Metadata of the article that will be visualized in OnlineFirst

ArticleTitle	Monetary Policy is Not Always Systematic and Data-Driven: Evidence from the Yield Curve
Article Sub-Title	
Article CopyRight	Springer Science+Business Media, LLC, part of Springer Nature (This will be the copyright line in the final PDF)
Journal Name	Open Economies Review

Corresponding Author	FamilyName	**Bulíř**
	Particle	
	Given Name	**Aleš**
	Suffix	
	Division	
	Organization	International Monetary Fund
	Address	Washington, D.C., USA
	Phone	
	Fax	
	Email	abulir@imf.org
	URL	
	ORCID	http://orcid.org/0000-0002-2334-7176
Author	FamilyName	**Vlček**
	Particle	
	Given Name	**Jan**
	Suffix	
	Division	
	Organization	Czech National Bank
	Address	Prague, Czech Republic
	Phone	
	Fax	
	Email	janvlcekatcz@gmail.com
	URL	
	ORCID	

Schedule	Received	
	Revised	
	Accepted	24 Jan 2022

Abstract

Does monetary policy react systematically to macroeconomic innovations in emerging and low-income countries? And do such systematic responses vary across monetary policy regimes? In a sample of 16 countries – operating under various monetary regimes – we find that monetary policy decisions, as expressed in yield curve movements, do react to macroeconomic innovations in almost all countries. The speed and strength of reactions are not identical across all countries, however, but reflect the monetary policy regime. While we find evidence of the primacy of the price stability objective in inflation-targeting countries, the links to inflation and the output gap are generally weaker and less systematic in money-targeting and multiple-objective countries.

Keywords (separated by '-') Monetary policy - Yield curve - FAVAR - Monetary regimes

Footnote Information

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

Open Economies Review
https://doi.org/10.1007/s11079-022-09663-9

RESEARCH ARTICLE

Monetary Policy is Not Always Systematic and Data-Driven: Evidence from the Yield Curve

Aleš Bulíř[1] · **Jan Vlček**[2]

Accepted: 24 January 2022

Abstract

Does monetary policy react systematically to macroeconomic innovations in emerging and low-income countries? And do such systematic responses vary across monetary policy regimes? In a sample of 16 countries – operating under various monetary regimes – we find that monetary policy decisions, as expressed in yield curve movements, do react to macroeconomic innovations in almost all countries. The speed and strength of reactions are not identical across all countries, however, but reflect the monetary policy regime. While we find evidence of the primacy of the price stability objective in inflation-targeting countries, the links to inflation and the output gap are generally weaker and less systematic in money-targeting and multiple-objective countries.

Keywords Monetary policy · Yield curve · FAVAR · Monetary regimes

1 Introduction

We ask whether central banks adjust their policy rates in response to macroeconomic developments and what these adjustments signal about inflation expectations. Following Taylor (1993), Henderson and McKibbin (1993), McCallum (1994), economists think of the conduct of monetary policy as a systematic, rule-based response to information about key macroeconomic conditions, rather than as a period-by-period optimization problem. As summarized in both the "monetarist" and New Keynesian paradigms, central banks are expected to adjust their instruments so that the policy rate moves sufficiently strongly in response to variations in inflation and

✉ Aleš Bulíř
abulir@imf.org

Jan Vlček
janvlcekatcz@gmail.com

[1] International Monetary Fund, Washington, D.C., USA

[2] Czech National Bank, Prague, Czech Republic

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

output, with the primacy of inflation stabilization thought to be the first-best policy (Galí 2018).[1] Monetary tightening can result either in a vertical shift of the yield curve or in a movement in the short-term rate only, either flattening or steepening the yield curve. Most central banks have adopted, or are in the process of adopting, such frameworks. In addition, some central banks have also used the policy rate systematically to target a certain level or limit the variance of the exchange rate, in some cases supplemented with capital flow controls (Rey 2018; Frankel 2019). But do all central banks do what they say? And does the monetary regime play a role?

Assessing policymakers' reaction to the macroeconomic variables has been challenging. Central banks claim to stabilize the domestic and external value of the currency and smooth output, however, there is ample empirical evidence that they react to other variables as well. For example, asset prices were found to be highly relevant as instruments in policy reaction functions (Siklos and Bohl 2009). No central bank has systematically published its monetary policy reaction function and the intuitive focus on the policy rate may anyway lead to spurious results, as these can be disconnected from short-term interbank market, longer-term bond, and lending rates due to inefficient liquidity operations and the impact of movements in inflation expectations. The task of assessing the reaction function is more difficult in central banks that formally target monetary aggregates or pursue multiple objectives as policymaking in these institutions tends to depart from the stated reaction functions more easily than in, say, central banks pursuing inflation targeting.[2]

The textbook view of the term structure of interest rates, Mishkin (1995), suggests that monetary policy innovations result in level and slope shifts of the yield curve, with the relative passthrough to these two factors depending on whether inflation expectations are anchored or not. In countries where inflation expectations are anchored, monetary policy innovations are predominantly propagated through changes in the slope of the yield curve. Agents believe that the policy innovations are designed so as to return the rate of inflation to the target at the end of the monetary transmission period and, hence, policy tightening and loosening are seen as both credible and relatively short-lived events. Consequently, there is little need for an adjustment in long-run interest rates and most of the policy-related action happen along the short end of the yield curve through a flattening/steepening of its slope (the dashed line in Fig. 1).[3]

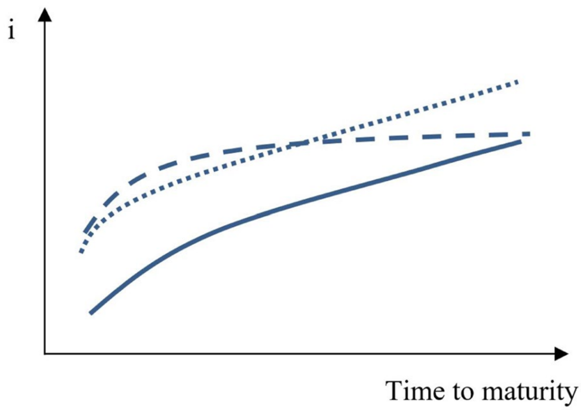
In contrast, in countries where (i) the commitment to price stability is weak; (ii) inflation expectations are linked to past inflation; (iii) or where actual inflation is volatile, agents do not know either the true inflation objective or the policy horizon, or

[1] Output stabilization is embedded both in interest rate and money targeting rules, such as the so-called Friedman and McCallum rules, see McCallum (1994). For a review of money targeting rules see Orphanides (2007) and IMF (2015).

[2] IMF (2015) in Appendix II argued that such deviations are not necessarily indicative of loose monetary conditions or inconsistent policies, but that the deviations typically reflect accommodation of money demand shocks.

[3] Following the term structure theory of interest rates, the long-term interest rate with a maturity of k months, i_t^k, is a function of all expected future policy rates. Hence, $i_t^k = i_t^{MP} + \sum_{i=1}^{k} \frac{E_t i_{t+i}^{MP}}{k} + tprem$, where i_t^{MP} is the policy rate with a monthly maturity and *tprem* is a time premium. Using the Fisher definition of the real interest rate, the equation can be rewritten as $i_t^k = i_t^{MP} + \sum_{i=1}^{k} \frac{\bar{r} + E_t \pi_{t+i}}{k} + tprem$, where π stands for inflation and $\bar{r}$ for the natural rate of interest.

