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Abstract

We analyze the impact of price stability-oriented monetary strategies (inflation targeting—IT—and constraining exchange rate arrangements) on inflation persistence using a time-varying coefficients framework in a panel of 68 countries (1993–2013). We show that explicit IT has a stronger effect on taming inflation persistence than implicit IT and is effective even during and after the financial crisis. We also show that once a country hits the ZLB its inflation persistence mildly decreases and that there exists a mild pull to return to inflation persistence mean once a central bank moves away from its inflation target. The link between inflation persistence and constraining exchange rate regimes is less pronounced than that of IT and regimes with the U.S. dollar as a reserve currency are less effective than those using the Euro (Deutsche mark). On other hand, the U.S. persistence transers disproportionately lower effect on other countries' persistence than the IP of Germany.

JEL-Codes: C220, C320, E310, E520, F310.

Keywords: inflation persistence, inflation targeting, exchange rate regime, flexible least squares.

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1. Introduction and motivation

"A key objective of recent inflation research has been to map observed or reduced-form persistence into the underlying economic structures that produce it" (Fuhrer, 2011; p. 431). In this paper we contribute to this broad debate by assessing the impact of price stability-oriented monetary strategies (inflation targeting and constraining exchange regimes) on inflation persistence. The topic is important to both macroeconomists and policymakers. Because of that, we analyze the issue in a comprehensive manner to circumvent some limitations found in earlier studies and provide less ambiguous results.

Aside from periods of hyperinflation, in normal times the inflation rate usually trails some reasonable steady-state level—an underlying trend inflation—from which it may deviate due to a variety of shocks (Ascari and Sbordone, 2014). Subsequent adjustments towards its long-run level can be described by the speed it takes for inflation to return to such a level. Inflation persistence (IP) is a measure of this convergence speed: the greater (lower) the speed, the less (more) persistent is inflation. A knowledge and quantification of inflation persistence is vital for monetary policy in its goal to maintain price stability. A higher persistence means (i) a smaller "policy space" to deal with temporary price shocks (Roache, 2014) and (ii) a higher "sacrifice ratio", representing the output costs associated with lowering inflation (Fuhrer, 1994; Ascari and Ropele, 2012). In other words, less persistent inflation means fewer complications for a central bank to maintain price stability.[1]

Two essential types of the IP measure exist. Structural persistence refers to persistence that originates from known economic sources. Reduced-form persistence represents the empirical property without an economic interpretation.[2] Stock and Watson (2007), Pivetta and Reis (2007), and Cogley et al. (2010) produced important contributions to inflation persistence dynamics in the U.S. and empirical evidence from many developed economies shows that inflation was highly persistent from the 1960s until the mid-1980s, but evidence in later periods is mixed (Fuhrer, 2011). Evidence on the sources of inflation persistence and its link to related monetary strategies remains controversial. However, the combined effects of past inflation rates (intrinsic persistence) are seen as a primary source of inflation persistence (Fuhrer, 2006, 2011).

Gerlach and Tillman (2012; p.361) argue that "any monetary policy strategy that attaches primary importance to price stability is likely to lead to a low level of inflation persistence". Central banks chose various strategies and inflation persistence is increasingly used as an indicator of monetary policy effectiveness (Meller and Nautz, 2012). Two relevant policy strategies employed by monetary authorities are inflation targeting (IT) and constraining exchange rate arrangement (Siklos, 1999; Alogoskoufis and Smith, 1991; respectively); in the next section we provide details on these strategies. Despite the price-stability character of both strategies, empirical evidence on their links

[1] Primarily for these reasons, the issue of inflation persistence has been the subject of considerable research. Fuhrer (2011) provides a thorough review of inflation persistence and relevant research. Pivetta and Reis (2007) review the debate on inflation persistence in the U.S.; Watson (2014) analyzes its development after the Great Recession. In Europe, inflation persistence prompted Euro area central banks to establish the formal Inflation Persistence Network (IPN), whose research output can be found at https://www.ecb.europa.eu/home/html/researcher_ipn_papers.en.html; for a summary of the IPN-based knowledge on inflation persistence in the Euro area see Altissimo et al. (2006). In this respect, Meller and Nautz (2012) document that inflation persistence has significantly decreased in the Euro area, potentially due to the more effective monetary policy of the European Central Bank (ECB). For inflation persistence in Central and Eastern Europe see Darvas and Varga (2014).

