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How Does Monetary Policy Change?
Evidence on Inflation Targeting Countries

Jaromír Baxa, Roman Horváth and Bořek Vašíček*

Abstract

We examine the evolution of monetary policy rules in a group of inflation targeting countries (Australia, Canada, New Zealand, Sweden and the United Kingdom) applying moment-based estimator at time-varying parameter model with endogenous regressors. Using this novel flexible framework, our main findings are threefold. First, monetary policy rules change gradually pointing to the importance of applying time-varying estimation framework. Second, the interest rate smoothing parameter is much lower that what previous time-invariant estimates of policy rules typically report. External factors matter for all countries, albeit the importance of exchange rate diminishes after the adoption of inflation targeting. Third, the response of interest rates on inflation is particularly strong during the periods, when central bankers want to break the record of high inflation such as in the U.K. or in Australia at the beginning of 1980s. Contrary to common wisdom, the response becomes less aggressive after the adoption of inflation targeting suggesting the positive effect of this regime on anchoring inflation expectations. This result is supported by our finding that inflation persistence as well as policy neutral rate typically decreased after the adoption of inflation targeting.

JEL Codes: E43, E52, E58.

Keywords: Endogenous regressors, inflation targeting, monetary policy, Taylor rule, time-varying parameter model.

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Nontechnical Summary

This paper examines the evolution of monetary policy in Australia, Canada, New Zealand, Sweden and the United Kingdom during last three decades. More specifically, it estimates the monetary policy rules for all countries and examines to what extent these rules change over time.

The main policy finding can be summarized as follows. Our research highlights the benefits of building credible monetary framework such as inflation targeting that anchors inflation expectations. With credibility and anchored inflation expectations, monetary policy does not have to be so aggressive. On the contrary, we show that the central banks had to be indeed quite aggressive, when they wanted to break the high built-in expectations of high inflation and decrease them to the levels consistent with price stability. The example is the U.K. in early 1980s.

Our results point to an importance of appropriate estimation framework for analysis of interest rate setting (the monetary policy rule) over time. We show that the degree of interest rate smoothing is much lower than many previous empirical contributions suggested. Specifically, we find that ignoring the time-varying nature of policy rules can be another reason for the overestimation of the degree of interest rate smoothing.

Next, we find that inflation is affected by its past values to a lesser extent after the adoption of inflation targeting. The lower degree of inflation persistence likely reflects, among other things, the signaling role of explicit inflation target. Our research also tackles the question whether the monetary policy changes are gradual or abrupt. The results indicate that the changes are gradual and coincide either with important institutional reforms such as the changes in monetary policy regime or with the periods of disinflation.

Last but not least, our regression results suggest that exchange rate and foreign interest rates had, along with expected inflation and output gap, statistically significant effect on the monetary policy rates quite often. Nevertheless, such statistical significance has to be interpreted carefully. It seems more plausible that the current values of exchange rate and foreign interest rates contain additional information about future economic activity and inflation and complement the uncertain measures of output gap and future realized inflation rate as the proxy for private inflation expectations of policy makers, rather than the central banks would target some specific values of external variables.

1. Introduction

The Taylor-type regressions have been applied extensively in order to describe the monetary policy setting for many countries. The research on the U.S. monetary policy usually assumed that the monetary policy was subject to structural breaks when the FED chairman changed. Clarida et al. (2000) claims that the U.S. inflation was unleashed during the 1970's because the FED's interest rate response to inflation upsurge was too weak, while the increase of such response in the 1980's was behind the inflation moderation. Although there is ongoing discussion on the sources of this Great Moderation (Benati and Surico, 2009), the fact that monetary policy setting evolves over time is generally accepted.

The evolution of monetary policy setting as well as the exogenous changes in economic system over time raises several issues for empirical analysis. In particular, the coefficients of monetary policy rules estimated over longer periods are structurally unstable. The common solution used in the literature is typically a sub-sample analysis (Clarida et al. 1998, 2000). Such an approach is based on rather strong assumption that the timing of structural breaks is known, but also that the policy setting does not evolve within each sub-period. Consequently, this gives impetus to applying the empirical framework that allows for regime changes or in other words the time variance in the model parameters (Cogley and Sargent, 2001, 2005). Countries that implemented the inflation targeting (IT) regime are especially suitable for such analysis because it is likely that the monetary policy stance with respect to inflation and other macroeconomic variables changed as a consequence of the IT implementation. Moreover, there is ongoing debate to what extent the IT represents a rule-based policy. Bernanke et al. (1999) claim the IT is a framework or a constrained discretion rather than being a mechanical rule. Consequently, the monetary policy rule of IT central bank is likely to be time varying.

Our study aims to investigate the evolution of monetary policy for the countries that have had a long experience with the IT regime. In particular, we analyze the time-varying monetary policy rules for Australia, Canada, New Zealand, Sweden and the United Kingdom. As we are interested in the monetary policy evolution over relatively longer period, we do not consider countries where the IT was in place for relatively short time (Finland, Spain), or was introduced relatively recently (such as Armenia, the Czech Republic, Hungary, Korea, Norway or South Africa). We apply the recently developed time-varying parameter model with endogenous regressors (Kim and Nelson, 2006), as this technique allows us to evaluate the changes in policy rules over time, unlike Markov-switching methods does not impose sudden policy switches between different regimes. On the top of that, it also deals with endogeneity of policy rules. Unlike Kim and Nelson (2006) we do not rely on the Kalman filter that is conventionally employed to estimate time-varying models, but employ the moment-based estimator proposed by Schlicht and Ludsteck (2006)[1] for its mathematical and descriptive transparency and minimal requirements on initial conditions. In addition, Kim and Nelson (2006) apply their estimator to evaluate the changes in the U.S. monetary policy, while we focus on inflation targeting economies.

Anticipating our results, we find that monetary policy changes gradually pointing to the importance of applying a time-varying estimation framework (see also Koop et al., 2009, on evidence that monetary policy changes gradually rather than abruptly). When the issue of endogeneity in time-varying monetary policy rules is neglected, the parameters are estimated inconsistently, albeit the resulting errors are economically not large. Second, the interest rate smoothing parameter is much lower that what previous time-invariant estimates of policy rules typically report. This is in line with a recent critique of Rudebush (2006), who emphasizes that the degree of smoothing is rather low. External factors matter for understanding of interest rate setting process for all countries, albeit the importance of the exchange rate diminishes after the adoption of inflation targeting. Third, the response of interest rates on inflation is particularly strong during the periods, when central bankers want to break the record of high inflation such as in the U.K. at the beginning of 1980s. Contrary to common wisdom, the response can become less aggressive after the adoption of inflation targeting suggesting the positive effect of this regime on anchoring inflation expectations or low inflation environment. This result is consistent with Kuttner and Posen (1999) and Sekine and Teranishi (2008) who show that inflation targeting can be associated with smaller response of interest rate to inflation developments, if previous inflation record was favorable.

The paper is organized as follows. Section 2 discusses the related literature. Section 3 describes our data and empirical methodology. Section 4 presents the results. Section 5 concludes. An appendix with detailed description of the methodology and additional results follows.

2. Related Literature

2.1 Monetary Policy Rules and Inflation Targeting

Although the theoretical literature on optimal monetary policy usually distinguishes between instrument rules (the Taylor rule) and targeting rules (the inflation-targeting based rule), the forward-looking specification of the Taylor rule, sometimes augmented with other variables, has been commonly used for the analysis of decision making of IT central banks. The existing studies feature great diversity of empirical frameworks, which makes the comparison of their

[1] The description of this estimator is also available in Schlicht (2005), but we refer to more recent working paper version, where this estimator is described in a great detail. Several important parts of this framework were introduced already in Schlicht (1981).

results sometimes complicated. In the following we provide a selective survey of empirical studies aimed at the countries that we focus on.

The United Kingdom adopted the IT in 1992 (currently, 2% target and ±1% tolerance band) and the policy of Bank of England (BoE) is subject to most extensive empirical research. Clarida et al. (1998) analyzed the monetary policy setting of BoE in pre-IT period, concluding its consistence with the Taylor rule, yet additionally constrained by foreign (German) interest rate setting. Adam et al. (2005) find by means of sub-sample analysis that the introduction of the IT did not represent a major change in monetary policy conduct unlike the granting of instrument independence in 1997. Davradakis and Taylor (2006) point to significant asymmetry of the British monetary policy during the IT period; in particular that the BoE was concerned with inflation only when it significantly exceeded its target. Assenmacher-Wesche (2006) concludes by means of Markov-switching model that no attention was paid to inflation until the IT was adopted. Conversely, Kishor (2008) finds that the response to inflation already increased especially since Thatcher took over the government (in 1979). Finally, Trecroci and Vassalli (2009) use a model with time-varying coefficients concluding that policy was gradually becoming more inflation-averse since early 1980's.

New Zealand was the first country to adopt the IT (in 1990). A particular feature besides an announcement of the inflation target (the band of 1-3%, currently) is that the governor of the Reserve Bank has an explicit agreement with the government. Huang et al. (2001) study the monetary policy rule over the first decade of the IT. He finds that the policy of the Reserve Bank (RBNZ) was clearly aimed at inflation target and did not respond to output fluctuations explicitly. The response to inflation was symmetric and backward-looking rule does as good job as forward-looking one for tracking the interest rate dynamics. Plantier and Scrimgeour (2002) allow for the possibility that neutral real interest rate (implicitly assumed in the Taylor rule to be constant) changes in time. In this framework they find that the response to inflation increased since the IT was implemented and the policy neutral interest rate tailed away. Ftiti (2008) additionally confirms that the RBNZ did not explicitly respond to exchange rate fluctuations and Karedekikli and Lees (2007) disregards asymmetries in the RBNZ policy rule.

The Reserve Bank of Australia (RBA) turned to the IT in 1993 (with the target of 2-3%) after the decades of exchange rate pegs (till 1984) and consecutive monetary targeting[2]. De Bouwer and Gilbert (2005) using sub-sample analysis confirm that RBA's consideration of inflation was very low in pre-IT period and the concern for output stabilization was clearly predominant.

[2] In Australia, adoption of inflation targeting was a gradual process. Since January 1990, the RBA increased the frequency of its communications via speeches and the style of the Banks's Bulletin started to correspond to the inflation reports as introduced in New Zealand. The exact inflation target was defined explicitly later in April 1993. Greenville (1997) describes the policy changes in Australia in a great detail.

The response to inflation (both actual and expected) increased substantially since the IT adoption but the RBA seemed to consider exchange rate and foreign interest rate developments as well. Leu and Sheen (2006) find a lot of discretionality in the RBA policy (low fit of time-invariant rule) in pre-IT period, consistent response to inflation during the IT and signs of asymmetry in both periods. Karedekikli and Lees (2007) document that the policy asymmetry is related to RBA's distaste for negative output gaps.

Bank of Canada (BoC) introduced the IT in 1991 in a form of a series of targets for reducing the inflation to the midpoint of a range of 1 to 3% by the end of 1995 (since then the target remains unchanged). Demers and Rodríguez (2002) find that an implementation of this framework was distinguished by higher inflation response, but the increase in the response to real economic activity was even more significant. Shih and Giles (2009) model the duration analysis of BoC interest rate changes with respect to different macroeconomic variables. They find that annual core inflation and monthly growth rate of real GDP drive the changes of policy rate while unemployment rate and exchange rate do not. On the contrary, Dong (2008) confirms the BoC considerations for real exchange rate movements.

Sweden adopted the IT in 1993 (2% target with a tolerance band of 1 percentage point) just after the korona was allowed to float. The independence of Sveriges Riksbank (SR) was legally increased in 1999. Jansson and Vredin (2003) studies its policy rule concluding that the inflation forecast (published by the Riksbank) is the only relevant variable driving interest rate changes. Kuttner (2004) finds additionally role for the output gap but in terms of its growth forecast (rather than its observed value). Berg et al. (2004) provide rigorous analysis of the sources of deviations between SR policy rate and the targets implied from diverse empirical rules. They claim that higher inflation forecasts at early stages of the IT regime (due to lack of credibility) generates higher implied target from the forward-looking rule and therefore induce spurious indication of policy shock. Their qualitative analysis of SR documents clarifies the rationale behind the actual policy shocks such as more gradualism (stronger inertia) in periods of macroeconomic uncertainty.

Finally, there are a few multi-country studies. Meirelless-Aurelio (2005) analyzes time-invariant rule of the same countries as us finding significant dependency of the results on the real-time versus historic measures of variables. Lubik and Shorfheide (2007) estimates by Bayesian methods an open economy structural model of 4 IT countries (AUS, CAN, NZ, UK) with the aim to see whether the IT central bank respond to exchange rate movements. They confirm this claim for the BoE and BoC. Dong (2008) enrich their setting by some more realistic assumptions (exchange rate endogeneity, incomplete exchange-rate pass-through) finding additionally the response to exchange rate for the RBA.

2.2 Time Variance in Monetary Policy Rules

The original empirical research on monetary policy rules used linear specification with time-invariant coefficients. Instrument variable estimators like GMM gained popularity in this context, because they are able to deal with the issue of endogeneity that arises in the forward-looking specification (Clarida et al., 1998).[3] While time-invariant policy rule may be a reasonable approximation when the analyzed period is short, structural stability usually fails over longer period.

The simplest empirical strategy to take the time variance into account is to use a sub-sample analysis (Taylor, 1999, Clarida et al., 2000). The drawback of this approach is rather subjective assumption about the points of structural change and the structural stability within each sub-period. An alternative is to apply an econometric model that allows time variance for the coefficients. There are various methods dealing with the time variance in the context of estimated monetary policy rules.

The most common option is the Markov-switching VAR method, originally used for business cycle analysis. Valente (2003) employes such model with the switches in the constant term representing the evolution of the inflation target (the inflation target together with the real equilibrium interest rate makes the constant term in a simple Taylor rule). Assenmacher-Wesche (2006) uses the Markov-switching model with the shifts both in the coefficients and the residual variances. Such separation between the evolution of policy preferences (coefficients) and the exogenous changes in economic system (residuals) is important for the continuing discussion on sources of the Great moderation (Benati and Surico, 2008, Canova and Gambetti, 2008). Sims and Zha (2006) present a multivariate model with discrete breaks in both coefficients and disturbances. Unlike Assenmacher-Wesche they find that the variance of the shock rather than the time variance of the monetary policy rule coefficient has shaped the macroeconomic development in the US in last four decades.

The application of Markov-switching VAR techniques turns out to be complicated for the IT countries, where the policy rules are usually characterized as forward-looking and some regressors become endogenous. The endogeneity bias can be avoided by means of backward-looking specification (lagged explanatory variables) but this is very likely inappropriate for IT

[3] One exception is when researcher uses real-time central bank forecasts for Taylor-type rule estimation, i.e. the data available to the central bank before the monetary policy meeting. In such a case, endogeneity problem shall not arise and least square estimation may perform well (Orphanides, 2001). However, as we will discuss in more detail below, the use of real-time data may not solve the issue of endogeneity completely.

central banks that are arguably forward-looking.[4] However, there is another distinct feature of the Markov-switching model that makes its use for the analysis of time variance in monetary policy rule rather questionable. The model assumes sudden switches from one policy regime to another rather than a gradual evolution of the monetary policy. Although at first sight, one may consider the introduction of the IT being an abrupt change, there are some reasons to believe that the smoothed transition of monetary policy is more appropriate description for the IT countries (Koop et al., 2009). Firstly, the IT regime is typically based on predictability and transparency, which does not seem to be consistent with the sudden switches. Secondly, it is likely that inflation played already a certain role for the interest rate setting even before the IT regime was introduced, because in many countries the major decrease of inflation rates occurred before the IT was implemented. Thirdly, the coefficient of different variables (such as inflation, the output gap or exchange rate) in the monetary policy rule may evolve independently rather than moving from one regime to another at the same time (see also Darvas, 2009). For instance, a central bank may assign more weight to observed or expected inflation rate when it implements the IT but it does not mean that it immediately disregard the information on real economic activity or foreign interest rate setting. Finally, there is relevant evidence, though mostly for the U.S., that the monetary policy evolves rather smoothly over time (Boivin, 2006, Canova and Gambetti, 2008, Koop et al., 2009). Therefore based on this research, a smooth transition seems to be a more adequate description of the reality. In a similar manner, there is a possibility to estimate the policy rule by STAR-type models. Nevertheless, it should be noted that STAR-type models assume specific type of smooth transition between the regimes, which can be more restrictive than flexible random walk specification that we employ in this paper. Therefore, we leave the empirical examination of Markov-switching as well as STAR-type models for further research.[5]

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[4] Psaradakis et al. (2006) proposed solution of the endogeneity problem in context of Markov-switching model in case of the term structure of interest rates.

