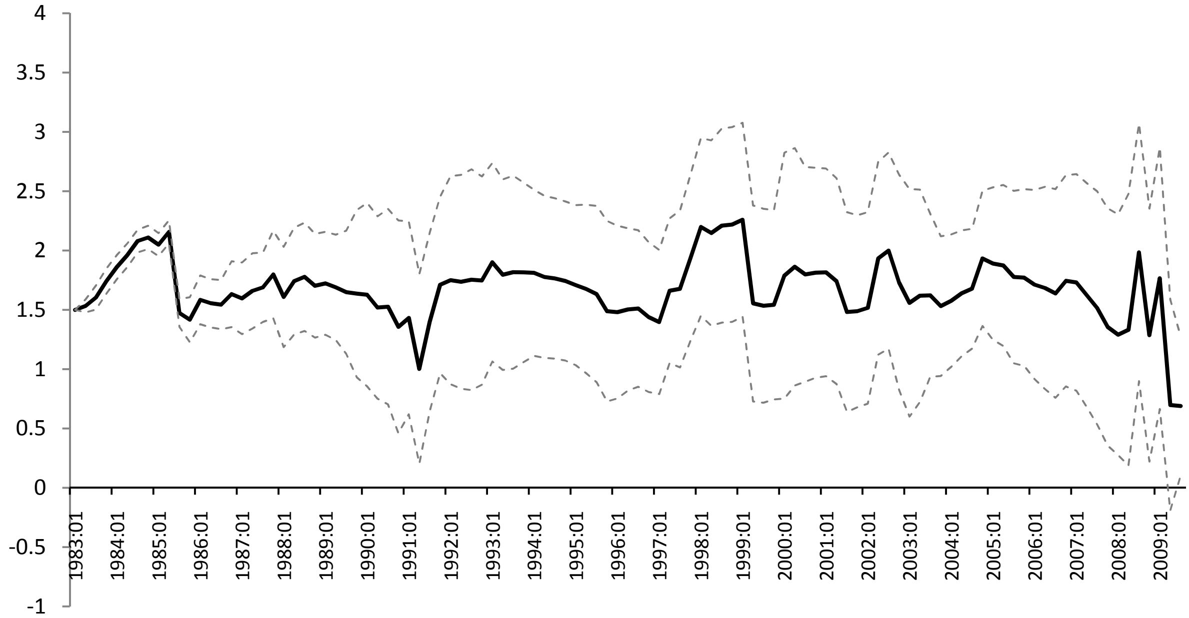

Figure 12: Recursive Estimation of the Policy Horizon for the UK
with a Time-Varying Inflation Target

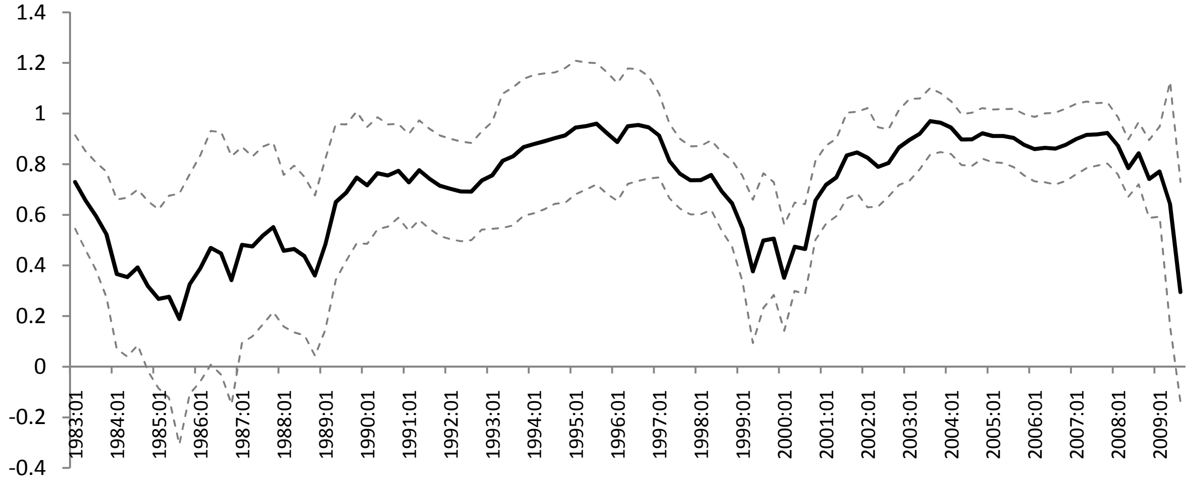

Figure 13: Recursive Estimation of the Partial Adjustment Coefficient for the UK with a Time-Varying Inflation Target