[2] Despite the fact that it is preferable to know the behavior of inflation persistence as well as its sources, the link between the two remains a considerable challenge. While we do not attempt to uncover the structural sources of IP in this paper, we analyze the link between specific monetary policy strategies and (reduced-form) inflation persistence. In the same way we do not analyze the potential effect of a fiscal policy, but we acknowledge that coordinated monetary and fiscal policies are likely to produce lower inflation volatility after a shock as demonstrated by Greenwood-Nimmo (2014).

with inflation persistence (reviewed in Section 2) does not point to unambiguous results. Possibly, it is because (i) often analyses are performed on individual countries or small sets of countries, (ii) quite frequently the employed methods do not allow for the time-varying nature of inflation persistence,[3] and (iii) researchers often rely on only a few persistence measures.

In this paper we take a firmly comprehensive approach in order to contribute to the literature in two ways. First, we assess inflation persistence in a panel data framework by using a sizeable data set of 68 countries from all over the world that represent both developed as well as emerging economies. We analyze our data in a time-varying coefficients framework, which enables us to derive inflation persistence while accounting for structural breaks that do exist in inflation persistence in the majority of countries in our sample. In our estimation we employ four different measures of inflation persistence that are established in the literature (see Section 3) and cover more measurement issues. Second, we focus on links between inflation persistence and two types of price stability-oriented monetary strategies. In doing so, we account for the endogeneity of inflation targeting and the exchange rate arrangement with respect to inflation persistence itself. Based on our comprehensive approach we show a contributing effect of inflation targeting with respect to inflation persistence and differences in the effect of the foreign exchange regime that depend on what reserve currency is used. Pattern of inflation persistence dynamics also shows that IT strategy is effective even under financial crisis as the inflation persistence remains on the declining track during the crisis as well as afterwards.

The rest of the paper is organized as follows. In Section 2 we provide the full context and review the literature related to inflation persistence in connection to constraining exchange regimes, inflation targeting, and structural breaks. In Section 3 we introduce the four inflation persistence measures employed in the literature. The methodological approach and our testable hypotheses are formally introduced in Section 4. Data are brought forth in Section 5. Empirical results with policy implications are offered in Section 6 and results of the principal components analysis are shown in Section 7. Finally, Section 8 concludes.

2. Inflation persistence, monetary strategies, and structural breaks: Context and related literature

Fuhrer (2011) thoroughly analyzes the concept of inflation persistence in macroeconomic theory. One of the results of his analysis is that "it is unlikely that any change in persistence has arisen from a change in the persistence of the driving process" (Fuhrer, 2011; p. 482). This suggests that an intrinsic factor rather than driving forces is the prevailing source of inflation persistence (Fuhrer, 2006). While the above claims are thoughtful and are supported by meticulous analysis, a number of studies that we review below analyze various monetary policy factors as potentially relevant in explaining (reduced form) inflation persistence. For the sake of space we refrain from a review of the inflation persistence literature *per se*. Rather, we review the related literature from the perspective of the two policy strategies introduced in Section 1 that exhibit a potential to impact inflation and its dynamics. Other parts of the inflation persistence literature are not reviewed.

2.1 Inflation targeting

A monetary policy framework designed to achieve a specific inflation target is known as inflation targeting (IT). As described in Mishkin (2008) and Heenan et al. (2006), the inflation targeting

[3] Influential contributions (Stock and Watson, 2007; Pivetta and Reis, 2007; Levin and Piger, 2004; among others) document the importance to account for the time-varying nature of persistence during empirical analysis.

monetary strategy includes four key elements: (i) price stability as the explicit mandate and objective of the central bank, (ii) a quantified inflation target, (iii) the accountability and transparency of the central bank, and (iv) a forward-looking assessment of inflation pressures.

IT was first adopted by New Zealand in 1990, followed by Canada one year later. The basic ingredients of inflation targets in countries that adopted IT in the early 1990s are comprehensively presented in Siklos (1999; Table 1), and a brief account of the experience over 25 years of IT is presented in Wheeler (2015). Approaches towards IT were discussed by Svensson (1997, 2002), Bernanke et al. (2001), Bofinger (2001), and ECB (2001). Although the definitions differ to some extent, explicit inflation targeting (EIT) requires a central bank to publicly recognize low inflation as its monetary policy priority along with announcing an official target for the inflation rate (Goodfriend, 2004). EIT is further characterized by a large degree of transparency related to the central bank's monetary policy. Countries using IT that do not adopt full-fledged EIT perform implicit inflation targeting (IIT). Low inflation might not be strictly their key policy objective. Rather, they declare their inflation objectives in broad terms but their "policy makers may have implicit inflation targets, which agents have to learn over time" (Ascari and Sbordone, 2014; p. 680); Doh (2012) shows that agents quickly learn inflation target. Such a characteristic is often complemented by lower financial stability and a weaker institutional framework (Carare and Stone, 2006), but not always as can be witnessed in the case of the U.S. where since 1992 the "Fed practiced a form of flexible inflation targeting in its pursuit of price stability" (Goodfriend, 2004; p. 322). A strong commitment to formal adoption of IT is "neither a necessary nor a sufficient condition for a drop in inflation persistence" (Gerlach and Tillman, 2012; p. 361). A similar assessment was made even earlier by Siklos (1999; p.47) who, however, claims that "inflation targeting seemingly lacks some of the drawbacks of other policy regimes."