[5] We run a number of experiments on simulated data with the true coefficients containing large sudden shifts to see whether the estimated coefficients are gradually changing or shifting. The specification of basic experiment was as follows: The intercept follows a slowly moving random walk (variance of innovations set to 0.3), for independent variable we have used the expected inflation in the U.K. with coefficient beta set to 0.75 to 60th observation and 1.75 afterwards. Then we included lag of dependent variable with constant coefficient equal to 0.5 and residuals with distribution N(0.15). The dependent variable was generated as a sum of these components. This example can be linked to a reaction function of hypothetical central bank that smoothes interest rate, that does not have the output gap in its reaction function and that changed its aggressiveness abruptly in the middle of the sample. Then we estimated the model using the VC method and stored the value of the estimated change of coefficient beta at time of switch in the data generating process. We repeated this small experiment 30 times for different sets of intercept and residuals and the estimated value of switch was 0.98 on average, ranging from 0.9 to 1.02. Average sizes of innovations in beta were below 0.09 in the remaining part of the samples. Clearly, in this simple setting the abrupt change in the policy is detected by the model with respect to size and timing of that change. Further experiments contained more variables in reaction function and more switches going upwards and downwards as well. We have found, that generally sudden changes (larger than average changes in other time varying coefficients) in the true coefficients resulted in switches in estimated time-varying coefficients, too, and the varying coefficients did

Besides simple recursive regression (e.g. Domenech et al., 2002), the Kalman filter was employed in a few studies to estimate a coefficient vector that varies over time. Such time-varying model is also suitable for reflection of possible asymmetry of the monetary policy rule (Dolado et al., 2004).[6] An example of such asymmetry is that policy maker responds more strongly to inflation rate when it is high than when it is low. Boivin (2006) uses such time varying model estimated via the Kalman filter for the US, Elkhoury (2006) for Switzerland and Trecrocci and Vasalli (2010) for the US, the UK, Germany, France and Italy. However, none of these studies provides a specific econometric treatment to the endogeneity that arise in forward-looking specifications.

In this respect, Kim (2006) proposes a two-step procedure dealing with the endogeneity problem in the time-varying parameter model. Kim and Nelson (2006) find with this methodology that the US monetary policy evolved in different manner than the previous research suggested. In particular that FED's interest in stabilization of real economic activity significantly increased since early 1990's.[7] Kishor (2008) applies the same technique for analysis of time-varying monetary policy rule of Japan, Germany, the UK, France and Italy. He detects time-varying response not only with respect to inflation rate and output gap but also to foreign interest rate. The relevance of the endogeneity correction can be demonstrated by the difference between Kishor's results and those of Trecrocci and Vasalli (2010), who both study the same sample of countries.[8] The time-varying parameter model with specific treatment of endogeneity can be relevant even when the real-time data are used instead of ex-post data (Orphanides, 2001). When the real-time forecast is not derived under assumption that nominal interest rates will remain constant within the forecasting horizon, the endogeneity may be still present in the model (see Boivin, 2006). Moreover, this estimation procedure is also viable to reflect the measurement error and the heteroscedasticity in the model (Kim et al., 2006). However, the Kalman filter applied at state-space model may suffer one important drawback in small samples, as it is rather sensitive to the initial values of the parameters, which are unknown. The moment-based estimator proposed by Schlicht (1981), Schlicht (2005), Schlicht and Ludsteck (2006), which is employed in our paper and described below, allows avoiding this problem. Moreover, it is flexible enough so to incorporate the endogeneity correction proposed by Kim (2006).

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not imply gradual changes in these cases. Nevertheless, ability of the time-varying parameter models to identify sudden structural breaks in parameters remains to be confirmed by careful Monte Carlo simulations, as pointed out by Sekine and Teranishi (2008).

[6] Granger (2008) shows that any non-linear model can be approximated by a time-varying parameter linear model.

[7] Kim et al. (2006) confirms this finding with real-time data and additionally detected significant decrease in the response to expected inflation during the 1990's.

[8] Horváth (2009) employs the time-varying model with endogenous regressors for estimation of the neutral interest rate for the Czech Republic confirming the importance of endogeneity bias correction terms.

3. Empirical Methodology

3.1 The Empirical Model

Pursuant to Taylor (1993) most empirical studies model assumes that the central bank targets to set the nominal interest rate in line with the state of the economy (see Clarida *et al*., 1998, 2000). Such policy rule, which is in case of IT central bank arguably forward-looking, can be written as follows:

$$r_t^* = \bar{r} + \beta\left(E\left[\pi_{t+i}\left|\Omega_t\right.\right] - \pi_{t+i}^*\right) + \gamma E\left[y_{t+j}\left|\Omega_t\right.\right] \tag{1}$$

where r_t^* denotes the targeted interest rate, $\bar{r}$ is the policy neutral rate[9], π_{t+i} stands for the central bank forecast of the yearly inflation rate *i* periods ahead, and π_{t+i}^* is the central bank's inflation target[10]. y_{t+j} represents a measure of the output gap. $E[\ ]$ is the expectation operator and Ω_t is the information set available at the time when interest rates are set. Eq. (1) links the policy instrument (nominal interest rates) to a constant term (the neutral rate – that would prevail if the expected inflation and output were at their targeted levels), the deviation of expected inflation from its target value and the output gap.

Nevertheless, Eq. (1) is often argued to be too restrictive to provide a reasonable description of actual interest rate setting. First, it does not account for interest rate smoothing of central banks. Most studies in line with Clarida *et al.* (1998) assume that the central bank adjusts the interest rate sluggishly to the targeted value, which can be tracked by simple partial-adjustment mechanism:

$$r_t = \rho r_{t-1} + \left(1-\rho\right) r_t^* \tag{2}$$

where $\rho \in [0,1]$ is the smoothing parameter. Although this is line with common wisdom that central banks are averse to abrupt changes, most studies that estimate time-invariant models find unusually high policy inertia. For instance, using quarterly data ρ typically exceeds 0.8. Rudebusch (2006) point to an inconsistency between this finding and practical impossibility to predict interest rate changes over a few quarters. Therefore, it is possible that the lagged

[9] Policy neutral rate is typically defined as the sum of real equilibrium rate and expected inflation.

[10] The definition of inflation target varies slightly across the IT countries. However, mostly it aims at mid-term rather than short-term period. The target value can also vary in time, which was pronounced especially in emerging countries that implemented IT as a gradual disinflation strategy. On the contrary, for countries that are studied here, the target value has not significantly changed over time.

dependent value takes over the impact of either autocorrelated shocks or omitted variables. The intensity of interest rate smoothing is logically reinforced in linear time-invariant specification as the response to some variables can be asymmetric and/or vary in time. Second, Eq. (1) assumes that central bank aims only at inflation rate and the output gap. However, many central banks that implemented the IT are small open economies that may consider additional variables, in particular exchange rate and foreign interest rate. Therefore, in our empirical model we substitute Eq. (2) into Eq. (1), eliminating unobserved forecast variables and include additional variables, which results in Eq. (3):

$$r_t = (1-\rho)\left[\alpha + \beta\left(\pi_{t+i} - \pi^*_{t+i}\right) + \gamma y_t + \delta x_t\right] + \rho r_{t-1} + \varepsilon_t \tag{3}$$

Also, α is the constant term, which in Eq. (1) coincide with the policy neutral rate $\overline{r}$. However, if the model is augmented by additional variables x_{t+k} that are not in a form of deviation from the target value, the constant term need not keep this interpretation. We set *i* equal to 2.[11] Consequently, the disturbance term ε_t is a combination of forecast errors and is thus orthogonal to all information available at time t (Ω_t).

Pursuant our previous discussion, the interest rate rule described above will be estimated within framework that allows time variance of the coefficients. Kim (2006) shows that the conventional time-varying parameter model (Kalman filter applied at state-space representation) delivers inconsistent estimates when explanatory variables are correlated with the disturbance term. The endogeneity arise in forward-looking policy rules based on ex-post data, but it can appear even with real-time data, as discussed before. Kim (2006) proposes an estimator of the time-varying coefficient model with endogenous regressors. A few recent contributions use this framework for estimation of monetary policy rules (Kim and Nelson, 2006, Kim et al. 2006, Kishor, 2008).[12] Following Kim (2006) we can rewrite Eq. (3) as follows:

$$r_t = (1-\rho_t)\left[\alpha_t + \beta_t\left(\pi_{t+i}\right) + \gamma_t y_t + \delta_t x_t\right] + \rho_t r_{t-1} + \varepsilon_t \tag{4}$$

$$\alpha_t = \alpha_{t-1} + \vartheta_{1t},\ \vartheta_t \sim i.i.d.N\left(0, \sigma^2_{\vartheta_1}\right) \tag{5}$$

[11] Although the targeting horizon of central banks is usually longer (4-8 quarters), we prefer to proxy inflation expectation by inflation in *t+2* for the following reasons. First, the endogeneity correction requires strong correlation between the endogenous regressor and its instruments. Second, the prediction error logically increases in longer horizons. Third, the countries that are subject to our analysis did not apply inflation targeting during the whole estimation period. Consequently, it is preferable due to data limitations to keep only two inflation leads rather than four or six.

[12] Note, however, that two of these contributions are, to our knowledge, unpublished yet.

$$\beta_t = \beta_{t-1} + \vartheta_{2t}\,,\ \vartheta_t \sim i.i.d.N\left(0, \sigma^2_{\vartheta_2}\right) \quad (6)$$

$$\gamma_t = \gamma_{t-1} + \vartheta_{3t}\,,\ \vartheta_t \sim i.i.d.N\left(0, \sigma^2_{\vartheta_3}\right) \quad (7)$$

$$\delta_t = \delta_{t-1} + \vartheta_{4t}\,,\ \vartheta_t \sim i.i.d.N\left(0, \sigma^2_{\vartheta_4}\right) \quad (8)$$

$$\rho_t = \rho_{t-1} + \vartheta_{5t}\,,\ \vartheta_t \sim i.i.d.N\left(0, \sigma^2_{\vartheta_5}\right) \quad (9)$$

$$\pi_{t+i} = Z'_{t-j}\xi + \sigma_\varphi \varphi_t\,,\ \varphi_t \sim i.i.d.N\left(0,1\right) \quad (10)$$

$$y_t = Z'_{t-j}\psi + \sigma_\nu \nu_t\,,\ \nu_t \sim i.i.d.N\left(0,1\right) \quad (11)$$

The measurement equation (4) of the state-space representation is the monetary policy rule. The transition equations (5) – (9) describe the time-varying coefficients as a random walk process without drift. The Eqs. (10) and (11) track the relationship between the endogenous regressors (π_{t+i} and y_t) and their instruments, Z_t. The list of instruments, Z_{t-j}, is as follows: π_{t-1}, π_{t-4}, y_{t-1}, y_{t-2}, r_{t-1} and r_t^+ (foreign interest rate). As in Kim (2006), we assume that the parameters in Eqs. (10) and (11) are time-invariant. Next, the correlation between the standardized residuals φ_t and ν_t and ε_t is $\kappa_{\varphi,\varepsilon}$ and $\kappa_{\nu,\varepsilon}$, respectively (note that σ_φ and σ_ν are standard errors of φ_t and ν_t, respectively). The consistent estimates of the coefficients in Eq. (4) are obtained in two steps. In the first step, we estimate the equations (10) and (11) and save the standardized residuals φ_t and ν_t. In the second step, we estimate Eq. (12) below along with Eq. (5) – (9). Note that (12) now includes bias correction terms[13], i.e. (standardized) residuals from Eqs. (10) and (11), to address the aforementioned endogeneity of the regressors. Consequently, the estimated parameters in Eq. (12) are consistent, as z_t is uncorrelated with the regressors.

$$r_t = \left(1-\rho_t\right)\left[\alpha_t + \beta_t\left(\pi_{t+i}\right) + \gamma_t y_t + \delta_t x_t\right] + \rho_t r_{t-1} + \kappa_{\nu,\varepsilon}\sigma_{\varepsilon,t}\nu_t + \kappa_{\varphi,\varepsilon}\sigma_{\varepsilon,t}\varphi_t + \zeta_t\,,$$

$$\zeta_t \sim N\left(0, (1-\kappa^2_{\nu,\varepsilon} - \kappa^2_{\varphi,\varepsilon})\sigma^2_{\varepsilon,t}\right) \quad (12)$$

The standard framework for second-step estimation is the maximum likelihood estimator via the Kalman filter (Kim, 2006). However, there are several difficulties with the estimation of the Kalman filter (and Kalman smoother) in applied work. First, if the variables are nonstationary, the results often depend on the proper choice of initial values, but those values

[13] Obviously, if the correction terms are statistically significant, it shows that endogeneity matters. Similarly to Kim and Nelson (2006) and Horváth (2009), we find that these terms are typically significant: In our sample the endogeneity correction for inflation is significant for all countries but the U.K. at least at 10% level, and for the GDP gap for Canada, see the table A.1 in appendix.

are not known in advance.[14] The problem with initial conditions is larger, if one-sided estimates are used, as illustrated in Leigh (2008) on estimates of time-varying natural rate of interest in the U.S. Applying Kalman smoother alleviates the issue and the differences in estimates at the beginning of the sample decrease sharply. Second, the log likelihood function is highly nonlinear and in some cases, optimization algorithms fail to minimize the negative of the log likelihood for several reasons (either it can fail to calculate the Hessian matrix throughout the iterations process or, when the likelihood function is approximated to facilitate computations, covariance matrix of observation vector can get singular for provided starting values).

In this paper, we adopt the "varying coefficients" (VC) method (Schlicht and Ludsteck, 2006). The VC method generalizes the standard ordinary least squares approach. In fact instead of minimizing the sum of squares of residuals $\sum_{t=1}^{T} \zeta^2$, it uses the minimization of the weighted sum of squares:

$$\sum_{t=1}^{T} \zeta^2 + \theta_1 \sum_{t=1}^{T} \vartheta_1^2 + \theta_2 \sum_{t=1}^{T} \vartheta_2^2 + \ldots + \theta_n \sum_{t=1}^{T} \vartheta_n^2 \tag{13}$$

where the weights θ_i are the inverse variance ratios of the regression residuals ζ_t and the shocks in time-varying coefficients ϑ_t, that is $\theta_i = \sigma^2 / \sigma_i^2$. Hence it balances the fit of the model and the parameter stability.[15] Additionally, the time averages of the regression coefficients, estimated by such weighted least squares estimator, are identical to their GLS estimates of the corresponding regression with fixed coefficients, that is $\frac{1}{T}\sum_{t=1}^{T} \hat{a}_t = \hat{a}_{GLS}$.

The VC method has a number of advantages. First, it does not require initial conditions even for non-stationary variables prior to the estimation procedure. Instead, both the variance ratios and the coefficients are estimated simultaneously. Second, the property of the estimator, that the time averages of estimated time-varying coefficients are equal to its time-invariant counterparts, permits easy interpretation of the results in relation to time-invariant results. The features of VC method make it feasible for our analysis: We deal with time-varying model,

[14] Although there are number of formal procedures for initialization of the Kalman filter in such cases (for example see Koopman et al., 1999) a fundamental uncertainty about their values remains.

[15] It should be noted, that throughout our computations, we did not have to solve problems with convergence of the moment estimator as it was almost always able to find equilibrium. Computational details of the VC method are described in the Appendix. Originally, Schlicht and Ludsteck (2006) start with a derivation of maximum likelihood estimator of parameters *a* based on the idea of orthogonal parameterization, which is described in the Appendix. Then they prove that the weighted least squares estimator is identical to the maximum likelihood estimator and also that the likelihood estimator is identical to the moment estimator for very large samples.

where coefficients are assumed to follow random walk, there is no *a priori* information about the initial values and the time series are rather short.[16]

Furthermore, Schlicht and Ludsteck (2006) compares the results from the VC method and from the Kalman filter, showing that both estimators give very similar results, given the assumption that the Kalman filter is initialized with correct initial conditions. Yet in this case, the VC estimator has slightly lower mean squared error and this difference is more pronounced on small samples[17].

We assume that the variance of disturbance term in Eq. (12) is not time-varying. Nevertheless, there is an ongoing discussion to what extent the changes in macroeconomic environment are driven by the changes in the variance of disturbance term (i.e. the exogenous changes in economic system) vis-à-vis the variance in the coefficients of monetary policy rule (see for example, Benati and Surico, 2008, Canova and Gambetti, 2008 or Sims and Zha, 2006).

One can also think about the Eqs. (4), (10) and (11) in terms of New Keynesian model with the Eqs. (10) and (11) representing Phillips and IS curves. It should be noted that our framework is in general less restrictive and imposes less structure than the full-blown New Keynesian model.

We expect β_t to be positive, as the central bank is likely to react to the increase of expected inflation by increasing its policy rate. Particularly, β_t should be greater than one in the long-run solution of Eq. (4), if monetary policy is stabilizing. The development of β_t over time may be driven by a number of factors such as the changes in monetary policy regime or institutional constraints (Adam et al., 2005). The effect of inflation targeting adoption on β_t is ambiguous. As put forward by Kuttner and Posen (1999), β_t can both increase or decrease. They show that under a conservative central bank, the response of short-term interest rates is greater than under discretion or the optimal state-contingent rule (inflation targeting),[18] while the strength of the

[16] Number of observations differs among countries and it ranges from 89 to 144 observations. In case of Kalman filter we can utilize the whole sample, if we opted for initial conditions equal to the full sample OLS estimated values (recommended for stationary systems). Another approach derives initial conditions related directly to the beginning of the sample from the first subset of available observations and the Kalman filter is performed on the latter part of the sample. Kim and Nelson (2006) adopted this approach and they use first 40 observations for initialization.