Fig. 1 Policy Innovations Under Alternative Inflation Expectations. Notes: The figure draws a hypothetical yield curve (the full line) and its reaction to policy tightening under anchored inflation expectations (the dashed line) reflected in a flatter yield curve, and under unanchored inflation expectations (the dotted line) reflected in a vertically-shifted yield curve



both. They tend to see policy innovations as possibly long-lasting events that necessitate a vertical shift of the yield curve (the dotted line in Fig. 1), moving both short and long rates in tandem. Hence, a dominant link between inflation and the first factor – the level – is a good indicator of unanchored inflation expectations, and conversely a dominant link between inflation and the second factor indicates anchored expectations. AQ2

We explore the adherence to data-based and systematic (rule-based) monetary policy by comparing key macroeconomic innovations with shifts in the yield curve in emerging market countries (EMCs) and low-income countries (LICs), with a set of advanced countries (ACs) used as a benchmark. First, we estimate the level and slope shifts of yield curves using the Christensen et al. (2008) methodology. Second, we estimate two-step, country-specific factor-augmented vector autoregressions (FAVAR) with the latent factors and relevant macroeconomic variables, such as inflation, the output gap, and the real exchange rate gap (Bernanke et al. 2005). Finally, we calculate the pass-through from the macroeconomic variables to the latent factors – level and slope shifts.

The link between yield curve factors and macroeconomics variables has been explored in the literature for advanced countries. However, our paper differs from the existing literature in terms of its objective and countries covered. First, our primary objective is the inference of systematic monetary policy response to macroeconomic developments. Second, we focus on emerging and low-income countries that have been largely ignored in the monetary transmission literature. Our approach broadly follows Ang et al. (2011) and Diebold et al. (2006). Ang et al. (2011) focus on the U.S. Fed and identify changes in monetary policy conduct over history using the term structure of yields. In order to identify changes, parameters in their model are considered as time varying. Our paper assumes constant parameters as the sample is too short to identify any dynamics in monetary policy responses to macro variables.

The focus of our paper is on systematic monetary policy response to macroeconomic developments in countries that have been less explored in the empirical literature (Diebold et al. 2006 use U.S. data.). While robust monetary transmission and well-established policy reaction functions have been the staple of literature dealing with advanced countries, there has been much doubt that these relationships hold in EMCs and LICs (Bulíř and Vlček 2021 list several such references). The key added value of the paper is the empirical result confirming adherence to the systematic (rule-based) policy paradigm in a broad range of monetary policy regimes and in countries that are at different stages of economic developments. We find that inflation and the output and real exchange rate gaps coincide with or precede, policy changes and are correlated with them. Or, to put it differently, we find that monetary policy in the sample institutions is generally predictable and data-driven. Furthermore, finding a link between macroeconomic developments and the slope factor could be an indication of anchored inflation expectations.

The results are nevertheless regime-dependent. The three advanced inflation-targeting central banks in our sample are found to react systematically to inflation and output innovations, with the reactions showing as both level and slope changes. Our findings are also broadly similar for evolving inflation-targeting countries, although the links to latent factors are somewhat less systematic and these countries pay attention to their exchange rate developments as well. Surprisingly, we find little evidence that inflation expectations are better anchored in advanced than in evolving inflation-targeting countries – the share of reactions through the level and slope factors is similar. The story is different for central banks that either target monetary aggregates or follow multiple objectives: interest rate setting appears to be only weakly related to the key macroeconomic variables.

In the remainder of the paper we proceed as follows. First, we outline our methodology. Second, we describe our sample. Third, we present our results and discuss robustness checks. Fourth, we sketch policy implications. The final section concludes. Data and estimates of the latent factors are presented in the Appendix 1 and the FAVAR setup is outlined in Appendix 2.

2 Methodology and Hypotheses

Following Ang and Piazzesi (2003) we focus on the whole yield curve, distinguishing between its level and slope shifts. To obtain estimates of these latent factors, we apply the Christensen et al. (2008), or CDR methodology, an arbitrage-free generalized representation of the Nelson-Siegel yield curve model. Following CDR, the yield at time t of a bond with maturity τ, $y_t(\tau)$, is defined as:

$$y_t(\tau) = \beta_{1t} + \beta^1_{2t}\left(\frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau}\right) + \beta^2_{2t}\left(\frac{1-e^{-\lambda_2\tau}}{\lambda_2\tau}\right) + \\ + \beta^1_{3t}\left(\frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau} - e^{-\lambda_1\tau}\right) + \beta^2_{3t}\left(\frac{1-e^{-\lambda_2\tau}}{\lambda_2\tau} - e^{-\lambda_2\tau}\right), \tag{1}$$

where β^1_{2t} and β^2_{2t} are two time-varying slope factors, and β^1_{3t} and β^2_{3t} are two time varying curvature factors. The slope and curvature factors differ in their λ parameters, when λ_1 is set to 0.85 and λ_2 set to 0.1, implying that the first and second curvature factors peak near to the 2-year maturity and 15-year maturity, respectively. Such a calibration matches the two most frequent sample maturities, namely the short end of the yield curve between than 1 and 2 years and the long end at around 15 years .

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

In order to identify unobserved time-varying parameters, we transformed the model to a state-space form. The transition equations driving the dynamics of yields are:

$$\begin{bmatrix} y_t(\tau_1) \\ y_t(\tau_2) \\ \vdots \\ y_t(\tau_N) \end{bmatrix} = A \begin{bmatrix} \beta_{1t} \\ \beta_{2t}^1 \\ \beta_{2t}^2 \\ \beta_{3t}^1 \\ \beta_{3t}^2 \end{bmatrix} + \begin{bmatrix} \varepsilon_t(\tau_1) \\ \varepsilon_t(\tau_2) \\ \vdots \\ \varepsilon_t(\tau_N) \end{bmatrix}, \tag{2}$$

where

$$A = \begin{bmatrix} 1 & \frac{1-e^{-\lambda_1\tau_1}}{\lambda_1\tau_1} & \frac{1-e^{-\lambda_2\tau_1}}{\lambda_2\tau_1} & \frac{1-e^{-\lambda_1\tau_1}}{\lambda_1\tau_1} - e^{-\lambda_1\tau_1} & \frac{1-e^{-\lambda_2\tau_1}}{\lambda_2\tau_1} - e^{-\lambda_2\tau_1} \\ 1 & \frac{1-e^{-\lambda_1\tau_2}}{\lambda_1\tau_2} & \frac{1-e^{-\lambda_2\tau_2}}{\lambda_2\tau_2} & \frac{1-e^{-\lambda_1\tau_2}}{\lambda_1\tau_2} - e^{-\lambda_1\tau_2} & \frac{1-e^{-\lambda_2\tau_2}}{\lambda_2\tau_2} - e^{-\lambda_2\tau_2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & \frac{1-e^{-\lambda_1\tau_N}}{\lambda_1\tau_N} & \frac{1-e^{-\lambda_2\tau_N}}{\lambda_2\tau_N} & \frac{1-e^{-\lambda_1\tau_N}}{\lambda_1\tau_N} - e^{-\lambda_1\tau_N} & \frac{1-e^{-\lambda_2\tau_N}}{\lambda_2\tau_N} - e^{-\lambda_2\tau_N} \end{bmatrix}. \tag{3}$$

The factors, β_i, are assumed to be random-walk processes:

$$\begin{bmatrix} \beta_{1t} \\ \beta_{2t}^1 \\ \beta_{2t}^2 \\ \beta_{3t}^1 \\ \beta_{3t}^2 \end{bmatrix} = \begin{bmatrix} \beta_{1t-1} \\ \beta_{2t-1}^1 \\ \beta_{2t-1}^2 \\ \beta_{3t-1}^1 \\ \beta_{3t-1}^2 \end{bmatrix} + \begin{bmatrix} \eta_{1t} \\ \eta_{2t} \\ \eta_{3t} \\ \eta_{4t} \\ \eta_{5t} \end{bmatrix}, \tag{4}$$

where ε and η are white-noise shocks with zero means and covariance matrices Q and H:

$$\begin{pmatrix} \varepsilon_t \\ \eta_t \end{pmatrix} \backsim WN\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} Q & 0 \\ 0 & H \end{pmatrix}\right].$$