Despite the persuasive reasoning, empirical evidence on the link between inflation targeting and inflation persistence is not entirely unified. One segment of the literature documents that well-anchored inflation expectations in a credible IT regime correlate with lower inflation persistence. This is shown by Mishkin and Schmidt-Hebel (2007), who use a wide panel of IT and non-IT countries. Benati (2008) shows that reduced-form persistence declines after the introduction of IT but is still present in countries without anchors (U.S. and Japan). Baxa et al. (2014) provide evidence of temporal coincidence between IT introduction and a drop in inflation persistence in countries that have long experience with an IT regime (Australia, Canada, New Zealand, Sweden, and the UK). On the other hand, Siklos (2008) finds that the introduction of IT resulted in reduced inflation persistence in only a few emerging countries. Filardo and Genberg (2010) in their survey show that persistence declined only in Australia, Korea, and New Zealand, while in other Asian countries it even increased when IT was adopted. In an analysis covering new European Union member states, Franta et al. (2010) show that some of the countries exhibit inflation persistence similar to that in the Euro area but other countries suffer from the high intrinsic and high expectations-based inflation persistence. Both groups of the cited research contain both IT and non-IT countries and this fact further underscores the ambiguity of the link between IT and inflation persistence.

2.2 Constraining exchange rate arrangement

A second strategy (factor) that is linked to inflation control indirectly is a constraining exchange rate arrangement. The policy strategy of the constraining exchange rate (regime) is primarily used to stabilize a domestic currency but its secondary role might be to control inflation (Alogoskoufis and Smith, 1991; Edwards, 2011). The value of a domestic currency (with respect to third currencies) fluctuates with the relative value of a reference currency and domestic inflation is to a large extent determined by the inflation of the reference currency's country. Further, under a constraining exchange rate regime, domestic monetary policy is effectively limited as well (Husain et al., 2004). In order to control for inflation, fixed exchange rates were employed, for example, in a number of Latin American countries towards the end of the 20th century, e.g., Argentina, Bolivia, Brazil, and Chile (Edwards, 2011).[4] Moreover, in highly externally indebted economies, the limitations of exchange rate fluctuations via a suitable foreign exchange arrangement might not only lower inflation but also stabilize output (Morón and Winkelried, 2005).

What is the mechanism linking the constraining foreign exchange regime and inflation persistence? The link goes via the degree of monetary accommodation. According to Dornbusch (1982), monetary policy responding to price shocks in a more accommodative manner is likely to produce more persistent inflation. For that reason, absence (in the policy) to accommodate inflation shocks is frequently perceived as a precondition for lower inflation persistence (Alogoskoufis and Smith, 1991). Hence, the lesser extent of monetary accommodation, linked with lower inflation persistence, can be achieved via credibly constraining the exchange rate arrangement (provided that such a regime truly delivers lower monetary accommodation). On other hand, Galí and Monacelli (2005; p.725) argue that complete stabilization of nominal exchange rate under a peg induces stationarity in domestic price level and, "in response to a shock, inflation initially falls but then rises persistently above the steady state."

The literature on the effect of a constraining exchange rate arrangement on inflation persistence does not provide unambiguous results. Alogoskoufis and Smith (1991) and Alogoskoufis (1992) analyze inflation dynamics in the U.S., the UK, and 21 OECD countries during periods of fixed exchange arrangements and more flexible arrangements. They find that inflation persistence was markedly higher under the flexible arrangements. Obstfeld (1995) provides similar evidence for 12 OECD countries, with the exception of the U.S. This type of result is questioned by Burdekin and Siklos (1999), who claim that other factors (notably oil price shocks and central bank reforms) could also be attributed to reduced inflation persistence instead of exchange arrangements alone.[5] Similarly, Anderton (1997) analyzes inflation dynamics among countries in and outside of the former Exchange Rate Mechanism (ERM) and shows that ERM was a key factor in inflation persistence reduction but it was neither necessary nor sufficient alone.[6] In an analysis of inflation in OECD countries from the 1950s to the early 1970s, Bleaney (2001) does not find differences in inflation persistence in connection to exchange rate regimes. Bleaney and Francisco (2005) show relatively high inflation persistence for both floating and pegged regimes in a large set of developing countries, but the results alter substantially when hard exchange rate pegs were distinguished from soft ones. More recent analyses from emerging markets on the other hand do not show differences in inflation persistence across tight and flexible exchange rate arrangements, specifically in Vietnam (Nguyen et al., 2014) and Thailand (Jiranyakul, 2014).