The estimation of the second step is carried out by Schlicht´s VC package that uses the moment estimator.

[17] For comparison, we estimated the equation (12) using the conventional Kalman filter in GROCER software using the function *tvp* (Dubois-Michaux, 2009). We parameterized the model by initial conditions taken from the OLS estimates of the parameters on the full sample and initial forecast error covariance matrix set to 0. Matrix of residuals of time-varying coefficients is assumed to be diagonal as in the VC method. The results were very similar to those obtained from the VC method, when the estimated variances were the same in both methods. The only country, where the estimated variance were different, was Sweden, with lower variance of smoothing parameter ρ and higher variance in β. Still, the results were consistent with ours. These results are available upon respect.

[18] See King (1997) on how inflation targeting allows coming close to optimal state-contingent rule.

response under inflation targeting as compared to discretion depends on the credibility of the regime. Credible monetary policy does not have to react so strongly to inflation surprises, as inflation expectations are likely to remain anchored. Sekine and Terashini (2008) provide a new Keynesian model that reaches to the same conclusions. Siklos and Weymark (2009) estimate that inflation targeting in Australia, Canada and New Zealand reduced the magnitude of interest rate changes to needed to maintain low inflation environment.

Similarly, ρ, a measure of interest rate smoothing, is expected to be positive with the values between zero and one. Many time-invariant estimates of monetary policy rules find the value of this parameter about 0.7-0.9 implying substantial degree of interest rate smoothing. Rudebusch (2006) claims that such are clearly overestimated in face of very low interest rate forecastability in the term structure of interest rates. On the contrary, the time-varying model in principle enables that some variables affect interest rate setting in some period but not in another and is less prone to autocorrelated shocks.

Next, the effect of output gap, γ_t, on interest rates is expected to be positive or insignificant. In the first case, the central bank may have an explicit concern for real activity or understand output gap as a useful predictor of future inflation. In the latter case, the insignificant coefficient may suggest that central bank is primarily focused on inflation developments and does not consider output gap important in delivering low inflation.

There is a debate in literature whether other variables should be included in the monetary policy rule. This is especially appealing for small open economies that may be concerned with exchange rate fluctuations as well as the developments of foreign interest rates. Taylor (2001) puts forward that even if exchange rate or foreign interest rates are not explicitly included in the policy rule, they still remain present implicitly, as exchange rate influences the inflation forecast to which inflation targeting central bank is likely to react. It is also worth to emphasize that the significance of exchange rate or foreign interest rates does not necessarily mean that the central bank targets some particular values of these variables, but rather that the bank considers the foreign developments important for its inflation forecast. On the other hand, empirical studies often favor to include these variables in the estimated policy rule. Having these considerations in mind, we decided to include exchange rate and foreign interest rates, too, in order to assess, whether these two variables carry any additional information to understand interest rate setting process in our sample countries.

3.2 The Dataset

We use quarterly data. The sample period varies by countries due to data availability (the UK 1975:1Q -2007:4Q, Australia 1975:1Q – 2007:4Q, Canada 1975:1Q – 2007:4Q, New Zealand 1985:1Q – 2007:3Q, Sweden 1982:2Q – 2007:3Q), but on average time coverage is about three decades.

Following Clarida, Galí and Gertler (1998), the dependent variable is a short-term interest rate that is typically closely linked to monetary policy rate. The reason for choosing short-term interest rate rather than monetary policy rate is the fact that the monetary policy rate as well as its change is censored (Podpiera, 2008). Therefore, the dependent variables capturing the policy rate is the discount rate (3-month treasury bills) for the UK, interbank 3-month interest rate for Australia, 3-month treasury bills rate for Canada, overnight interbank 90 days interest rate for NZ and interbank 3-month interest rate for Sweden. We choose the interest rate so as to be closely linked to monetary policy, but also to be available for sufficiently long period. The foreign interest rate is the German 3-month EUROLIBOR for the UK and Sweden and the US 3-month interbank interest rate for Australia, NZ, and Canada.

The inflation is measured as year-on-year change of CPI, besides the UK where we use RPIX (retail price index excluding mortgage interest payments) and the NZ where we use CPIX (CPI without interest payments).[19]

The output gap is taken as reported in the OECD Economic Outlook (production function method based on NAWRU - non-accelerating wages rate of unemployment) besides for NZ where this series is short and where we use the output gap derived from the Hodrick-Prescott filter applied at GDP series (constant prices, seasonally adjusted).[20] Exchange rate is measured by chain-linked nominal effective exchange rate (NEER) besides Canada where we use bilateral exchange rate USD/CAD. For the regressions we use the deviation of the index from the HP trend (first differences have been used for robustness check), see also Lubik and Schorfheide (2007).

[19] We use year-on-year data, as the inflation target is also defined on a year-on-year basis.

[20] There is no agreement what is the best method for extraction of the unobserved output gap (Billmeier, 2009). We prefer to use the output gaps obtained by the OECD by means production function approach because they are based on substantially richer information set that simple statistical detrending. Somewhat surprisingly, the OECD output gap and simple HP gap evolves very closely.

4. Results

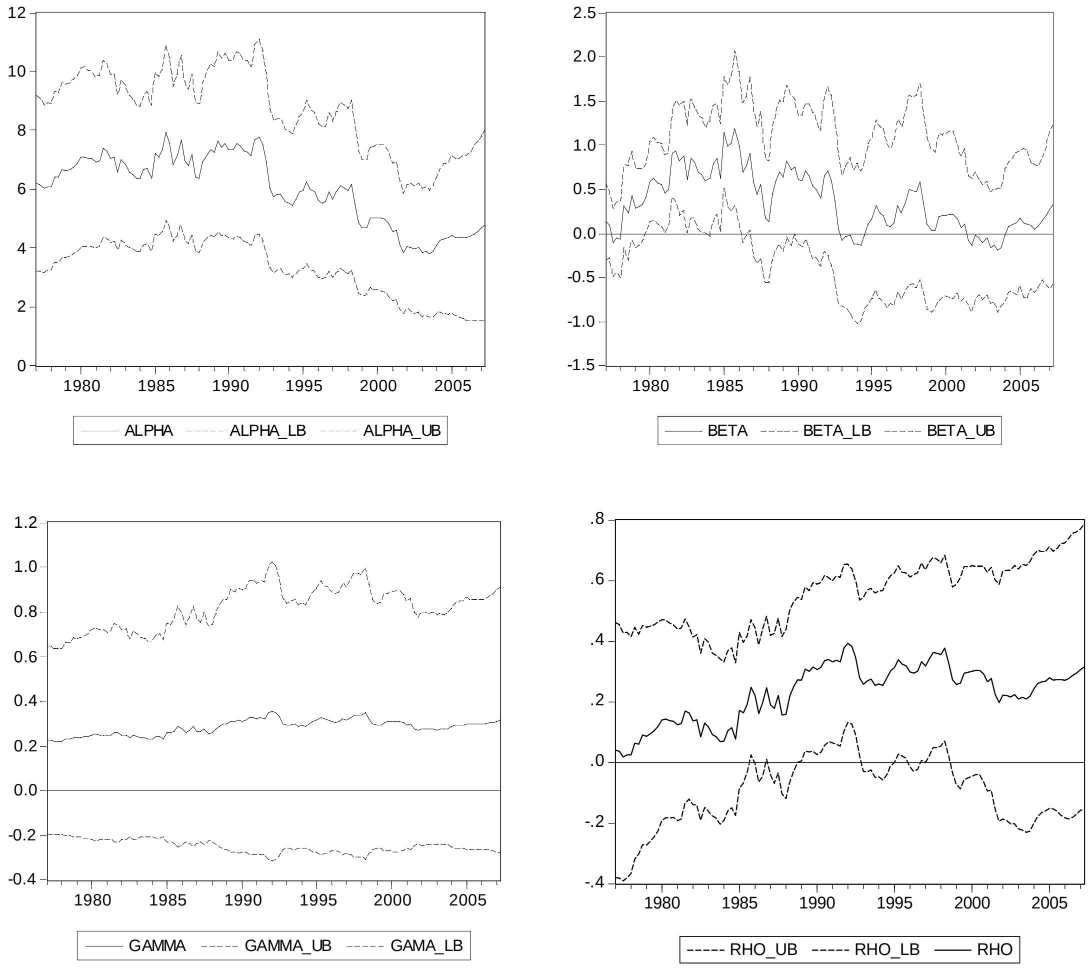
First, this section presents the country-specific estimates of time-varying monetary policy rules in the sub-section 4.1-4.5, the sub-section 4.6 contains the estimates of time-varying inflation persistence and the sub-section 4.7 provides the summary of main policy relevant findings.

4.1 United Kingdom

Our results show that the BoE significantly increased its response to inflation since late 1970’s till mid-eighties. This overlaps with the Thatcher government and its major priority being the inflation control. The overall decline of the response since 1985 can be related to the dismissal of medium-term financial strategy (adopted in 1979). We find that the response of interest rates on inflation was gradually decreasing during the 1990s in spite of the introduction of the IT. Although this finding can seem at the first sight contra-intuitive, it is important to keep in mind that, unlike in some emerging countries, the IT was not implemented in the UK as a strong anti-inflationist strategy. The inflation was already contained in the 1980’s and very benign inflation enviroment was also supported by declining prices of raw materials on the world markets. This corroborates with the findings of Kuttner and Posen (1999) and Sekine and Teranishi (2008) who show that inflation targeting can be associated with less aggressive monetary policy.

The effect of the output gap is estimated positive (albeit the confidence intervals are rather large probably reflecting that the gap is unobserved variable and calculated ex post) and does not vary substantially over time. Interest rate smoothing parameter is found to have values between 0.1-0.3, which is much lower than what time-invariant estimates of monetary policy rules typically report (Clarida et al., 1998, 2000). Our estimates seem to be reasonable in face of the recent critique of Rudebush (2006). Finally, the intercept can be in this basic model interpreted as policy neutral (nominal) interest rate. We can see that it steadily declined over time, which complies with the low inflation environment in the 1990s that prevailed in the U.K.

Figure 1: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, the U.K.



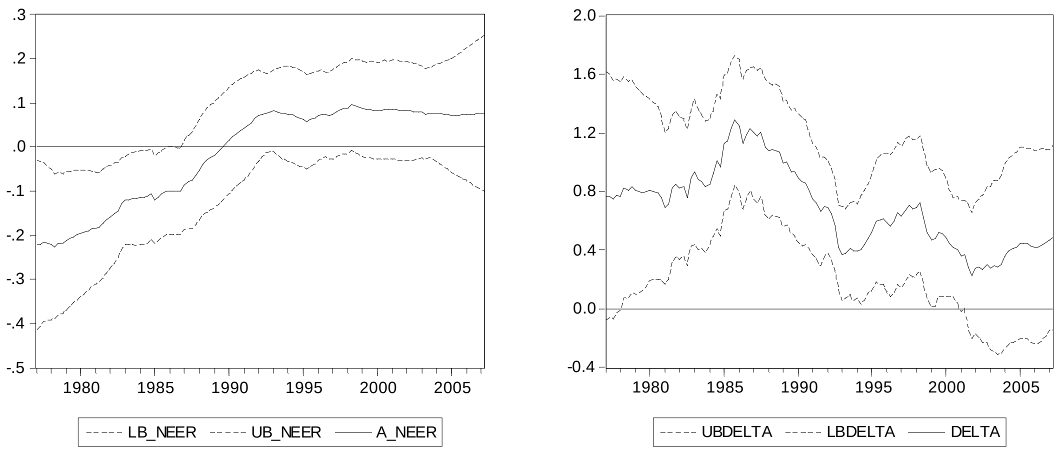
Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Upper left graph depicts the evolution of neutral rate. Upper right graph depicts the evolution of the response of interest rates to inflation. Lower left graph depicts the evolution of the response of interest rates to output gap. Lower right graph depicts the evolution of the interest rate smoothing parameter.

The results of our augmented model show that the monetary policy of the BoE was influenced by external factors albeit their importance was greater in the 1980s than recently.[21] In

[21] In what follows, we present the evolution of the coefficients for the response on exchange rate and foreign interest rates, other coefficients remain largely unchanged and are not reported for the sake of brevity.

particular, we find evidence that the BoE decreased its policy rate as nominal effective exchange rate (NEER) strengthened during the 1980's even before the pound officially joined the ERM (1990). Yet, once the U.K. abandoned the ERM and introduced the IT, the BoE no longer seemed to explicitly react to exchange rate. Obviously, it has considered exchange rate indirectly, as exchange rate fluctuations influence the inflation forecast (more on this see Taylor (2001)). The same reasoning applies to the response to foreign interest rate (Euribor). It was particularly strong during the 1980's and consequently its importance somewhat declined. Our results show little support that the monetary policy of the BoE follows the ECB as the estimated response of the coefficient declined and the confidence intervals widened after the launch of euro.

Figure 2 – Time-Varying Response Coefficients in Augmented (Open Economy) Policy Rule, the U.K.



Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Left graph depicts the evolution of the response of interest rate to nominal effective exchange rate (deviation from HP trend). Right graph depicts the evolution of the response of interest rate to foreign interest rate.

There are two directly comparable studies to this paper. Kishor (2008) obtains the results similar to ours in spite of using monthly data known to have slightly different dynamics. He finds that the anti-inflation stance was at peak in mid-eighties and since than was rather declining in spite of the IT adoption. Similarly, his finding that the response to foreign interest rate significantly declined since the ERM crises is complementary to our result that the BoE was giving much less consideration to exchange rate evolution (NEER gap).

Trecroci and Vassalli (2010), who unlike Kishor (2008) and this paper do not correct for endogeneity in time-varying model, come to an opposite conclusion that the BoE response to inflation increased over time. Yet, some counterintuitive results of their study point to possibility of endogeneity bias. First, the interest rate smoothing parameter takes on significantly negative values from 1980 till 1995. This would have implied not only that policy was not inertial but that there was actually a negative correlation between the present and past interest rate, which is inconsistent even in face of simple visual inspection of interest rate series. When we estimate our model without the endogeneity-correcting coefficients we obtain similar result (see Appendix, Figure A.1).[22] Second, their coefficient of foreign (German) interest rate peaks in 1990 and is *de facto* invariant since than, which the authors interpret that as an implicit exchange-rate targeting. This finding is doubtful given the pound demise from the ERM and the IT implementation from 1992 onwards. In fact, British and German short-term that were almost at par in 1992 diverged and the interbank interest rate in the UK exceeded the German one by almost 4% on the eve of the euro adoption.

