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Abstract

This paper assesses time variation in monetary policy rules by applying a Time-Varying Parameter Generalised Methods of Moments (TVP-GMM) framework. Using monthly data until December 2022 for five inflation targeting countries (the UK, Canada, Australia, New Zealand, Sweden) and five countries with alternative monetary regimes (the US, Japan, Denmark, the Euro Area, Switzerland), we find that monetary policy has become more averse to inflation and more responsive to the output gap in both sets of countries over time. In particular, there has been a clear shift in inflation targeting countries towards a more hawkish stance on inflation since the adoption of this regime and a greater response to both inflation and the output gap in most countries after the global financial crisis, which indicates a stronger reliance on monetary rules to stabilise the economy in recent years. It also appears that inflation targeting countries pay greater attention to the exchange rate pass-through channel when setting interest rates. Finally, monetary surprises do not seem to be an important determinant of the evolution over time of the Taylor rule parameters, which suggests a high degree of monetary policy transparency in the countries under examination.

Keywords: Taylor rules, Monetary policy rules, Generalised Methods of Moments, Time-varying parameters

JEL Classification: C14; C52; E52; E58

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1. Introduction

In recent decades, monetary authorities in major central banks have managed to achieve low and stable inflation rates, which has been seen as a direct result of the adoption of monetary policy rules. Taylor rules appear to explain monetary policy well in inflation targeting countries (Taylor and Davradakis, 2006; Çağlayan and Astar, 2010; Neuenkirch and Tillmann, 2014), but even central banks which operate alternative monetary regimes are known to follow at times such a rule to stabilise inflation (Woodford, 2001; Orphanides, 2003; Sauer and Sturm, 2007; Sanchez-Robles and Maza, 2013; Nitschka and Markov, 2016). However, regardless of the type of monetary regime in place, policymakers and their objectives can change over time, and thus their monetary stance can also change to respond effectively to shocks.

Several studies have recognised this fact and investigated possible shifts in the parameters of monetary policy rules over time. Sub-period analyses in this context provide evidence for changing interest rate policies, but tend to focus primarily on the US, which experienced such changes during the Volcker-Greenspan era (Judd and Rudebusch, 1998; Clarida et al., 2000; Orphanides, 2004), while more complex regime-switching models have been used to capture shifts in the Taylor rule parameters in other developed as well as emerging economies (Zheng et al., 2012; Alba and Wang, 2017; Caporale et al., 2018). Other studies, which employ maximum likelihood and Kalman filtering methods, report that time-varying parameter Taylor rules explain monetary policy better than constant parameter ones (Kim and Nelson, 2006; Trecroci and Vassalli, 2010; Yüksel et al., 2013). However, as Partouche (2007) points out, Kalman filter methods are restrictive since they impose constraints on the form of heteroscedasticity and the correlations between the disturbances and the regressors; he proposes using instead a version of the Generalised Methods of Moments (GMM) which allows for time variation to capture changes in monetary policy rules and applies this framework to analyse the behaviour of the Federal Reserve.

The present paper contributes to this area of the literature by applying the procedure developed by Partouche (2007) to a greater range of countries with different monetary frameworks, and for an extended sample including recent crisis periods characterised by monetary policy shifts. More specifically, it uses a Time-Varying Parameter Generalised Methods of Moments (TVP-GMM) framework as in Partouche (2007) to estimate Taylor rules for five inflation targeting countries, i.e. the UK, Canada, Australia, New Zealand and Sweden. For comparison purposes, the exercise is also carried out for a set of countries which have instead adopted alternative monetary regimes but followed a Taylor rule at times, namely the US, Japan, Denmark, the Euro Area and Switzerland. Both standard and augmented forward-looking time-varying parameter Taylor rules are estimated and assessed against constant parameter rules.

The layout of the paper is the following: Section 2 reviews the existing literature on the Taylor rule; Section 3 outlines the econometric method used; Section 4 discusses the data and the empirical results; Section 5 offers some concluding remarks.

2. Literature Review

Several monetary authorities around the world have been operating an inflation targeting regime since the 1990s, while central banks with alternative monetary frameworks have at times targeted the inflation rate according to a monetary policy rule. The well-known Taylor rule (Taylor, 1993; Taylor, 1999) describes monetary policy as an interest rate setting mechanism to respond to deviations of inflation and output from their targets. It has been found that monetary authorities who follow a Taylor rule experience greater macroeconomic stability (Fregert and Jonung, 2008; Çağlayan and Astar, 2010; Beaudry and Ruge-Murcia, 2017; Zhu et al., 2021). Further evidence suggests that monetary policy can best be described by a Taylor rule even in countries which did not adopt an inflation targeting framework, for instance the US (Woodford, 2001; Orphanides, 2003), the Euro Area (Sauer and Sturm, 2007; Sanchez-Robles and Maza, 2013), Switzerland (Nitschka and Markov, 2016) and the seven largest Latin American countries (Moura and De Carvalho, 2010).

In the empirical literature several types of Taylor rules have been estimated using various methods. The augmented Taylor rule, which includes the real exchange rate in addition to the inflation and output gaps, seems to explain monetary policy well in open economies (Batini et al., 2003; Adolfson, 2007; Aizenman et al., 2011), and forward-looking rules in particular have found much support in the literature (Batini and Haldane, 1998; Fendel et al., 2007; Nikolsko-Rzhevskyy, 2011). The methods used include Ordinary Least Squares (OLS), Maximum Likelihood (ML) and system methods (Cochrane, 2011). The seminal paper by Clarida et al. (1998) was the first to apply the GMM framework to forward-looking Taylor rules; its findings suggest that monetary policy can be explained accurately using this method in the case of the G3 (Germany, Japan and the US) and to some extent in that of the E3 (the UK, France and Italy). Subsequent empirical studies found that GMM is the most suitable methodology to deal with endogeneity when estimating monetary policy rules (Florens et al., 2001; Yau, 2010; Rühl, 2015).

Other studies have allowed for time variation in the Taylor rule parameters using a variety of estimation methods. Judd and Rudebusch (1998), for instance, performed a sub-sample analysis of the Fed's policy rule using Ordinary Least Squares (OLS) and found substantial differences in the parameters between the sub-periods considered. Clarida et al. (2000) assessed forward-looking Taylor rules in a GMM framework and reported significant monetary policy regime shifts for the Fed during the Volcker-Greenspan era. Similar results were obtained by Orphanides (2004) when including real-time information in the model. McCulloch (2007) used an Adaptive Least Squares approach and confirmed previous findings that the parameters in the US Taylor rule are not constant. Conrad and Eife (2012) performed rolling window regressions to obtain time-varying parameter estimates of the Taylor rule reaction function for the Fed, their findings also explaining changes in the US inflation-gap persistence. Papadamou et al. (2018) applied the GMM method to conduct sub-sample analysis for a period including the global financial crisis and found evidence of substantial asymmetries in the ECB's reaction function. Orphanides and Williams (2005) adopted a time-varying parameter VAR (Vector Autoregressive) framework and found that their model provided a good description of US monetary policy. Similar results were obtained by Sims and Zha (2006), who employed a structural VAR model with time-varying parameters. Several studies have modelled time variation by using regime-switching models. Caporale et al. (2018), for instance, estimated augmented Taylor rules for selected emerging economies by using a Threshold GMM, which seems to capture well the behaviour of central banks in those countries. Markov-switching and Smooth Transition applications also provide ample evidence for parameter shifts in the monetary policy rule for various developed and emerging economies (Perruchoud, 2009; Alcidi et al., 2011; Zheng et al., 2012; Alba and Wang, 2017).

More recent studies employ a Kalman filtering approach to model policy shifts and structural changes in the Taylor rule. Trecroci and Vassalli (2010) found that a time-varying parameter specification using the Kalman filter outperforms the constant parameter one by capturing changes in the monetary policy rule for the US, the UK, Germany, France and Italy. Yüksel et al. (2013) applied the extended Kalman filter to estimate time-varying parameters in the monetary policy rule in the case of Turkey, and found that this specification outperforms the standard one for the central bank reaction function. Boivin (2006) used the Kalman filter to estimate a likelihood function for the US and found evidence of gradual changes in the Taylor rule parameters. Using a two-step maximum likelihood method, Kim and Nelson (2006) showed that US monetary policy can be classified according to three distinct periods with different Taylor rule parameters rather than the two identified previously.

Although the abovementioned studies suggest that the Kalman filter captures gradual variations in the Taylor rule better than constant parameter models, this approach suffers from a major drawback, since it imposes constraints on the form of heteroscedasticity of the error term. To address this issue, Partouche (2007) developed a GMM framework with time-varying parameters to assess parameter shifts in the monetary policy rule. This model has the advantage that it is robust to heteroscedasticity, unlike Kalman filtering approaches, and is applied in the present study to carry out the empirical analysis.

3. Empirical Framework

3.1 The Taylor Rule

Taylor (1993; 1998) proposes the following monetary rule to capture the behaviour of a central bank:

$$i_t = \pi_t + a(\pi_t - \bar{\pi}) + by_t + r_t \tag{1}$$

where i_t is the policy rate, π_t is the inflation rate and $\bar{\pi}$ the inflation target, y_t is the output gap, i.e. the deviation of real GDP from target, and r_t is the equilibrium real interest rate. The size of the parameters a and b indicates the central bank's degree of inflation aversion (higher a) compared to unemployment aversion (higher b), and were originally set equal to 1.5 and 0.5 respectively in Taylor (1998).

The empirical Taylor rule estimated in this paper is a forward-looking one of the following form:

$$i_t = \bar{r} + \varphi_\pi \sum_{k=1}^{3} (E_{t-1}\pi_{t+k} - \bar{\pi}) + \varphi_y \sum_{k=1}^{3} (E_{t-1}y_{t+k}) + u_t \tag{2}$$

where i_t is the interest rate set by the central bank, and $\bar{r}$ is the equilibrium real interest rate, which is unobserved and is measured by the constant in the regression as in most studies (e.g., Razzak, 2003; Adanur Aklan and Nargelecekenler, 2008; Belke and Klose, 2009; Judd and Rudebusch. 2020). π_{t+k} and y_{t+k} are the k-period ahead forecasts of inflation and the output gap respectively, and u_t is an error term. Instead of contemporaneous or lagged values of the variables, we include proxies for forecasts based on the 3-month lead average for the inflation rate and the output gap. Since backward-looking specifications of the Taylor rule have been rejected in favour of forward-looking ones, the above should capture monetary policy more accurately (Clarida et al., 1998).

The Taylor rule given by equation (2) is suitable for closed economies; however, in open economies, monetary policy can be influenced by the behaviour of the real exchange rate, which has been considered in several studies (Svensson, 2000; Caporale et al., 2018, Tiryaki et al., 2018). Therefore, we also estimate the following augmented Taylor rule:

$$i_t = \bar{r} + \varphi_\pi \sum_{k=1}^{3} (E_{t-1}\pi_{t+k} - \bar{\pi}) + \varphi_y \sum_{k=1}^{3} (E_{t-1}y_{t+k}) + \\ + \varphi_q \sum_{k=1}^{3} (E_{t-1}q_{t+k}) + u_t \quad (3)$$

where q_{t+k} is the forward-looking real effective exchange rate. We use the Generalised Methods of Moments (GMM) framework to estimate the Taylor rules in equations (2) and (3).

3.2 The Constant Parameter GMM

The Generalised Methods of Moments (GMM) is a semiparametric framework which is a suitable alternative to Ordinary Least Squares (OLS) approaches in cases where the error term is correlated with the regressors. This is likely to happen in forward-looking models which include (expected) future rather than contemporaneous values of the regressors; these are then correlated with the expectational errors usually contained in the error term (Taylor and Davradakis, 2006).

The estimation of a GMM model with constant parameters δ follows a two-step procedure as outlined in Clarida et al. (2000). Let Z_t denote a vector of q instruments which satisfy the orthogonality condition $E(Z'u) = 0$. The GMM framework with an optimal weighting matrix

S accounts for any possible serial correlation in the error term u_t. The weighting matrix S depends on the population moments and the model parameters δ:

$$\min_{\delta}\left\{\left(\sum_{t=1}^{T}(x_t - z_t'\,\delta)Z_t\right)' S\left(\sum_{t=1}^{T}(x_t - z_t'\,\delta)Z_t\right)\right\} \tag{4}$$

where x_t stands for the endogenous variable in the model (in our case the policy rate), and z_t for the explanatory variables. The moment conditions in the static parameter case are:

$$E(x_t - z_t'\,\delta|I_{t-1}) = 0 \Rightarrow E\big((x_t - z_t'\,\delta)Z_t\big) = 0 \tag{5}$$

For cases where the number of instruments Z_t exceeds the number of parameters, overidentifying restrictions need to be imposed. We use the Sargan Test (Sargan, 1958) FOR the validity of the instruments in the overidentified case. Since this method requires all variables to be stationary, we carry out unit root tests for all of them, specifically the Dickey-Fuller Generalised Least Squares (DF-GLS) test, the Zivot and Andrews (1992) test allowing for a break in the intercept and/or the trend, and the Lee and Strazicich (2003) Lagrange Multiplier test allowing for a structural break under both the null and the alternative hypothesis.

To detect the possible presence of time-variation, one can estimate in the first instance a constant coefficient GMM model for some suitably identified sub-samples. This is often done in the literature (see, e.g., Orphanides, 2004; Papadamou et al., 2018) to distinguish between periods characterised by different policy regimes. Following this approach, we split the sample into sub-periods, first doing visual inspection of the inflation and policy rate series to determine the break points, and next applying a more rigorous method, namely the $supF$ structural break test developed by Andrews (1993), to detect the unknown break points.

3.3 A GMM Model with Time-Varying Parameters

While sub-period analysis can provide some evidence on time-variation in the Taylor rule parameters, the choice of the break dates could be arbitrary and the sub-periods too short for reliable statistical inference. Furthermore, this approach can only capture discrete parameter shifts. By contrast, the method suggested by Partouche (2007) allows for gradually evolving parameters within a GMM framework. Specifically, the minimisation problem in equation (4) can be written as follows using the Lagrange Multiplier:

$$\min_{(\delta_i)_{i\in[0,T]}} \left(\frac{1}{T}\sum_{t=1}^{T}(x_t - z_t'\,\delta_t)Z_t\right)' S\left(\frac{1}{T}\sum_{t=1}^{T}(x_t - z_t'\,\delta_t)Z_t\right) + \frac{1}{T}\sum_{t=1}^{T} T^2\Delta\delta_t' R\Delta\delta_t \qquad (6)$$

with the underlying statistical model:

$$\begin{cases} x_t = z_t'\,\delta_t + v_t \\ E(Z_t v_t) = 0 \\ \delta_t = \delta_{t-1} + e_t \\ e_t \approx N(0, Q_e) \end{cases} \qquad (7)$$

where R is the Lagrange Multiplier and Q_e is the covariance matrix of the innovation of the time-varying coefficient vector δ_t. Note that $\delta_t = (\varphi_0, \varphi_i, \varphi_\pi, \varphi_y, \varphi_q)'$ is assumed to follow a random walk. The corresponding moment conditions in the time-varying case are:

$$E(x_t - z_t'\,\delta_t | I_{t-1}) = 0 \Rightarrow E\big((x_t - z_t'\,\delta_t)Z_t\big) = 0$$

where the subscript t denotes the time-varying element.

The problem in equation (6) can be solved using non-parametric smoothing splines rather than the semi-parametric constant parameter GMM (Craven and Wahba, 1978). This method allows to carry out the estimation independently of a specific statistical model. The values of R and S are then chosen so as to obtain the estimates with the lowest mean squared error (MSE).

Modelling time variation in the parameters of the GMM directly is a more flexible method than sub-period analysis, and it does not face the issue of the small numbers of observations within sub-periods. Unlike the Kalman filtering approach suggested by Kim and Nelson (2006), which requires assuming a specific form of heteroscedasticity, the time-varying parameter GMM framework is robust to the type of heteroscedasticity in the errors. To deal with possible autocorrelation, Stock and Watson (1998) suggest using an autoregressive filter, whilst the endogeneity problem can be addressed by using the median unbiased estimate calculation developed by Stock and Watson (1998).