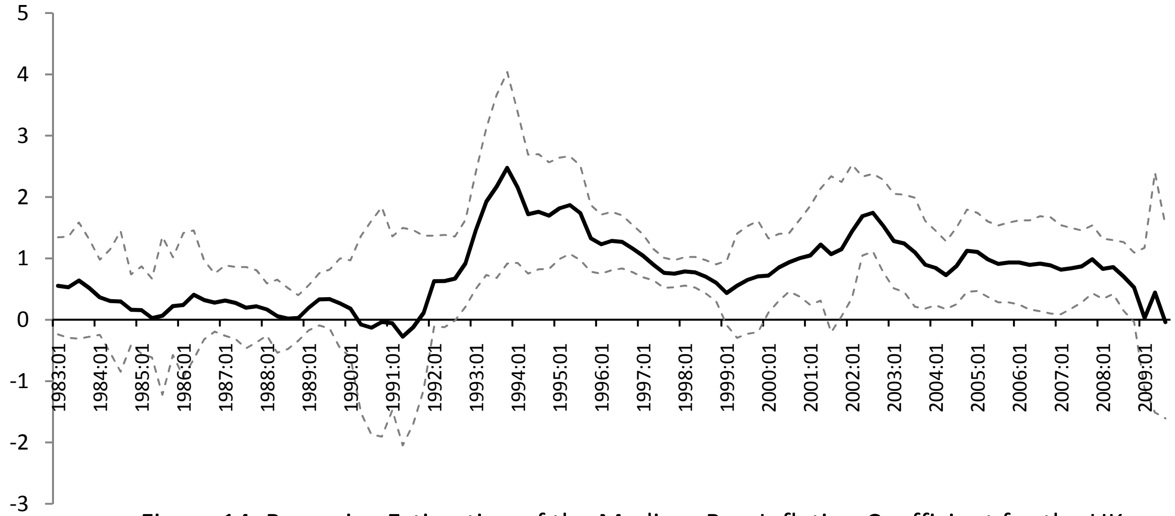

Figure 14: Recursive Estimation of the Medium Run Inflation Coefficient for the UK with a Time-Varying Inflation Target