4.2 New Zealand

The inflation targeting was introduced in New Zealand as the first country in the world by the Federal Bank Act signed in March 1990.[23] Our results indicate that the response of the RBNZ to the expected inflation was very close to unity during the whole sample period (1985-2007). In fact, it is clearly visible that the interest rate and inflation series move together very closely. However, in Figure 3 we can also see that the official introduction of the IT does not seem to have represented a significant change in the interest rate setting (if anything there is very slight decrease of the response coefficient on inflation). Unlike in the UK, the response coefficient does not decrease substantially. This can be related to the fact that at the time the IT was introduced in New Zealand inflation rate was not far from double-digit values. Therefore, this policy was implemented in different context than e.g. in the U.K. where the inflation below double digit levels was already achieved during the 1980´s.[24] This result is together with the estimated insignificant response to the output gap consistent with the findings of time-invariant studies (Huang et al., 2001, Plantier and Scrimgeour, 2002) that the RBNZ applied rather strict

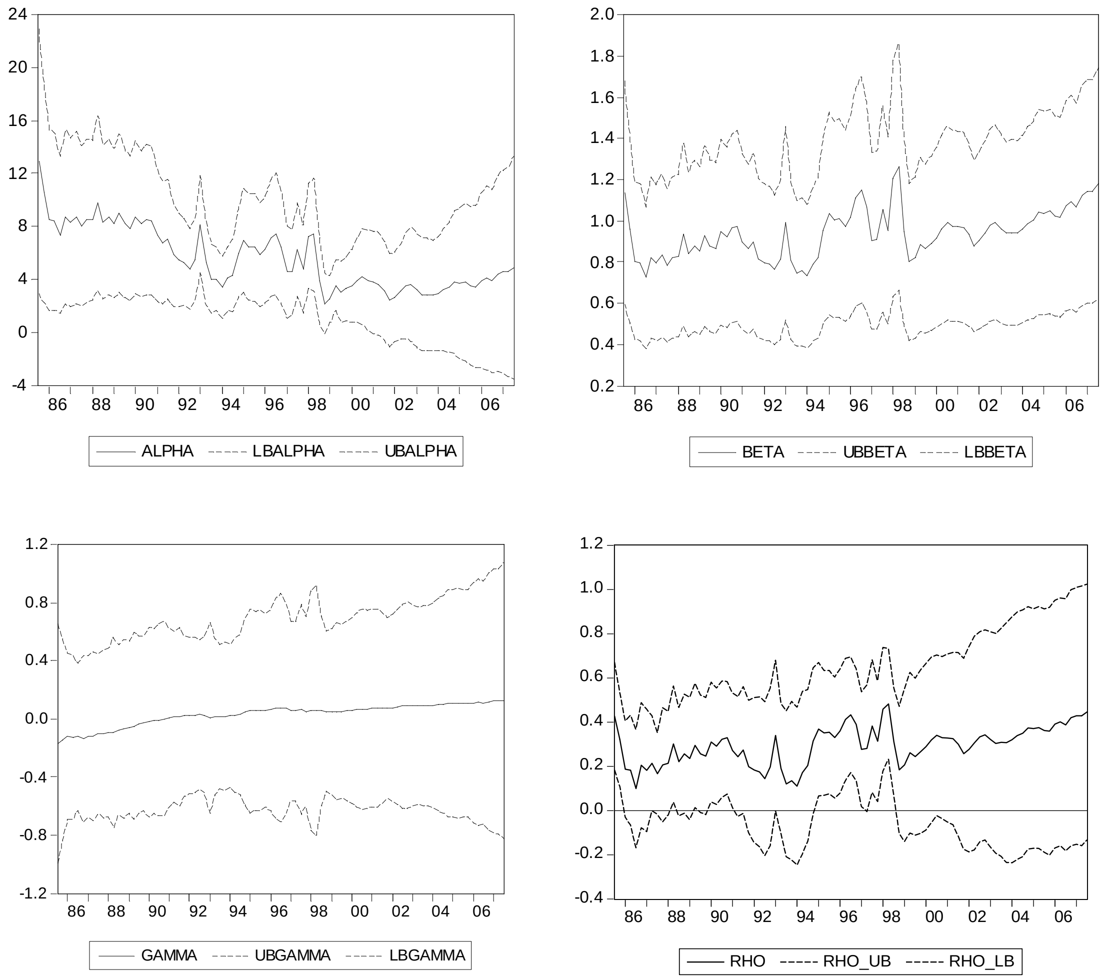
[22] The bias correction terms are significant, when we estimate the model addressing endogeneity, even though the economic significance is in general not large, see the Appendix.

[23] Huang et al. (2001) argues that this policy was in effect since the end of 1988 when the RBNZ abandoned both monetary and exchange rate targeting. He also points to a specific feature of the monetary policy of the RBNZ that could be referred to as 'Open Mouth Operations'. Between 1989 and 1999 the RBNZ specified 90-days bank bill rate consistent with price stability and threatened to use quantitative controls to achieve desired market rate if it was to deviate from the target. Therefore, the RBNZ did not control permanently and directly this interest rate.

[24] At the end of 1986 New Zealand introduced the VAT, which had direct impact on the inflation rate in the following two quarters. Consequently, we include time dummy in Q1 and Q2 1987, whose coefficient is estimated as positive and significant.

version of inflation targeting. Finally, we find that the interest rate smoothing parameter is again rather modest.

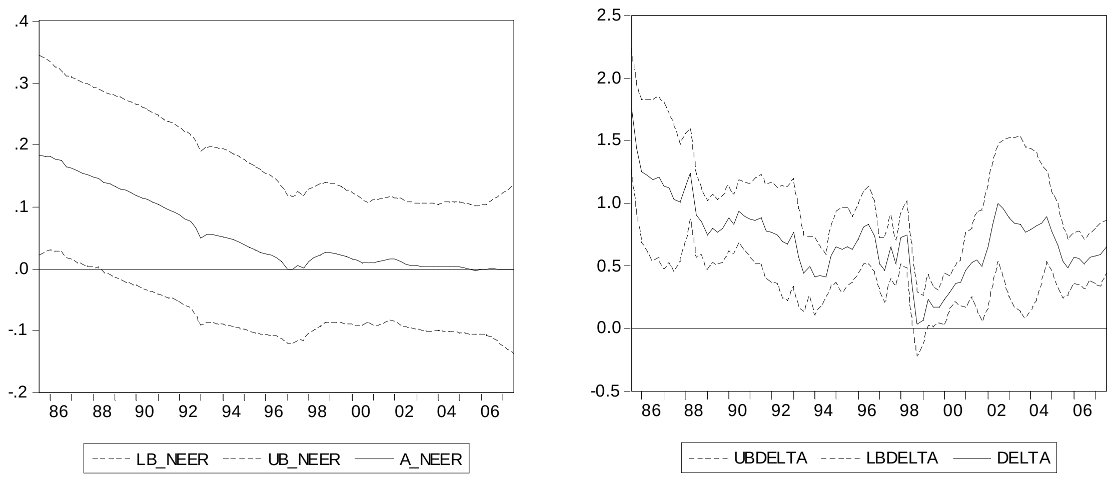
Figure 3: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, New Zealand



Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Upper left graph depicts the evolution of neutral rate. Upper right graph depicts the evolution of the response of interest rates to inflation. Lower left graph depicts the evolution of the response of interest rates to output gap. Lower right graph depicts the evolution of the interest rate smoothing parameter.

Estimating the augmented model for New Zealand, the evidence for exchange rate is not conclusive. We find positive response to NEER, which is rather counterintuitive in terms of the Taylor rule. However, the coefficient is significant only before the introduction of the IT and its positive sign is likely related to currency appreciation following the interest rate increase. In that period the RBNZ aimed to keep exchange rate in the predefined range and the interest rate was likely set so as to influence exchange rate *ex-ante* rather than *ex-post*. Consistently with this finding, Ftiti (2008) rejects in a time-invariant model that the RBNZ responded to exchange rate. On the other hand, we find some evidence in favor of consideration of foreign interest rate, yet its response coefficient generally decreased since the IT launch.

Figure 4: Time-Varying Response Coefficients in Augmented (Open Economy) Policy Rule, New Zealand



Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Left graph depicts the evolution of the response of interest rate to nominal effective exchange rate (deviation from HP trend). Right graph depicts the evolution of the response of interest rate to foreign interest rate.

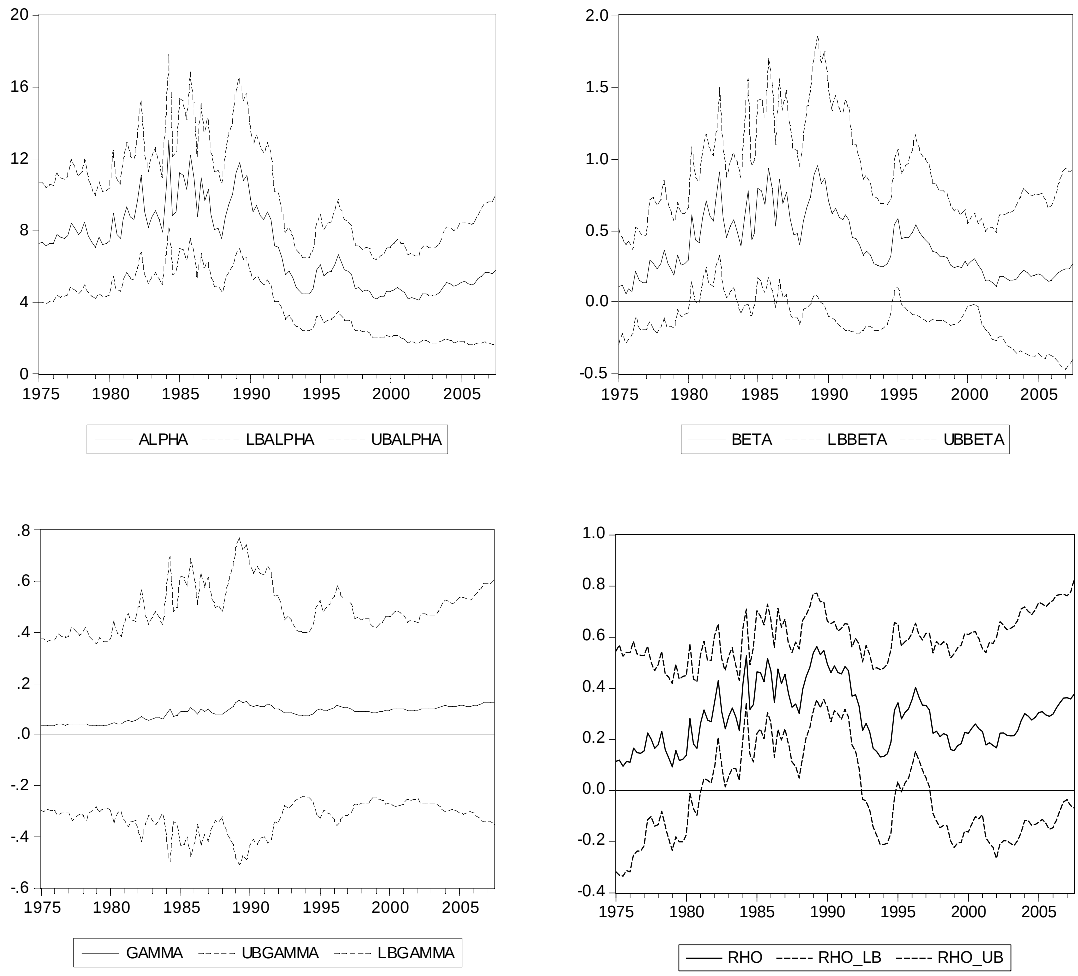
4.3 Australia

Our results on Australia are available in Figure 5 and 6. The response of interest rate to inflation is strongest in the 1980s, which is very similar to the U.K. experience. This period was characterized by inflation rates around 10% and the central bankers had to be quite aggressive in interest rate setting in order to break the record of high inflation built deeply in the public expectations. Neither the monetary targeting (employed until 1984) nor checklist approach (1985-1990) seemed to be successful in this regard. The fluctuation of the inflation response coefficient point to discretionary nature of policy decisions (making this finding consistent with Leu and Sheen, 2006). The response coefficient peaks in 1990 on the eve of the

IT but declines after adoption of this regime. It is again arguable whether it was the credibility of this regime what anchored the inflation expectations and allowed the RBA to behave less aggressively. The original inflation decline could be also related to the world recession in early 1990s. Our results dispute the finding of De Brouwer and Gordon (2005) arguing that the inflation response of the RBA increased as a result of inflation targeting launch.

As for other countries, the neutral rate declines in the 1990s reflecting global low inflation environment. The output gap is not found to be significant and the estimated interest rate smoothing is again rather low.

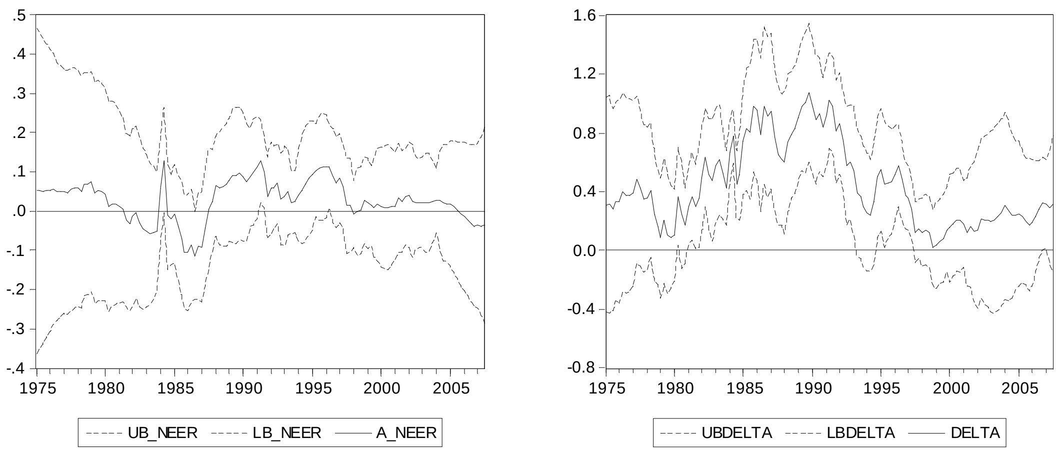
Figure 5: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, Australia



Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Upper left graph depicts the evolution of neutral rate. Upper right graph depicts the evolution of the response of interest rates to inflation. Lower left graph depicts the evolution of the response of interest rates to output gap. Lower right graph depicts the evolution of the interest rate smoothing parameter.

We find that exchange rate does not have a significant effect on the short-term interest rate (besides NEER we use also trade weighted index – TWI, which is exchange rate measure reported and often referred to by RBA) besides the period of 1985-87 when the currency depreciation (Australian dollar was allowed to float in 1983 after period of moving peg vis-à-vis TWI) was compensated by interest rate increase so as to curb the inflation pressures (see Greenville, 1997). Foreign interest rate parameter is estimated always positive, albeit it is significant only in the 1990s and its importance fades back as the IT was introduced. Since 2001 the Australian and the US interest rates diverge and the response coefficient approaches zero. This may be related to idiosyncratic developments in the U.S. when the FED lowered interest rate so as to face the fear of recession following September 2001 terrorist attack.

Figure 6: Time-Varying Response Coefficients in Augmented (Open Economy) Policy Rule, Australia



Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Left graph depicts the evolution of the response of interest rate to nominal effective exchange rate (deviation from HP trend). Right graph depicts the evolution of the response of interest rate to foreign interest rate.

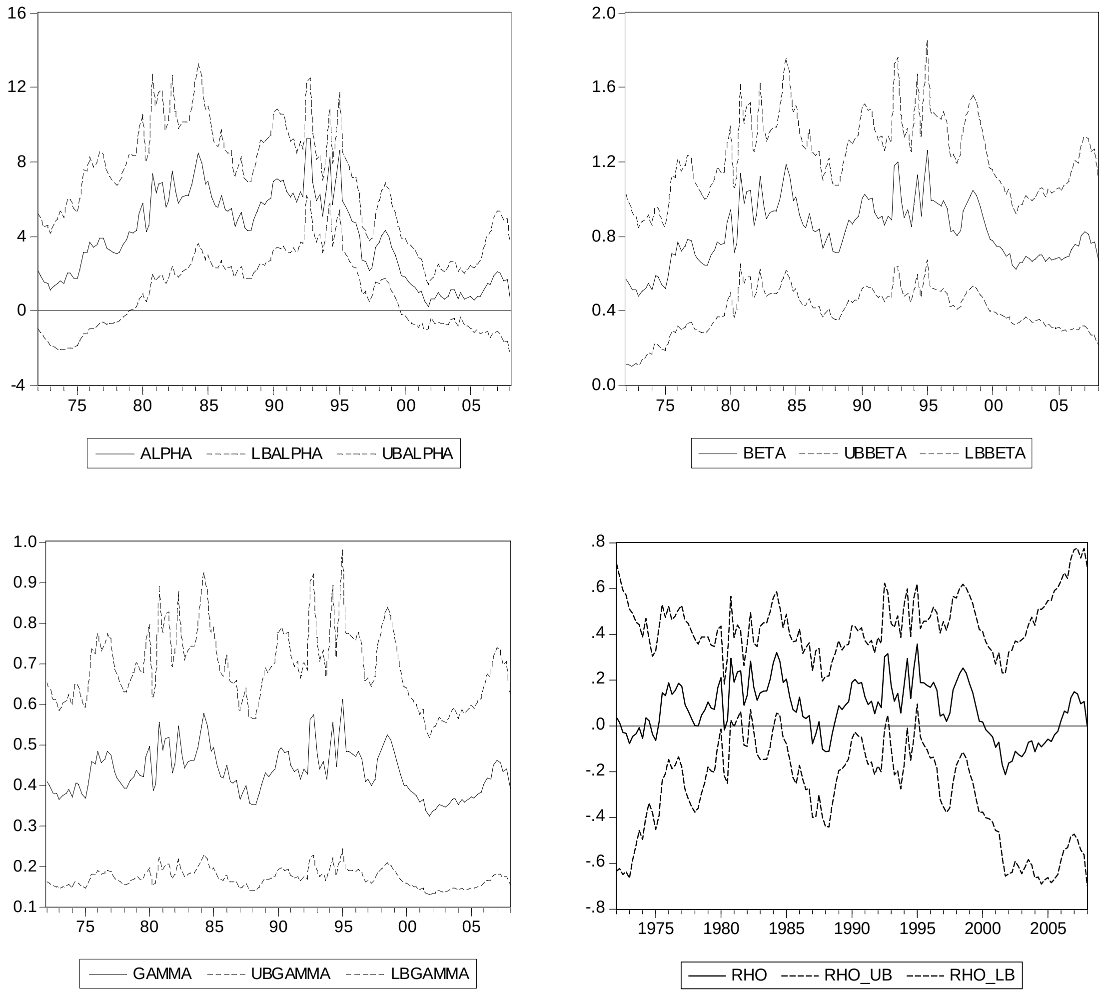
4.4 Canada

The monetary policy rules estimates for Canada are presented in Figure 7 and 8. The response of interest rate to inflation peaks in the first half of 1980s and mid-1990s. The former period was characterized by relatively high inflation rates that unquestionably drove rather aggressive policy of the BoC similarly as in the U.K. or Australia. It is arguable whether the original inflation rate was a consequence of accommodative policy of monetary targeting applied between 1978 and 1982 (see Figure 7). Unlike in the U.K. or Australia, the inflation response coefficient increased temporarily after announcement of IT, which reflects the fact that IT was adopted as a part of joint disinflation strategy of the BoC and federal government. Then it decreases only in the last decade (due to almost negligible inflation rates).[25]

The response to the output gap is significant and almost invariant in time (as in the UK) confirming long-term preference of the BoC to smooth the economic fluctuations. The intensity of the response is unique among the IT countries in our sample. The interest rate smoothing is almost negligible.