The measurement equations then link the observed yields with the state variables assuming no measurement errors:

$$\begin{bmatrix} y_t(\tau_1) \\ y_t(\tau_2) \\ \vdots \\ y_t(\tau_N) \end{bmatrix} = \begin{bmatrix} y_t^{obs}(\tau_1) \\ y_t^{obs}(\tau_2) \\ \vdots \\ y_t^{obs}(\tau_N) \end{bmatrix}. \tag{5}$$

The above mentioned framework modifies the CDR in three respects, without losing its arbitrage-free advantage. First, we reduce the number of estimated parameters imposing the random walk for the latent factors instead of autoregressive processes. Second, we do not allow for cross-factor dynamics and correlations. These modifications follow Diebold et al. (2006), who found the yield curve factors to be highly persistent with insignificant cross-factor dynamics. We define the comprehensive slope β_{2t} as a sum of partial slope estimates, that is, $\beta_{2t} = \beta_{2t}^1 + \beta_{2t}^2$; similarly for the curvature β_{3t}, to make the the level and the slope of yield curve usable in the FAVAR analysis. Finally, we match the state-space model with the monthly

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

yields using the Kalman filter. For each country we estimate matrices Q and H using the Bayesian estimation techniques with the inverse-gamma distribution of priors.

In the previous step we extracted the yield curve factors and in the second step we estimate the FAVAR models to observe the endogenous dynamics of the system. The FAVAR models encompass inflation, the output gap, the real exchange rate gap, and the yield curve level ans slope. In addition to the endogenous variables, we employ the VIX index and world oil prices as exogenous factors. The rule-based, data-driven policy paradigm defines the expected reactions of policy rates and various short- and long-term interest rates to current and future macroeconomic developments.[4] A positive and unexpected inflation increase requires policy tightening through a hike in the short-term rate, resulting in either an upward level shift of the yield curve, or a flatter yield curve, or a combination of the two. This policy reaction is certainly true for demand-driven inflationary developments. Arguably, advanced inflation targeters tend to ignore short-lived supply-driven inflation shocks and react only to the second-round effects thereof. Hence, for both demand and supply shocks, we would expect to find a positive correlation between inflation and the first latent factor, a negative correlation between inflation and the second latent factor, or both correlations simultaneously. In principle, the expected correlation of inflation with yield curve factors should be higher with demand shocks than with supply shocks, however, we leave the empirical testing of this hypothesis to further research.

Positive demand shocks as drivers of the output gap also imply higher interest rates to prevent future inflation. If the central bank additionally uses the interest rate to manage the exchange rate, following depreciation one should again observe policy tightening. By expressing the exchange rate in domestic currency terms, a positive first difference is equivalent to currency depreciation. Furthermore, in countries with managed floats one would expect to find an over-sized importance of the link from the exchange rate to the yield curve, as the exchange rate developments effectively capture and accumulate all other shocks.

We test the expected policy reaction using FAVAR-based impulse responses. To this end, we check the sequencing between the observed developments in the macroeconomic variables and policy responses by observing the relevant impulse response in the FAVAR framework (Appendix 2). We interpret the FAVAR equations as quasi policy reaction functions that tell us how does the yield curve moves in response to macroeconomic innovations, controlling for the global financial and business cycles. We prefer the qualitative assessment for two reasons. First, there is no obvious way of aggregating the level and slope shifts into a summary policy rate term in an explicit reaction function of the Taylor (1993) type as in Ang et al. (2011). Second, given the wide confidence bands in the FAVAR regressions, point estimates for the output and inflation gaps would give a false sense of precision.

[4] The authorities may not have the correct macroeconomic data at the time of the decision, of course. U.S. Fed real-time policy recommendations differ considerably from those obtained with ex post revised data (Orphanides 2001). The magnitude of the informational problems is likely to be larger in emerging and low-income countries. It is generally accepted that there have been important changes in the conduct of monetary policy after the Great Inflation episode (Clarida et al. 2000).

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

3 Data Issues

Identification of the latent factors in emerging market countries (EMCs) and low-income countries (LICs) carries unique challenges. Government securities are less frequently traded on secondary markets; primary issue data often contain gaps; some central banks provide liquidity at rates different from the policy rates; and so on. Ideally, we would have liked to estimate zero-coupon yield equivalents for bonds with coupons, but these are regularly available for advanced countries only, and estimation thereof for EMCs and LICs is hindered by a lack of benchmark issues. Furthermore, interest rate series in all countries have unit roots attributable to their disinflationary, or in some cases inflationary, periods that are difficult to remove. The quality of national account data varies as well.

3.1 Sample Countries

We are primarily interested in testing the data-driven and rule-based policy paradigm in EMCs and LICs and in the widest possible range of monetary regimes, as opposed to re-examining data-rich U.S. or other advanced countries. Our macroeconomically and regime-diverse sample contains 16 countries and the country selection is driven primarily by yield data availability, with the length of the country series ranging from seven years (Rwanda) to 24 years (Sweden), see Table 1. Such sample periods are shorter than that used by Ang et al. (2011), however, we see this as an advantage of sort: we don't need to worry much about regime switches and time-varying loading coefficients.

Our diverse sample contains seven emerging market countries (EMCs): Egypt (EGY), Georgia (GEO), Indonesia (IDN), Malaysia (MYS), Morocco (MAR), South Africa (ZAF), and Turkey (TUR). The six low-income countries (LICs) are Ghana (GHA), Kenya (KEN), Nigeria (NGA), Rwanda (RWA), Tanzania (TZA) and Uganda (UGA). The control group of three small open and advanced countries (ACs) as per the IMF classification comprises the Czech Republic (CZE), Israel (ISR), and Sweden (SWE). The ACs all practice inflation-forecast targeting (Svensson 1997), and five out of the 11 countries in the EMC/LIC group are identified as inflation targeters as well. All inflation targeters' currencies either float freely or within a float-like arrangements as noted in IMF's AREAER database (IMF 2019). Non-IT countries' currencies either float or, in addition to the managed exchange rate regimes, they put in place restrictions on movement of capital, thus enabling central banks to sterilize their exchange rate interventions and steer domestic interest rates (for the Chinn-Ito index see IMF 2019). Most of non-IT countries pursue multiple policy objectives (IMF 2015). We purposefully avoid examining countries with large-scale unconventional monetary policy (Japan) or members of a currency union (Euro area) as these circumstances are likely to affect movements of the yield curve.[5]

[5] While some of the ACs in our sample briefly experimented with unconventional monetary policy, none of them employed them for extended period of time to affect our results significantly. For example, the Swedish Riksbank was for a while "leaning against the wind", however, the central bank abandoned this policy as soon as it conflicted with credibility of its inflation target. The Czech National Bank during 2014–2017 prevented the domestic currency from appreciating above a certain threshold, but this policy was abandoned when the deflationary pressures subsided.