Partouche (2007) recommends checking robustness with respect to the covariance matrix $Q_u = \frac{\mu^2}{T^2}\bar{Q}$. In particular, in the TVP-GMM model, the variance of the innovations $\bar{Q}$ is constrained to be diagonal. Following Partouche (2007), we redo the estimation after removing this restriction. Finally, as an additional robustness test, we also estimate time-varying parameters in a backward-looking version of the standard and augmented Taylor rules by entering the first lags of the regressors.

4. Data and Empirical Results

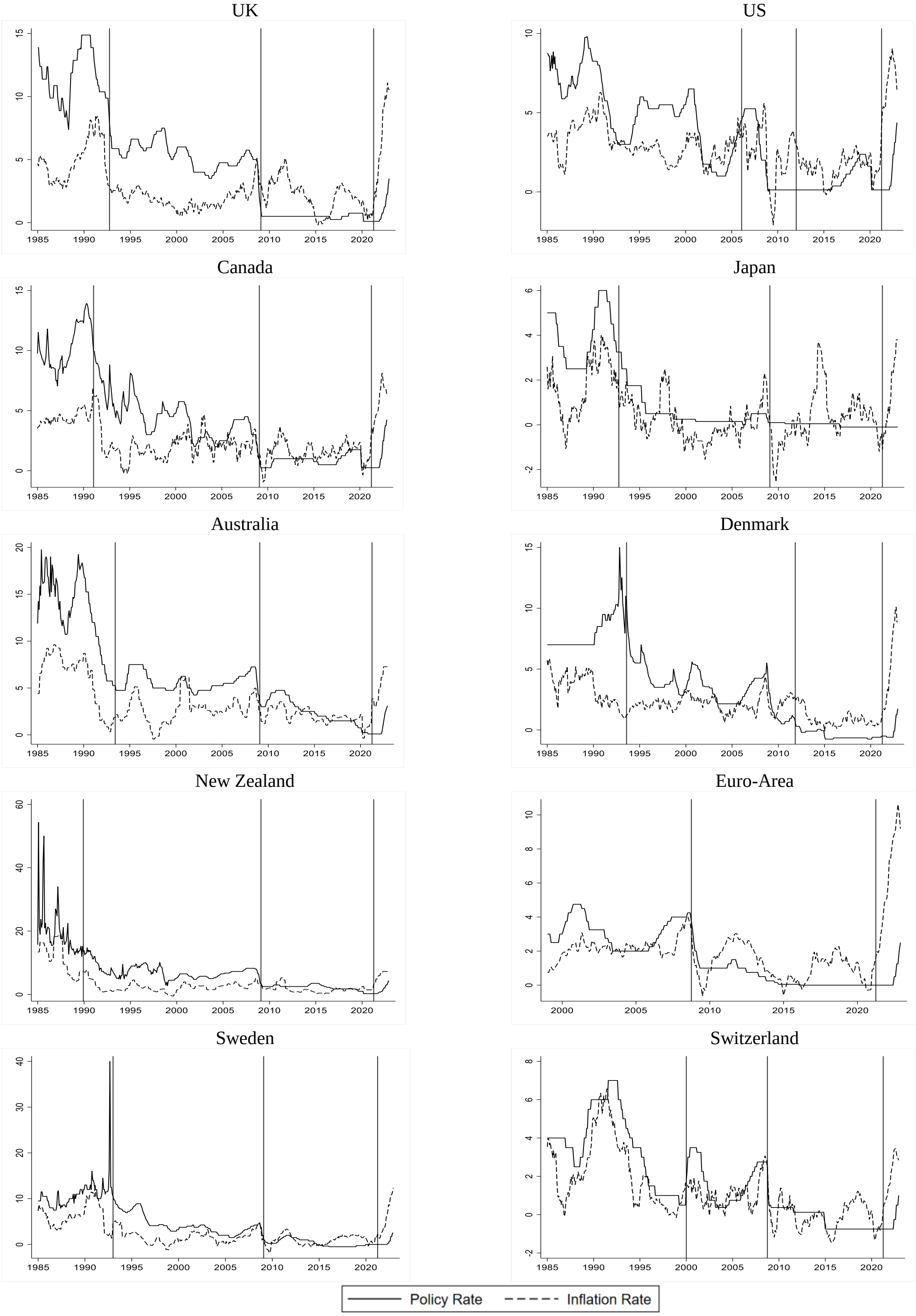
4.1 Data Description

We estimate the Taylor rule for countries which adopted an inflation targeting regime in the early 1990s, namely the UK, Canada, Australia, New Zealand and Sweden, as well as for a set of countries with alternative monetary regimes which, however, have at times followed a policy rule, more precisely, the US, Japan, Denmark, the Euro Area and Switzerland. We use monthly data from January 1985 up until December 2022 for all countries except the Euro Area, for which data are only available from January 1999.[1]

The Consumer Price Inflation (CPI) series have been obtained from the Bank for International Settlements (BIS) Consumer Prices dataset for all countries and used to construct the inflation gap.[2] The interest rate series is the central bank policy rate which has been taken from the BIS Central Bank Policy Rates dataset. The output series is the Organisation for Economic Co-operation and Development (OECD) Normalised Gross Domestic Product (GDP) series obtained from the Federal Reserve Bank of St Louis Economic Database (FRED). The Hodrick-Prescott filter is used to estimate the output gap.[3] The real effective exchange rate series have been retrieved from the BIS Effective Exchange Rate Narrow Indices dataset.

[1] The sample period includes in the case of inflation targeting countries the point when this monetary regime was adopted and for all countries several periods characterised by economic turbulence and uncertainty (such as the global financial crisis, the Covid-19 pandemic and the Russia-Ukraine conflict).
[2] The exact inflation targets are obtained from the websites of the central banks investigated in this paper.
[3] The filter allows to split output into a trend and a cyclical component.

Figure 1 – Inflation and Policy Rates



We also obtain from Bloomberg central bank announcements together with forecasts of interest rate decisions; this allows us to establish whether an announcement included an unexpected component S_t, which is the difference between what the central bank announces (A_t) and what the market expected (F_t), i.e. $S_t = A_t - F_t$. A value of S_t which is different from zero indicates that the central bank is implementing stronger monetary policy measures than anticipated by the market. Details regarding the announcement dates for all countries are included in Appendix A. This information helps to interpret the evolution of the Taylor rule parameters over time. As instruments in both the constant and the time-varying parameter GMM models we use a constant and the first, third, sixth and twelfth lag of the interest rate, the inflation rate and the output gap to estimate the standard Taylor rule as in equation (2), and for the augmented Taylor rule as in equation (3) we include the first, third, sixth and twelfth lag of the real effective exchange rate as additional instruments.

Figure 1 plots the inflation and interest rate series for each country over time. Vertical lines correspond to the main shifts in monetary policy. For inflation targeting countries, this includes the point when the inflation targeting regime was officially adopted, but also turning points when the attitude towards inflation changed – for instance, immediately after the global financial crisis, when several countries resorted to unconventional monetary policies, such as quantitative easing and forward guidance. For countries with alternative monetary policy regimes the vertical lines indicate points in time when the respective central banks began to use actively a monetary policy rule to target the inflation rate. Monetary policy appears to have been contractionary in almost all countries up until the global financial crisis, when it became more accommodating. Noticeable changes in inflation and policy rate behaviour occurred also as a result of the recent Covid-19 pandemic. However, a split of the full sample into subsamples around these dates would result in insufficient data points to allow for meaningful statistical inference.

Before starting the empirical estimation we test for stationarity of the individual time series since this is a requirement of the GMM model. Table 1 reports the results of the three unit roots tests we carry out. The DF-GLS and the Lee and Strazicich tests indicate that all series are stationary except the real effective exchange rate ones, which are integrated of order I(1) and therefore are entered into the model in first differences; however, the Zivot-Andrews test implies that in some cases the policy and inflation rates are also integrated of order I(1).

Table 1. DF-GLS, Zivot-Andrews (ZA) and Lee and Strazicich (LS) Unit Root Test Results for the Individual Series						
	$\boldsymbol{i_t}$			$\Delta\boldsymbol{i_t}$		
	DF-GLS	**ZA**	**LS**	**DF-GLS**	**ZA**	**LS**
United Kingdom	-3.237**	-2.309	-5.901***	-4.898***	-9.377***	-9.765***
Canada	-3.784***	-3.750	-5.720***	-4.680***	-9.153***	-9.381***
Australia	-5.122***	-2.897	-6.236***	-7.502***	-7.449***	-12.754***
New Zealand	-3.552***	-2.878	-5.609***	-5.025***	-11.443***	-12.821***
Sweden	-3.361**	-3.815	-5.442***	-11.951***	-12.285***	-12.383***
United States	-3.084**	-2.644	-4.613**	-11.670***	-9.807***	-5.330***
Japan	-3.889***	-4.797**	-4.238**	-11.415***	-17.709***	-25.812***
Denmark	-3.303**	-2.892	-4.291**	-4.072***	-17.387***	-17.154***
Euro-Area	-3.168**	-1.112	-5.170***	-10.758***	-17.847***	-17.662***
Switzerland	-3.291**	-3.040	-3.002	-6.561***	-17.647***	-11.876***
	$\boldsymbol{y_t}$			$\Delta\boldsymbol{y_t}$		
	DF-GLS	**ZA**	**LS**	**DF-GLS**	**ZA**	**LS**
United Kingdom	-5.112***	-6.114***	-5.528***	-6.681***	-11.990***	-6.509***
Canada	-5.246***	-5.331***	-5.233***	-10.136***	-10.298***	-10.083***
Australia	-5.248***	-5.214***	-5.328***	-4.590***	-10.628***	-10.636***
New Zealand	-3.323**	-6.430***	-4.537***	-6.580***	-9.602***	-8.915***
Sweden	-5.970***	-4.453**	-5.558***	-6.235***	-7.350***	-6.350***
United States	-5.431***	-5.707***	-5.317***	-7.660***	-9.544***	-9.598***
Japan	-5.560***	-5.240***	-5.606***	-6.038***	-7.859***	-7.312***
Denmark	-4.154***	-6.070***	-4.742***	-7.203***	-8.891***	-7.348***
Euro-Area	-3.802***	-4.425**	-4.465**	-11.715***	-12.067***	-12.458***
Switzerland	-5.185***	-4.845**	-4.447**	-6.443***	-10.743***	-6.799***
	$\boldsymbol{\pi_t}$			$\Delta\boldsymbol{\pi_t}$		
	DF-GLS	**ZA**	**LS**	**DF-GLS**	**ZA**	**LS**
United Kingdom	-3.160**	-4.166	-4.832***	-8.709***	-12.397***	-9.160***
Canada	-5.141***	-4.501**	-6.807***	-8.140***	-10.373***	-8.676***
Australia	-3.327**	-3.889	-4.004**	-5.589***	-21.285***	-21.347***
New Zealand	-3.792***	-3.519	-3.664	-6.394***	-21.294***	-6.543***
Sweden	-3.504***	-4.425**	-3.681	-5.597***	-11.695***	-11.699***
United States	-4.084***	-5.801***	-5.406***	-8.079***	-12.165***	-7.890***
Japan	-4.951***	-6.672***	-5.085***	-14.245***	-13.612***	-13.428***
Denmark	-3.220**	-2.831	-4.125**	-5.466***	-12.765***	-13.028***
Euro-Area	-3.005**	-3.265	-4.830***	-4.675***	-6.995***	-16.790***
Switzerland	-3.495***	-5.127***	-4.704***	-12.045***	-12.616***	-12.760***
	$\boldsymbol{q_t}$			$\Delta\boldsymbol{q_t}$		
	DF-GLS	**ZA**	**LS**	**DF-GLS**	**ZA**	**LS**
United Kingdom	-2.562	-3.471	-3.731	-5.537***	-11.066***	-11.305***
Canada	-1.750	-2.109	-2.431	-3.549***	-9.366***	-9.779***
Australia	-1.561	-2.929	-3.140	-5.646***	-14.709***	-13.304***
New Zealand	-2.342	-3.423	-3.164	-4.776***	-11.665***	-6.628***
Sweden	-2.739	-3.505	-4.002**	-3.601***	-13.746***	-14.352***
United States	-0.605	-3.968	-2.650	-5.883***	-14.439***	-13.586***
Japan	-1.569	-3.716	-3.707	-3.841***	-10.356***	-10.539***
Denmark	-1.681	-4.322	-4.837***	-3.257**	-14.710***	-14.780***
Euro-Area	-2.331	-4.248	-2.817	-3.135**	-12.069***	-12.225***
Switzerland	-2.708	-3.264	-3.425	-3.881***	-11.722***	-11.796***

DF-GLS Test hypothesis:
H_0: $series\ contains\ a\ unit\ root$
H_1: $series\ is\ stationary$

Zivot-Andrews Test hypothesis:
H_0: $series\ contains\ a\ unit\ root\ with\ a\ break$
H_1: $series\ is\ stationary\ with\ a\ break$

Lee and Strazicich Test hypothesis:
H_0: $series\ contains\ a\ unit\ root\ with\ breaks$
H_1: $series\ is\ stationary\ with\ breaks$

This is not an uncommon finding; nevertheless, many authors, such as Clarida et al. (1998, 2000), treat the policy rate and in some cases also the inflation rate as stationary, which they view as a reasonable assumption to estimate the Taylor rules without too much information loss from differencing. For this reason, and given the fact that the majority of the unit root tests we employ suggest that both these variables are stationary, we also treat them as such.

4.2 Results for the Constant Parameter Taylor Rule

For a start we estimate the standard and augmented Taylor rules using the constant parameter GMM for the entire sample and report the results in Table 2 for all countries. On first inspection one can note that the coefficients on the inflation and output gap are not particularly close to the values of 1.5 and 0.5 suggested by Taylor (1998). The inflation gap parameters range between 1.09 and 2.23 and the output gap ones between 0.32 and 0.82 for the countries in our sample. The real effective exchange rate included in the augmented Taylor rule seems to play an important role mainly in the case of Australia and Sweden, whilst it is less relevant in the other cases.

No significant differences emerge in the Taylor rule parameters between inflation targeting countries and those which adopted an alternative monetary regime instead. For the US, the coefficients are higher than those reported by some previous studies such as Österholm (2005) and Castro (2011), but very close to those estimated for the post-1982 period by Silva et al. (2021). They also seem to be higher for the case of Australia and Sweden compared, for instance, to those in Österholm (2005), while for the UK, New Zealand and the Euro Area they are lower than those reported in the previous literature (Castro, 2011; Kendall and Ng, 2013), although for sample periods rather different from that of the present study.

Next we perform sub-period analysis for both types of Taylor rules. At first, the sample is split into two sub-samples for each country according to the break dates identified from visual inspection of the series and corresponding to the main policy shift in each country (see Appendix B for details); note that creating more sub-samples would make the inference unreliable owing to the small number of observations in each case. Table 3 reports these results. The parameters seem to have changed significantly in most countries. More specifically, the inflation gap coefficients are lower in both sub-periods than the full-sample ones and now range between 0.38 and 1.32, whilst the output gap coefficients are mainly insignificant and range between 0.10 and 0.89.