[25] The BoC also reported the monetary condition index (MCI) as a compound of policy instrument (interest rate) and exchange rate. MCI accompanies the proposed of Ball (1999) to target long-term inflation, i.g. inflation rate adjusted for the transitory effect of exchange rate on import prices. However, there is no indication that BoC actually ever used MCI for practical policy making and it ceased to publish it in 2006.

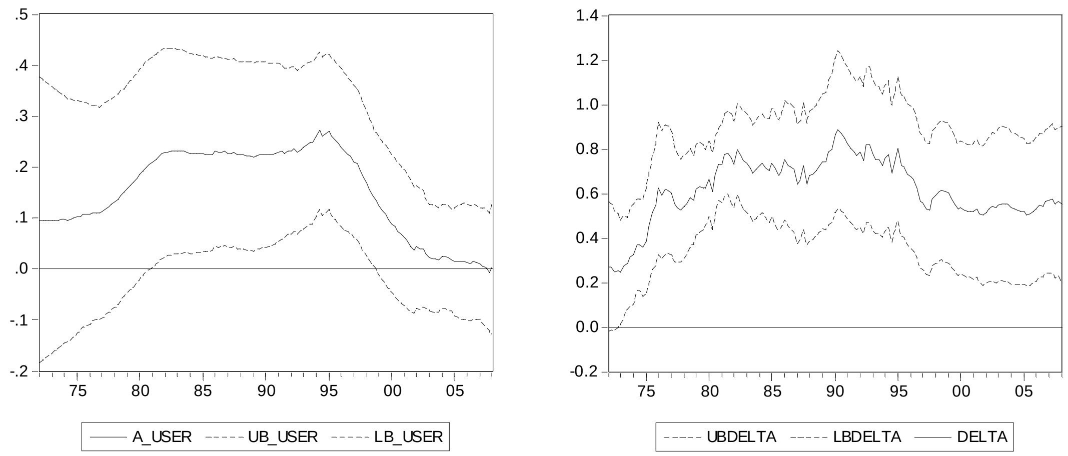
Figure 7: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, Canada



Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Upper left graph depicts the evolution of neutral rate. Upper right graph depicts the evolution of the response of interest rates to inflation. Lower left graph depicts the evolution of the response of interest rates to output gap. Lower right graph depicts the evolution of the interest rate smoothing parameter.

The dependence of Canadian monetary policy on external factors, in particular the developments in the U.S., is confirmed in model augmented by exchange rate and foreign interest rate. The response to exchange rate is positive but almost insignificant and dissipates in the last decade. On the other hand, a response to the US interest rate dynamics has been substantial for the whole period of analysis until the end of sample.

Figure 8: Time-Varying Response Coefficients in Augmented (Open Economy) Policy Rule, Canada



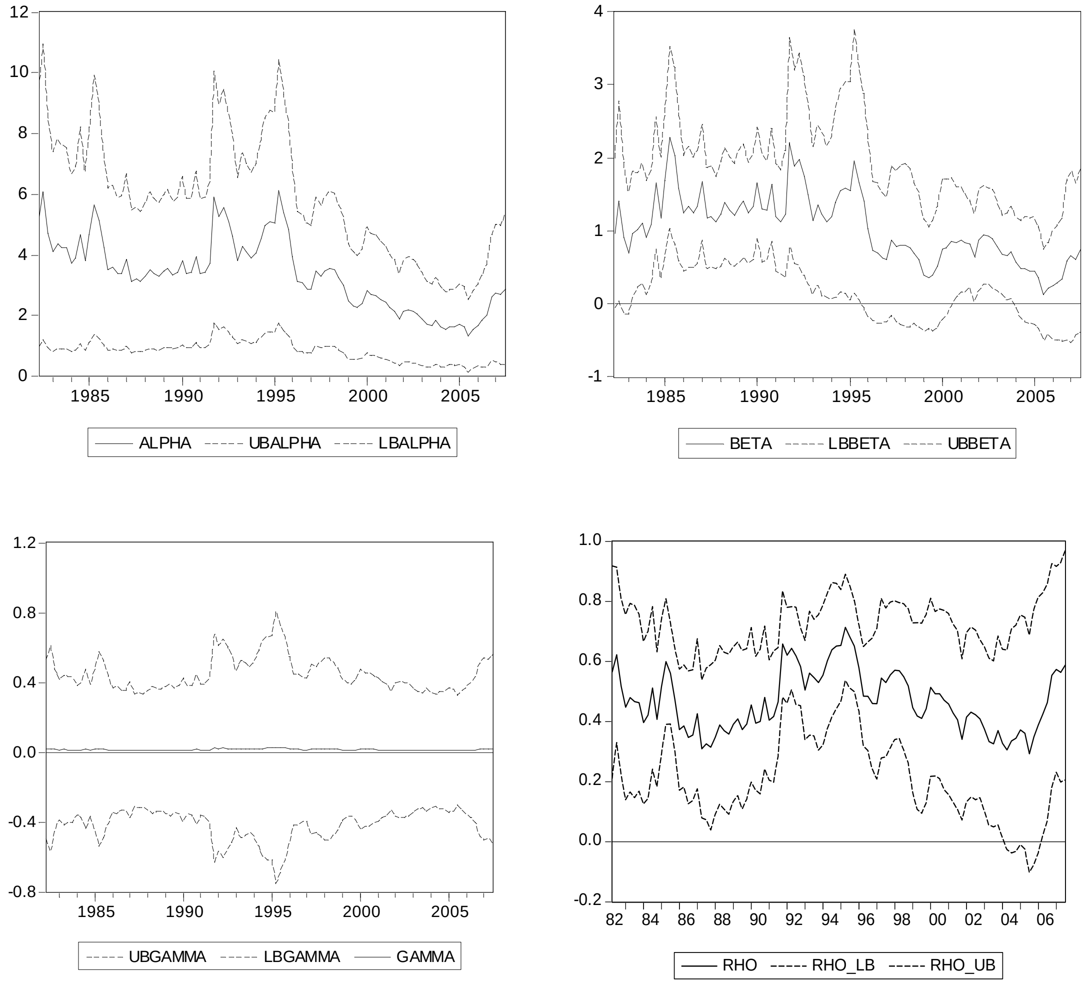
Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Left graph depicts the evolution of the response of interest rate to nominal effective exchange rate (deviation from HP trend). Right graph depicts the evolution of the response of interest rate to foreign interest rate.

4.5 Sweden

Our results suggest that the response of interest rates to inflation was stronger before and at the beginning of the IT. This complies with Berg et al. (2004), who argue that the introductory phase of the IT in Sweden was characterized by building credibility of the new regime. The decline of neutral rate reflects the prevailing low inflation environment in Sweden from mid-1990s onwards. The time-varying coefficient on interest rate smoothing is estimated to be somewhat larger in Sweden than in case of other countries. This suggests that Sveriges Riksbank is likely to smooth its interest rates to a greater degree.[26]

[26] At the time of ERM crisis (September 1992), Swedish krone started to depreciate. SR intended (unsuccessfully) to maintain the previous exchange rate and massively increased the short-term interest rate. Consequently, we have included time dummy in Q3 of 1992.

Figure 9: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, Sweden

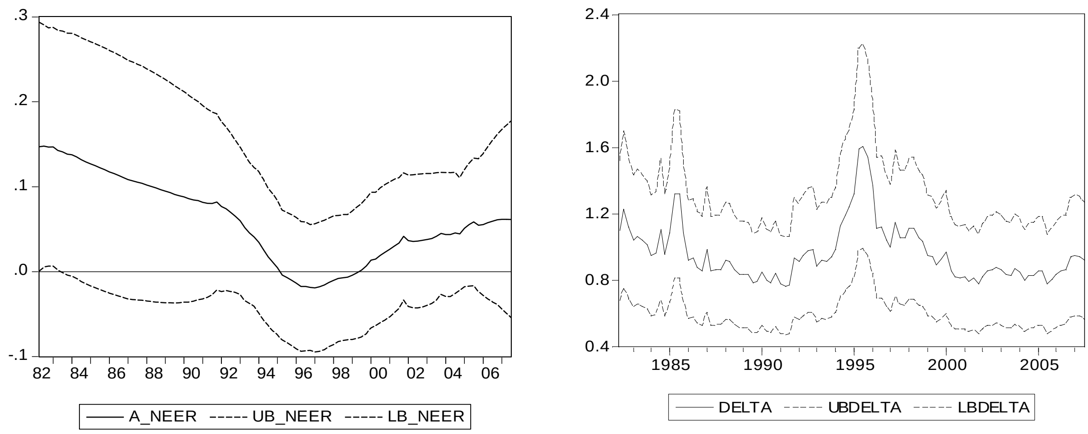


Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Upper left graph depicts the evolution of neutral rate. Upper right graph depicts the evolution of the response of interest rates to inflation. Lower left graph depicts the evolution of the response of interest rates to output gap. Lower right graph depicts the evolution of the interest rate smoothing parameter.

Our results imply a prominent role for the external factors rather than the output gap for determination of Swedish monetary policy. In particular the coefficient on foreign interest rate (Eurolibor) is sizeable during the whole sample period, which is rather interesting given that Swedish monetary policy has not officially been subject to any external constrain (at least since krone's departure from the ERM in 1992). On the other hand, the role of exchange rate is unclear. The NEER response coefficient is mostly positive but with very wide confidence intervals pointing to its insignificance.

Our results are in overall consistent with the surveyed time-invariant studies emphasizing the predominant role of inflation forecast (Jansson and Vredin, 2003) as well as more cautious policy decisions leading to more policy inertia during periods of macroeconomic instability such as the ERM crisis (Berg at al., 2004).

Figure 10: Time-Varying Response Coefficients in Augmented (Open Economy) Policy Rule, Sweden



Note: 95% confidence bands; model with bias correction terms, i.e. dealing with endogeneity in monetary policy rules. Left graph depicts the evolution of the response of interest rate to nominal effective exchange rate (deviation from HP trend). Right graph depicts the evolution of the response of interest rate to foreign interest rate.

4.6 Inflation Targeting and Inflation Persistence

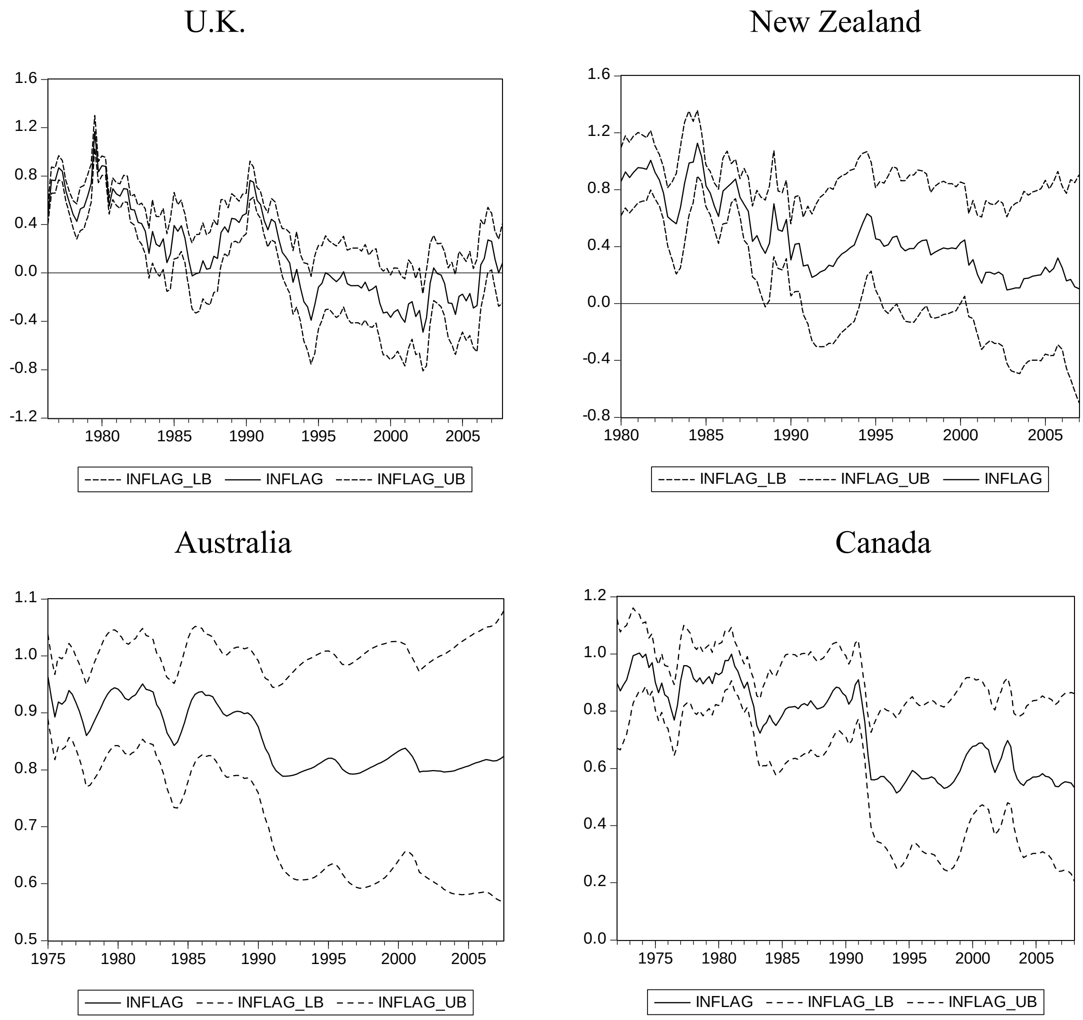
We have related our finding that the inflation response coefficient often falls after the adoption of the IT to the hypothesis that this monetary framework has a positive effect on inflation expectations of economic agents. If the expected inflation is low, the monetary policy needs not be as aggressive as under discretionary regime in order to achieve price stability. This argument is in line with recent studies on inflation dynamics (Benati, 2008, Zhang et al., 2008) claiming that under credible policy regime (such as the IT), inflation persistence (the dependence of current inflation on past values) fades away.

As to shed some light on this issue, we have used our estimation framework and fitted the AR(1) model with drift to inflation series, allowing the coefficient on the lagged inflation as well as the constant to be time-varying. Our results indicate (as reported Figure 11) that inflation persistence decreased over the course of the time for all the countries. Moreover, it is notable that the persistence fell down especially during the 1990's as the IT was introduced. This finding is confirmed when we, in the spirit of the backward-looking Phillips curve, include the lagged output gap as a forcing variable.[27] In addition, the results reported in Figure 11 clearly indicate that moment estimator applied at time-varying coefficient approach is suitable even if the estimated coefficient is subject to sudden switches rather than smooth transition (see the UK after the adoption of inflation targeting).

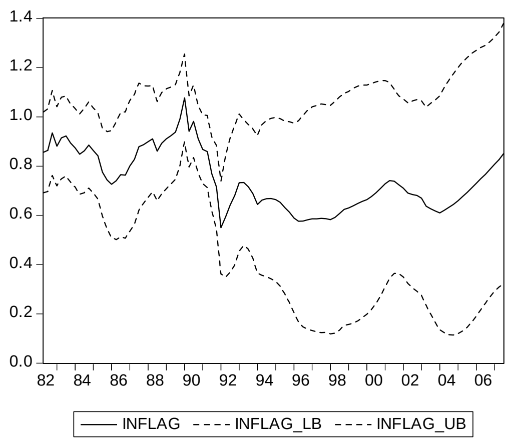
In general, our results are broadly consistent with Benati (2008) who performs sub-sample analysis under different policy regimes. Unlike Benati (2008), our approach does not need to impose breaks in inflation process at any particular date but simply observe whether and when such breaks occur. Our findings does not exclude the possibility that the inflation persistence decreased because of other factors (the "good luck" hypothesis), but the temporal coincidence between the introduction of the IT and significant decrease of inflation persistence in several countries make rather a case for the "good policy" hypothesis. Taking the example of the U.K., we can see that the inflation (rate) moderation goes back to 1980's when we still observe rather high inflation persistence, in spite of very aggressive anti-inflationary (yet discretional) policy. Unfortunately, as we do not have a full structural model we cannot tell much about the nature of shock in pre- and post-IT period as done in VAR studies on the Great Moderation. Using standard tests of structural stability, we can clearly reject structural stability of inflation process defined by AR(1) in pre- and post-IT period.