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

Table 1 Sample Stylized Facts

Country	De jure MP regime	Inflation, in percent	Interbank rate, in percent	Per capita GDP, PPP US$ in 2017	Sample
Czech Republic (CZE)	Inflation targeting, advanced	2.1	1.8	36,915	2000M4–2018M3
Israel (ISR)	Inflation targeting, advanced	1.6	1.3	38,412	2008M1–2018M6
Sweden (SWE)	Inflation targeting, advanced	1.2	2.6	50,069	1994M6–2018M6
Georgia (GEO)	Inflation targeting	3.4	6.2	10,698	2010M9–2018M4
Ghana (GHA)	Inflation targeting	12.7	18.0	4,641	2007M1–2018M4
Indonesia (IDN)	Inflation targeting	6.2	7.6	12,283	2005M7–2018M6
South Africa (ZAF)	Inflation targeting	5.5	8.1	13,497	1999M12–2018M6
Turkey (TUR)	Inflation targeting	8.5	11.3	27,916	2007M6–2018M6
Uganda (UGA)	Monetary aggregate targeting until 2010, inflation targeting thereafter	6.7	11.0	1,863	2005M1–2018M6
Egypt (EGY)	Multiple objectives	6.6	9.2	11,582	2006M7–2015M4
Malaysia (MYS)	Multiple objectives	2.5	3.0	29,431	2008M1–2018M5
Kenya (KEN)	Monetary-aggregate targeting	8.9	7.4	3,285	2007M1–2018M5
Morocco (MAR)	Peg with closed capital account/multiple objectives	1.5	3.0	8,217	2008M1–2018M6
Nigeria (NGA)	Monetary aggregate targeting	10.6	12.0	5,860	2006M9–2018M6
Rwanda (RWA)	Monetary-aggregate targeting	4.0	6.5	2,035	2012M1–2018M6
Tanzania (TZA)	Monetary-aggregate targeting	7.4	7.4	1,384	2003M1–2018M5

Source: National databases; *International Financial Statistics (IFS)* and *Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER)* databases (IMF 2019)

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

3.2 Macroeconomic Developments

The data for headline inflation, real GDP, and the exchange rate are either from the Haver databases or from national databases (see Appendix 1, Figs. 2, 3, 4, and 5; left-hand column). The CPI and exchange rate series are collected at monthly frequency and the rate of inflation and the rate of depreciation are calculated as the quarterly average of the year-on-year log-difference. Nonstationarity of the inflation series is removed by applying the Hodrick-Prescott filter with the usual smoothing coefficient for monthly data.[6] The output and real exchange rate gaps are calculated by taking logs of quarterly real GDP and the CPI-based real exchange rate, applying the Hodrick-Prescott filter ($\lambda = 1,600$), and subtracting the trends, hence obtaining approximations of the gaps in percent of the trend values.

3.3 The Yield Curve

Only advanced and some emerging market central banks use the policy rate as an effective rate for liquidity operations – most LICs have occasionally provided liquidity at rates different from their official policy rates (Berg et al. 2013; IMF 2015). Hence, we use the de jure policy rate only if the bank has used it consistently as a policy instrument and the interbank rates have been close to the central bank rate, otherwise we use the shortest maturity as the de facto policy rate. For maturities beyond 3 months, we occasionally have to rely on yields at issue on the primary market, as secondary markets are either nonexistent or illiquid. In turn, the primary market yields may be subject to non-market forces, as short maturities are used by the central bank for managing market liquidity, and demand for longer tenors is affected by regulatory measures targeting the capital and liquidity ratios of various financial institutions.

The empirical work is further complicated by secular movements in inflation and corresponding long-lasting movements in nominal interest rates. Such underlying trends tend to bias upward the importance of the level factor in our analysis. Individual yields cannot be detrended separately, as the underlying inflation trends need to be common across all maturities. To this end, we remove nonstationarity in all yields using the trend of the country's monetary policy rate (defined as the Hodrick-Prescott filter with $\lambda = 14,400$ as the yield data are in monthly frequency), as in Bulíř and Vlček (2021). The HP pre-filtering of the series implies that all yields are expressed as quasi term premiums and the cyclical component of the risk-neutral yield. Still, even after such detrending we cannot reject nonstationarity in about one fifth of all yields. The nonstationarity problem is not unusual – it has been reported in earlier research (Kim and Orphanides 2007; Adrian et al. 2013).

[6] Filtering of the inflation series with the Hodrick-Prescott filter gives us, of course, a different inflation gap than those calculated as deviations from the typically constant official targets. The key benefit of a time-varying inflation target is that we are more likely to capture an effective and/or credible inflation objective as opposed to a publicly announced but noncredible one. The credibility problem has been severe in some of sample inflation-targeting countries, such as Ghana or Indonesia. Ireland (2007) provided evidence in favor of a slowly evolving latent monetary policy objective, see also Castelnuovo et al. (2008) for a literature review.

4 Results

We use the CDR methodology to obtain the first two latent yield-curve factors – the level and slope – for the sample countries. Visual observation of these factors in the right-hand column in Appendix 1 Figs. 2–5 suggests that the level and slope develop differently in our sample countries. For example, in Malaysia and Sweden the slope movements seems to reinforce the level movements, while in the Czech Republic and most of the sub-Saharan countries no link seems immediately obvious. We then include the latent yield-curve factors in a simple macro FAVAR models to evaluate whether the factors respond to macroeconomic innovations, see Appendix 2. The impulse responses (IRFs) are identified using the Choleski ordering, ensuring that the macroeconomic variables affects the latent yield-curve factors instantaneously, while the latent factors feed to the macroeconomic variables with a lag.

The novel finding in this paper is that central banks have adjusted the interest rate in response to variations in inflation and output and the result holds for all but one sample country. Our assessments below are based on finding a correctly signed and statistically significant impulse response between the past macroeconomic variables and the latent factors at any relevant horizon (from t to $t + 2$). We start the overview of our findings with country-specific results and move to grouped results afterward. The full FAVAR results are available at http://ales-bulir.wbs.cz/results_var_based_analysis_final.pdf.

4.1 Country-Specific Results

We focus first on individual countries, summarizing our results in Table 2. In 11 out of 16 countries interest rates are linked to inflation, based on the FAVAR impulse response evidence. Using the same methodology, the link between interest rates and the output rate gap has been found in 11 countries and between interest rates and the exchange rate gap in ten countries. Business cycle developments – the output gap – appear to matter for monetary policy under monetary targeting as much as inflation developments. There are differences, of course, across countries in our sample. For example, the EMCs and LICs countries pay more often attention to the exchange rate as compared to the advanced IT countries. Only for Nigeria we fail to find any relationship between the latent factors and macroeconomic variables.

As a robustness check, we supplement the population-type evidence from the FAVARs with sample-type evidence from the bivariate Pearson correlation coefficients (Table 3) and find that these results are not materially different, with some minor exceptions. For example, we find a significant relationship between the latent factors and inflation, the output and exchange rate gaps in Georgia (we find a significant relationship only between the factors and the exchange rate using the FAVAR IRFs); the latent factors and the exchange in Morocco (we find none using the FAVAR IRFs); no relationship in Tanzania (we found some relationship for both inflation and the output gap using the IRFs); some for Nigeria (we find none using the FAVAR IRFs), and so on.

Journal : SmallExtended 11079	Article No : 9663	Pages : 20	MS Code : 9663	Dispatch : 13-2-2022

Table 2 Country Results – Impulse Response Evidence

Country	Policy regime	Inflation		Output gap		Exchange rate	
		Level	Slope	Level	Slope	Level	Slope
Czech Republic	IT_A	X	X	–	X	X	–
Israel	IT_A	X	–	X	X	–	–
Sweden	IT_A	–	X	X	X	–	–
Georgia	IT	–	–	–	–	X	–
Ghana	IT	–	–	X	–	X	–
Indonesia	IT	X	X	X	–	X	–
South Africa	IT	X	X	–	–	X	–
Turkey	IT	X	X	–	X	X	–
Uganda	MA/IT	X	X	–	X	X	–
Egypt	MO	–	X	–	–	–	–
Malaysia	MO	–	–	X	X	–	–
Kenya	MA	–	X	X	–	–	X
Morocco	Peg/MO	–	X	–	–	X	–
Nigeria	MA	–	–	–	–	–	–
Rwanda	MA	–	–	X	X	–	X
Tanzania	MA	X	–	X	–	–	–