Table 2. Constant Parameter GMM Results for the Full Sample						
		$\bar{r}$	φ_π	φ_y	φ_q	Sargan Test
United Kingdom	Standard	1.7817***	1.3449***	0.3187**	-	0.2586
		(0.1458)	(0.2647)	(0.1471)	-	
	Augmented	0.9997***	1.1259***	0.3089**	0.0160***	0.4289
		(0.0176)	(0.2858)	(0.1290)	(0.0011)	
Canada	Standard	1.7536***	1.6404***	0.8117***	-	0.3287
		(0.1705)	(0.2786)	(0.1955)	-	
	Augmented	5.1436***	1.6239***	0.3265**	-0.0310	0.7383
		(1.1107)	(0.2271)	(0.1621)	(0.0100)	
Australia	Standard	1.1849***	0.4671***	0.5258***	-	0.2053
		(0.2116)	(0.0916)	(0.1879)	-	
	Augmented	1.6268***	0.5487***	0.7800***	0.5349**	0.7975
		(0.1150)	(0.1151)	(0.2571)	(0.1901)	
New Zealand	Standard	3.7458***	0.7886***	0.8215***	-	0.1376
		(0.0797)	(0.0540)	(0.2890)	-	
	Augmented	1.4981***	0.6428***	0.4049***	-0.0411***	0.4302
		(0.0799)	(0.1156)	(0.1406)	(0.0087)	
Sweden	Standard	0.7525***	1.4415***	0.5082**	-	0.1915
		(0.1766)	(0.3284)	(0.2123)	-	
	Augmented	-0.8318***	1.1942***	0.2945**	0.1441***	0.6648
		(0.0231)	(0.3811)	(0.1476)	(0.0159)	
United States	Standard	1.3516***	2.2289***	0.5012	-	0.6254
		(0.1988)	(0.4419)	(0.3146)	-	
	Augmented	1.2051***	1.6267***	0.7833**	-0.2621	0.3776
		(0.1821)	(0.3626)	(0.3412)	(0.6842)	
Japan	Standard	0.4518**	1.6097***	1.1090***	-	0.1039
		(0.2183)	(0.1336)	(0.1685)	-	
	Augmented	0.4911**	1.5800***	1.0321***	0.0914	0.2314
		(0.2173)	(0.1547)	(0.1914)	(0.1656)	
Denmark	Standard	0.7385***	0.9078***	0.0561	-	0.1074
		(0.0858)	(0.0787)	(0.1368)	-	
	Augmented	0.7121***	0.9028***	0.0675	0.5901	0.2607
		(0.0876)	(0.0979)	(0.1366)	(0.4862)	
Euro-Area	Standard	0.8326**	1.2938***	0.2584	-	0.2239
		(0.3573)	(0.1946)	(0.1995)	-	
	Augmented	-2.0375	1.0908***	0.5412***	0.0142	0.3793
		(2.4212)	(0.2351)	(0.1664)	(0.0216)	
Switzerland	Standard	2.2613***	1.4127***	0.4490**	-	0.2548
		(0.3257)	(0.0772)	(0.2271)	-	
	Augmented	5.8376***	1.2209***	0.3293**	0.0408**	0.3418
		(1.6809)	(0.0965)	(0.1376)	(0.0200)	

Standard errors in parentheses. The regression specification for the standard Taylor rule is that in equation (2), while the specification for the extended Taylor rule is that in equation (3). Overidentification restrictions are tested using the Sargan J-Test with probabilities reported.

In sub-period I, which includes the time period at least up until the global financial crisis for all countries, monetary authorities appear to be rather responsive to inflation, regardless of the type of monetary regime in place. In sub-period II, which includes the post-financial crisis period, the inflation aversion of all central banks seems to have decreased. In some cases (the UK, New Zealand, Sweden, Japan and the Euro Area) the Taylor rule estimates indicate lower responsiveness to output and inflation changes in the period after the global financial crisis, which has been frequently characterised by unconventional monetary policies and during which countries not identifying themselves as inflation targeters (Japan, Denmark, the Euro Area and Switzerland) have cut their policy rates below zero, the coefficient on the real interest rate becoming negative.

Table 3. Constant Parameter GMM Results with Sub-period Comparison with Visual Break Point Determination

		Sub-period	$\bar{r}$	φ_π	φ_y	φ_q	Sargan Test
United Kingdom	Standard	1985:1–2009:2	2.0280***	0.4263***	0.1127***	-	0.2844
		2009:3–2022:12	0.6623***	0.0862	0.0650	-	0.7460
	Augmented	1985:1–2009:2	4.6656***	0.4702***	0.0717	0.0229***	0.5581
		2009:3–2022:12	2.8348*	0.2325	0.1497***	0.0190	0.7193
Canada	Standard	1985:1–2009:2	1.8616***	0.6037***	0.0509	-	0.1620
		2009:3–2022:12	0.6192***	0.5930***	0.0836	-	0.3777
	Augmented	1985:1–2009:2	0.5029	0.5208***	0.0321	0.0118***	0.4692
		2009:3–2022:12	4.1342***	0.5520***	0.0286	0.0323***	0.4857
Australia	Standard	1985:1–2009:2	2.0076***	0.3780***	0.2499***	-	0.2052
		2009:3–2022:12	0.7704**	1.1906***	0.0230	-	0.2832
	Augmented	1985:1–2009:2	1.8081***	0.3838***	0.2431***	0.0668	0.2618
		2009:3–2022:12	0.9820**	1.2566***	0.3153	0.7365**	0.3400
New Zealand	Standard	1985:1–2009:2	3.1846***	1.0709***	0.8930***	-	0.0965
		2009:3–2022:12	2.8008***	0.1379	0.7645	-	0.8410
	Augmented	1985:1–2009:2	1.2420	0.4684***	0.0240	0.0088	0.8885
		2009:3–2022:12	1.7630	0.0590	0.4561	0.0089	0.5553
Sweden	Standard	1985:1–2009:2	1.5008***	0.5784***	0.0542	-	0.1417
		2009:3–2022:12	1.0279***	0.2022	0.1024	-	0.2327
	Augmented	1985:1–2009:2	1.4921***	0.5959***	0.0948	0.4427**	0.7223
		2009:3–2022:12	0.4838	0.2812	0.0279	0.2064	0.6930
United States	Standard	1985:1–2011:12	1.4947***	1.1820***	0.1888	-	0.4244
		2012:1–2022:12	1.5057***	0.5294***	0.1143	-	0.5105
	Augmented	1985:1–2011:12	1.5077***	1.0574***	0.2121	0.0537	0.6010
		2012:1–2022:12	1.7893***	0.6971**	1.5594	0.5802	0.6319
Japan	Standard	1985:1–2012:12	0.9308***	1.3223***	0.4237***	-	0.0997
		2013:1–2022:12	-2.2996***	0.0026	0.0075	-	0.2347
	Augmented	1985:1–2012:12	0.8392***	1.2815***	0.3707***	0.0656	0.2188
		2013:1–2022:12	-2.5901***	0.1751**	0.1631	0.0563	0.2583
Denmark	Standard	1985:1–2011:10	1.2101***	0.3912***	0.1010**	-	0.2169
		2011:11–2022:12	-0.4845	0.0701	0.0769	-	0.5639
	Augmented	1985:1–2011:10	1.2097***	0.3874***	0.0779	0.0827	0.4267
		2011:11–2022:12	-0.5010**	0.0801	0.0744	0.1887	0.8195
Euro-Area	Standard	1985:1–2008:9	2.5416***	0.0962	0.7390***	-	0.1555
		2008:10–2022:12	-0.2033	0.4564**	0.1392	-	0.3102
	Augmented	1985:1–2008:9	9.2304***	0.4160	0.6263***	0.0526***	0.3172
		2008:10–2022:12	-7.6741***	0.2106	0.0471	0.0764***	0.0590
Switzerland	Standard	1985:1–2008:9	2.8604***	1.2634***	0.0092	-	0.1672
		2008:10–2022:12	-0.6278	0.9355**	1.2838**	-	0.6628
	Augmented	1985:1–2008:9	1.2931	1.2275***	0.5091***	0.0260	0.7134
		2008:10–2022:12	-5.7931***	0.7538**	0.8497**	0.1735***	0.7452

Standard errors not reported. The regression specification for the standard Taylor rule is that in equation (2), while the specification for the extended Taylor rule is that in equation (3). Overidentification restrictions are tested using the Sargan J-Test with probabilities reported.

Table 4. Constant Parameter GMM Results with Sub-period Comparison using Empirical Break Date Determination for the Standard Taylor Rule

	Sub-period	$\bar{r}$	φ_{π}	φ_{y}	φ_{q}	Sargan Test
United Kingdom	1985:1–1993:1	2.2361***	0.2505***	0.0161	-	0.3343
	1993:2–2001:10	1.8013***	0.0271	0.0250	-	0.4445
	2001:11–2009:4	1.4783***	0.0478	0.1779***	-	0.8733
	2009:5–2022:12	0.8402***	0.2396	0.2029***	-	0.4861
Canada	1985:1–1993:5	2.0727***	0.2418***	0.0572***	-	0.4189
	1993:6–2001:12	1.6320***	0.0704	0.0520	-	0.3569
	2002:1–2009:5	1.1086***	0.1292	0.2637	-	0.3360
	2009:6–2022:12	-0.6689***	0.5731***	0.1124	-	0.3437
Australia	1985:1–1992:7	2.3979***	0.2384***	0.0222	-	0.6969
	1992:8–2011:10	1.7043***	0.3165***	0.2143***	-	0.3558
	2011:11–2017:4	0.8338***	0.1504	0.6367*	-	0.5852
	2017:4–2022:12	-1.3245***	0.8293***	0.0361	-	0.5963
New Zealand	1985:1–1991:11	2.1463***	0.3904***	0.0527	-	0.5399
	1991:12–2009:3	1.7381***	0.1331*	0.1232**	-	0.0760
	2009:4–2017:6	0.9488***	0.0111	0.0992	-	0.5653
	2017:7–2022:12	0.1924	0.2911*	0.2320*	-	0.6327
Sweden	1985:1–1996:10	2.1032***	0.1880***	0.0603	-	0.5672
	1996:11–2009:4	1.3526***	0.0486	0.0219	-	0.4250
	2009:5–2017:6	-0.9833***	0.2518	0.0010	-	0.1134
	2017:7–2022:12	-5.7824***	2.1897***	1.3284*	-	0.7922
United States	1985:1–2001:12	1.7526***	0.2574***	0.0593	-	0.0908
	2002:1–2009:2	0.6952***	0.2373**	0.6969***	-	0.1462
	2009:3–2016:2	-2.0770***	0.0036	-0.0004	-	0.9965
	2016:3–2022:12	-0.8103***	0.6225***	0.2418	-	0.2650
Japan	1985:1–1995:6	1.0971***	0.2879**	0.3257***	-	0.5752
	1995:7–2009:9	-1.2144***	0.5576**	0.0899	-	0.5790
	2009:10–2012:3	-3.9960***	1.6215***	0.0875	-	0.8121
	2012:4–2022:12	-2.3026***	0.0000	0.0000	-	0.2623
Denmark	1985:1–1994:3	2.0977***	0.1860***	0.0249	-	0.5701
	1994:4–2003:8	1.0955***	0.1659***	0.2224***	-	0.5623
	2003:9–2009:12	1.0107***	0.1322**	0.2122***	-	0.4953
	2010:1–2022:12	-0.7439***	0.2516	0.1220	-	0.8209
Euro-Area	1999:1–2009:6	2.7230***	0.1093	0.6182***	-	0.4114
	2009:7–2013:1	1.0005***	0.0003	0.0003	-	0.8913
	2013:2–2016:5	-0.0115	0.2219**	1.0194***	-	0.7990
	2016:6–2022:12	0.0001	0.0000	0.0000	-	0.9982
Switzerland	1985:1–1995:12	1.5396***	0.2591***	0.0326	-	0.1991
	1996:1–2009:9	0.1948***	0.0786	0.5147***	-	0.1953
	2009:10–2015:3	-0.5977***	1.2604***	0.6325*	-	0.3406
	2015:4–2022:12	-0.2877***	0.0000	0.0000	-	0.9786

Standard errors not reported. The regression specification for the standard Taylor rule is that in equation (2). Overidentification restrictions are tested using the Sargan J-Test with probabilities reported.

The above sub-period analysis is based on break points chosen through visual inspection. A more rigorous approach is followed next by testing for structural breaks by means of the $supF$ test by Andrews (1993) and splitting the sample accordingly. The test results are reported in Appendix C, while the sub-period estimates are displayed in Tables 4 and 5 for the standard and augmented Taylor rules, respectively. In contrast to the previous set of results based on visual inspection, it now seems that in all countries monetary authorities started reacting more strongly to both inflation and output gaps after the global financial crisis, their overall stance becoming more hawkish following the global financial crisis, but again some of the subsample are too short for reliable inference.

Table 5. Constant Parameter GMM Results with Sub-period Comparison using Empirical Break Date Determination for the Augmented Taylor Rule

	Sub-period	$\bar{r}$	φ_π	φ_y	φ_q	Sargan Test
United Kingdom	1985:1–1993:1	2.9018***	0.3001***	0.0134	-0.0059	0.4372
	1993:2–2001:10	2.5147***	0.1140**	0.0391	-0.0057**	0.5931
	2001:11–2009:4	-0.2644	0.0630	0.1707***	0.0145	0.7530
	2009:5–2022:12	-0.3113	0.0023	0.1603***	-0.0035	0.7480
Canada	1985:1–1993:5	-0.2272	0.1934***	0.0204	0.0202***	0.6209
	1993:6–2001:12	1.4941*	0.0068	0.0398	0.0011	0.4572
	2002:1–2009:5	-0.9872	0.2320**	0.1349	0.0164	0.5182
	2009:6–2022:12	-3.5234**	0.5210**	0.5010***	0.0243*	0.5769
Australia	1985:1–1992:7	2.2919***	0.2278***	0.0457	-0.0921**	0.8158
	1992:8–2011:10	1.7122***	0.1808***	0.0837	-0.1372***	0.3540
	2011:11–2017:4	0.7821***	0.1684	0.6608**	0.0362	0.7133
	2017:4–2022:12	-1.3385***	0.8292***	0.0350	0.0326	0.7557
New Zealand	1985:1–1991:11	2.2947***	0.3261***	0.1552**	0.1058*	0.7625
	1991:12–2009:3	1.7950***	0.0853*	0.0522	0.1686***	0.1592
	2009:4–2017:6	0.9458***	0.0083	0.1074	-0.0014	0.7792
	2017:7–2022:12	-0.4877**	0.6622***	0.0623	-0.2480	0.7766
Sweden	1985:1–1996:10	2.0871***	0.1829***	0.0201	0.0537	0.5195
	1996:11–2009:4	1.3498***	0.0340	0.0200	-0.0129	0.6247
	2009:5–2017:6	-0.2821	0.4625	0.3116	0.1121	0.4851
	2017:7–2022:12	-3.650***	0.5040	3.0061***	0.6713	0.8643
United States	1985:1–2001:12	1.8125***	0.1834***	0.1110***	0.0355	0.4599
	2002:1–2009:2	0.7984***	0.7136***	0.6590***	0.2326***	0.7538
	2009:3–2016:2	-2.0794***	0.0000	0.0000	0.0000	0.9998
	2016:3–2022:12	-1.3946***	0.8223***	0.8764***	0.3810***	0.8687
Japan	1985:1–1995:6	1.0790***	0.2615**	0.2886***	-0.0364	0.6764
	1995:7–2009:9	-1.2171***	0.6167**	0.0800	-0.1067	0.7179
	2009:10–2012:3	-3.6137***	1.1932***	0.1305	-0.0067	0.8803
	2012:4–2022:12	-2.6376***	0.6658**	0.1707	0.1393	0.6200
Denmark	1985:1–1994:3	2.0498***	0.1166***	0.0126	0.0093	0.5842
	1994:4–2003:8	1.1738***	0.1147**	0.2066***	0.0904	0.6234
	2003:9–2009:12	1.0755***	0.1506**	0.1675***	0.9020***	0.7616
	2010:1–2022:12	-0.7306***	0.2643	0.0882	0.3958	0.9627
Euro-Area	1999:1–2009:6	8.4953***	0.3843**	0.6925***	-0.0512***	0.5977
	2009:7–2013:1	1.0045	0.0001	0.0001	0.0000	0.9757
	2013:2–2016:5	0.4106	0.1705**	1.2498***	-0.0051	0.9306
	2016:6–2022:12	0.0001	0.0000	0.0000	0.0000	0.9315
Switzerland	1985:1–1995:12	1.4153***	0.1941***	0.0971*	-0.0595	0.3684
	1996:1–2009:9	0.2076***	0.0287	0.5577***	-0.1627	0.1877
	2009:10–2015:3	1.2990*	0.9524	0.3083	0.2454	0.8284
	2015:4–2022:12	-0.2877***	0.0000	0.0000	0.0000	0.9909

Standard errors not reported. The regression specification for the augmented Taylor rule is that in equation (3). Overidentification restrictions are tested using the Sargan J-Test with probabilities reported.

The above analysis provides some preliminary evidence about changes over time in the Taylor rule parameters. In the next step we estimate the TVP-GMM model to shed further light on the evolution of the parameters in the Taylor rule over the entire time period.