[27] See Hondroyiannis et al. (2009) on estimation of the Phillips curve within somewhat different time-varying framework.

Figure 11: Time-Varying Response Coefficients in AR(1) Model for Inflation



Sweden

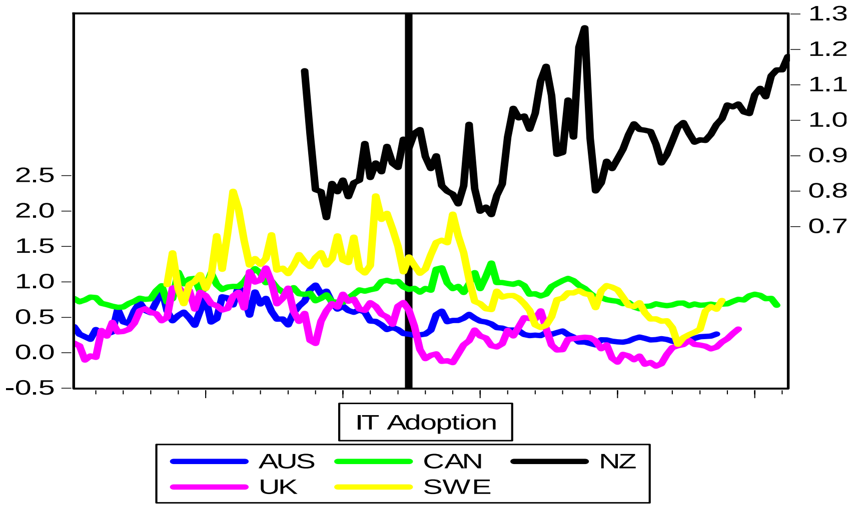


Note: 95% confidence bands; the coefficient of AR(1) term (i.e. model $\pi_t = \alpha_t + \rho_t \pi_{t-1} + \varepsilon_t$) for inflation series employed in previous analysis for each country.

4.7 Monetary Policy Rules – Wrap-Up of Main Policy Findings

This sub-section summarizes the main policy relevant findings of this paper. We focus on the four following issues: 1) monetary policy aggressiveness and inflation rate, 2) monetary policy aggressiveness and inflation targeting, 3) interest rate smoothing and 4) inflation persistence and inflation targeting.

Figure 12: Monetary Policy Aggressiveness and Inflation Targeting

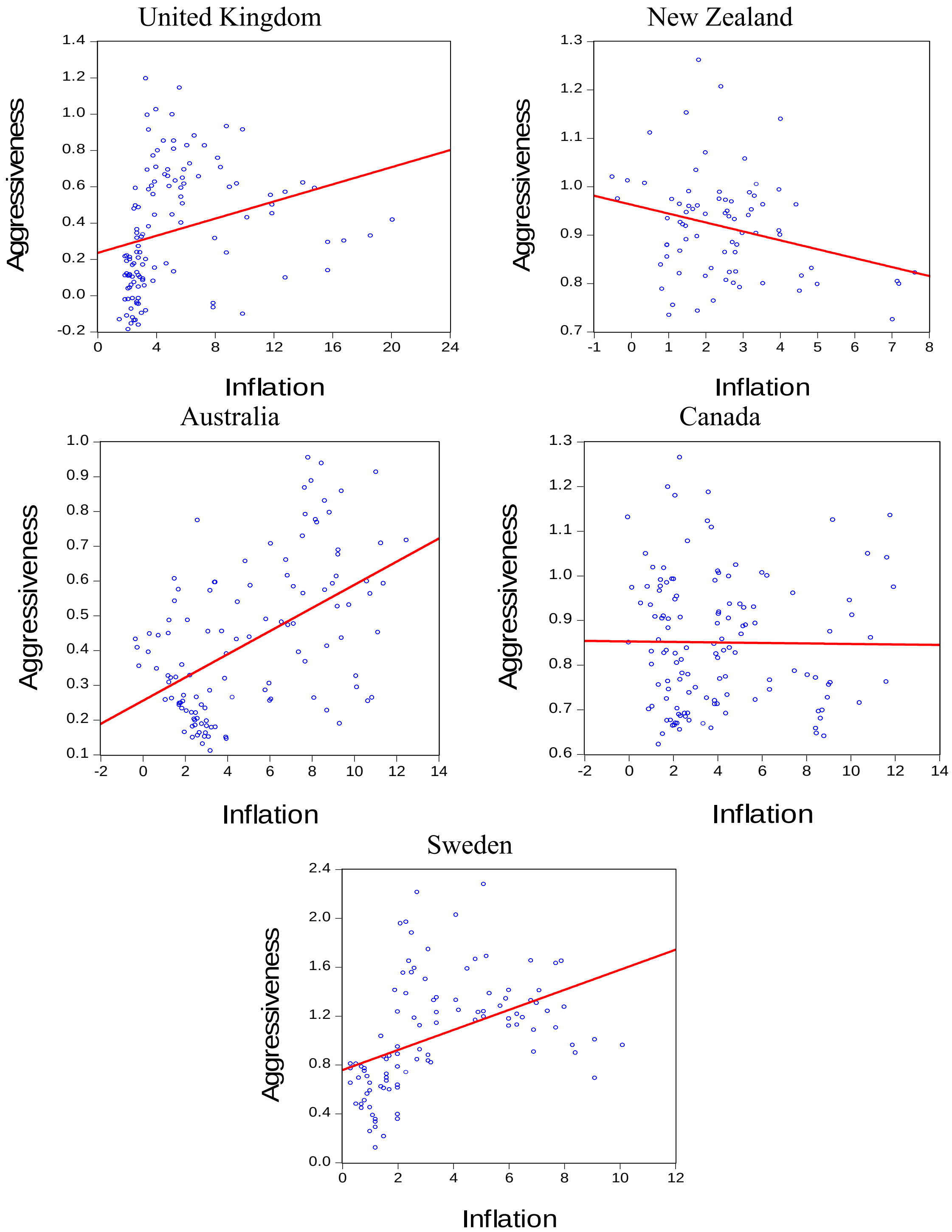


Note: The y axis depicts the evolution of the estimated parameter (β) (the response of interest rates to expected inflation), x axis represents time with the year of inflation targeting adoption denoted with black vertical line. The value of β for New Zealand is plotted on right axis.

Figure 12 presents the link between monetary policy aggressiveness (defined as the estimate of the response on interest rates on expected inflation) and inflation targeting. It can be seen that in no country the aggressiveness parameter increased after the adoption of inflation targeting. In fact, this aggressiveness substantially decreased in the U.K., Australia and Sweden. If we look at the link between aggressiveness and expected inflation within the IT period, the results suggest that the aggressiveness is higher in most countries the more the expected inflation deviates from its target. This broadly corresponds to the findings of Davradakis and Taylor (2006), who document a non-linear policy rule for the U.K. of a similar pattern.

Figure 13 documents a relatively strong link between the level of inflation and monetary policy aggressiveness for the U.K., Australia and Sweden. This is because 1) the response of interest rates to inflation has been particularly strong during the periods, when central bankers want to break the record of high inflation and 2) the response has been less aggressive after the adoption of inflation targeting with well-anchored inflation expectations. In contrast, New Zealand and Canada do not seem to exhibit the link between aggressiveness and inflation.

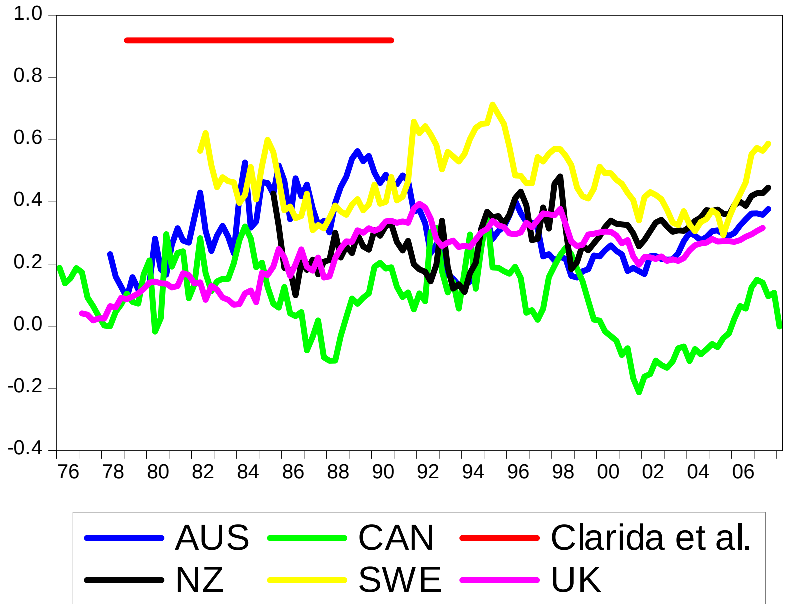
Figure 13: Monetary Policy Aggressiveness and Inflation Rate



Note: The figure present the scatter plots between inflation rate and the response of interest rates to expected inflation (β), labeled as aggressiveness, for each country individually.

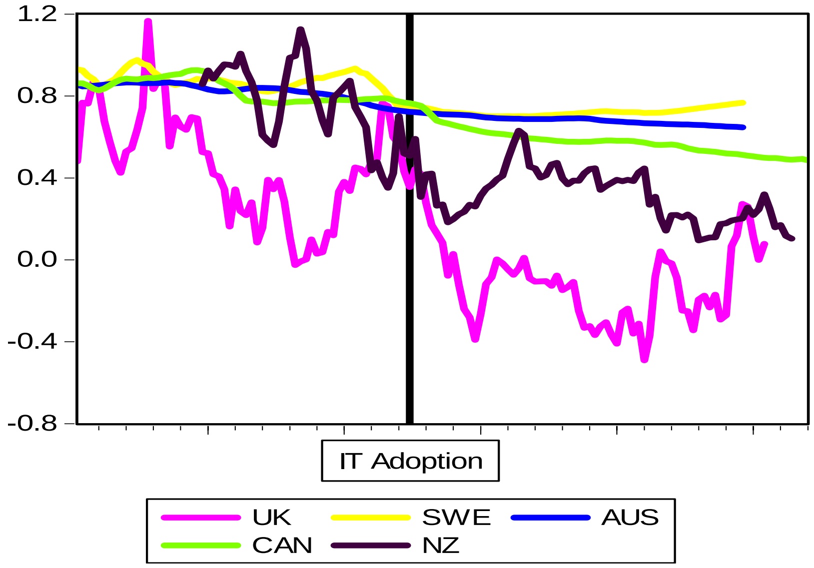
The evolution of estimated interest rate smoothing parameter in comparison to the time-invariant estimates for the U.K. in 1979-1990 by Clarida et al. (2000) is available in Figure 14. Our time-varying estimates of interest rate smoothing are well below the time-invariant one, which seems to be reasonable in the light of the recent critique of Rudebusch (2006), who puts forward that the degree of interest rate smoothing is actually low. While omitted variables or persistent shocks were deemed to be behind the implausible degree of policy inertia, our empirical results suggest that omission of time-varying nature of the response coefficient can another reason for the overestimation of smoothing coefficient r in time-invariant policy rules. Moreover, given that policy rule is modeled as a partial adjustment (see Eq. (3)), overestimation of smoothing coefficient r can drive upper bias in all other coefficient. This seems to explain why our long-term inflation multiplier b is substantially lower than found in time-invariant studies. Though high b is consistent with common wisdom, we suspect that it is a by-product of upper bias in r.

Figure 14: Interest Rate Smoothing



Note: The figure presents the evolution of the estimated interest rate smoothing parameter ρ over time in comparison to the interest rate smoothing parameter estimated in time-invariant model of Clarida et al. (2000) for the U.K..

Figure 15: Inflation Targeting and Inflation Persistence



Note: The y axis depicts the evolution of the estimated inflation persistence parameter, y axis represents time with the year of inflation targeting adoption denoted with black vertical line.

Finally, the results in Figure 15 plot the estimates of inflation persistence over time for all countries with respect to the date of inflation targeting adoption. The results suggest that inflation persistence has decreased after the adoption of inflation targeting with a very distinct fall in the U.K., New Zealand.

5. Concluding Remarks

In this paper, we shed light on the evolution of monetary policy in main inflation targeting central banks during the last three decades. The evolution of monetary policy is evaluated within novel framework of a time-varying parameter model with endogenous regressors (Kim and Nelson, 2006), addressing further the small sample issues (Schlicht, 1981, Schlicht, 2005, Schlicht and Ludsteck, 2006).

In our view, the results points to the usefulness of this econometric framework for analysis of evolution of monetary policy setting. Estimating standard monetary policy rules shows that the policy changes gradually and the changes coincide with several important institutional reforms as well as with the periods, when respective central banks successfully decreased double-digit inflation rates to the rates consistent with the central banks' definitions of price stability.

In this respect, our results suggest that the response of interest rates to inflation is particularly high during the periods, when central bankers want to break the record of high inflation such as in the U.K. in early 1980s. Contrary to common wisdom, the response is often found to be less aggressive after the adoption of inflation targeting suggesting the positive effect of this regime on anchoring inflation expectations. In other words, the monetary policy need not be as aggressive as under discretionary regime in order to achieve price stability (Kuttner and Posen, 1999). This result is supported by our finding that inflation becomes less inertial and policy neutral rate decreases after the adoption of inflation targeting.

We find that external factors matter for interest rate setting in all our sample countries. To be more precise, foreign interest rate is found to enter the monetary policy rule significantly. The importance of the exchange rate varies, being apparently more important before the countries adopted inflation targeting than afterwards.

Our results also indicate that the interest rate smoothing is much lower than what time-invariant estimates of monetary policy rules typically report (see for example, Clarida et al., 1998, 2000). Our estimates support the recent critique of Rudebusch (2006), who argues that the degree of interest rate smoothing is rather low. We suggest that negligence of changes in monetary policy setting in time is the reason for implausible degree of policy inertia previously found. Moreover, the fact that upper bias in smoothing parameter affects all the estimates can explain some fundamental differences between our findings and those established in literature such as the size of inflation response coefficient.

In terms of future research we believe that it would be worthwhile to apply this framework to understand better whether and how monetary policy reacts to the periods of financial instability and which types of financial instability are for central banks the most worrying. In consequence, this would improve the understanding of both the interest rate setting process and the reaction of monetary policy makers to current global financial crisis in a more systematic manner.

References

ADAM, CH., D. COBHAM, AND E. GIRARDIN (2005): "Monetary Frameworks and Institutional Constraints: UK Monetary Policy Reaction Functions, 1985-2003." *Oxford Bulletin of Economics and Statistics* 67, pp. 497-516.

ASSENMACHER-WESCHE, K. (2006): "Estimating Central Banks' Preferences from a Time-varying Empirical Reaction Function." *European Economic Review* 50, pp. 1951-1974.

BALL, L. (1999B): "Policy Rules for Open Economies," in J. Taylor (ed.): Monetary Policy Rules. University of Chicago Press for NBER, Cambridge, pp.127-144.

BENATI, L. AND P. SURICO (2009): "VAR Analysis and the Great Moderation." *American Economic Review*, 99(4), pp. 1636-1652.

BENATI, L. (2008): "Investigating Inflation Persistence across Monetary Regimes." *The Quarterly Journal of Economics* 123, pp. 1005-1060.

BERG, C., P. JANSSON, AND A. VREDIN (2004): "How Useful Are Simple Rules for Monetary Policy? The Swedish Experience." Sveriges Riksbank Working Paper Series, No. 169.

BERNANKE, B. S., T. LAUBACH, F. MISHKIN, AND A. S. POSEN (1999): "*Inflation Targeting: Lessons from the International Experience*." Princeton University Press, Princeton.

BILLMEIER, A. (2009): "Ghostbusting: which output gap really matters?" *International Economics and Economic Policy* 6(4), pp. 319-419.

BLINDER, A. (2007): "Monetary policy by committee: Why and how?" *European Journal of Political Economy* 23, pp. 106–123.

BOIVIN, J. (2006): "Has U.S. Monetary Policy Changed? Evidence from Drifting Coefficients and Real-Time Data." *Journal of Money, Credit and Banking* 38(5), pp. 1149-1173.

CANOVA, F. AND L. GAMBETTI (2008): "Structural Changes in the US economy: Is There a Role for Monetary Policy?" *Journal of Economic Dynamics & Control* 33, pp. 477-490.

CLARIDA, R., J. GALÍ, AND M. GERTLER (1998): "Monetary Policy Rules in Practice: Some International Evidence." *European Economic Review* 42, pp. 1033-1067.

CLARIDA, R., J. GALÍ, AND M. GERTLER (2000): "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *The Quarterly Journal of Economics*, 115, pp.147-180.