IT and IT_A indicate evolving and advanced inflation targeting, respectively; MA indicates monetary-aggregate targeting; and MO indicates multiple objectives. Uganda's monetary regime switched from money targeting to inflation targeting during our sample period

X denotes instances where (i) we find the expected sign of the impulse response between the past macroeconomic variables and the latent factors and (ii) the estimate is statistically significant at a p-value of 0.2 at the horizon from t to $t + 2$;

– indicates that either no statistically significant impulse response is found or the response sign is going in the opposite direction to economic theory;

Source: Authors' calculations

4.2 Results for Country Groupings

In this section we group individual countries by their monetary policy regime, focusing on the salient differences across three groups of monetary regimes: advanced inflation targeting, evolving inflation targeting, and other (monetary-aggregate-targeting and multiple-objective regimes), see Table 4. First, the three advanced IT countries (IT_A) react to inflation and output developments either through the second latent factor or through both the first and second latent factors, and – given their freely floating exchange rates – all but the Czech Republic appear to ignore exchange rate misalignments. The shapes of the impulse responses are flat after t and t+1 and the estimated correlations are generally high, suggesting fast and robust reactions to macroeconomic innovations. The Czech yield curve appears to react one quarter faster to macroeconomic innovations than the Israeli or Swedish yield curves. In other words, Czech National Bank monetary policy seems to be more forward looking than that of the two other sample advanced countries. Furthermore, only in the Czech Republic, which has

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

Table 3 Summary Results – Sample Correlation Evidence

Country	Policy regime	Inflation		Output gap		Exchange rate	
		Level	Slope	Level	Slope	Level	Slope
Czech Republic	IT_A	–	X	–	X	–	–
Israel	IT_A	X	–	–	X	–	X
Sweden	IT_A	–	–	–	X	–	–
Georgia	IT	X	X	–	X	–	–
Ghana	IT	–	X	X	–	–	X
Indonesia	IT	X	X	X	–	X	–
South Africa	IT	–	X	X	–	–	–
Turkey	IT	–	X	X	–	X	–
Uganda	MA/IT	X	X	X	–	X	X
Egypt	MO	X	X	–	X	–	–
Malaysia	MO	–	–	X	X	–	–
Kenya	MA	–	X	–	–	X	–
Morocco	Peg/MO	–	–	–	–	–	X
Nigeria	MA	X	–	–	X	X	–
Rwanda	MA	–	X	X	–	X	–
Tanzania	MA	–	–	–	–	–	–

IT and IT_A indicate evolving and advanced inflation targeting, respectively; MA indicates monetary-aggregate targeting; and MO indicates multiple objectives. Uganda's monetary regime switched from money targeting to inflation targeting during our sample period

Although there are no critical points for correlation coefficients, partial correlations bigger than ± 0.3 are typically deemed to be satisfactorily large (Doucouliagos 2011)

X denotes instances where (i) we find the expected sign of the correlation coefficient between past macroeconomic variables and the latent factor, and (ii) the correlation coefficient is statistically significant;

– indicates either no statistically significant correlation found or the relationship is going in the opposite direction to economic theory

Source: Authors' calculations

an important exchange rate channel, we find a link between the interest and exchange rates.

Second, we find that the first and second factors react to macroeconomic innovations in a broadly similar manner across both advanced and evolving inflation targeting regimes. For example, the IT_A as well as evolving IT countries adjust both the level and the slope in response to inflation innovations. Thus, we find little evidence of the dilemma posited by Rey (2018), namely that independent monetary policy is possible only if the capital account is managed directly or indirectly. None of the sample inflation targeting countries have systematically managed their capital accounts (IMF 2019).

That said, the results for countries with the evolving IT regimes are more varied and generally less robust than those with advanced IT regimes. These countries appear to react more often through the level factor to inflation and the output gap. In addition, we fail to find evidence of an inflation-to-interest rate link in Georgia and

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

Table 4 Results Grouped by Policy Regimes – Impulse Response Evidence

	Inflation		Output Gap		Exchange Rate		Number of countries
	Level	Slope	Level	Slope	Level	Slope	
IT_A	2/3	2/3	2/3	3/3	1/3	0	3
IT	4/6	4/6	2/6	2/6	6/6	0	6
Other	1/7	3/7	4/7	2/7	1/7	2/7	7

IT and IT_A indicate evolving and advanced inflation targeting, respectively; and Other comprises countries with monetary-aggregate-targeting and multiple-objective regimes. These sub-samples contain three, six, and seven countries, respectively

The ratios indicate in what group of countries and for which relationship (i) we found the expected sign of the impulse response between the macroeconomic variables and the latent factors, and (ii) the impulse response estimate is statistically significant at a p-value of 0.2 at the horizon from t to $t + 2$. For example, the IT_A row indicate that in all advanced ITers the yield curve reacts to the output gap, typically through both level and slope shifts

Source: Authors' calculations; see Table 2 for individual-country results

Ghana, two relative newcomers to inflation targeting. All of the EMC IT countries appear to react to the exchange rate.

Third, to our surprise, we find little evidence that inflation expectations are better anchored in advanced than in evolving inflation-targeting countries. Empirically, the share of reactions through the level and slope factors is broadly similar across the IT_A and IT groups. We conclude that the methodology of differentiating between the level-based and slope-based reactions to macroeconomic innovations does not provide a useful test for anchoring of inflation expectations.

Fourth, the results for multiple-objective and money-targeting central banks are even more varied: interest rate setting appears to be weakly related to the key macroeconomic variables. We fail to find evidence of the price stability objective in Malaysia, Nigeria, and Rwanda, that is, almost one-half of the Other group in our sample. Only in Kenya do we find links to both inflation and the business cycle. A link to exchange rates is found in Kenya, Morocco, Nigeria, and Rwanda, all but Morocco formally money-targeting countries.

5 Policy Implications

Our findings answer two key questions: does monetary policy react to macroeconomic innovations, and through what channel(s) does monetary policy react to these innovations? First, monetary policy decisions in our sample countries, as expressed in yield curve movements, do react to macroeconomic innovations and these reactions reflect the monetary policy regime. On the one hand, we find clear evidence of the primacy of the price stability objective in the IT countries, especially the advanced ones. On the other hand, the links to inflation and the output gap are generally weaker and less systematic in both money-targeting and multiple-objective countries. Nevertheless, some money-targeting countries, such as Kenya or Tanzania, exercise monetary policy with an eye on both inflation and the business cycle. Others appear to loosely focus on one objective only, such as Malaysia on output. The fact that monetary policy under money targeting does not react to macroeconomic innovations in a forward-looking manner is hardly surprising – the finding is consistent with the manner in which the regime has been executed in most low-income countries (IMF 2015).

Second, we see a divide between the advanced and evolving IT countries with respect to exchange rate developments. While all emerging ITers respond to exchange rate dynamics in addition to inflation and the output gap, we found such a relationship in only one advanced IT country – the Czech Republic, where the central bank used the exchange rate as an unconventional monetary policy instrument from November 2013 until April 2017. Third, we find little evidence that a lack of control over the capital account constrains monetary policy responses to macroeconomic innovations.

6 Conclusions

Examining a sample of 16 countries – operating under inflation-targeting, money-targeting, or multiple-objective regimes – we find that in most of them the yield curve responds to variations in inflation, output, and the exchange rate, sometimes to all three innovations. In other words, monetary policy appears to be data- and rule-driven, irrespective of monetary regime and level of development and these results seem robust to alternative estimation techniques. The evidence of the primacy of the price stability objective – policy responses to inflation – is strongest in the sample of advanced IT countries and, to a lesser degree, in the other IT countries. In contrast, links to inflation, output, and the exchange rate are generally weaker in multiple-objective countries, although in some money-targeting countries, we do find evidence of inflation and output gap innovations influencing monetary policy decisions as reflected in yield curve movements. Almost all of the nonadvanced countries appear to keep an eye on the exchange rate. AQ3

Appendix 1

Macroeconomic Developments and Latent Factors

In this section we present graphically the three macroeconomic variables of interest (inflation, the output and real exchange rate gaps) and the first two latent factors estimated using the CDR methodology.