4.3 Results for the Time-varying Parameter Taylor Rule

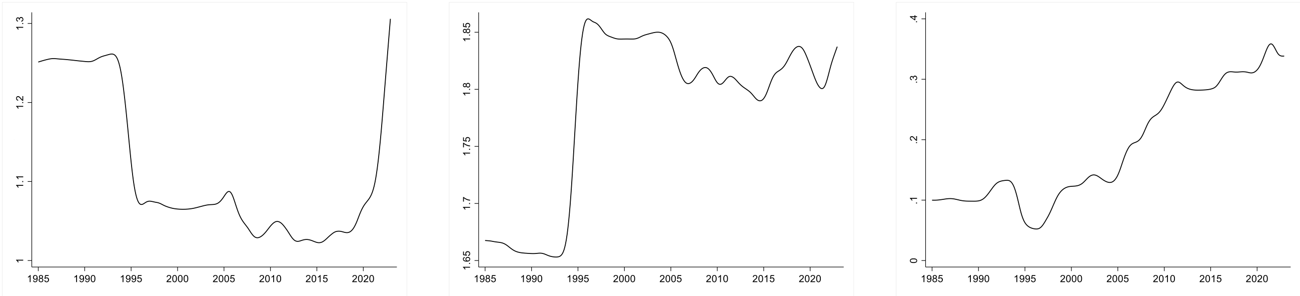
Figure 2 and 3 display the time-varying parameters of the forward-looking standard Taylor rule for inflation targeting countries and for those with alternative monetary regimes respectively. While some of the parameter shifts coincide with those suggested by the structural break analysis, the time-varying approach identifies more shifts than both the structural break tests or the initial visual inspection. These results imply that most countries have become more responsive to both inflation and the output gap over time. In inflation targeting countries, the adoption of inflation targeting coincides with an increase in the inflation coefficient (which is particularly sharp in the case of the UK, Canada and New Zealand), in contrast to the decrease estimated when doing sub-period analysis based on visual inspection. This shift also corresponds to a period of lower inflation and lower interest period in all inflation targeting countries (see Figure 1).

A second sharp rise in the inflation coefficient occurred after the global financial crisis in most countries. It seems that, regardless of the type of monetary regime, the crisis prompted central banks to put stronger emphasis on inflation and output stabilisation. Again this coincided with a shift towards lower inflation and policy rates in all countries (see Figure 1), which suggests that the increased emphasis on targeting inflation in the monetary policy rule was successful in reducing inflation. Consistently with the findings by Partouche (2007), our results indicate that monetary policy became more countercyclical over time, as indicated by the bigger coefficient on the output gap, which is a measure of the business cycle.

Figure 2 – Time-varying Standard Taylor Rule Parameters for Inflation Targeting Countries

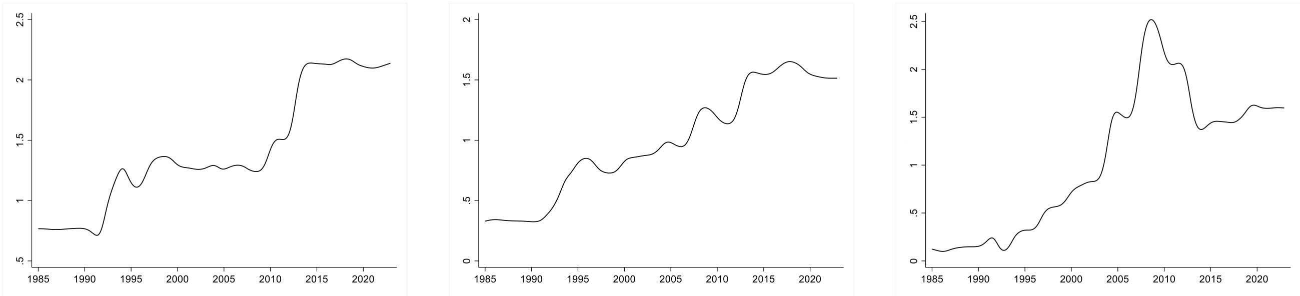
$\bar{r}$ φ_π φ_y

UK

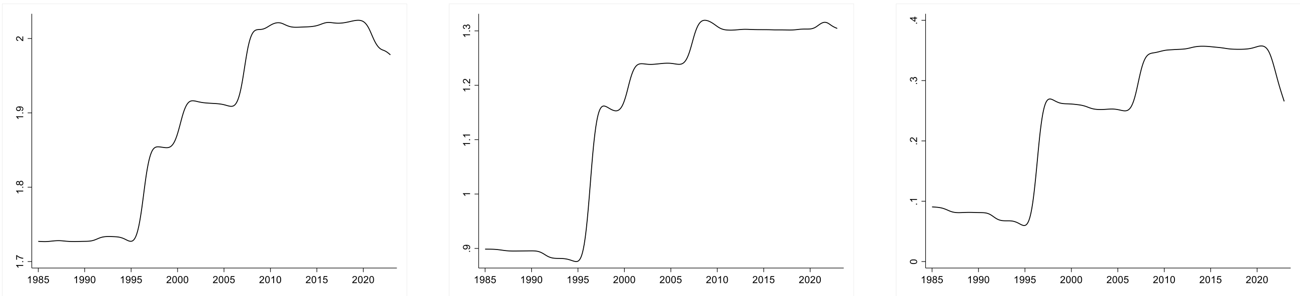


Canada

Australia



New Zealand



Sweden

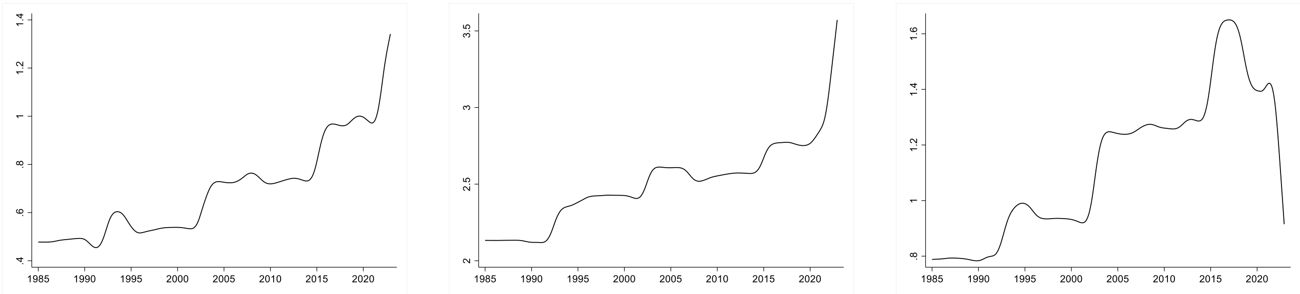


Figure 3 – Time-varying Standard Taylor Rule Parameters for Non-targeting Countries

$\bar{r}$ φ_{π} φ_{y}

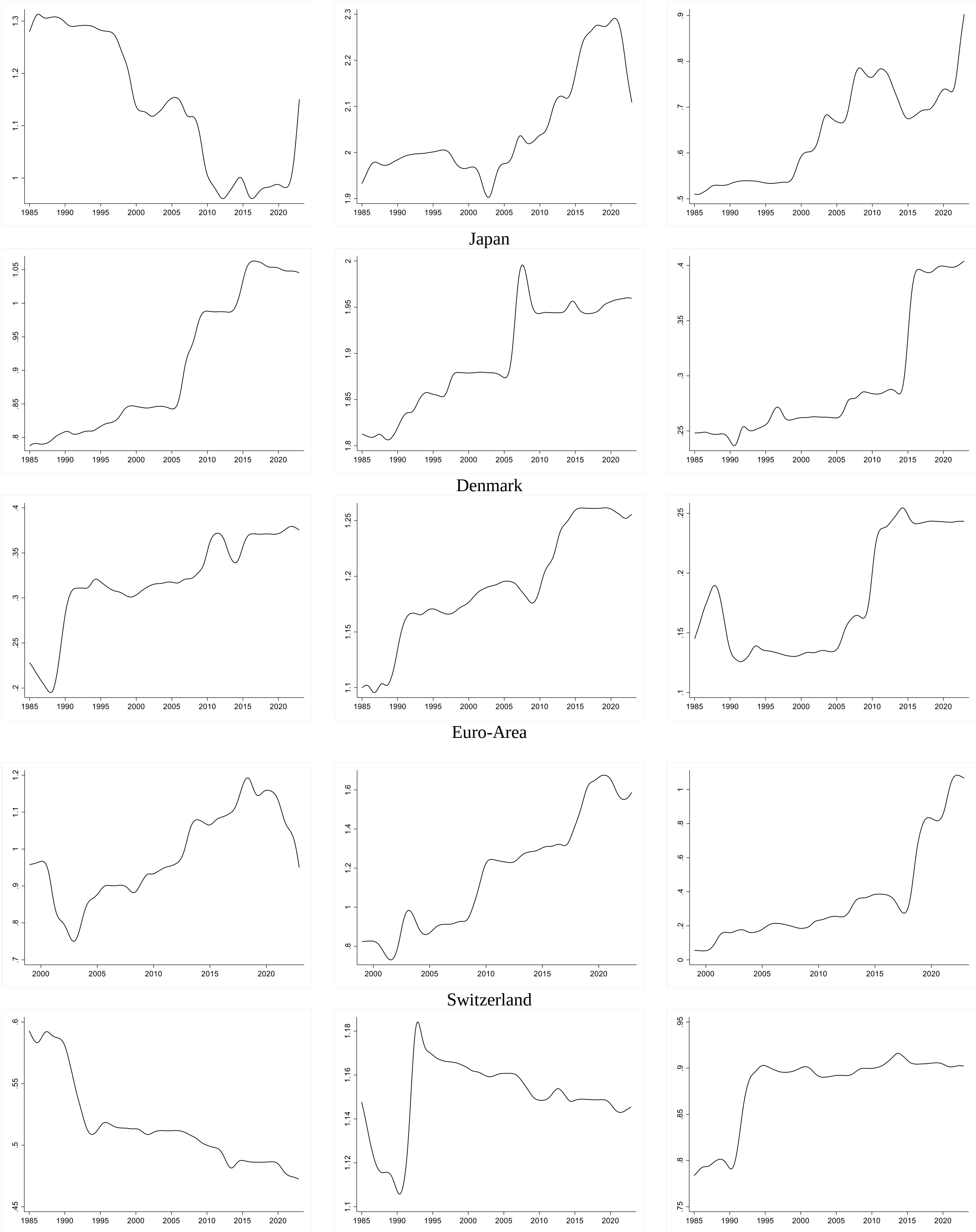
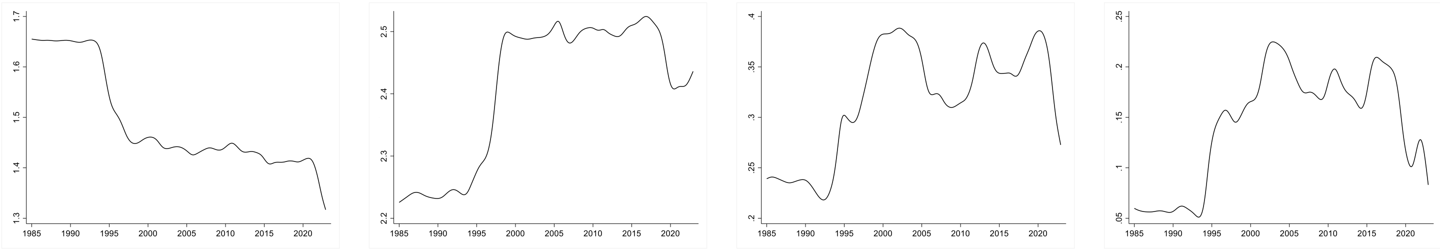


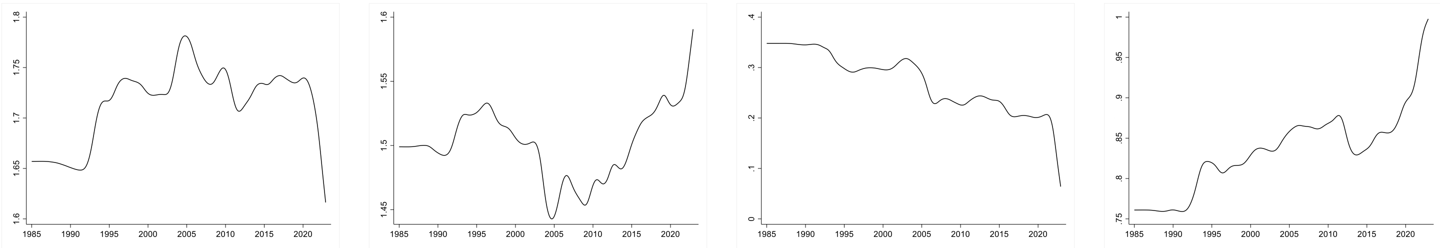
Figure 4 – Time-varying Augmented Taylor Rule Parameters for Inflation Targeting Countries