2.3 Structural breaks in inflation persistence

[4] Many countries have used currency pegs primarily for international trade purposes and inflation became a secondary issue, though.

[5] This claim is in accord with the results of Beechey and Österholm (2012), who suggest that by placing emphasis on inflation stability in recent decades, the Federal Reserve acted favorably in lowering U.S. inflation persistence.

[6] An exchange rate peg to a reserve currency serves as a disciplining device that enables a high-inflation economy to import monetary stability from a low inflation reserve currency country (Husain et al., 2004); this behavior is shown in Kočenda and Papell (1997) on the example of the members of the former European Monetary System (EMS). Lower inflation persistence can be potentially imported as well, if the persistence is low in the reserve country in the first place.

Analysis of inflation persistence is often complicated by potentially existing, but unaccounted for, structural breaks. Potential shifts in the inflation mean should be accounted for as they might considerably affect estimates of inflation persistence. Bleaney (2001) argues that estimates of inflation persistence are quite sensitive to shifts in mean and a smaller (larger) number of accounted-for shifts biases inflation persistence estimates upwards (downwards). Indeed, Levin and Piger (2004) and Cecchetti and Debelle (2006) show that estimates of inflation persistence are considerably lower when structural breaks are accounted for. Since unaccounted-for breaks in inflation series are likely to result in an upward bias in inflation persistence estimates, an adequate methodology has to be used for analysis.

Burdekin and Siklos (1999; p. 246) pioneered the issue by employing a set of tests to endogenously determine breaks in the inflation persistence of four developed countries (Canada, Sweden, the U.S.A., the UK) and showed that "economists should not automatically assume that changes in the exchange rate regime are as important" as Alogoskoufis and Smith (1991) imply. Cogley and Sargent (2001) were probably the first to estimate a model with continuously changing inflation persistence for the U.S. using Bayesian analysis in a VAR framework. Pivetta and Reis (2007) summed up the univariate changing persistence measures also in a Bayesian setting and concluded that U.S. inflation persistence is constantly high and not changing. They based this result mainly on two facts: first, although the estimated persistence sequence did show signs of change, the broad confidence intervals could also accommodate the constant persistence view, namely, a "horizontal", unchanging line could be drawn into the ribbon bounded by confidence limits. Second, formal tests by Banerjee et al. (1992) signaled no change. We have to note, though, that these tests have been later overridden in terms of size and power. Kim (2000) proposed a new formal test for the persistence change of a time series that was later corrected by Kim et al. (2002), extended by Busetti and Taylor (2004), and then put into a workable framework by Harvey et al. (2006). Their approach unifies the alternative hypotheses of persistence increase and decrease. Using these newer formal tests, Darvas and Varga (2014) showed changes in inflation persistence dynamics, including its decline in a number of European countries. Noriega et al. (2013) carried out an analysis of 45 countries using a test based on Harvey et al. (2006) to detect multiple changes in the countries' inflation persistence series. They found that about half of the countries exhibited changes in persistence.

3. Inflation persistence measures

We divide our methodology section into two parts. In the present Section 3 we introduce four inflation persistence measures. In Section 4 we describe our time-varying estimation technique, introduce the specification linking inflation persistence with monetary strategies, and formally outline the hypotheses.

Fuhrer (2011, p. 431) points out that there is no definitive measure of reduced-form persistence and provides a list of the most common inflation persistence measures employed in the literature. These are (i) conventional unit root tests, (ii) the autocorrelation function (ACF) of the inflation series, (iii) the first autocorrelation of the inflation series, (iv) the dominant root of the univariate autoregressive inflation process, (v) the sum of the coefficients from a univariate AR for inflation, and (vi) the unobserved component decompositions of inflation proposed by Stock and Watson (2007).