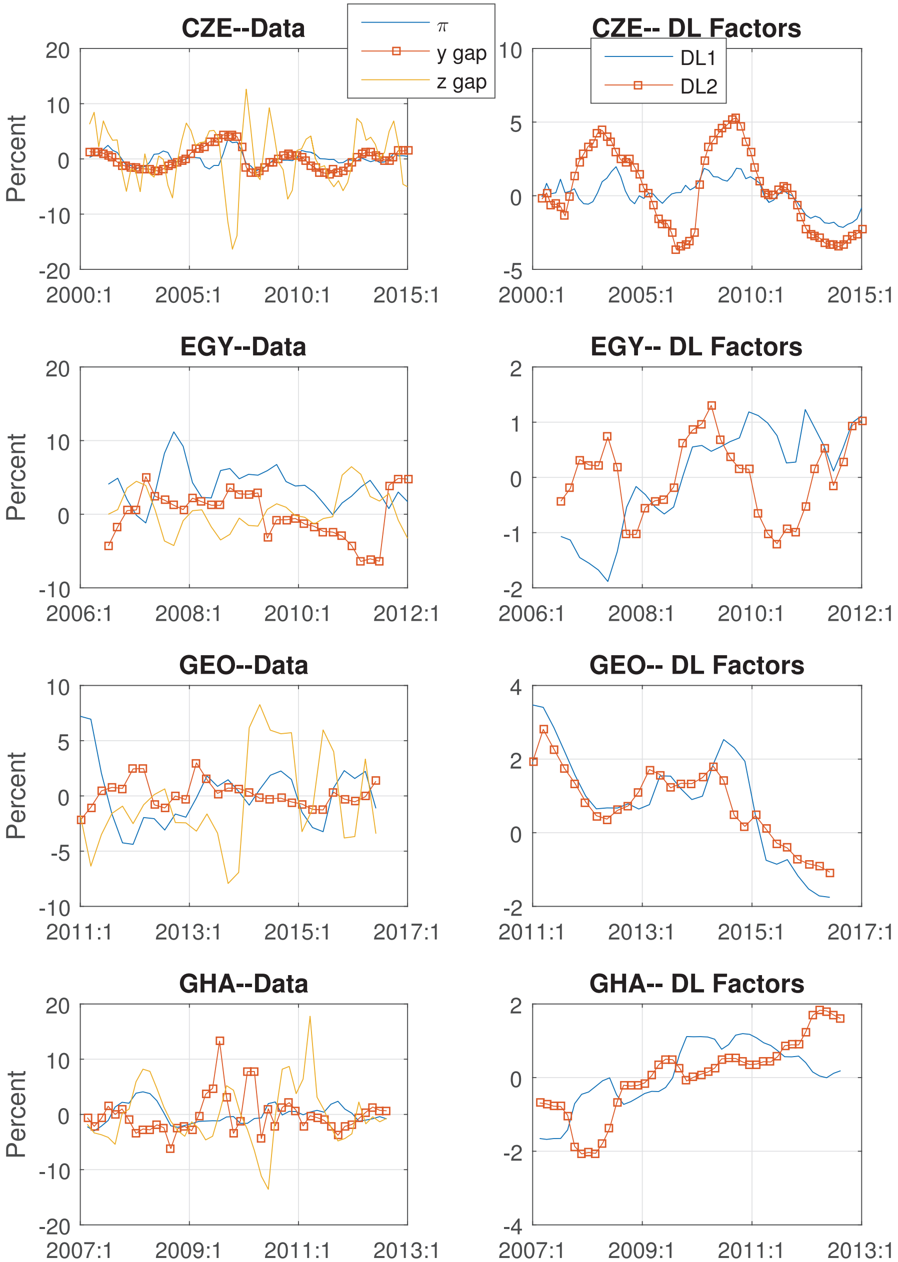


Fig. 2 Macroeconomic Developments and the First Two Latent Factors. Notes: Inflation (π) is calculated as the quarterly average from the detrended monthly year-on-year log-differences in the headline CPI, and the output gap (y gap) and the real exchange rate gap are estimated by applying the Hodrick-Prescott filter ($\lambda = 1,600$). The shift and slope latent factors are estimated using the CDR methodology and are denoted as DL1 and DL2, respectively. Source: Authors' calculations

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

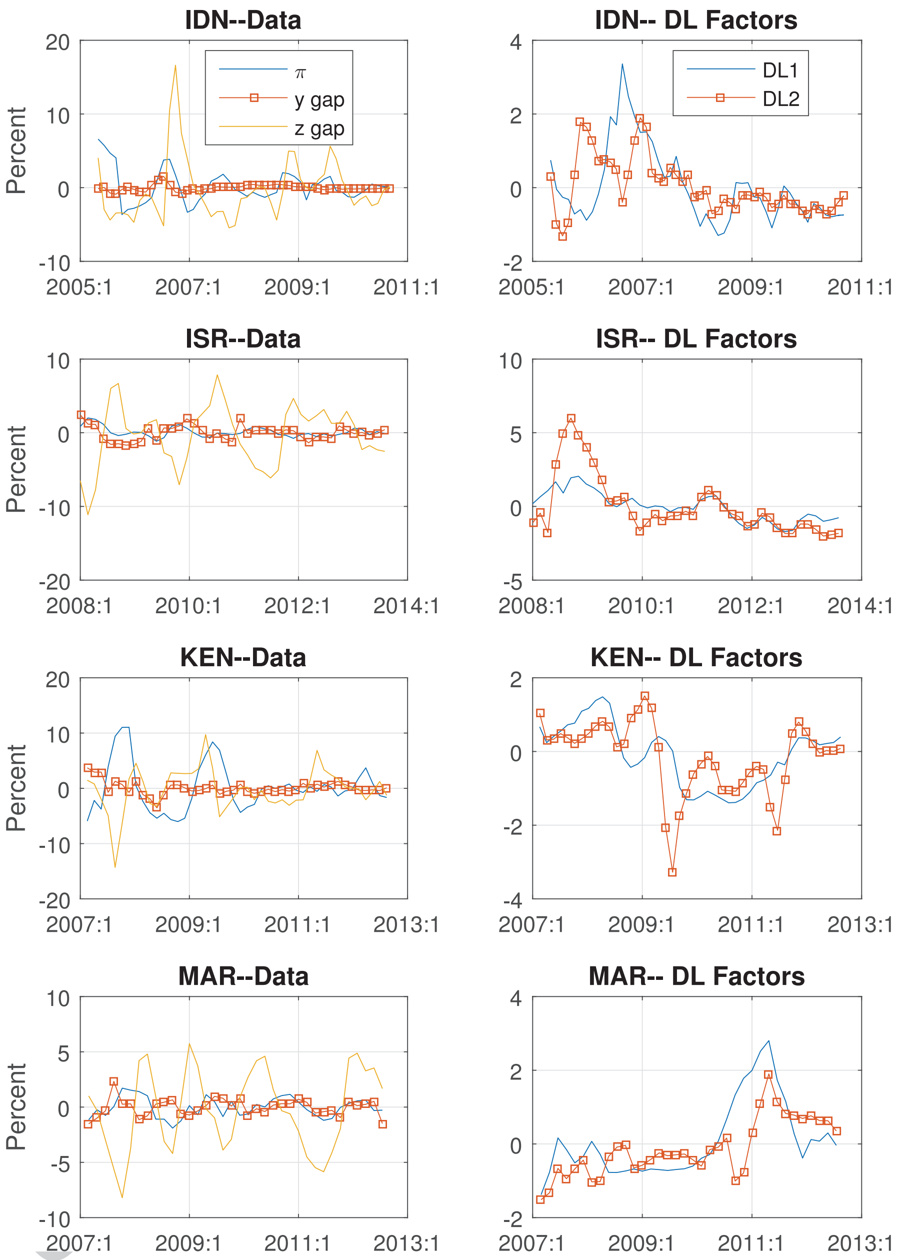


Fig. 3 Macroeconomic Developments and the First Two Latent Factors. Notes: Inflation (π) is calculated as the quarterly average from the detrended monthly year-on-year log-differences in the headline CPI, and the output gap (y gap) and the real exchange rate gap are estimated by applying the Hodrick-Prescott filter ($\lambda = 1,600$). The shift and slope latent factors are estimated using the CDR methodology and are denoted as DL1 and DL2, respectively. Source: Authors' calculations