$\bar{r}$ | φ_π | φ_y | φ_q

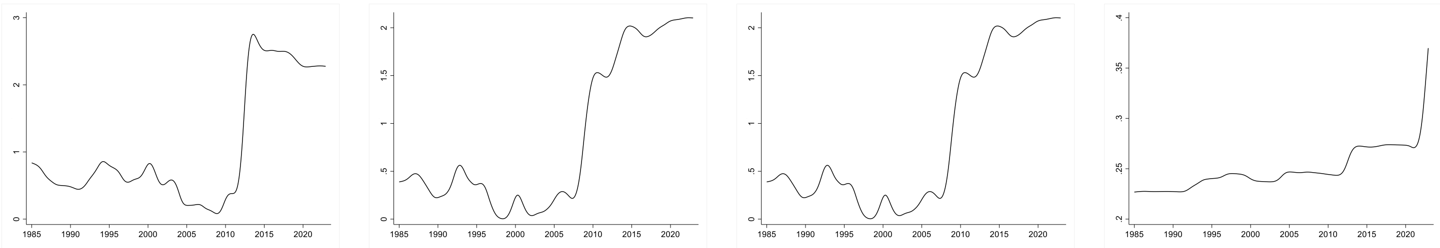
UK



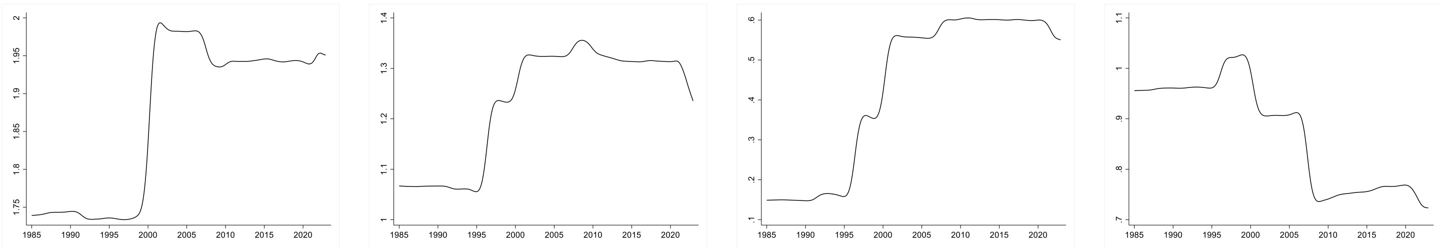
Canada



Australia



New Zealand



Sweden

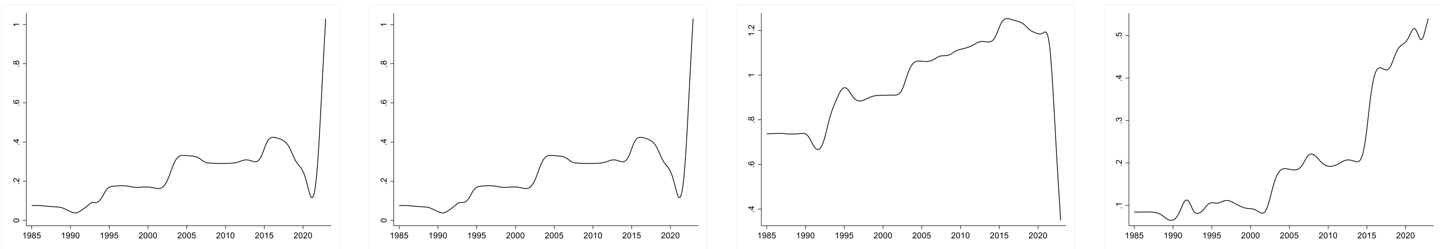
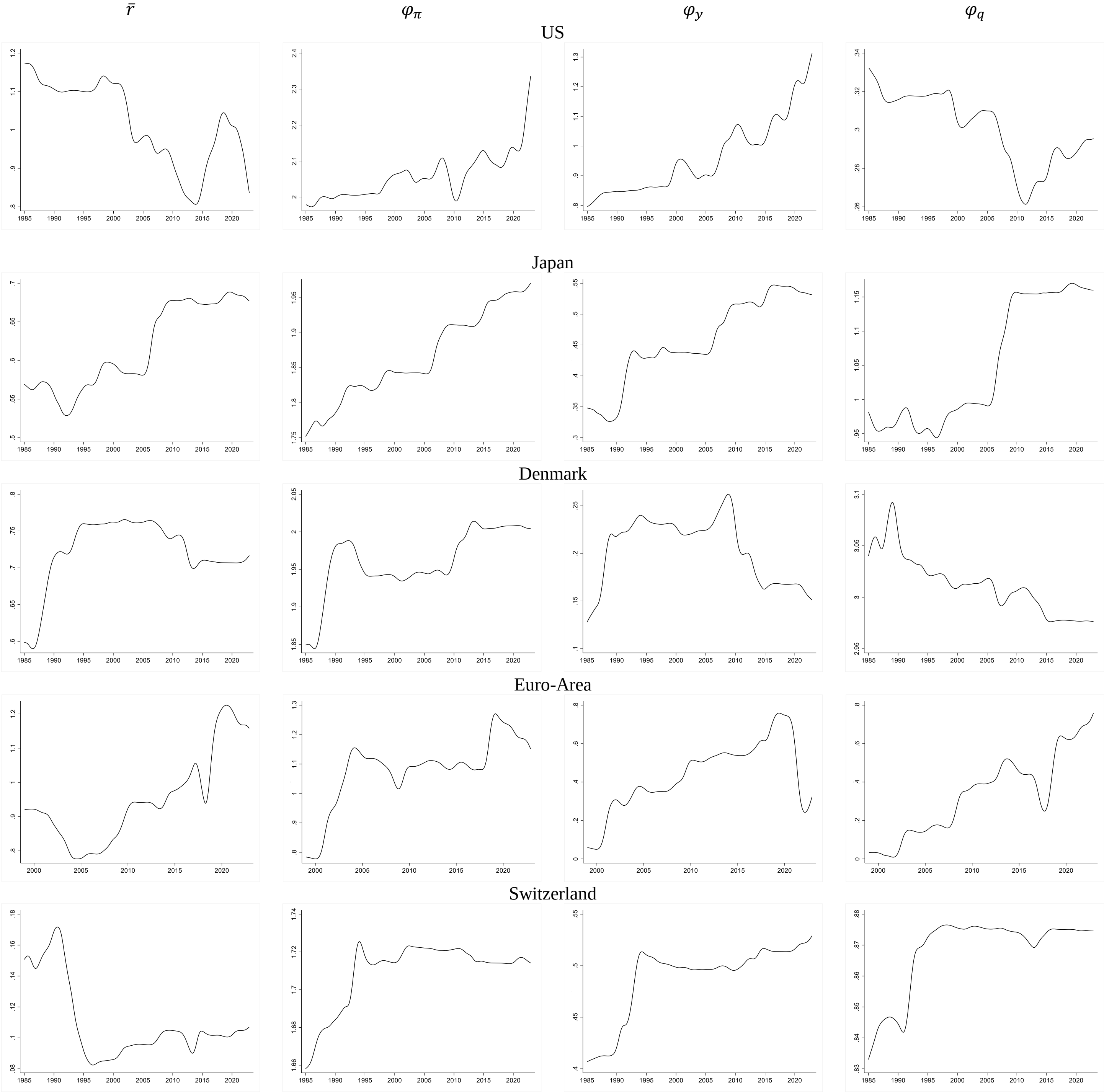


Figure 5 – Time-varying Augmented Taylor Rule Parameters for Non-targeting Countries



The standard Taylor rule is useful to assess monetary policy in closed economies, but in open economies inflation can be influenced by exchange rate changes through the exchange rate pass-through, which is why the real exchange rate should also be included in the Taylor rule. Of the countries in our sample only Switzerland and Japan are known officially to take the real exchange rate into account when setting interest rates. Figures 4 and 5 show the time-varying Taylor rule parameters for the forward-looking augmented Taylor rule which includes the real exchange rate for inflation targeting and non-targeting countries respectively. Central banks in in former are now found to be more responsive to changes in the inflation as opposed to the output gap, whilst those in countries with alternative monetary regimes appear to be less responsive to either in the open-economy case. Therefore this evidence suggests differences between countries with strict inflation targeting mandates and those with discretionary monetary flexibility in the extent to which they take into account the exchange rate pass-through in their interest rate setting.

Finally, in order to investigate the possible impact of monetary surprises on the evolution of the Taylor rule parameters, in Appendix D we display the latter together with vertical bars corresponding to interest rate announcements with an unexpected component. In the case of Denmark, no such component could be identified in any announcement. As for the other countries, in most cases no clear linkage can be seen between unexpected interest rate announcements and shifts in the Taylor rule parameters; the exceptions are the UK and Japan, where the output gap parameter increases sharply in the aftermath of unexpected announcements in 2015, and the US, where the interest rate and inflation parameters exhibit a sizeable decrease and increase respectively after the arrival of unexpected announcements during the financial crisis, in 2008. Overall, the evidence suggests that central banks communicate their current and future policy objectives in a timely manner and that their announcements are consistent with the policy rule; as a result, monetary surprises do not appear to play a major role as drivers of the Taylor rule parameters.

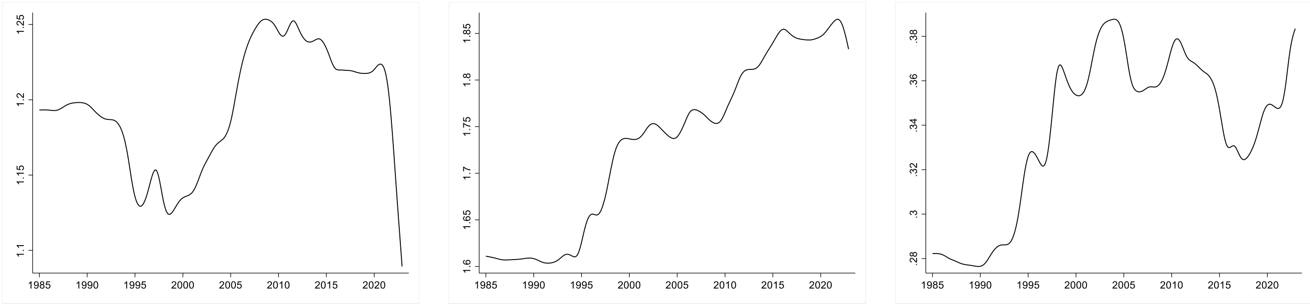
4.4 Robustness Analysis

Following Partouche (2007), we check robustness by allowing the matrix $\bar{Q}$ to be non-restricted. These results are reported in Appendix E and confirm robustness, especially in the case of the inflation and output gap parameters.

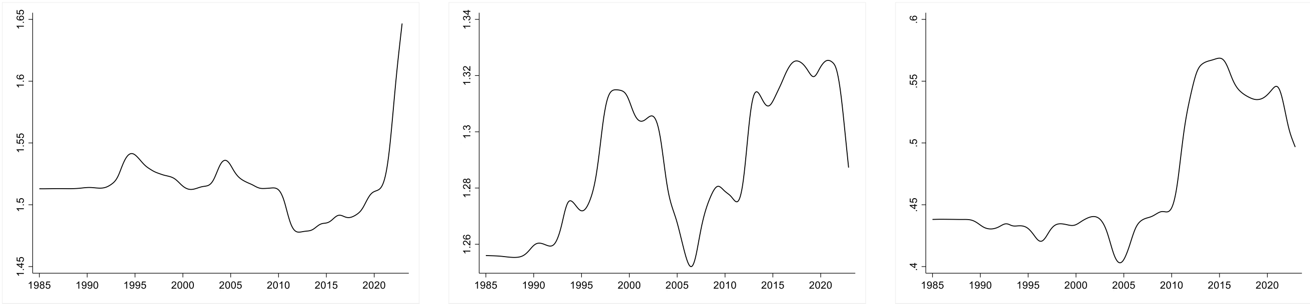
Figure 6 – Time-varying Standard Backward-looking Taylor Rule Parameters for Inflation Targeting Countries

$\bar{r}$ | φ_π | φ_y

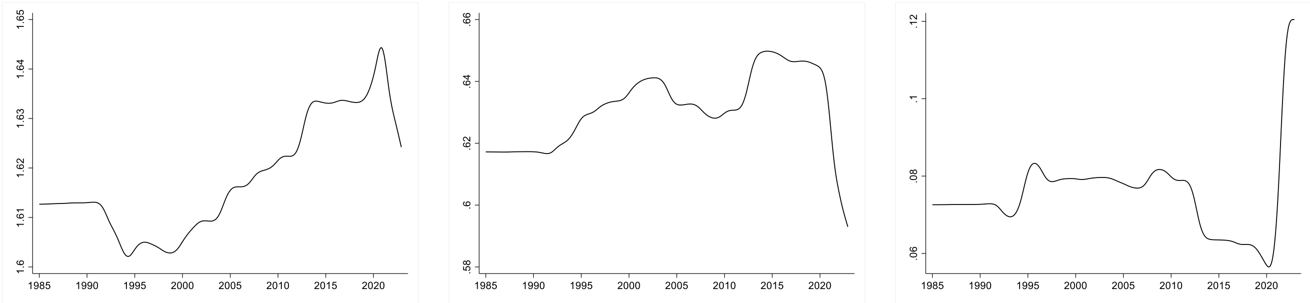
UK



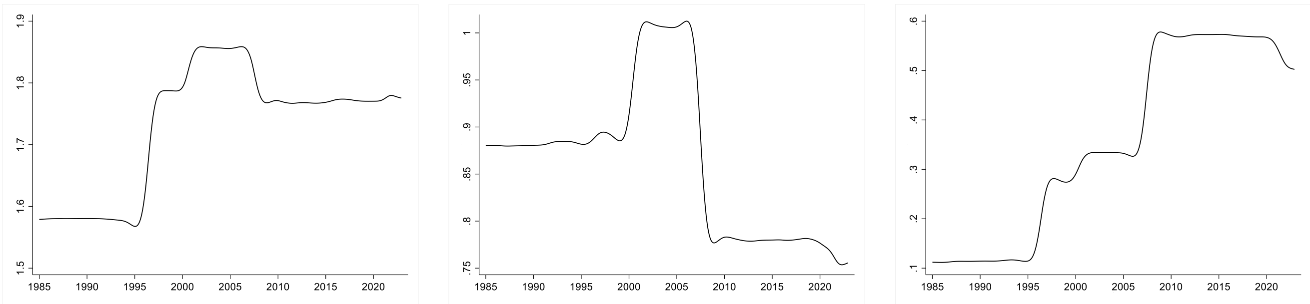
Canada



Australia



New Zealand



Sweden

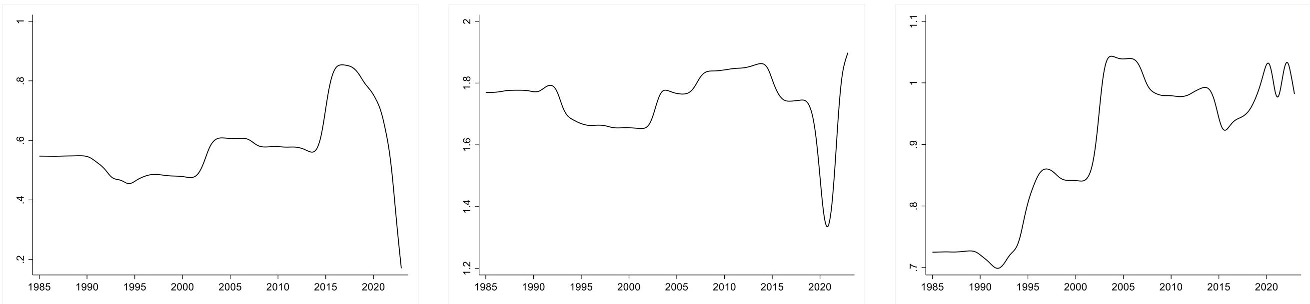
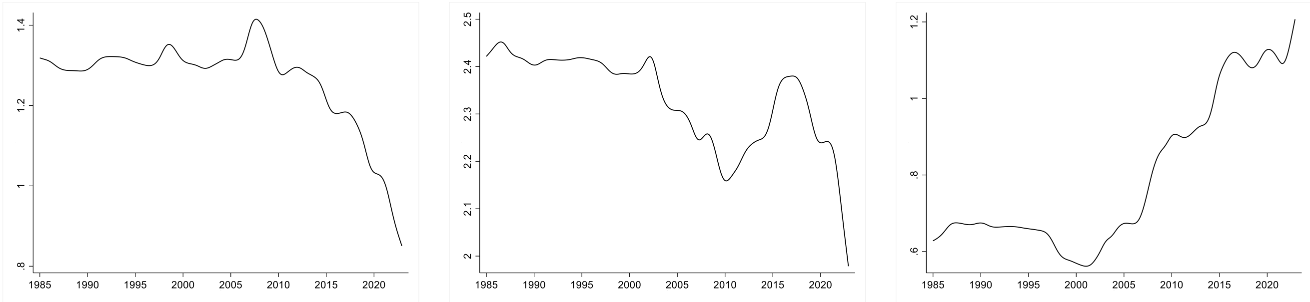


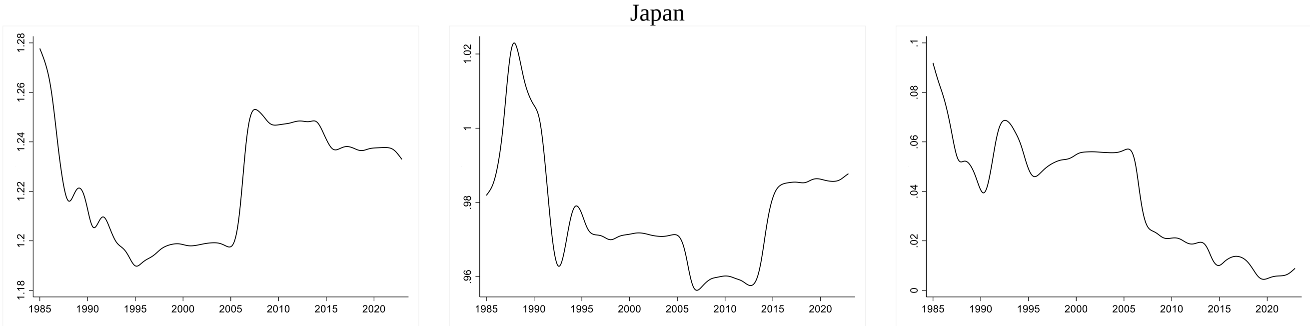
Figure 7 – Time-varying Standard Backward-looking Taylor Rule Parameters for Non-targeting Countries

$\bar{r}$ φ_{π} φ_{y}

US

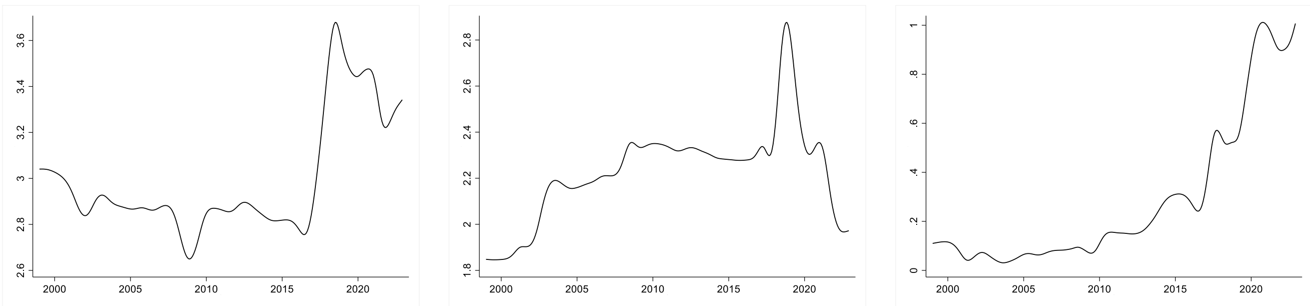


Japan



Denmark

Euro-Area



Switzerland

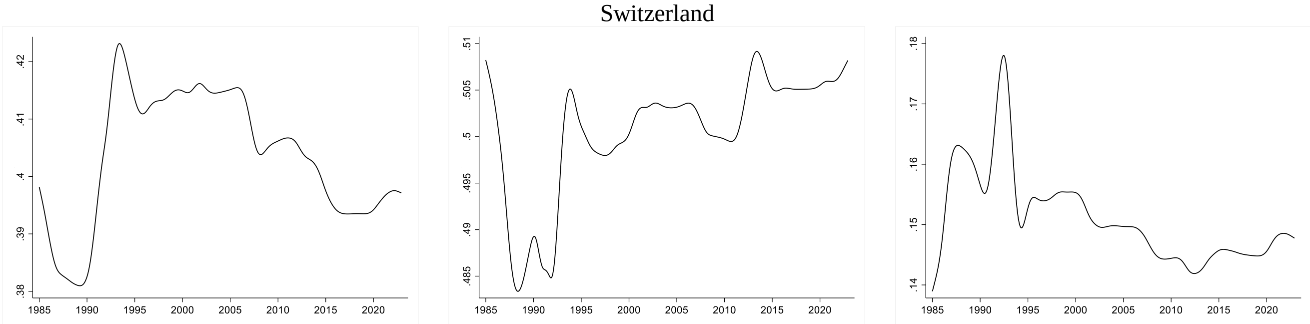


Figure 8 – Time-varying Augmented Backward-looking Taylor Rule Parameters for Inflation Targeting Countries