These measures have their pros and cons, though. Conventional unit root tests are easy to perform but they pose two problems. First, they produce yes-no type answers rather than real measures. Also, their application to rolling-window samples does not represent a truly time-varying approach. The ACF of inflation series is rather an eyeball measure as it does not provide the specific extent of inflation persistence at a given time and is not comparable across countries. The first autocorrelation of inflation series is easy to perform but it does not account for the potentially more complex dynamic structure of inflation persistence. The dominant root (or Largest Autoregressive Root, LAR) and sum of the AR coefficients represent more versatile measures that account for dynamics in inflation persistence and provide an opportunity to explore its potentially time-varying nature. Both methods were employed by Pivetta and Reis (2007) in their study of U.S. inflation persistence along with the measure termed the half-life (HLF) that they define as the number of periods in which inflation remains above 0.5 following a unit shock. Finally, Cogley et al. (2010; p. 44) recently define an R^2-based "measure of persistence in terms of inflation-gap predictability, in particular, as the fraction of total inflation-gap variation j quarters ahead that is due to past shocks" (henceforth RJT).

Therefore, following the methodological approaches outlined in Fuhrer (2011), Pivetta and Reis (2007), and Cogley et al. (2010), we employ in our analysis the sum of the AR coefficients (SUM) as our primary inflation persistence measure, and the LAR, HLF, and RJT measures as alternative ones. All four measures are formally defined presently along with a description of how they fit into our estimation strategy.

3.1 The time-varying AR(n) process as a framework

Univariate autoregressive modeling is an intuitively appealing approach because it can be easily linked to a simple central bank behavior model. First, from a backward-looking perspective, change in inflation ($y_t - y_{t-1}$) in a simple Phillips curve specification can be modelled as being positively dependent on an output gap g_t. The output gap is then negatively linked to the central bank's key interest rate i_t and, finally, the bank's policy interest rate is directly linked to the inflation rate y_t. Substitution from step three to one yields exactly an AR(1) process, as can been seen from the following equations:

$$y_t - y_{t-1} = \alpha g_t \quad (1a)$$

$$g_t = -\beta i_t \quad (1b)$$

$$i_t = \gamma y_t \quad (1c)$$

$$y_t = \phi y_{t-1} = \frac{1}{1+\alpha\beta\gamma} y_{t-1}. \quad (1d)$$

A natural extension of an AR(1) process is a higher-order auto-regressive process in which intrinsic inflation persistence can be captured in a more subtle way. Specifically, we adopt an autoregression of order p and allow for time varying coefficients:

$$y_t = \phi_{0t} + \phi_{1t} y_{t-1} + \phi_{2t} y_{t-2} + \cdots + \phi_{pt} y_{t-p} + \varepsilon_t \qquad t = 1,2,\ldots,T, \quad (2)$$

where y_t is the observed inflation variable, ϕ_{it} denotes the i-th order coefficient at time t, and ε_t is the error term.[7]

The derivation of persistence may come from a hypothetical setting where there is only a one-unit-sized shock at some point t in time and no shocks before or after. We define the j-th value of the impulse response function (IRF_j) as the derivative of y_{t+j} with respect to shock ε_t:

$$IRF_j = \frac{\partial y_{t+j}}{\partial \varepsilon_t}.$$

[7] In our empirical analysis we use quarterly data; therefore, we allow for five lags in the autoregression. Another option would be using a lag selection criterion for each country. However, since later we aggregate the estimated coefficient sequences, we find it more appropriate to use the same lag length for all country series.

In a stable system, the impulse response decays down to zero and persistence measures the speed of this decay. In all of our calculations we suppose that for every time point the actual autoregressive parameters will stay in place indefinitely.

3.2 Sum of autoregressive coefficients (SUM)

Our main measure of inflation persistence is the sum of autoregressive parameters at a given time point t:

$$IP_t^{SUM} = \sum_{i=1}^{p} \phi_{it}. \quad (3)$$

There are more motivations for this measure than those provided in Section 3.1. An intuitive one emerges if we take a steady state of the system and impose a sudden shock: the deterministic part of the response in the first period after the shock will be exactly the sum of the coefficients multiplied by the value of the steady state.