COGLEY, T. AND T. SARGENT (2001): "Evolving post World War II U.S. inflation." NBER Macroeconomics Annual, vol. 16.

COGLEY, T. AND T. SARGENT (2003): "Drifts and volatilities: monetary policies and outcomes in the post WWII U.S." *Review of Economic Dynamics*, 8(2), pp. 262-302.

DARVAS, Z. (2009): "Monetary Transmission in Three Central European Countries: Evidence from Time-Varying Coefficient Vector Autoregressions." DNB Working Paper, No. 209.

DAVRADAKIS, E. AND M. P. TAYLOR (2006): "Interest Rate Setting and Inflation Targeting: Evidence of a Nonlinear Taylor Rule for the United Kingdom." Studies in Nonlinear Dynamics & Econometrics, 10(4), Article 1.

DE BROUWER, G. AND J. GILBER (2005): "Monetary Policy Reaction Functions in Australia." *The Economic Record* 81(253), pp. 124-134.

DEMERS, F. AND G. RODRÍGUEZ (2002): "Estimation of the Taylor Rule for Canada Under Multiple Structural Changes." Working Paper No.107E, University of Ottawa.

DOLADO, J. J., R. MARÍA-DOLORES, AND F. RUGE-MURCIA (2004): "Nonlinear Monetary Policy Rules: Some New Evidence for the U.S." Studies in Nonlinear Dynamics & Econometrics 8(3), Article 2.

DOMENECH, R., M. LEDO, AND D. TAGUAS (2002): "Some New Results on the Interest Rate Rules in EMU and in the US." *Journal of Economics and Business* 54, pp. 431-446.

DONG, W. (2008): "Do Central Banks Respond to Exchange Rate Movements? Some New Evidence from Structural Estimation." Working Paper No. 24, Bank of Canada.

DUBOIS, É. AND E. MICHAUX (2009): "Grocer 1.4: an econometric toolbox for Scilab." Available at http://dubois.ensae.net/grocer.html.

ELKHOURY, M. (2006): "Time-Varying Parameter Model of a Monetary Policy Rule in the Switzerland." Working Paper No.01, HEI Geneva.

FTITI, Z. (2008): "Taylor Rule and Inflation Targeting: Evidence from New Zealand." *International Business & Economics Research Journal* 7, pp. 131-150.

GRANGER, CLIVE W.J.: (2008): "Non-Linear Models: Where Do We Go Next – Time-Varying Parameter Models?" Studies in Nonlinear Dynamics & Econometrics, 12(3), Article 1.

GRENVILLE, S. (1997): "The Evolution of Monetary Policy: From Money Targets to Inflation Targets," in P.W. Lowe (ed.), Monetary Policy and Inflation Targeting. Reserve Bank of Australia, Sydney, pp. 125-158.

HORVÁTH, R. (2009): "The Time-Varying Policy Neutral Rate in Real Time: A Predictor for Future Inflation?" *Economic Modelling*, 26(1), pp. 71-81.

HONDROYIANNIS, G., P.A.V.B. SWAMY, AND G. TAVLAS (2009): "The New Keynesian Phillips Curve in a Time-Varying Coefficient Environment: Some European Evidence." *Macroeconomic Dynamics* 13, pp. 149-166.

HUANG, A., D. MARGARITIS, AND D. MAYES (2001): "Monetary Policy Rules in Practice: Evidence from New Zealand." *Multinational Finance Journal* 5(3), pp. 175-2000.

JANSSON, P. AND A. VREDIN (2003): "Forecast-Based Monetary Policy: The Case of Sweden." *International Finance* 6:3, pp. 349-380.

KAREDEKIKLI, O. AND K. LEES (2007): "Do the Central Banks of Australia and New Zealand Behave Asymmetrically? Evidence from Monetary Policy Reaction Functions." *The Economic Record* 83(261), pp. 131-142.

KIM, CH.-J. (2006): "Time-Varying Parameter Models with Endogenous Regressors." *Economics Letters* 91, pp. 21-26.

KIM, CH.-J. AND CH. R. NELSON (2006): "Estimation of a Forward-Looking Monetary Policy Rule: A Time-Varying Parameter Model Using Ex-post Data,." *Journal of Monetary Economics* 53, pp. 1949-1966.

KIM, CH.-J., K. KISHOR, AND CH. NELSON (2006): "A Time-Varying Parameter Model for a Forward-Lokking Monetary Policy Rule based on Real-Time Data," mimeo.

KING, M. (1997): "Changes in UK Monetary Policy: Rules and Discretion in Practice." *Journal of Monetary Economics* 39, pp. 81-87.

KISHOR, K. (2008): "International Evidence on Time Variation in a Forward-Looking Monetary Policy Rule," mimeo.

KOOP, G., R. LEON-GONZALEZ, AND R. W. STRACHAN (2009): "On the Evolution of the Monetary Policy Transmission Mechanism." *Journal of Economic Dynamics and Control* 33, pp. 997–1017.

KOOPMAN, S. J., N. SHEPHARD, AND J. A. DOORNIK (1999): "Statistical Algorithms for Models in State Space using SsfPack 2.2." *Econometrics Journal* 2(1), pp. 107-160.

KUTTNER, K. N. (2004): "The Role of Policy Rules in Inflation Targeting." *Federal Reserve Bank of St. Louis Review* 86(4), pp. 1-23.

KUTTNER, K. N. AND A. S. POSEN (1999): "Does Talk Matter After All? Inflation Targeting and Central Bank Behavior." Federal Reserve Bank of New York, Staff Reports 88

LEU, S. CH.-Y. AND J. SHEEN (2006): "Asymmetric Monetary Policy in Australia." *The Economic Record* 82 (Special Issue), pp. 85-96.

LUBIK, T. A. AND F. SCHORFHEIDE (2007): "Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation." *Journal of Monetary Economics* 54, pp. 1069-1087.

MEIRELESS-AURELIANO, M. (2005): "Do We Really Know How Inflation Targeters Set Interest Rates?" Federal Reserve Bank of Kansas City, Research Working Paper No. 02.

ORPHANIDES, A. (2001): "Monetary Policy Rules Based on Real-Time Data." *American Economic Review* 91, pp. 964-985.

PLANTIER, L. CH. AND D. SCRIMGEOUR (2002): "Estimating a Taylor Rule for New Zealand with a Time-Varying Neutral Real Rate." Reserve Bank of New Zealand, Discussion Paper No. 06.

PODPIERA, J. (2008): "The role of ad hoc factors in policy rate settings." *Economic Modelling* 25(5), pp. 1003-1010.

PSARADAKIS, Z., M. SOLA, AND F. SPAGNOLO (2006): "Instrumental-Variables Estimation in Markov Switching Models with Endogenous Explanatory Variables: An Application to the Term Structure of Interest Rates." Studies in Nonlinear Dynamics & Econometrics 10(2), Article 1.

RUDEBUSCH, G. (2006): "Monetary Policy Inertia: Fact or Fiction?" *International Journal of Central Banking* 2(4), pp. 85-136.

SCHLICHT, E. (1981): "A Seasonal Adjustment Principle and a Seasonal Adjustment Method Derived From this Principle." *Journal of the American Statistical Association* 76(374), pp. 374-378.

SCHLICHT, E. (2005): "Estimating the Smoothing Parameter in the So-called Hodrick-Prescott Filter." *Journal of the Japan Statistical Society* 35(1), pp. 99-119.

SCHLICHT, E. AND J. LUDSTECK (2006): "Variance Estimation in a Random Coefficients Model." IZA Discussion paper No. 2031.

SIKLOS, P. AND D. WEYMARK (2009): "Has Inflation Targeting Improved Monetary Policy? Evaluating Policy Effectiveness in Australia, Canada, and New Zealand." Vanderbilt University working paper 0906.

SEKINE, T. AND Y. TERANISHI (2008): "Inflation Targeting and Monetary Policy Activism." IMES Discussion Paper Series 2008-E-13, Bank of Japan.

SHIH, R. AND D. E. GILES (2008): "Modelling the Duration of Interest Rate Spells under Inflation Targeting in Canada." *Applied Economics* 41, pp. 1229–1239.

SIMS, CH. AND T. ZHA (2006): "Were there Regime Switches in US Monetary Policy." *American Economic Review* 96(1), pp. 54-81.

TAYLOR, J. B. (1993): "Discretion versus Policy Rules in Practice." Carnegie-Rochester Conference Series on Public Policy 39, pp. 195-214.

TAYLOR, J. B. (ED. 1999): "*Monetary Policy Rules*." The University of Chicago Press: Chicago.

TAYLOR, J. B. (2001): "The Role of Exchange Rate in Monetary-Policy Rules." *American Economic Review* 91, pp. 263-267.

TRECROCCI, C. AND M. VASSALLI (2010): "Monetary Policy Regime Shifts: New Evidence from Time-Varying Interest-Rate Rules." Economic Inquiry, forthcoming.

VALENTE, G. (2003): "Monetary Policy Rules and Regime Shifts." *Applied Financial Economics* 13, pp. 525-535.

ZHANG, CH., D. R. OSBORN, AND D. H. KIM (2008): "The New Keynesian Phillips Curve: From Sticky Inflation to Sticky Prices." *Journal of Money, Credit and Banking* 40, pp. 667-699.

Appendix 1: The VC Method (Schlicht and Ludsteck, 2006)

In this section, we closely follow the Schlicht and Ludsteck (2006) paper. Consider a standard linear model:

$$y_t = a'x_t + u_t, \quad a, x_t \in \mathbf{R}^n, u_t \sim N\left(0,\sigma^2\right), \quad t = 1,2,\ldots T \tag{A.1}$$

It can be extended for the case in which the coefficients a are allowed to follow a random walk. Then the equation (A.1) is replaced by a system

$$y_t = a_t'x_t + u_t, \quad u_t \sim N\left(0,\sigma^2\right) \tag{A.2}$$

$$a_{t+1} = a_t + v_t, \quad v_t \sim N\left(0,\Sigma\right) \tag{A.3}$$

with one signal equation (A.2) and n state equations (A.3) for each time-varying parameter. The variance-covariance matrix Σ is assumed to be diagonal, that is

$$\Sigma = \begin{pmatrix} \sigma_1^2 & 0 & \ldots & 0 \\ 0 & \sigma_2^2 & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \ldots & \sigma_n^2 \end{pmatrix}$$

Define following matrices:

$$X = \begin{pmatrix} x'_1 & 0 & \ldots & 0 \\ 0 & x'_2 & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \ldots & x'_T \end{pmatrix} \qquad P = \begin{pmatrix} -I_n & I_n & 0 & \ldots & 0 \\ 0 & -I_n & I_n & \ldots & 0 \\ \vdots & \vdots & \ddots & \ddots & \vdots \\ 0 & 0 & \ldots & -I_n & I_n \end{pmatrix}$$

of order T × Tn (T-1)n × Tn

$$y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_T \end{pmatrix} \qquad u = \begin{pmatrix} u_1 \\ u_2 \\ \vdots \\ u_T \end{pmatrix} \qquad a = \begin{pmatrix} a_1 \\ a_2 \\ \vdots \\ a_T \end{pmatrix} \qquad v = \begin{pmatrix} v_2 \\ v_3 \\ \vdots \\ v_T \end{pmatrix}$$

of order T × 1 T ×1 Tn × 1 (T-1)n × 1

The system (A.2) and (A.3) can be rewritten as

$$y = Xa + u, \quad u \sim N\left(0,\sigma^2 I_T\right) \tag{A.4}$$

$$Pa = v, \quad v \sim N\left(0,V\right), V = I_{T-1} \otimes \Sigma \tag{A.5}$$

Estimation of the model based on the equations (A.4) and (A.5) requires derivation of a distribution function that maps the random variables u_t and v_t to a set of observations X_t. However, such inference is not possible because the matrix P in (A.5) is of rank $(T-1)n$ rather than Tn and thus it cannot be inverted. Furthermore any v does not determine the path of a_t uniquely.

1.1 Orthogonal Parameterization

The VC method used in this paper starts with explicit definition of a set of possible values of a conditioned by matrix *P* and random variable *v*. Following the equation (A.5) any solution *a* can be written as

$$a = P'\left(PP'\right)^{-1} v + Z\lambda \tag{A.6}$$

with $\lambda \in \mathbf{R}$ and $Z = \frac{1}{\sqrt{T}}\begin{pmatrix} I_n \\ I_n \\ \vdots \\ I_n \end{pmatrix}$.

Hence equation (A.5) can becomes

$$y = u + XP'\left(PP'\right)^{-1} v + XZ\lambda \tag{A.7}$$

Equations (A.6) and (A.7) build an *orthogonal parameterization* of the true model (A.4) and (A5). The orthogonally parametrized model implies, that a_t follows a random walk and, that its path depends on all realizations of a random variable v_t .

The equation (A.7) can be written as

$$y = XZ\lambda + w \tag{A.8}$$

where

$$w = XP'\left(PP'\right)^{-1} v + u \tag{A.9}$$

Variable w is normally distributed:

$$w \sim N\left(0,W\right), \quad W = XBX' + \sigma^2 I_T \tag{A.10}$$

with

$$B = P'\left(PP'\right)^{-1} V\left(PP'\right)^{-1} P \tag{A.11}$$

Let the matrix of the observations follow a conventional format:

$$X^* = \sqrt{T}\,XZ = X\begin{pmatrix} I_n \\ I_n \\ \vdots \\ I_n \end{pmatrix} = \begin{pmatrix} x_1' \\ x_2' \\ \vdots \\ x_T' \end{pmatrix} \tag{A.12}$$

Inserting (A.12) into (A.8) implies a generalized linear regression model

$$y = \frac{1}{\sqrt{T}} X^* \lambda + w = X\beta + w \tag{A.13}$$

with

$$\hat{\beta} = \frac{1}{\sqrt{T}}\hat{\lambda} \tag{A.14}$$

The estimate of $\hat{\lambda}$ satisfies

$$\hat{\lambda} = \left(Z'X'W^{-1}XZ\right)^{-1} Z'X'W^{-1}y \tag{A.15}$$

which is a standard GLS estimator of the classical regression problem with covariance matrix of residuals W and observations ZX. Taking expectations of a from (A.6) and substituting $\hat{\lambda}$ for λ implies $Z'a = \lambda$ and hence $\frac{1}{T}\sum_{t=1}^{T} a_t = \beta$ in the GLS regression (A.13).

1.2 Estimation of Coefficients

The orthogonal parameterization derived in the previous section might be used for direct ML estimation of the time varying parameters *a*. However, the derivation of the ML estimate of the vector of parameters a leads to a formulation that is equivalent to the minimization of weighted sum of squares

$$\sum_{t=1}^{T} u^2 + \theta_1 \sum_{t=1}^{T} v_1^2 + \theta_2 \sum_{t=1}^{T} v_2^2 + \ldots + \theta_n \sum_{t=1}^{T} v_n^2 \tag{A.16}$$

where the weights θ_i are the inverse variance ratios of the regression residuals u_t and the shocks in time-varying coefficients v_t, that is $\theta_i = \sigma^2 / \sigma_i^2$. The proof can be found in Schlicht and Ludsteck, 2006, section 5. Hence the estimator balances the fit of the model and the parameter stability[28].

Now we derive the formula used for estimation of the coefficients. For given X and y the estimated disturbances are

$$\begin{aligned} \hat{u} &= y - X\hat{a} \\ \hat{v} &= P\hat{a} \end{aligned} \tag{A.17}$$

Using the expressions for the estimated disturbances (16), minimization of the weighted sum of squares (15) implies

$$\left(X'X + \sigma^2 P'V^{-1}P\right)\hat{a} = X'y \tag{A.18}$$

which is used for the estimation of coefficients $\hat{a}_t$.