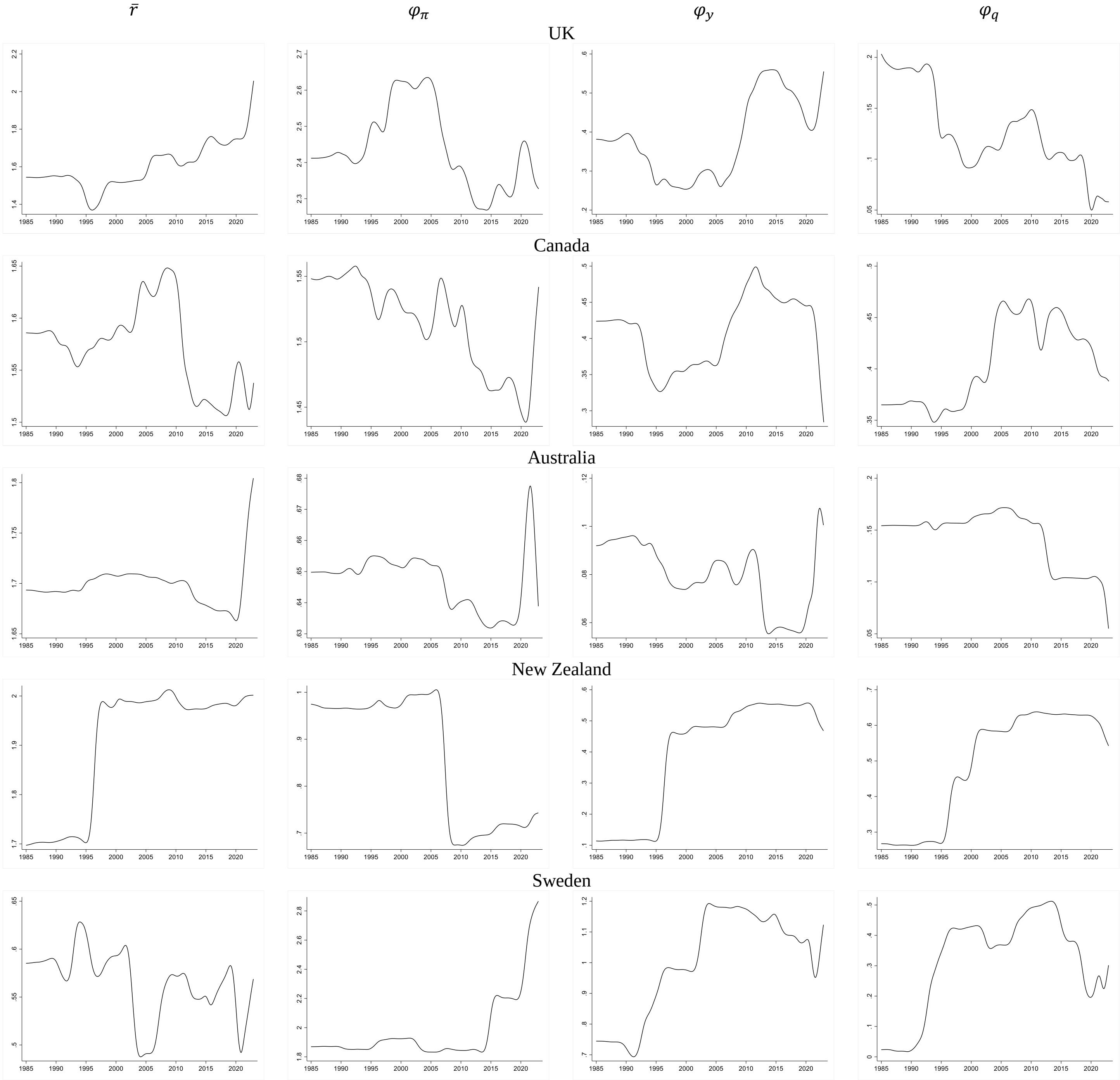
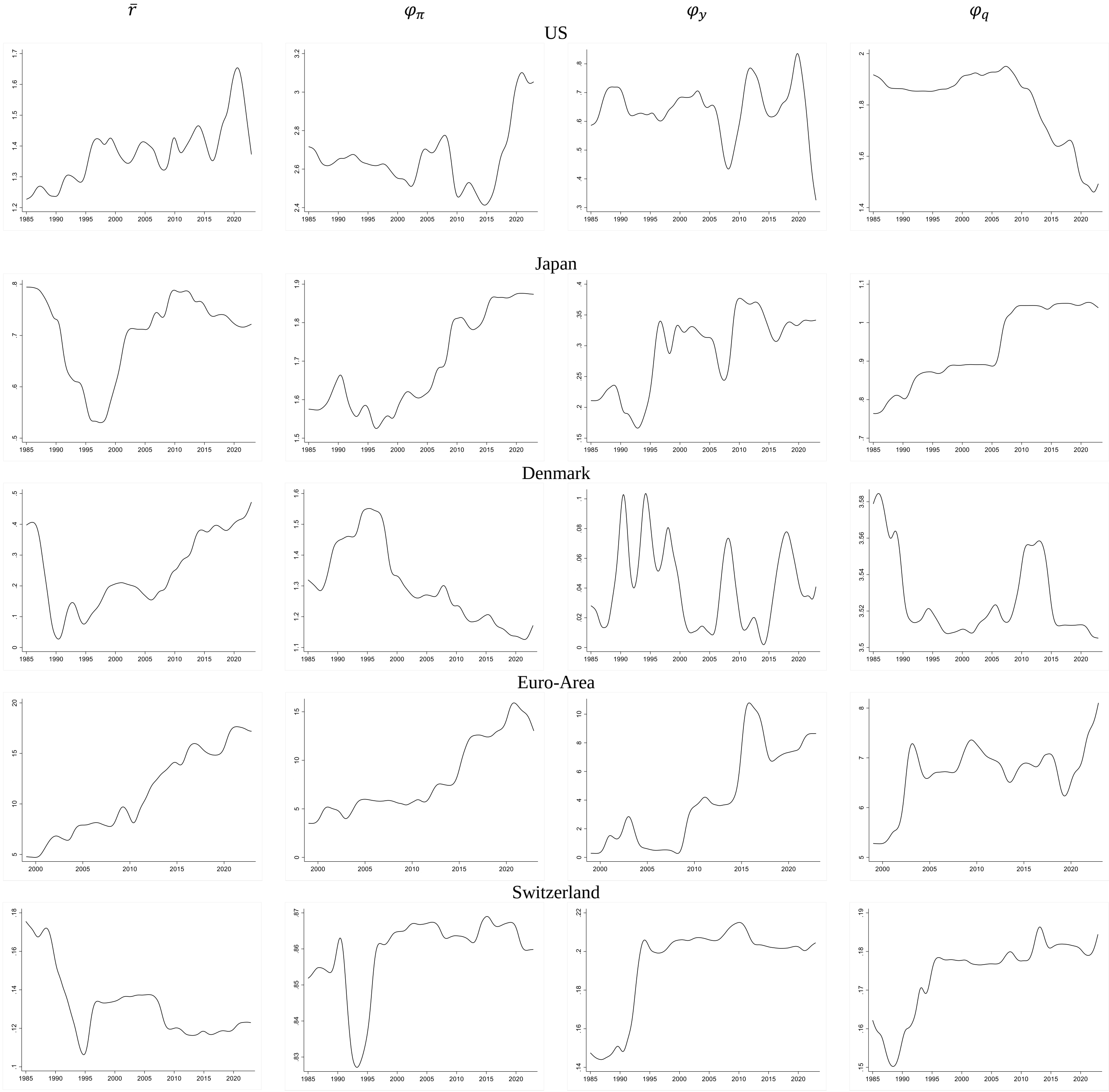


Figure 9 – Time-varying Augmented Backward-looking Taylor Rule Parameters for Non-targeting Countries



Although central banks are known to respond to anticipated inflation instead of past inflation, as a further robustness check we also estimate backward-looking Taylor rules by including the first lag of all variables. These additional results are reported in Figures 6 and 7 for the standard Taylor rules and in Figures 8 and 9 for the augmented one; compared to the forward-looking Taylor rules there are only slight differences in the inflation parameter estimates, particularly in non-targeting countries. The backward-looking rules seem to be less suitable to capture major shifts (such as the introduction of the inflation targeting regime) and display greater variation in the estimated Taylor rule parameters.

5. Conclusions

This paper assesses time variation in the monetary policy rules of inflation targeting countries (the UK, Canada, Australia, New Zealand and Sweden) and others with alternative monetary regimes but known to target inflation at times (the US, Japan, Denmark, the EuroArea and Switzerland). Initially, sub-period analysis was conducted using visual inspection as well as formal break tests to identify the break dates. Then, following Partouche (2007), a Time-Varying Parameter Generalised Methods of Moments (TVP-GMM) framework was applied to estimate time-varying parameters in forward-looking standard and augmented Taylor rules.

The results can be summarised as follows. First, monetary policy appears to have become more averse to inflation and more responsive to the output gap over time in both inflation targeting and non-targeting countries. In the former the shift to inflation targeting coincides with a sharp increase in the inflation coefficient in the Taylor rule. For both sets of countries, a sizeable shift occurred after the global financial crisis when monetary policy became more accommodating. Second, monetary policy has become more countercyclical in all countries over time, with an increased focus on stabilisation policies since the global financial crisis. Third, there seem to be differences between countries with strict inflation targeting mandates and those with discretionary monetary flexibility in terms of the extent to which the exchange rate pass-through channel for inflation is taken into account, the former set of countries paying greater attention to it. Fourth, the time-varying parameter framework is more informative than the sub-period analysis for detecting shifts in the parameters of the Taylor rule. Finally, monetary surprises do not seem to be an important determinant of their evolution over time, which suggests a high degree of monetary policy transparency in the countries under examination. On the whole, our findings provide extensive evidence that constant parameter Taylor rules cannot capture accurately the behaviour of monetary authorities. In particular, it is clear that, following the global financial crisis, central banks have started to put greater emphasis on inflation and output stabilisation, be they inflation targeters or not.

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Appendix A

Central Bank Announcements of Interest Rate Changes and Forecasts

(source: Bloomberg)

Country	Date	Central Bank Announcement	Market Forecast	Unexpected Element
United Kingdom	January 2009	2.00%	2.50%	-0.50
	July 2016	0.50%	0.25%	0.25
	March 2020	0.10%	0.75%	-0.65
	December 2021	0.25%	0.10%	0.15
Canada	February 2008	3.50%	3.75%	-0.25
	September 2008	2.50%	3.00%	-0.50
	October 2008	2.25%	2.00%	0.25
	November 2008	1.50%	1.75%	-0.25
	April 2009	0.25%	0.50%	-0.25
	April 2010	0.50%	0.25%	0.25
	June 2010	0.75%	0.50%	0.25
	July 2010	1.00%	0.75%	0.25
	December 2014	0.75%	1.00%	-0.25
	July 2015	0.50%	0.75%	-0.25
	October 2016	0.75%	0.50%	0.25
	July 2017	1.00%	0.75%	0.25
	November 2017	1.25%	1.00%	0.25
	May 2018	1.50%	1.25%	0.25
	August 2018	1.75%	1.50%	0.25
	July 2019	1.25%	1.75%	-0.50
	September 2019	0.75%	1.75%	-1.00
	October 2019	0.75%	0.75%	-0.50
	February 2020	0.25%	0.75%	-0.50
	January 2022	0.50%	0.25%	0.25
	February 2022	1.00%	0.50%	0.50
	April 2022	1.50%	1.00%	0.50
	June 2022	2.50%	2.25%	0.25
	October 2022	3.75%	4.00%	-0.25
Australia	October 2008	6.00%	6.50%	-0.50
	November 2008	5.25%	5.50%	-0.25
	December 2008	4.25%	4.75%	-0.50
	February 2009	3.25%	4.25%	-1.00
	March 2009	3.25%	3.00%	0.25
	April 2009	3.00%	2.75%	0.25
	October 2009	3.25%	3.00%	0.25
	February 2010	3.75%	4.00%	-0.25
	October 2010	4.50%	4.75%	-0.25
	November 2010	4.75%	4.50%	0.25
	November 2011	4.50%	4.75%	-0.25
	February 2012	4.25%	4.00%	0.25
	May 2012	3.75%	4.00%	-0.25
	June 2012	3.50%	3.75%	-0.25
	October 2012	3.25%	3.50%	-0.25
	November 2012	3.25%	3.00%	0.25
	May 2013	2.75%	3.00%	-0.25
	February 2015	2.25%	2.50%	-0.25
	March 2015	2.25%	2.00%	0.25
	May 2016	1.75%	2.00%	-0.25
	March 2020	0.50%	0.75%	-0.25

	May 2022	0.35%	0.25%	0.10
	June 2022	0.85%	0.60%	0.25
	October 2022	2.60%	2.85%	-0.25
New Zealand	July 2008	8.00%	8.25%	-0.25
	September 2008	7.50%	7.75%	-0.25
	January 2009	3.50%	4.00%	-0.50
	March 2009	3.00%	2.75%	0.25
	March 2011	2.50%	2.75%	-0.25
	June 2015	3.25%	3.50%	-0.25
	March 2016	2.25%	2.50%	-0.25
	August 2019	1.00%	1.25%	-0.25
	November 2019	1.00%	0.75%	0.25
	March 2020	0.25%	1.00%	-0.75
	August 2021	0.25%	0.50%	-0.25
	April 2022	1.50%	1.25%	0.25
Sweden	July 2010	0.50%	0.25%	0.25
	September 2010	0.75%	0.50%	0.25
	October 2010	1.00%	0.75%	0.25
	July 2011	2.00%	1.75%	0.25
	September 2012	1.25%	1.50%	-0.25
	February 2013	1.00%	0.75%	0.25
	July 2014	0.25%	0.50%	-.025
	October 2014	0.00%	0.10%	-0.10
	February 2015	-0.10%	0.00%	-0.10
	April 2015	-0.25%	-0.35%	-0.10
	July 2015	-0.35%	-0.25%	-0.10
	February 2016	-0.50%	-0.45%	-0.05
	December 2018	-0.25%	-0.50%	0.25
	December 2019	0.00%	-0.25%	0.25
	April 2022	0.25%	0.00%	0.25
	September 2022	1.75%	1.50%	0.25
United States	October 2008	1.50%	2.00%	-0.50
	December 2009	0.25%	0.50%	-0.25
	April 2020	1.25%	1.75%	-0.50
	June 2022	1.75%	1.50%	0.25
Japan	November 2008	3.75%	4.25%	-0.50
	January 2009	2.50%	2.75%	-0.25
	May 2009	1.25%	1.00%	0.25
	November 2011	1.25%	1.50%	-0.25
	November 2013	0.25%	0.50%	-0.25
	June 2014	0.15%	0.10%	0.05
	September 2014	0.05%	0.15%	-0.10
	March 2016	0.00%	0.05%	-0.05
	July 2022	0.50%	0.25%	0.25
Euro-Area	October 2008	3.75%	4.25%	-0.50
	December 2008	2.50%	2.75%	-0.25
	April 2009	1.25%	1.00%	0.25
	November 2011	1.25%	1.50%	-0.25
	November 2013	0.25%	0.50%	-0.25
	June 2014	0.15%	0.10%	0.05
	September 2014	0.05%	0.15%	-0.10
	March 2016	0.00%	0.05%	-0.05
	August 2022	0.50%	0.25%	0.25
Switzerland	December 2014	-0.25%	0.00%	-0.25
	January 2015	-0.75%	-0.25%	-0.50
	June 2022	-0.25%	-0.75%	0.50
	September 2022	0.50%	-0.25%	0.75
	December 2022	1.00%	0.50%	0.50

Appendix B

Policy shifts corresponding to the breaks identified through visual inspection

Country	Policy Shift I	Date	Policy Shift II	Date	Policy Shift III	Date
United Kingdom	Adoption of Inflation Targeting	October 1992	Move towards Zero Lower Bound	March 2009	End of Low Inflation Era	April 2021
Canada	Adoption of Inflation Targeting	February 1991	Move towards Zero Lower Bound	March 2009	End of Low Inflation Era	April 2021
Australia	Adoption of Inflation Targeting	June 1993	Utilisation of Unconventional Policies	March 2009	End of Low Inflation Era	April 2021
New Zealand	Adoption of Inflation Targeting	December 1989	Utilisation of Unconventional Policies	March 2009	End of Low Inflation Era	April 2021
Sweden	Adoption of Inflation Targeting	January 1993	Move towards Zero Lower Bound	March 2009	End of Low Inflation Era	April 2021
United States	End of Greenspan Era	February 2006	Start of Inflation Targeting	January 2012	End of Low Inflation Era	April 2021
Japan	Start of Higher Liquidity Era	July 1991	Start of Inflation Targeting	January 2013	End of Low Inflation Era	April 2021
Denmark	Start of Higher Liquidity Era	August 1993	Move towards Zero Lower Bound	November 2011	End of Low Inflation Era	April 2021
Euro-Area	-	-	Move towards Zero Lower Bound	October 2008	End of Low Inflation Era	April 2021
Switzerland	Medium-term inflation targeting	January 2000	Move towards Zero Lower Bound	October 2008	End of Low Inflation Era	April 2021
Several periods of changing monetary policies are not accounted for in the above, such as the ERM crisis and various exchange rate-related shocks.						