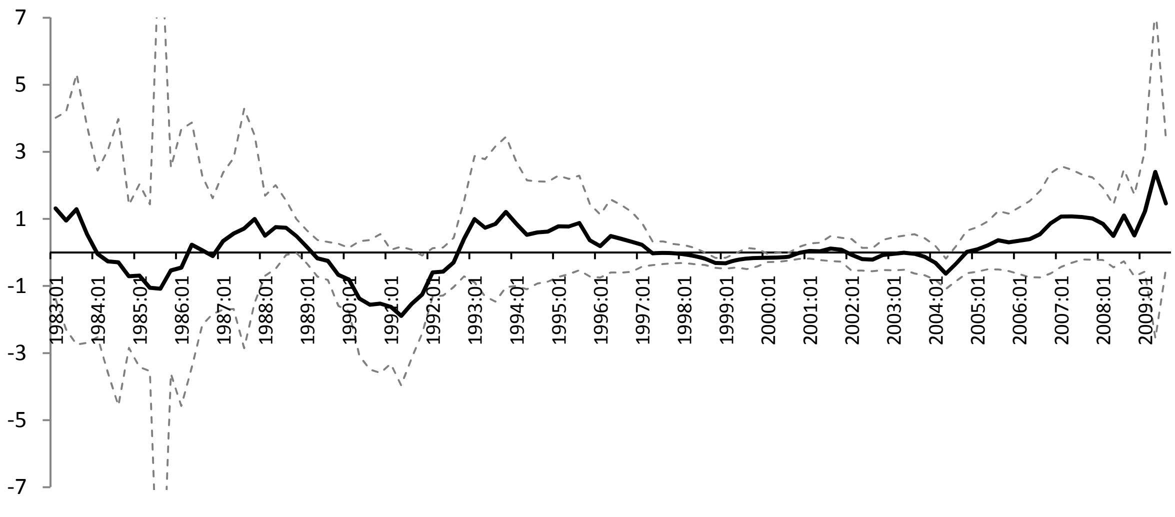

Figure 15: Recursive Estimation of the Medium Run Output Gap Coefficient for the UK with a Time-Varying Inflation Target

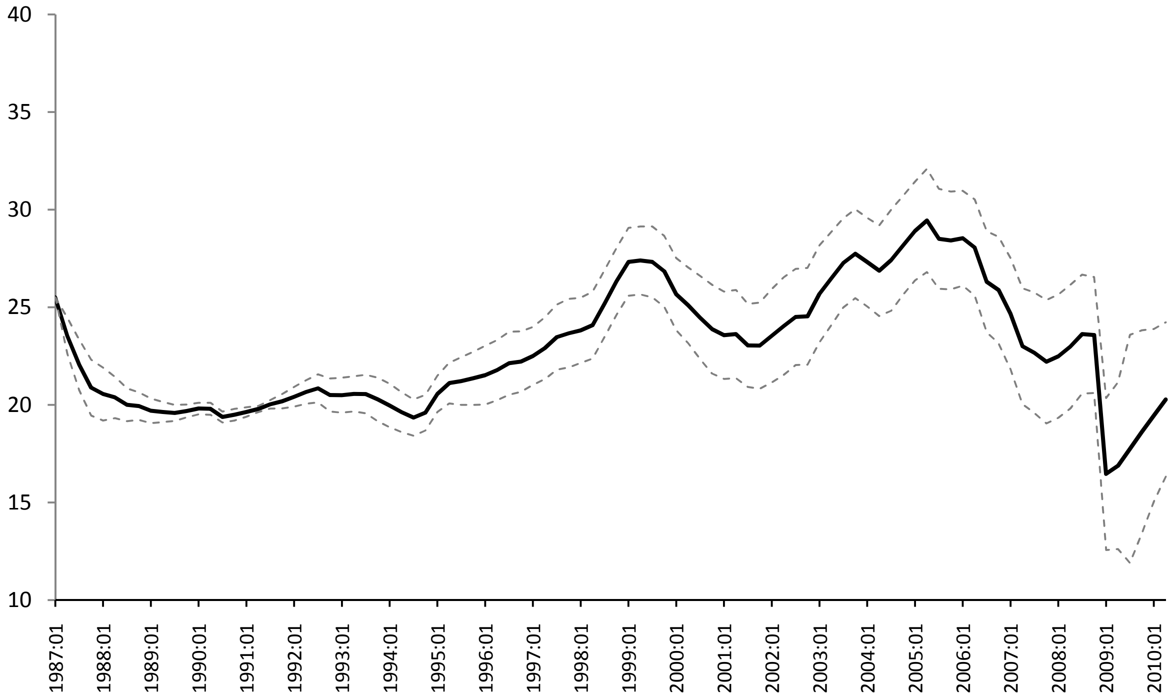

Figure 16: Recursive Estimation of the Sample Horzion for Australia
with a Time-Varying Inflation Target