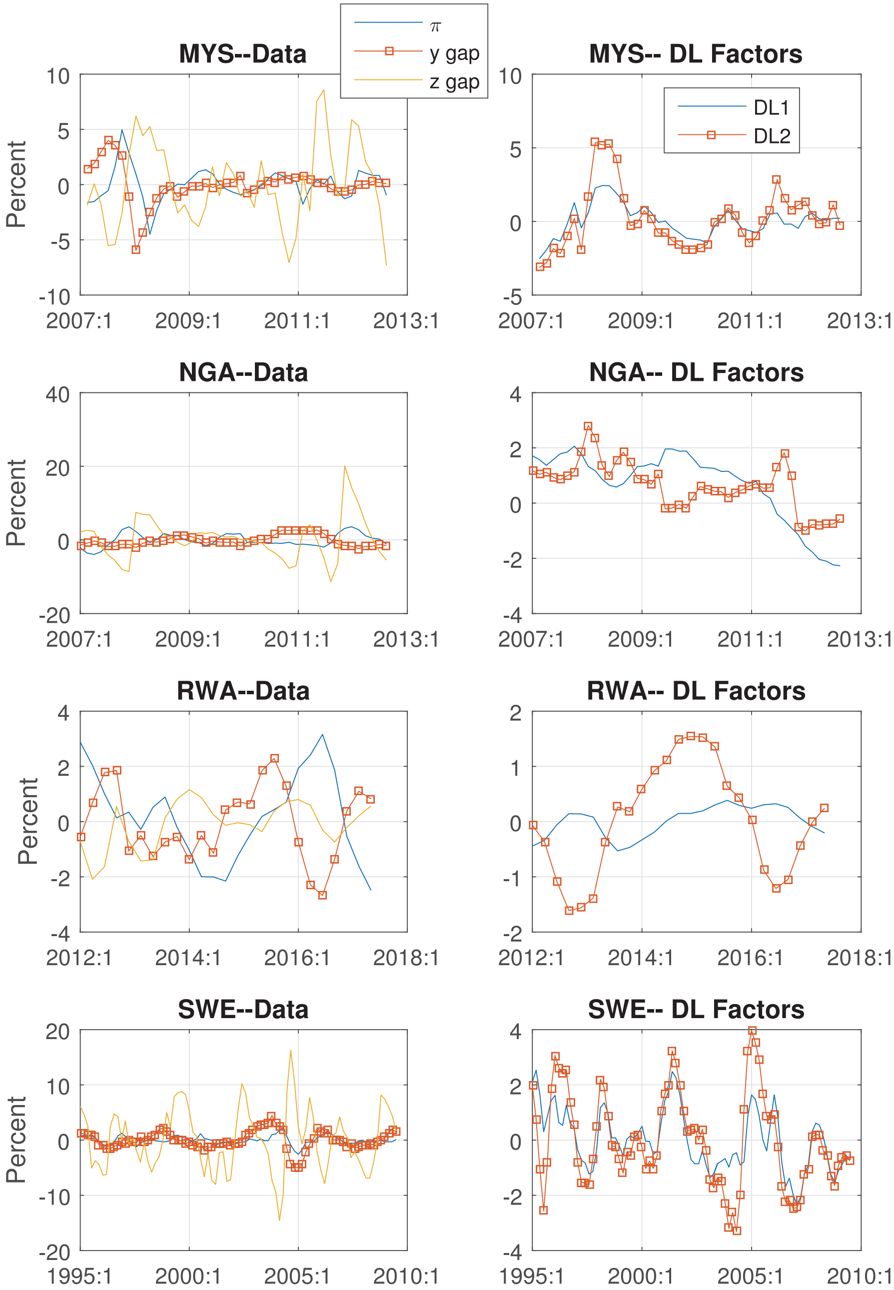


Fig. 4 Macroeconomic Developments and the First Two Latent Factors. Notes: Inflation (π) is calculated as the quarterly average from the detrended monthly year-on-year log-differences in the headline CPI, and the output gap (y gap) and the real exchange rate gap are estimated by applying the Hodrick-Prescott filter ($\lambda = 1,600$). The shift and slope latent factors are estimated using the CDR methodology and are denoted as DL1 and DL2, respectively. Source: Authors' calculations

Journal : SmallExtended 11079 | Article No : 9663 | Pages : 20 | MS Code : 9663 | Dispatch : 13-2-2022