Appendix C

Break dates identified by means of the *supF* test

Country	Break Date I	Break Date II	Break Date III	Break Date IV	*supF* Test p-value
United Kingdom	January 1993	October 2001	April 2009	October 2016	0.0006***
Canada	May 1993	December 2001	May 2009	May 2017	0.0000***
Australia	July 1992	October 2011	April 2017		0.0000***
New Zealand	November 1991	March 2009	June 2017		0.0000***
Sweden	October 1996	April 2009	June 2017		0.0146**
United States	December 2001	February 2009	February 2016		0.0002***
Japan	June 1995	September 2009	March 2012		0.0000***
Denmark	March 1994	August 2003	December 2009	June 2015	0.0002***
Euro-Area	June 2009	January 2013	May 2016		0.0263**
Switzerland	December 1995	September 2009	March 2015		0.0002***

Appendix D

Figure D1 – Time-varying Standard Taylor Rule Parameters for Inflation Targeting Countries Including Unexpected Announcements

$\bar{r}$ φ_{π} φ_{y}

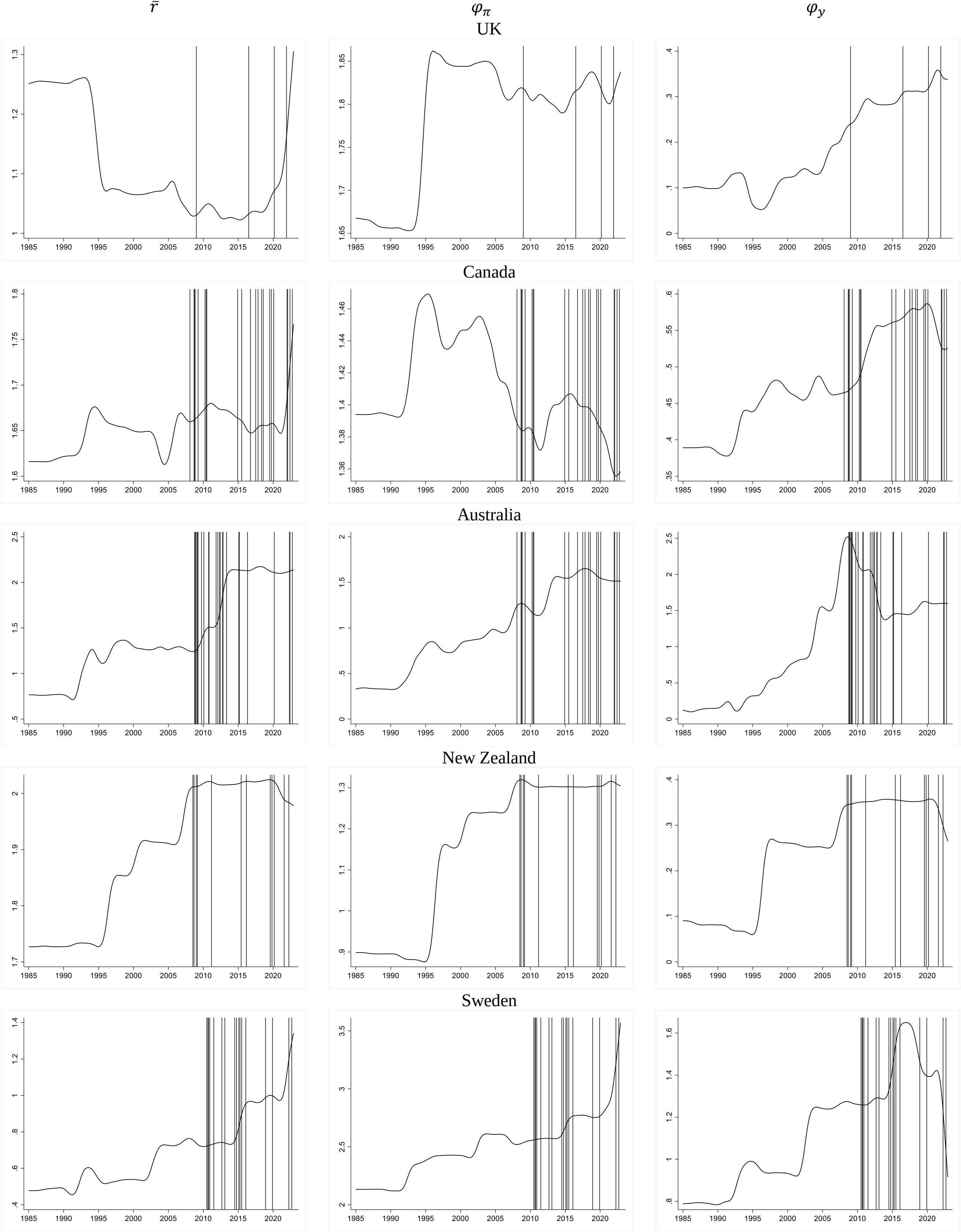


Figure D2 – Time-varying Standard Taylor Rule Parameters for Non-targeting Countries Including Unexpected Announcements

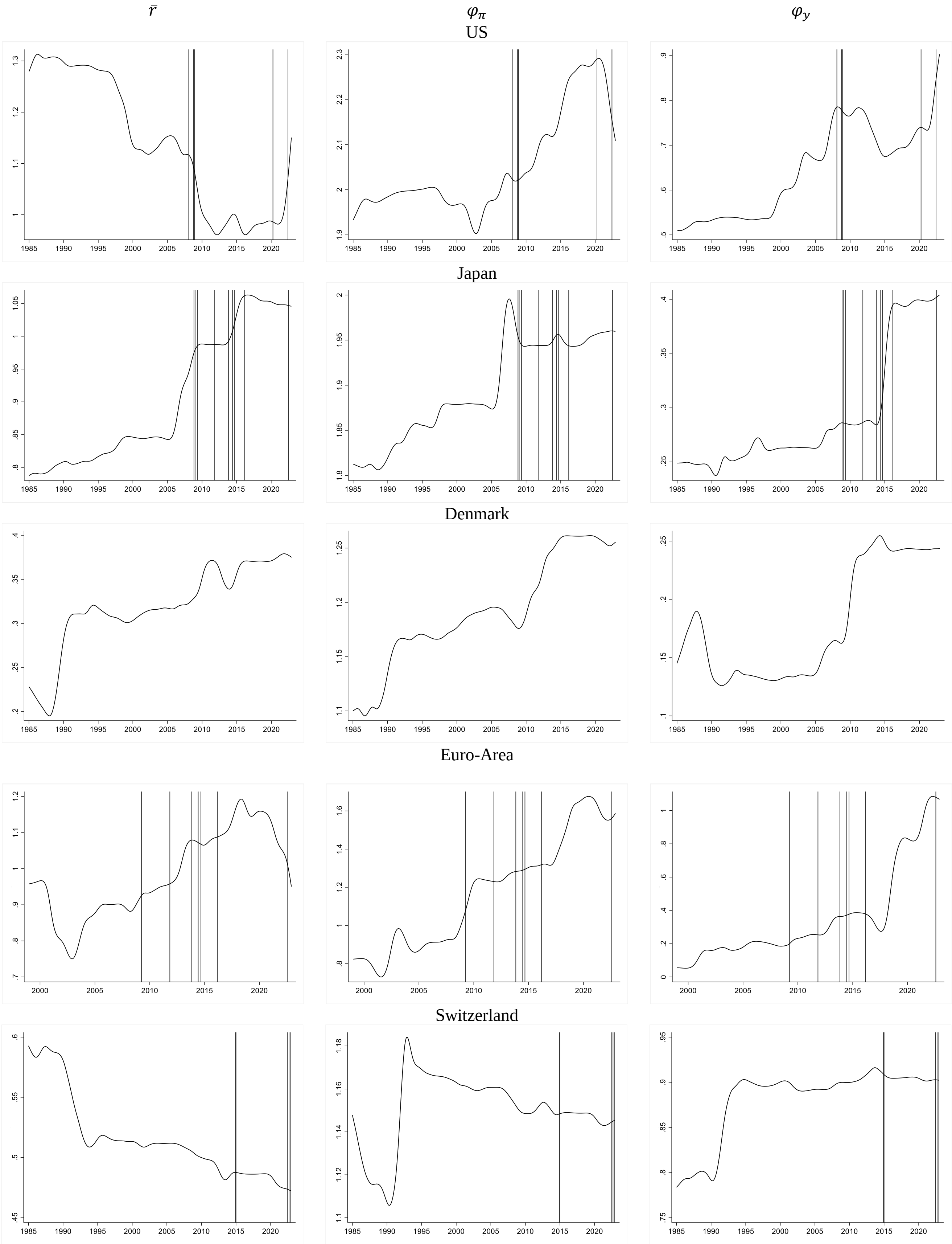
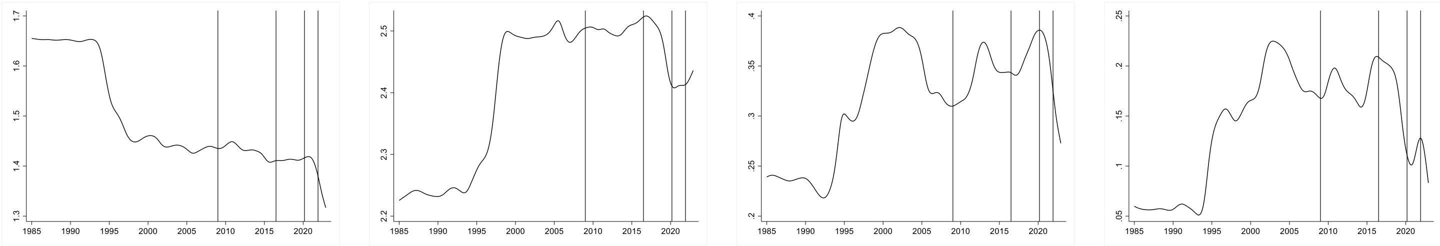


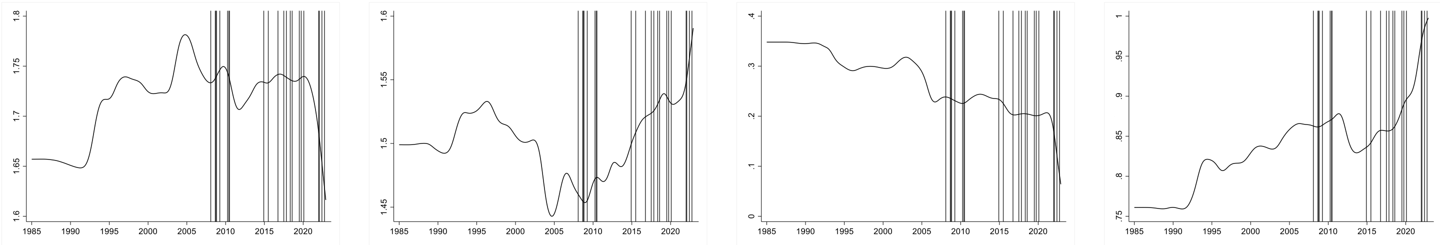
Figure D3 – Time-varying Augmented Taylor Rule Parameters for Inflation Targeting Countries Including Unexpected Announcements