A more formal way to justify the SUM measure is to compute the convergence limit of the cumulated sum of the impulse response, which is naturally in a positive relationship with persistence. It is linked to our measure as follows:

$$\sum_{j=0}^{\infty} \frac{\partial y_{t+j}}{\partial \varepsilon_t} = \frac{1}{1-\sum_{i=1}^{p} \phi_{it}} = \frac{1}{1-IP_t^{SUM}}. \quad (4)$$

3.2 Largest Autoregressive Root (LAR)

It can be shown easily with difference equations that the impulse response of an autoregressive system always yields an exponential trajectory in time. More specifically, if we zero out the residuals, the solution to (4) has the form

$$IRF_j = \sum_{i=1}^{p} c_i \lambda_i^j, \quad (5)$$

where $\lambda_{1,} \lambda_{2,} \ldots, \lambda_p$ are the roots of the inverse autoregressive polynomial (which may be complex but if so, they appear as conjugate pairs) and $c_{1,} c_{2,} \ldots, c_p$ are constants that sum to 1 and can be computed using the roots. This is a sum of exponentials which all diminish in time (stability assumed), and the one with the largest absolute base will dominate the sum. Therefore the speed of decay will be determined by the largest root, which gives support to the LAR persistence measure defined as:

$$IP_t^{LAR} = \max_i |\lambda_i|. \quad (6)$$

3.3 Half-life (HLF)

Another approach to measuring the speed of decay is the number of periods needed to reach a certain threshold, for example half of the initial shock size. In an AR(1) model where the autoregressive coefficient is positive, the decay is strictly exponential and the half-life can be expressed explicitly as a function of the coefficient. However, with the introduction of negative coefficients and a higher order (multiple and complex roots), the impulse response may become oscillating, jumping around the threshold. In our definition the half-life is the number of periods passed after which the absolute value of the impulse response is indefinitely below 0.5. The HLF persistence measure is then defined as:

$$IP_t^{HLF} = \min_k \{k \mid j \geq k \Longrightarrow |IRF_j| < 0.5\}. \quad (7)$$

3.4 Inflation-gap predictability measure (RJT)

Last, we adapt the persistence measure of Cogley et al. (2010) in our univariate model. This involves converting our time-varying AR(n) model to a time-varying VAR(1) and then calculating the forecast variances. The idea of the RJT measure is to compare the variation due to shocks inherited from the past to the total forecast variance, thus producing a variance ratio that is an R^2-like measure. The first VAR conversion step is straightforward:

$$z_{t+1} = \mu_t + A_t z_t + \varepsilon_{z,t+1}, \tag{8}$$

where we stack up lags of y_t in vector z_t. Further, the A_t coefficient matrix contains the AR coefficients and ones and zeros. Finally, $\varepsilon_{z,t}$ contains the AR residual and zeros, thus indicating that the vector equation consists of one meaningful equation plus identities. The location of that meaningful equation within the vector z_t—which shows where we have y_t on the left hand side—is shown by the selector vector e.

In the VAR model we are already able to express the conditional forecast variance on a given horizon j and compare it to the total unconditional forecast variance. Our R^2_{jt} measure is then defined in the following way:

$$IP_t^{RJT} = 1 - \frac{var_j(e\hat{z}_{t+j})}{var(e\hat{z}_{t+j})} \approx 1 - \frac{e\left[\sum_{k=0}^{j-1}(A_t^k)var(\varepsilon_{z,t+1})(A_t^k)'\right]e'}{e\left[\sum_{k=0}^{\infty}(A_t^k)var(\varepsilon_{z,t+1})(A_t^k)'\right]e'}. \tag{9}$$

Note that in our case the persistence measure is invariant on the residual variance $var(\varepsilon_{z,t+1})$, which makes the measure computable even without estimating it. For the selection of the forecast horizon j we use the values 1, 4, and 8, similarly as Cogley et al. (2010).

4. Time-varying estimation methodology and hypotheses

4.1 Estimating time-varying inflation persistence

In order to capture the truly time-varying nature of inflation persistence, we employ the maximum likelihood estimation of a state-space model by using the Flexible Least Squares (FLS) estimator introduced by Kalaba and Tesfatsion (1988) and estimate the time-varying coefficient autoregression (2). We do not use the OLS approach that, by construction, assumes constant parameters. The most important advantage is that the employment of the time-varying coefficient framework eliminates the need to account for known and unknown structural breaks. On the other hand, employing the time-varying coefficient method is only fruitful if the data support the hypothesis of no constancy. For that we later (in section 6.1) apply persistence change tests to underpin the use of our time-varying coefficient model, and we note that the persistence change tests confirm the correctness of our approach. Hence, with the above method both sudden and continuous changes are revealed, and so beyond the break dates we have the additional advantage of identifying the tendency of the persistence sequences. By using time-varying parameter models we argue that only the deviations from the estimated time-varying mean should be taken into account when estimating persistence. Thus, with the FLS estimation we go one step further than studies that employ a multiple structural breaks approach.