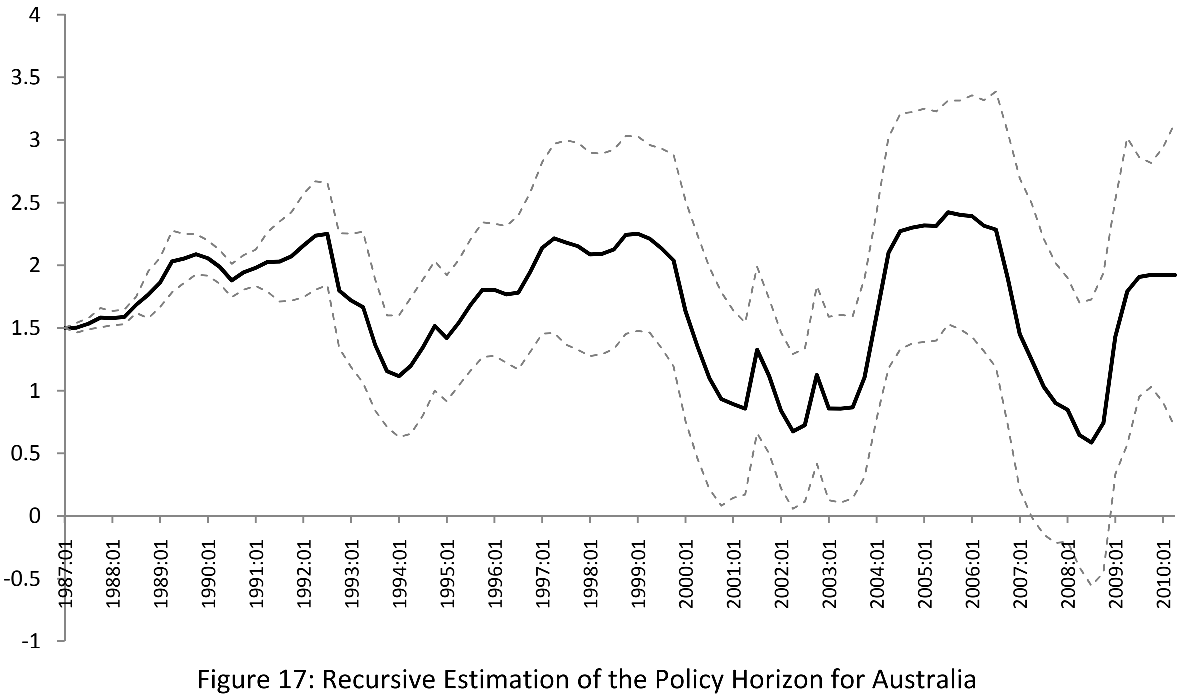

Figure 17: Recursive Estimation of the Policy Horizon for Australia
with a Time-Varying Inflation Target

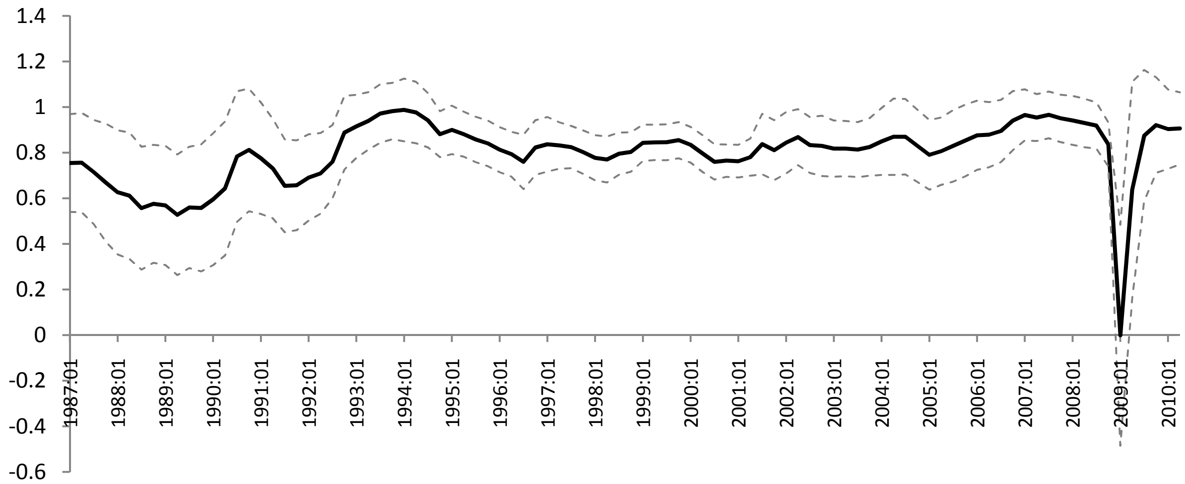

Figure 18: Recursive Estimation of the Partial Adjustment Coefficient for Australia with a Time-Varying Inflation Target