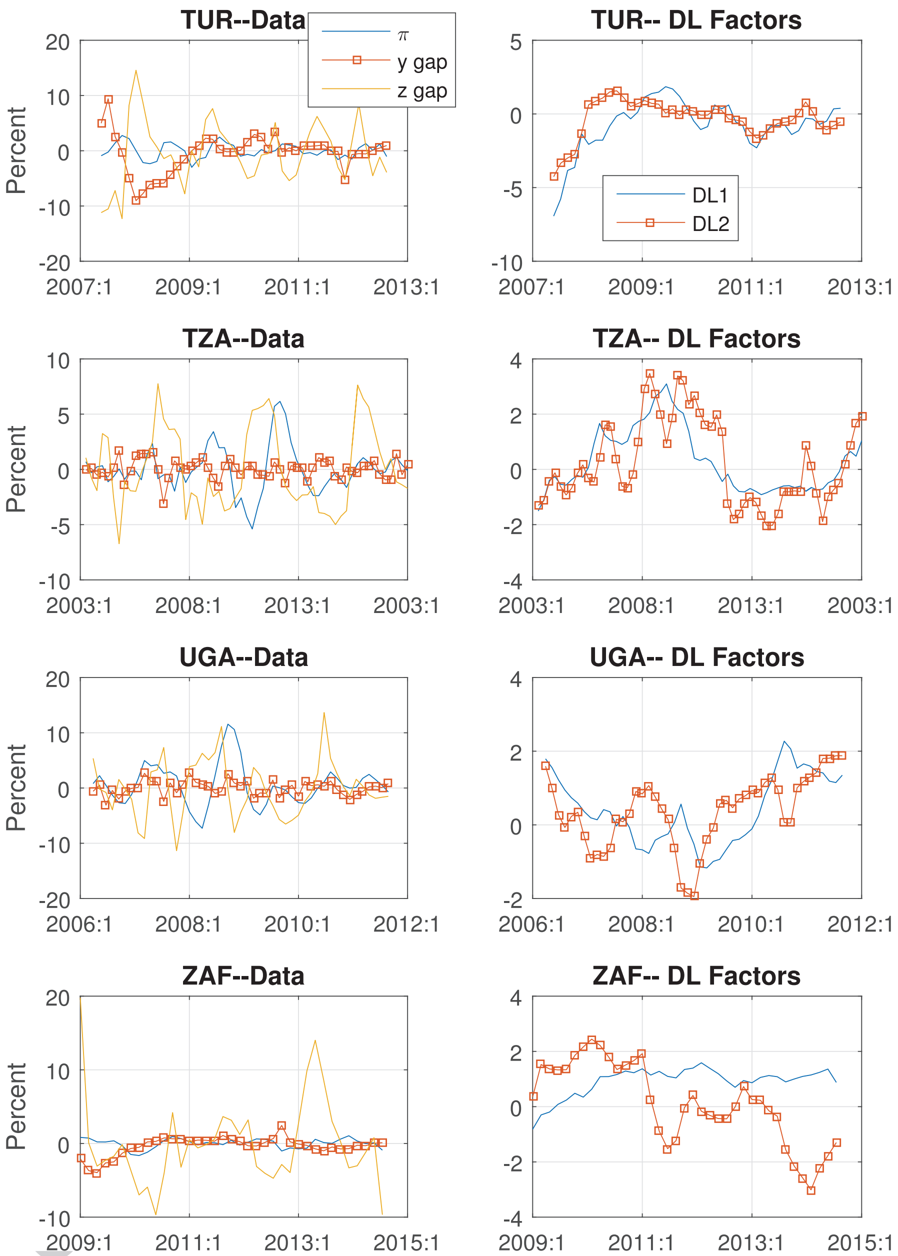


Fig. 5 Macroeconomic Developments and the First Two Latent Factors. Notes: Inflation (π) is calculated as the quarterly average from the detrended monthly year-on-year log-differences in the headline CPI, and the output gap (y gap) and the real exchange rate gap are estimated by applying the Hodrick-Prescott filter ($\lambda = 1,600$). The shift and slope latent factors are estimated using the CDR methodology and are denoted as DL1 and DL2, respectively. Source: Authors' calculations

Appendix 2

Factor-Augmented Vector Autoregression (FAVAR) Evidence

We estimate a two-step, open-economy FAVAR model for each country to assess the transmission of domestic macroeconomic innovations to the first two latent factors that describe interest rate behavior (Bernanke et al. 2005). In the first step we extract the factors and in the second step we estimate the system dynamics. The FAVAR model has two lags ($p = 2$), three domestic macroeconomic variables (inflation expressed as the quarter-on-quarter log difference, π, the output gap identified from the HP-filter, $\hat{y}$, and the real exchange rate gap identified from the HP-filter of the CPI-based real exchange rate vis-à-vis the U.S. dollar, $\hat{z}$), and two factor variables measuring the yield curve derived from the CDR model, that is, level and slope estimates (DL1 and DL2, respectively). These five variables are treated as endogenous. In addition, the model is conditioned on two external and exogenous variables: the VIX index and world oil prices, both expressed as quarter-on-quarter log differences. These two series are proxies for the global financial cycle and global business cycle, respectively. All series, with the exception of interest rates, are from the Haver database. Impulse responses are defined as one-percent shocks using the structural FAVARs, applying the following Choleski ordering restrictions: inflation, the output gap, the exchange rate gap, and the latent factors.

Acknowledgements We are indebted to Andy Berg, Yu-Chin Chen, Michal Franta, Gunes Kamber, Laura Kodres, Adam Kučera, Norbert Funke, Adam Remo, Marika Santoro, Tao Wu, and two anonymous referees for valuable suggestions. The paper benefited from comments in IMF and Czech National Bank seminars. The views expressed are those of the authors and do not necessarily reflect the official view of the IMF or CNB.

References

Adrian T, Crump RK, Moench E (2013) Pricing the term structure with linear regressions. J Financ Econ 110(1):110–138

Ang A, Boivin J, Dong S, Loo-Kung R (2011) Monetary policy shifts and the term structure. Rev Econ Stud 78(2):429–457

Ang A, Piazzesi M (2003) A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables. J Monet Econ 50:745–787

Bernanke B, Boivin J, Eliasz P (2005) Measuring the effects of monetary policy: A factor-augmented vector autoregressive (FAVAR) approach. Q J Econ 120:387–422

Berg A, Charry L, Portillo RA, Vlček J (2013) The monetary transmission mechanism in the tropics: A narrative approach, IMFWP/13/197. International Monetary Fund, Washington, DC

Bulíř A, Vlček J (2021) Monetary transmission: Are emerging market and low-income countries different? J Policy Model 42(1):95–108

Castelnuovo E, Greco LG, Raggi D (2008) Estimating regime-switching Taylor rules with trend inflation. Bank of Finland research discussion paper no. 20/2008. Bank of Finland, Helsinki

Christensen JHE, Diebold FX, Rudebusch GD (2008) An arbitrage-free generalized Nelson-Siegel term structure model. NBER WP 14463

Clarida R, Galí J, Gertler M (2000) Monetary policy rules and macroeconomic stability: Evidence and some theory. Q J Econ 115:147–180

Diebold FX, Rudebusch GD, Boragan Aruoba S (2006) The macroeconomy and the yield curve: A dynamic latent factor approach. J Econ 131(1–2):309–338

Doucouliagos H (2011) How large is large? Preliminary and relative guidelines for interpreting partial correlations in economics. Deakin University working paper, SWP 2011/5

Frankel Jeffrey (2019) Systematic managed floating. Open Econ Rev 30(April):255–295

Galí J (2018) The state of new Keynesian economics: A partial assessment. NBER working paper no. 24845

Henderson DW, McKibbin W (1993) A comparison of some basic monetary policy regimes for open economies: implications of different degrees of instrument adjustment and wage persistence. Carn-Roch Conf Ser Public Policy 39:221–318

IMF (2015) Evolving monetary policy frameworks in low-income and other developing countries. International Monetary Fund: Washington, DC

IMF (2019) The Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). AQ4 International Monetary Fund: Washington, DC. Available at: https://www.elibrary-areaer.imf.org/Pages/Home.aspx

Ireland P (2007) Changes in Federal Reserve's inflation target: Causes and consequences. J Money Credit Bank 39:1851–1882

Kim DH, Orphanides A (2007) The bond market term premium: What is it, and how can we measure it? BIS Quarterly Review (June) 27–40

McCallum BT (1994) Monetary policy and the term structure of interest rates. NBER working paper 4938

Mishkin FS (1995) Symposium on the monetary transmission mechanism. J Econ Perspect 9(4):3–10

Orphanides A (2001) Monetary policy rules and real-time data. Am Econ Rev 91(4):964–985

Orphanides A (2007) Taylor rules. FEDS working paper no. 2007-18

Rey H (2018) Dilemma not trilemma: The global financial cycle and monetary policy independence. NBER working paper 21162

Siklos Pierre L, Bohl Martin T (2009) Asset prices as indicators of Euro area monetary policy: An empirical assessment of their role in a Taylor rule. Open Econ Rev 20:39–59

Svensson LEO (1997) Inflation forecast targeting: Implementing and monitoring inflation targets. Eur Econ Rev 41:1111–1146

Taylor JB (1993) Discretion versus policy rules in practice. Carn-Roch Conf Ser Public Policy 39:195–214

Journal:	**11079**
Article:	**9663**

Author Query Form

Please ensure you fill out your response to the queries raised below and return this form along with your corrections

Dear Author

During the process of typesetting your article, the following queries have arisen. Please check your typeset proof carefully against the queries listed below and mark the necessary changes either directly on the proof/online grid or in the 'Author's response' area provided below

Query	Details Required	Author's Response
AQ1	JEL Classification is desired in this journal. Please provide only the codes. Thank you	
AQ2	Kindly check if figure caption has been capture appropriately. Thank you.	
AQ3	Statement "We are indebted to Andy Berg..." has been capture in the backmatter as Acknowledgement. Please check if the action taken is correct and amend as necessary. Thank you.	
AQ4	Please provide Accessed date for URL reference [IMF, 2019]	