We now formally introduce the flexible least squares methodology.[8] The main advantage of the FLS algorithm is that it does not require any distributional assumptions. Suppose y_t is the time t realization of a time series for which a time-varying coefficient model is to be fitted,

$$y_t = \beta_t' x_t + \varepsilon_t \qquad t = 1,2,\ldots,T. \tag{10}$$

In (10) we compress our regressors into the $k \times 1$ coefficient vector x_t, which in our specific case contains a constant and the lagged values of y_t. The time-varying $k \times 1$ vector of unknown coefficients to be estimated is denoted by β_t. Finally, ε_t is the approximation error.

The two main assumptions of the method are formulated without any distributional requisites:

[8] The flexible least squares methodology is in some respects similar to Kalman filtering, but better suits our purpose. A detailed introduction of FLS and a comparison to Kalman filtering can be found in Montana et al. (2009).

$$y_t - \beta_t' x_t \approx 0 \qquad t = 1,2,\ldots,T \qquad (11a)$$
$$\beta_{t+1} - \beta_t \approx 0^{k\times 1} \qquad t = 1,2,\ldots,T-1. \qquad (11b)$$

That is, the prior measurement specification (11a) states that the residual errors of the regression are small, and the prior dynamic specification (11b) declares that the vector of coefficients evolves slowly over time.

The idea of the FLS method is to assign two types of residual error to each possible coefficient sequence estimate. A quadratic cost function is assumed to be:

$$C(\beta_1,\ldots,\beta_T,\mu,T) = \sum_{t=1}^{T}(y_t - \beta_t' x_t)^2 + \mu \sum_{t=1}^{T-1}(\beta_{t+1} - \beta_t)'(\beta_{t+1} - \beta_t), \qquad (12)$$

where μ is the weighting parameter. The minimization of this cost function for $\beta_1,\ldots,\beta_T$, given any $\mu > 0$, leads to a unique estimate for $\beta_1,\ldots,\beta_T$. Consequently, there is a continuum of numbers of FLS solutions for a given set of observations, depending on the weighting parameter. The selection of the weighing parameter is a highly critical part of the FLS procedure, as the appropriate coefficient sequence lies somewhere between the most erratic (μ approaches zero) and the most stable (μ approaches infinity) OLS solution. In this paper we use an FLS-smoother with a weighing parameter of 100, which conforms to the simulation experiments conducted by Darvas and Varga (2012).

4.2 Inflation persistence and monetary strategies

Once the FLS smoothed inflation persistence estimates are available for each country, we use panel regression techniques to explore the effects of exchange rate and inflation targeting strategies. Formally, we estimate the following specification:

$$\widehat{IP}_{ct} = \alpha_0 + \alpha_1 ER_{ct}^{USD} + \alpha_2 ER_{ct}^{EUR} + \alpha_3 IT_{ct}^{IMP} + \alpha_{4a} IT_{ct}^{EXP} + \alpha_5 ZLB_{ct} + CFE_c + TFE_t + u_{ct}. \ (13a)$$

Using c as the country and t as the time subscript, $\widehat{IP}_{ct}$ is the smoothed estimate of the inflation persistence of country *c* at time *t*, CFE_c is a country fixed effect, TFE_t is a time (period) fixed effect, and u_{ct} denotes the unobserved error. All five regressors are dummy variables formed based on our reasoning in Section 1 and further detailed in Section 5. They have the following meaning: ER_{ct}^{USD} equals one when the constraining exchange regime of a domestic currency uses the U.S. dollar as a reserve currency and zero otherwise; ER_{ct}^{EUR} is defined in the same way when the reserve currency is the Euro (or Deutsche mark before 1999); IT_{ct}^{EXP} equals one when the country follows an explicitly stated inflation targeting regime and zero otherwise; IT_{ct}^{IMP} equals one when the country practices implicit inflation targeting and zero otherwise (IT_{ct}^{IMP} and IT_{ct}^{EXP} are mutually exclusive dummy variables; for more details see the data section). Note that an explicit *IT* regime is considered to be stronger than an implicit *IT* regime in terms of its credibility and usually efficiency as well (Goodfriend, 2004).

Zero lower bound (ZLB) or zero interest rate policy has been analyzed as an important factor affecting inflation persistence because it constrains conventional monetary policy (Buiter, 2009; Swanson and Williams, 2014). In order to explicitly control for the ZLB we also incorporated the ZLB-dummy in (13) which takes the value of 1 when a country has hit the ZLB during the sample period, and zero otherwise.