$\bar{r}$ | φ_{π} | φ_{y} | φ_{q}

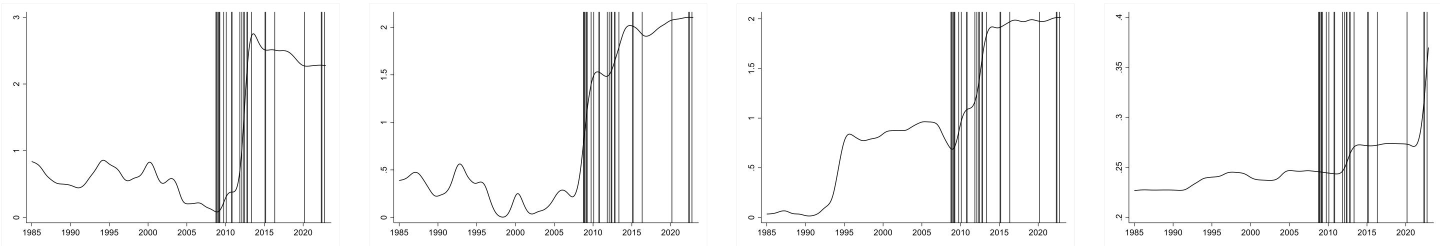
UK



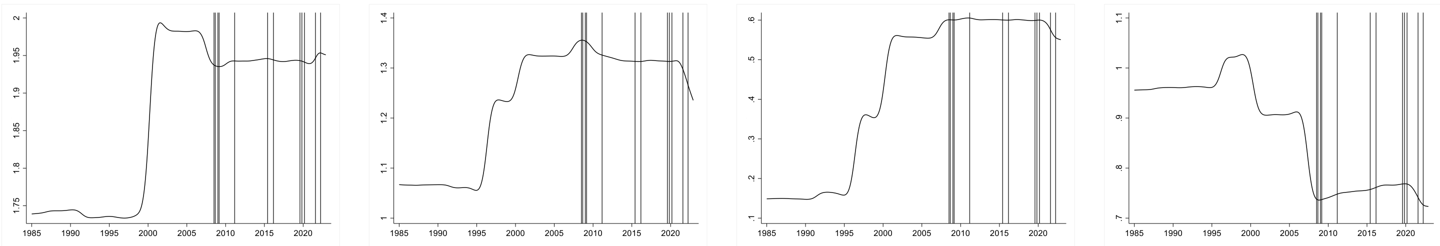
Canada



Australia



New Zealand



Sweden

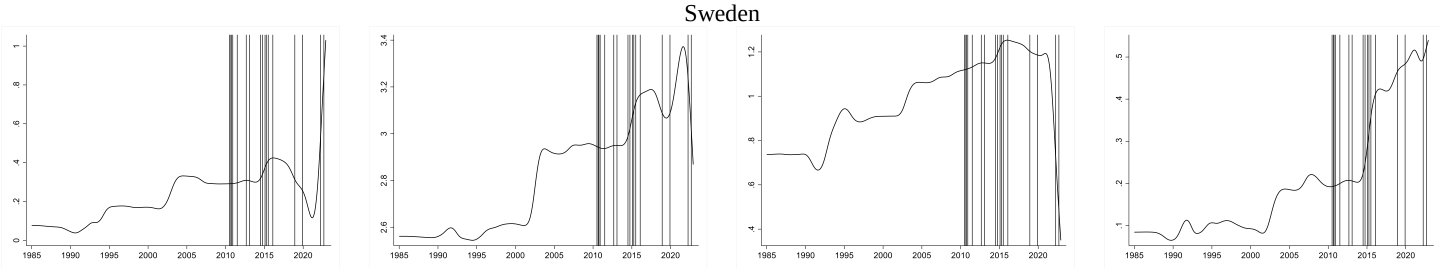
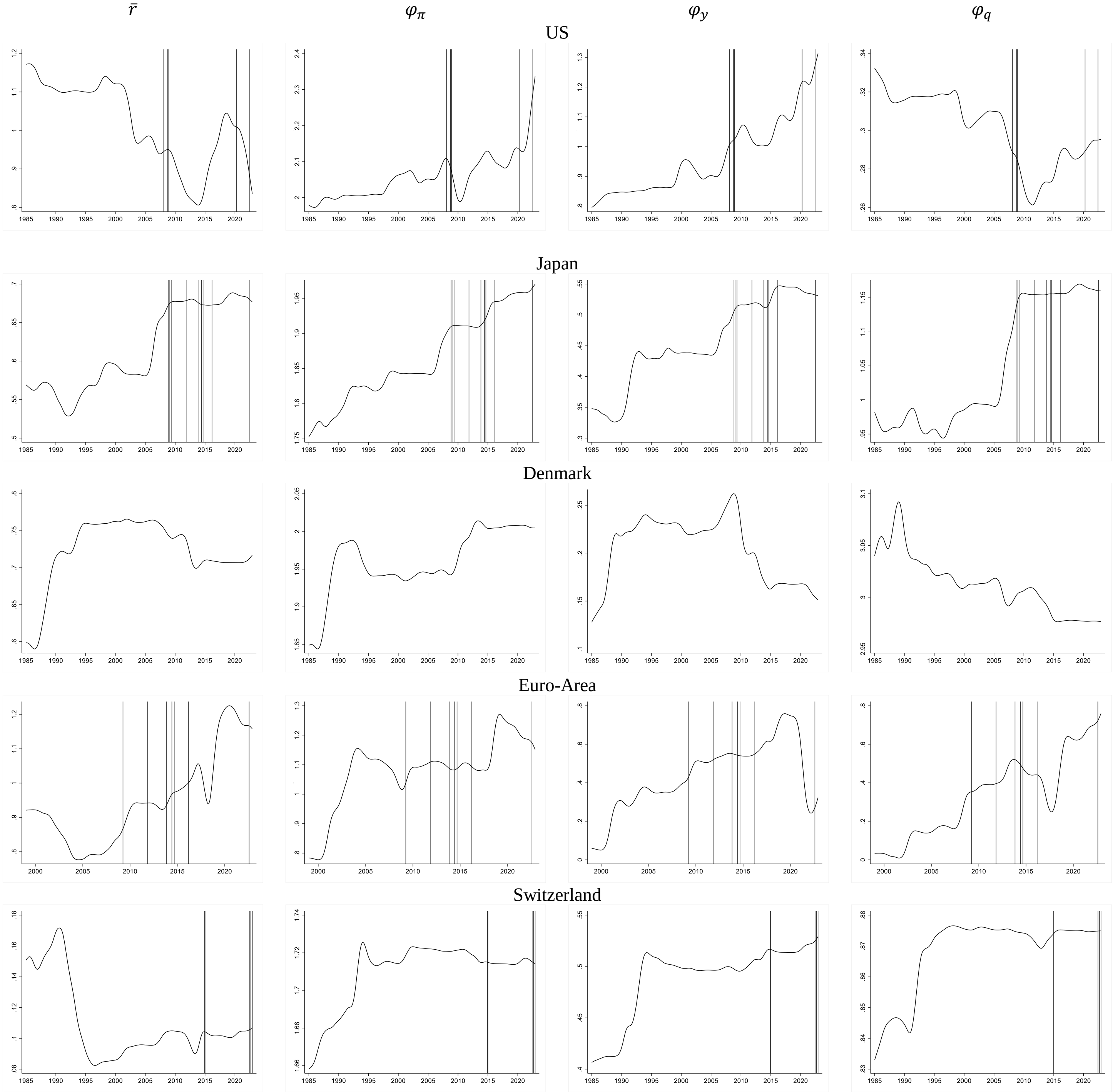


Figure D4 – Time-varying Augmented Taylor Rule Parameters for Non-targeting Countries Including Unexpected Announcements



Appendix E

Robustness with respect to $\bar{Q}$

Figure E1. Standard Taylor Rule Parameters in Inflation Targeting Countries

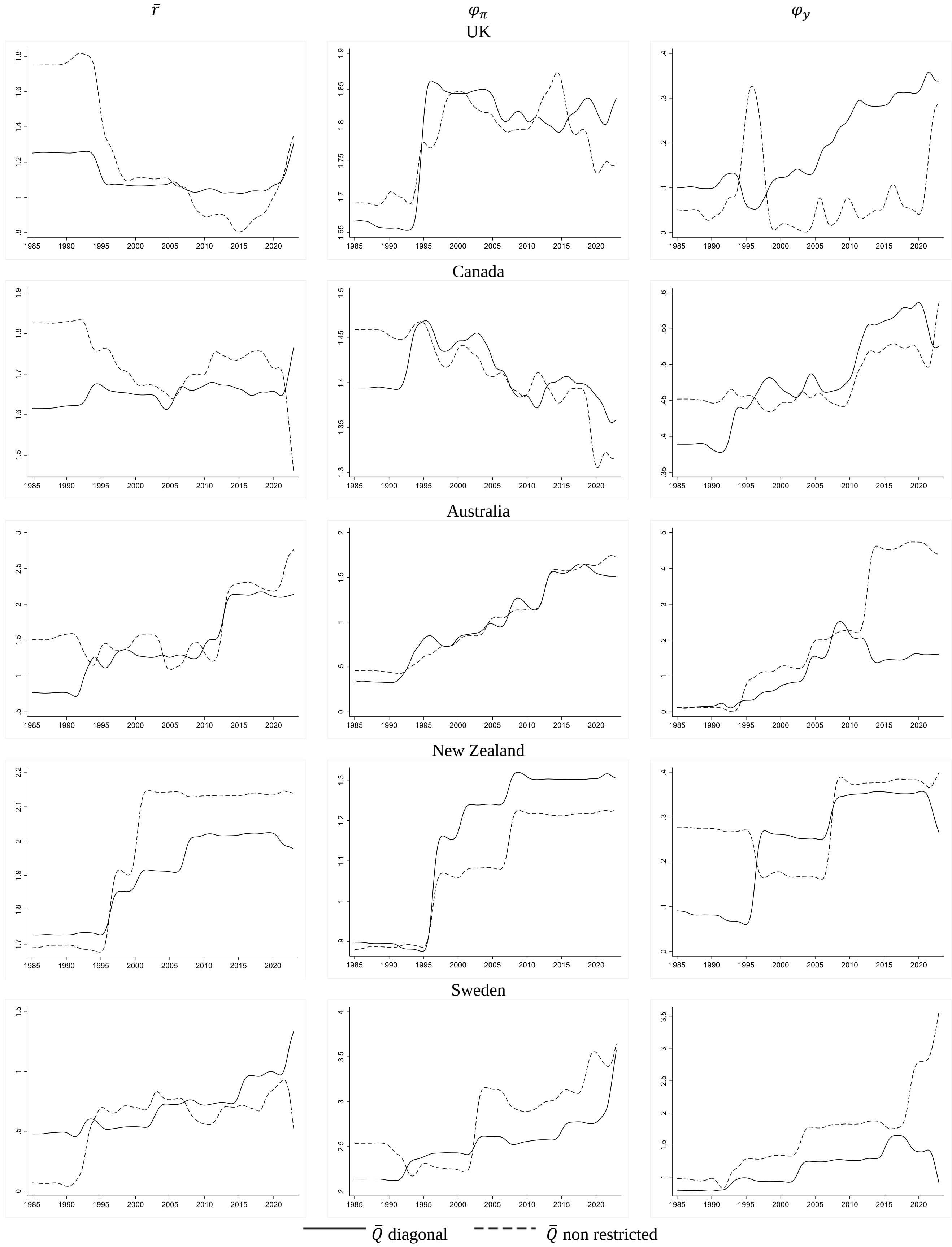


Figure E2. Standard Taylor Rule Parameters in Non-Targeting Countries

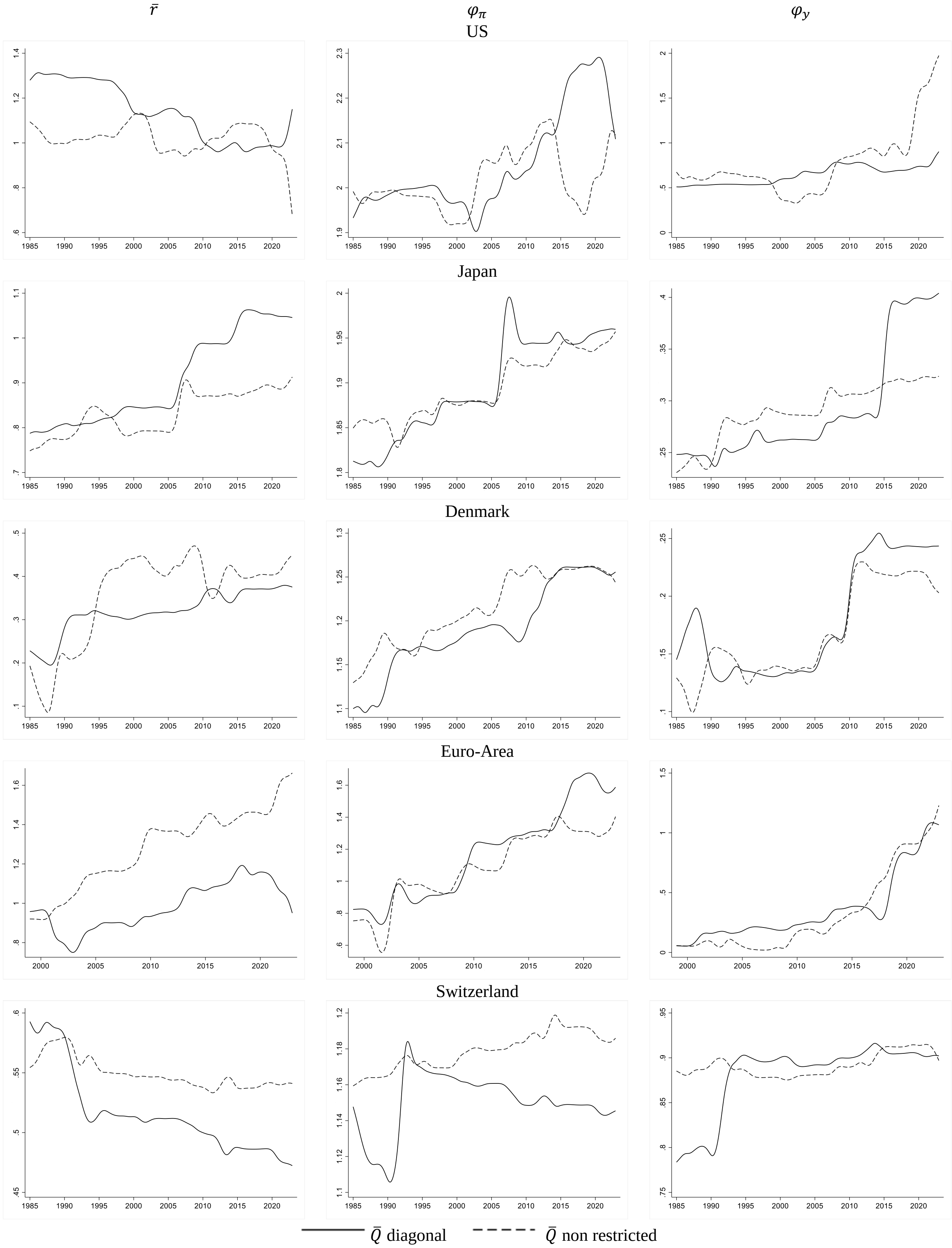


Figure E3 – Time-varying Augmented Backward-looking Taylor Rule Parameters for Inflation Targeting Countries

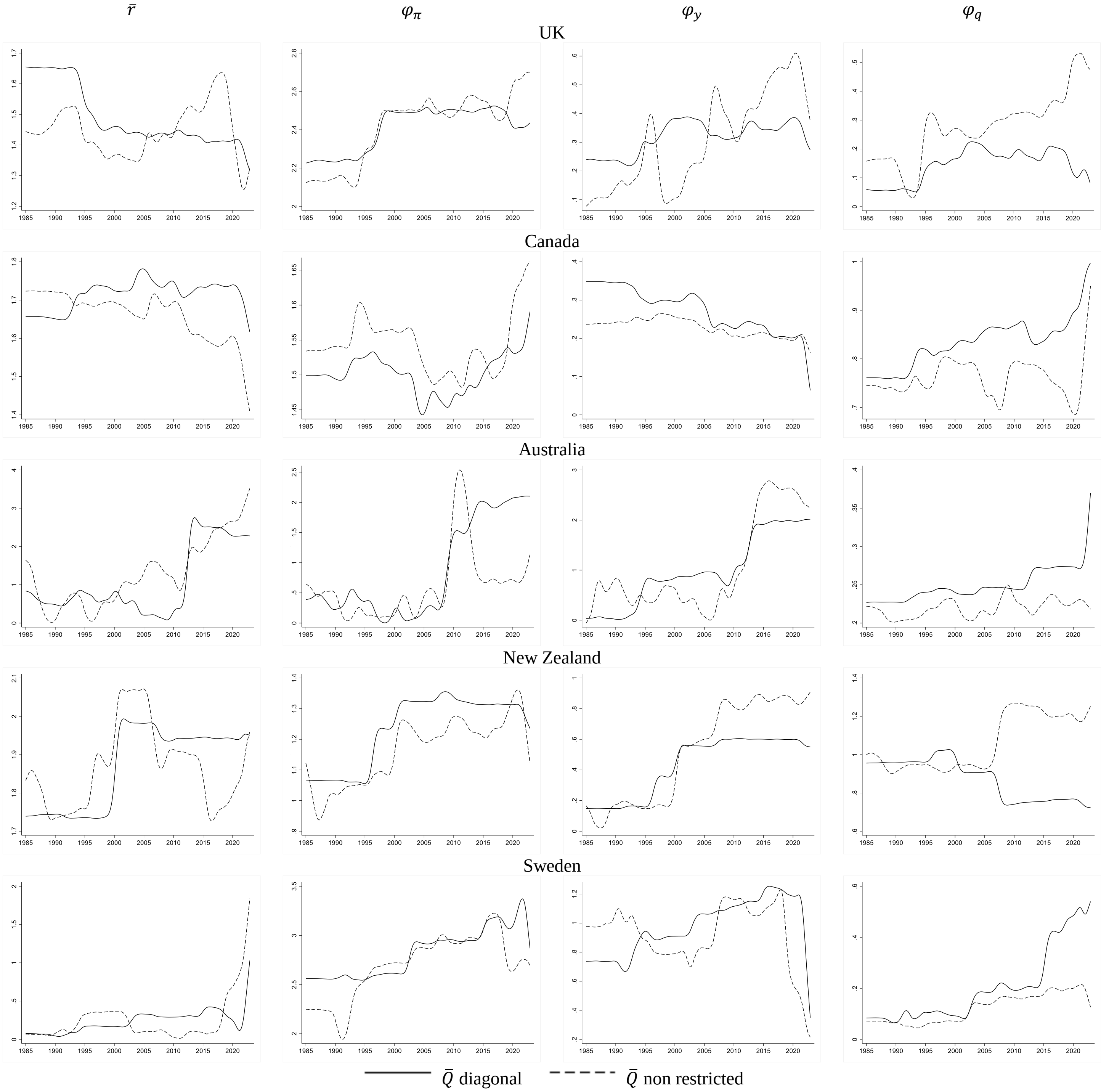


Figure E4 – Time-varying Augmented Backward-looking Taylor Rule Parameters for Non-targeting Countries