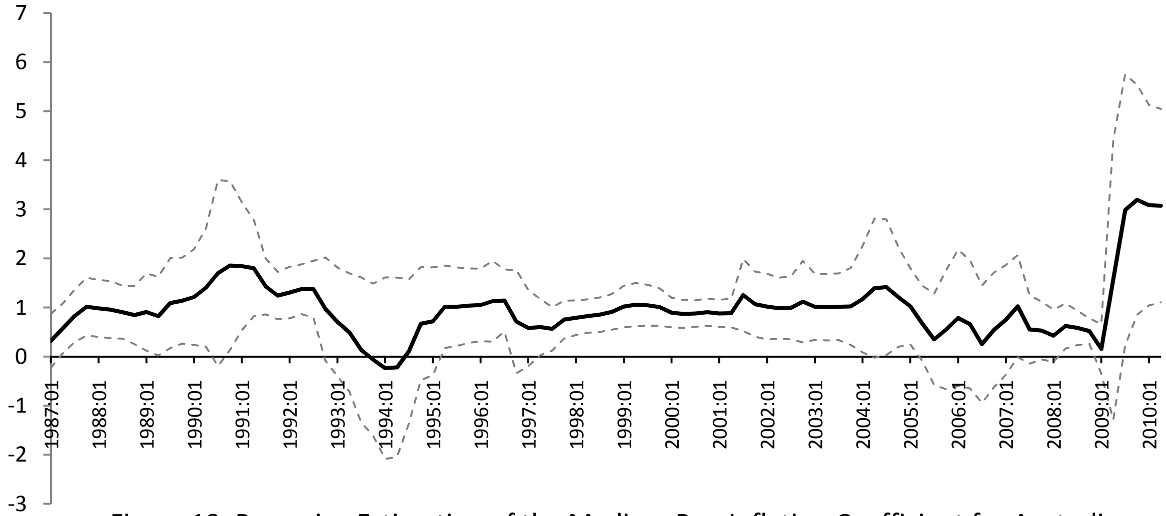

Figure 19: Recursive Estimation of the Medium Run Inflation Coefficient for Australia with a Time-Varying Inflation Target

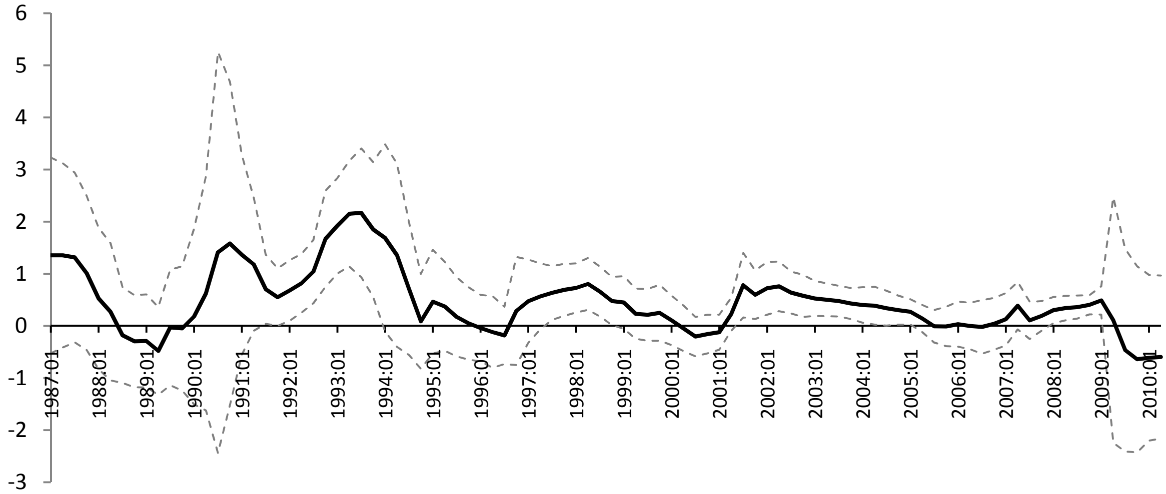

Figure 20: Recursive Estimation of the Medium Run Output Gap Coefficient for Australia with a Time-Varying Inflation Target