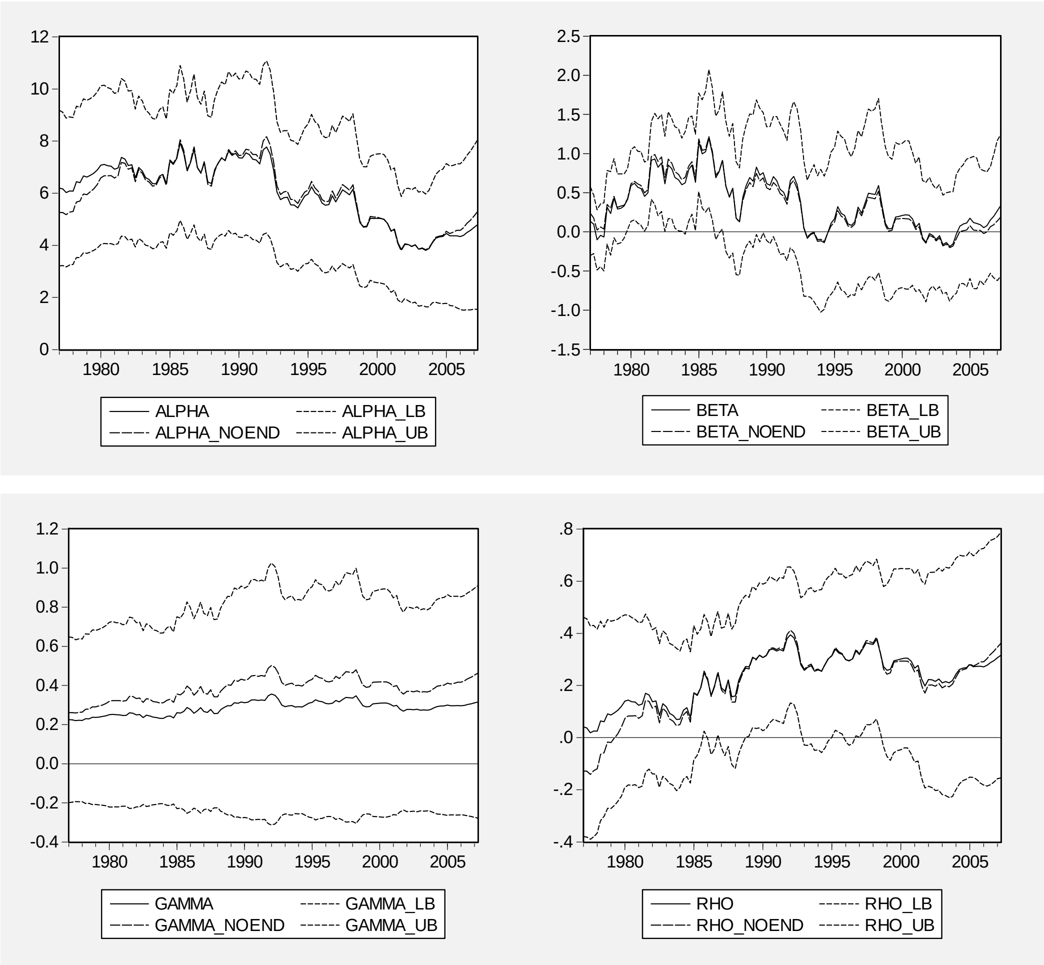
The coefficients estimated using the VC method have a straightforward interpretation: They have a time-invariant part, determined by a regression with fixed coefficients, and a random part reflecting the idea that some proportion of variance of dependent variable is caused by a change in coefficients.

[28] Originally, Schlicht and Ludsteck (2006) start with a derivation of maximum likelihood estimator of parameters *a* based on the idea of orthogonal parameterization, which is described in the Appendix. Then they prove that the weighted least squares estimator is identical to the maximum likelihood estimator.

The estimation procedure proceeds as follows. The iterative procedure has two steps. First, given variances of residuals in both equations in (15), σ^2 and σ_i^2, the coefficients at are estimated using (17). Second, the estimated residuals are calculated using (16) and their estimated second moments $\hat{u}'\hat{u}$ and $\hat{v}'_i\hat{v}_i$ are compared to their expected moments $E\left[\hat{u}'\hat{u}\right]$ and $E\left[\hat{v}'_i\hat{v}_i\right]$. These steps are repeated until the estimated moments are identical to their expected counterparts (for a precise derivation of the moment estimator as well as computational details see Schlicht and Ludsteck, 2006, sections 6-9).

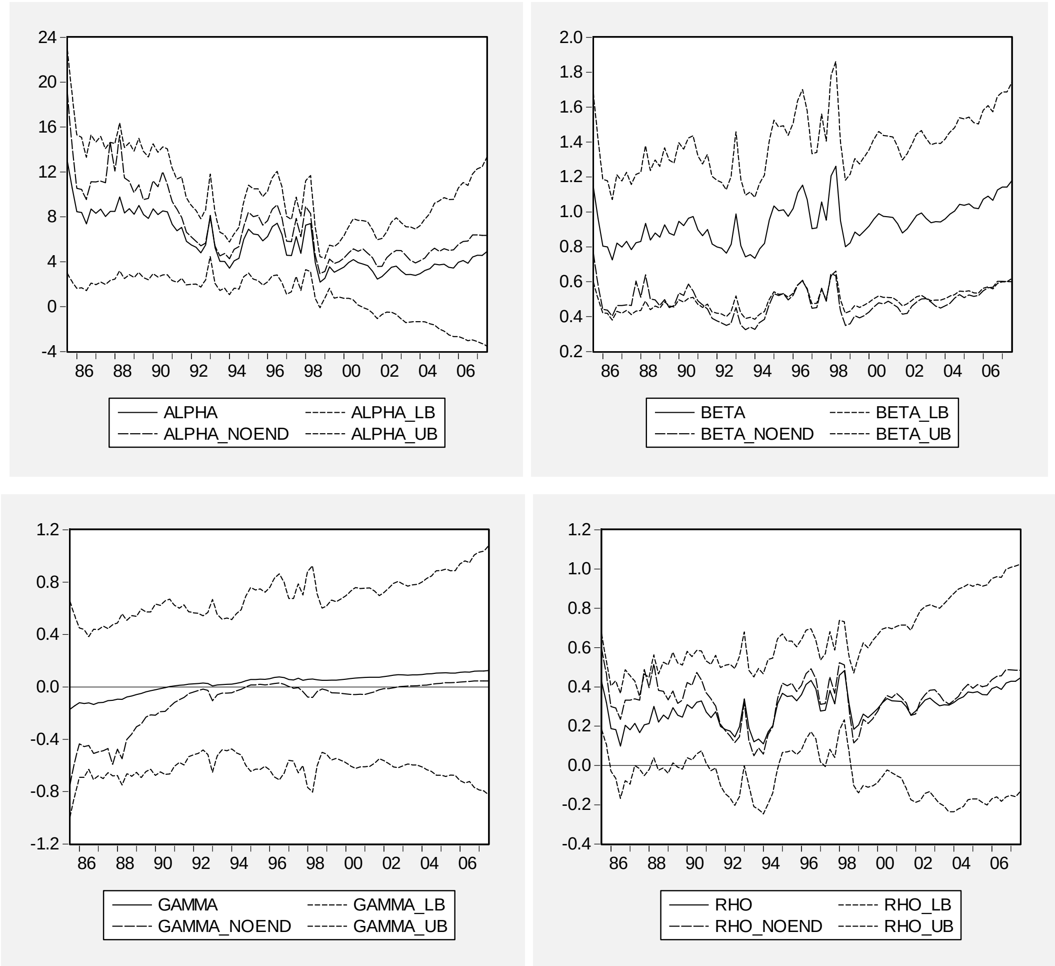
Appendix 2: The Effect of Endogeneity in Policy Rule

Figure A.1: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, the U.K.



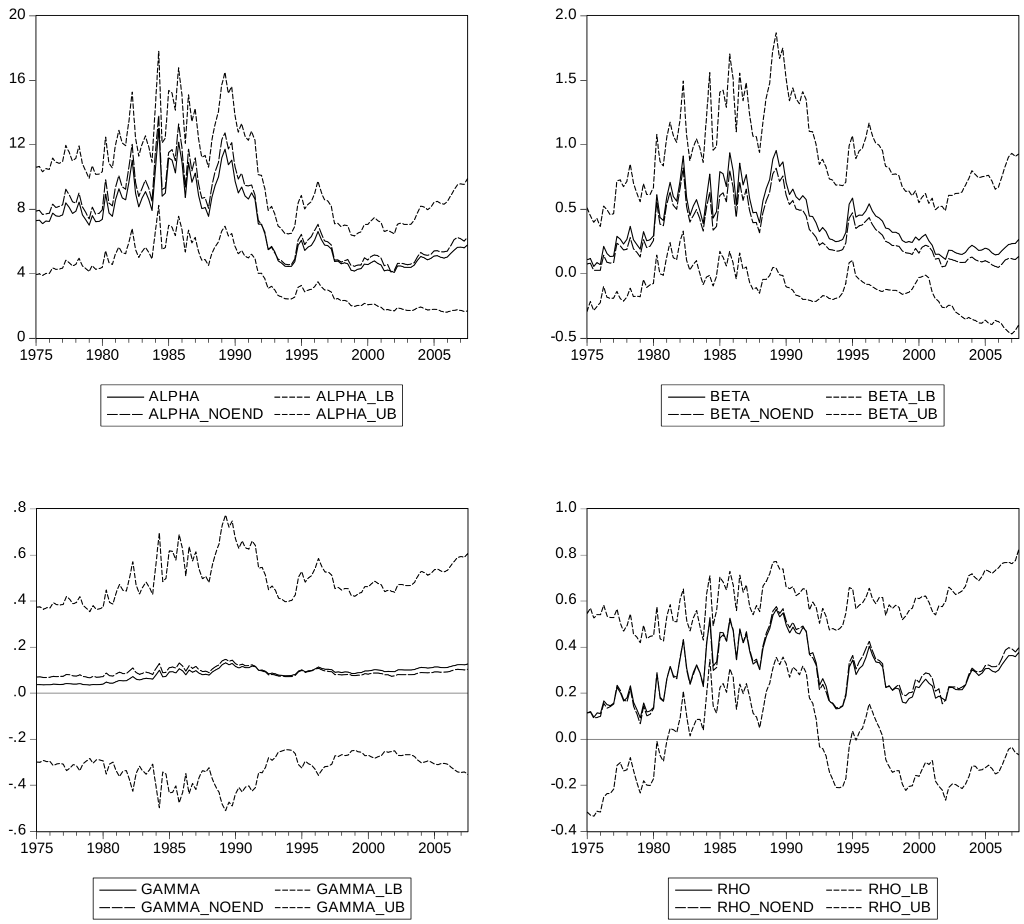
Note: Model with bias correction terms (solid line), model not dealing with endogeneity in monetary policy rules (dashed line). The 95% confidence bands correspond to the model with bias correction terms.

Figure A.2: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, New Zealand



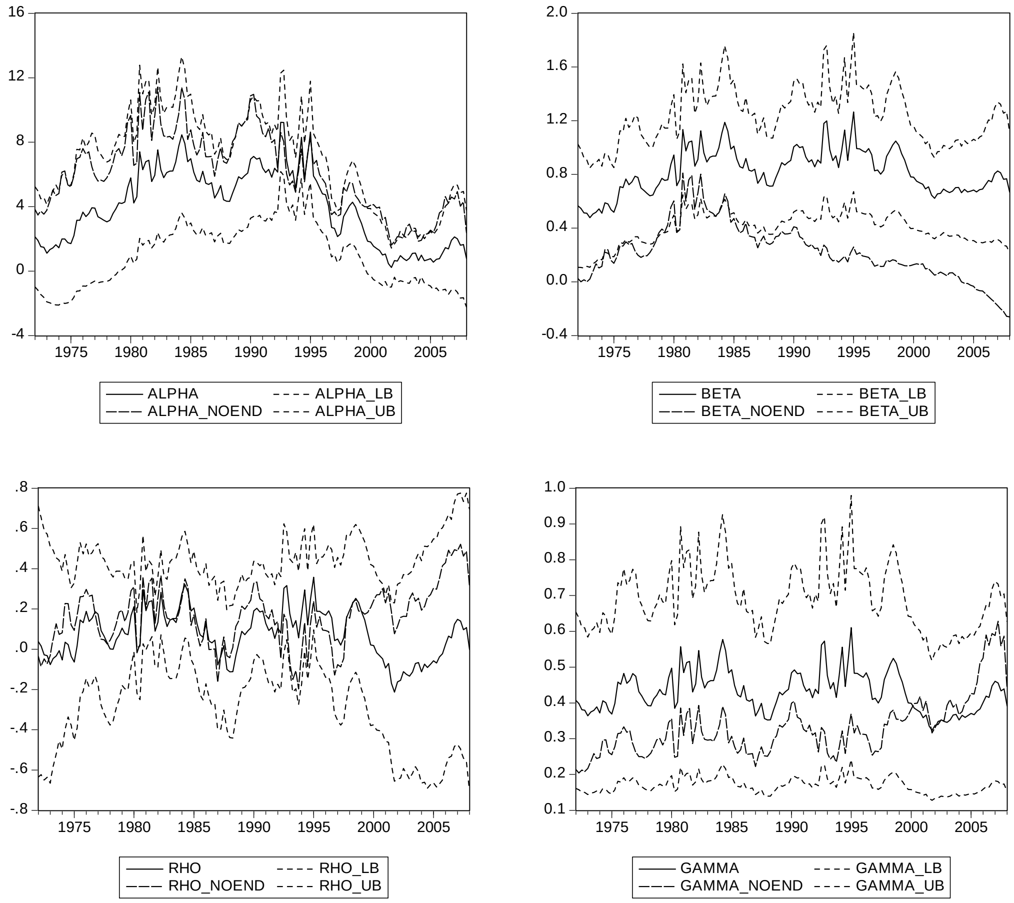
Note: Model with bias correction terms (solid line), model not dealing with endogeneity in monetary policy rules (dashed line). The 95% confidence bands correspond to the model with bias correction terms.

Figure A.3: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, Australia



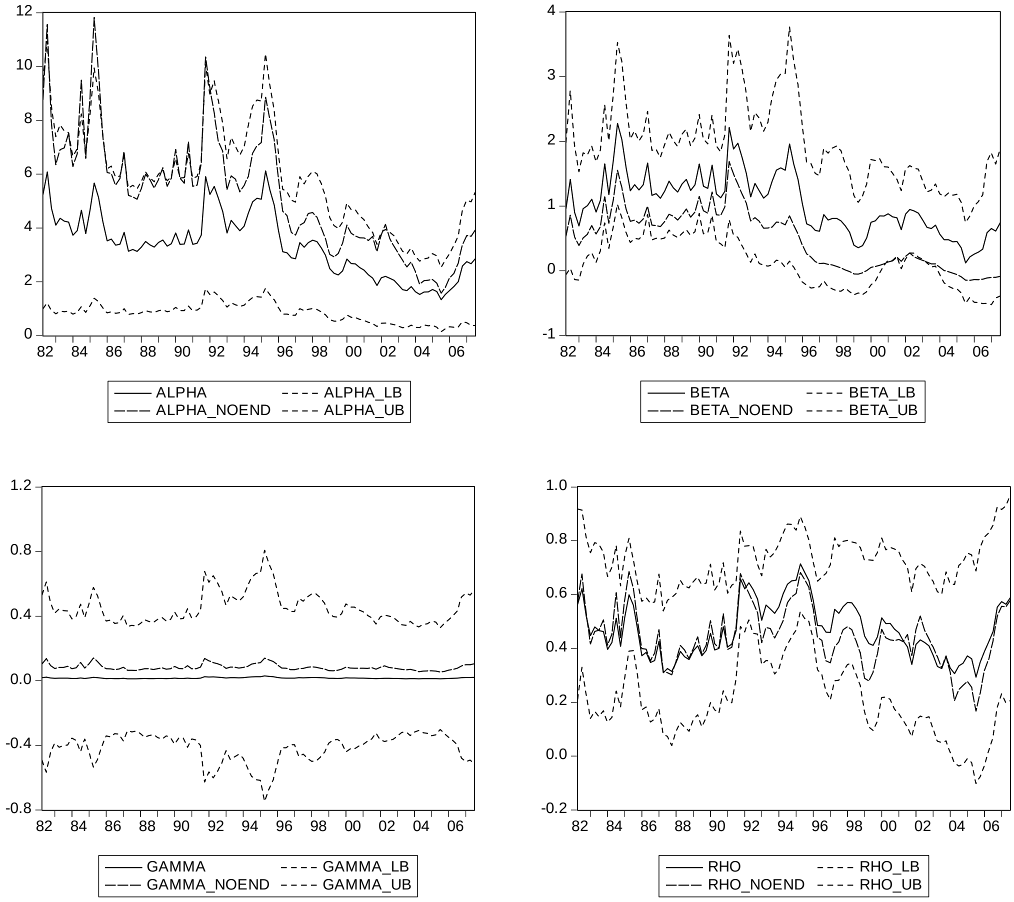
Note: Model with bias correction terms (solid line), model not dealing with endogeneity in monetary policy rules (dashed line). The 95% confidence bands correspond to the model with bias correction terms.

Figure A.4: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, Canada



Note: Model with bias correction terms (solid line), model not dealing with endogeneity in monetary policy rules (dashed line). The 95% confidence bands correspond to the model with bias correction terms.

Figure A.5: Time-Varying Response Coefficients in Baseline (Closed Economy) Policy Rule, Sweden



Note: Model with bias correction terms (solid line), model not dealing with endogeneity in monetary policy rules (dashed line). The 95% confidence bands correspond to the model with bias correction terms.

Table A.1: Estimated Coefficients of Endogeneity Correction Terms

		UK	NZ	Aus	Can	Swe
Inflation	mean	-0.0183	**-1.06**	*-0.17*	**-0.873**	**-0.329**
	s.e.	0.269	0.337	0.0912	0.146	0.119
GDP gap	mean	0.0745	-0.031	0.014	**-0.127**	0.0781
	s.e.	0.125	0.27	0.092	0.0559	0.0808

Note: Bold: sign. at 5%, italic: sign. at 10%.

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