In the next step we modify (13a) to account for the effect of imperfections in (explicit) inflation targeting. Despite of their strong commitment central banks might deviate from their inflation targets. We account for this formally in specification (13b):

$$\widehat{IP}_{ct} = \alpha_0 + \alpha_1 ER_{ct}^{USD} + \alpha_2 ER_{ct}^{EUR} + \alpha_3 IT_{ct}^{IMP} + \alpha_{4b} IT_{ct}^{EXP} \cdot Abs(Inflation - Target)_{ct} + \alpha_5 ZLB_{ct} + CFE_c + TFE_t + z_{ct} \qquad (13b)$$

In (13b) the variable $IT_{ct}^{EXP} \cdot Abs(Inflation - Target)_{ct}$ captures deviations of the inflation rate from the central bank's target when a country follows explicit inflation targeting. The construction of the variable allows for deviations above as well as below the policy-intended level of the inflation rate.

In terms of estimation, by using the cross-section fixed effects, we account for any level differences between the countries, and in doing so we eliminate any possible time-invariant endogeneity (Greene, 2003, p. 291; Wooldridge, 2002, p. 248). By applying period fixed effects we also account for any common trend among the persistence series (Wooldridge, 2002, p. 278). We acknowledge that there still can be an omitted variable which is time-varying and not common in all countries, though. However, country-specific and time period fixed effects approach ensures to a high extent that the effects associated with the dummy variables for monetary strategies are not spurious and the potential endogeneity of monetary strategies with respect to inflation persistence is accounted for. To check for any excess kurtosis or skewness in the residuals which might be caused by inflation targeting, we apply a bootstrap test to the residuals of the regression and verify whether the coefficients remain statistically significant.[9]

4.3 Testable hypotheses

Our methodological approach accounts for time-varying inflation persistence and potential structural breaks. We use break point tests (Chow test, Quandt-Andrews test) to analyze the stability of the estimated inflation persistence equation within the class of I(0) series. We assess the null hypothesis H_0: no break at 5% significance and report results in Section 6.1.

Further, we assess the link between the exchange rate regime and inflation persistence. Our working hypothesis is that there is no such link. We specify two possibilities of reserve currency in a constraining exchange arrangement (U.S. dollar and Euro, or Deutsche mark before 1999) and assess the coefficients α_1 and α_2 in specification (13). We formally test two null hypotheses, H_0: $\alpha_1 = 0$ for USD and H_0: $\alpha_2 = 0$ for EUR, against the respective alternative hypotheses H_A: $\alpha_1 \neq 0$ and H_A: $\alpha_2 \neq 0$. In case of the null rejection, a negative (positive) coefficient indicates the existence of a link between exchange rate regime and a decrease (increase) in inflation persistence. Results are reported in Section 6.2.

Finally, we uncover the link between two degrees of inflation targeting and inflation persistence via an assessment of coefficients α_3 and α_4 in specification (13). Here again we formally test two null hypotheses depending on the type of the IT strategy. Specifically, we test H_0: $\alpha_3 = 0$ for implicit IT and H_0: $\alpha_4 = 0$ for explicit IT against their respective alternatives H_A: $\alpha_3 \neq 0$ and H_A: $\alpha_4 \neq 0$. Similarly as above, when null is rejected, a negative (positive) coefficient points at a decrease (increase) in inflation persistence with respect to the inflation targeting strategy. Results are reported in Section 6.3.

5. Data

[9] As an alternative, the entire estimation of (2) and (13) could be done in one step via Maximum Likelihood, but that would induce two significant drawbacks: (i) we would be obliged to impose distributional assumptions and (ii) the numerical optimization would involve an enormous amount of dimensions, which could lead to false local optima and produce practical difficulties. For those reasons we prefer the well-established and distribution-free two-stage methodology.

We use quarterly inflation rates computed as changes in the consumer price index (CPI). CPI values were obtained from International Financial Statistics (IFS) of the IMF for two decades from 1993:Q1 to 2013:Q4.[10] In addition to the main source, and in cases of need, the data were cross-checked or augmented with the information provided by the statistical offices or central banks of the countries under research. The data were obtained for a sample of 68 countries around the world that are listed in the Appendix, Table A1. The set contains both developed countries and countries belonging to the category of emerging markets according to the Dow Jones list.

Further, in order to analyze the effect of monetary strategies we form a data set containing the relevant information. For each country in Table A1, we indicate the date when implicit inflation targeting (IIT) and explicit inflation targeting (EIT) were adopted. Dummy variables for IIT or EIT take values of 1 during the period when a country can be classified as exercising IIT or EIT and zero otherwise. Both classifications are mutually exclusive; hence, the estimated effects of both IT regimes are net effects. IIT and EIT classification is based on the information obtained from the individual central banks and numerous articles in the academic literature, and follows the classification strategy outlined in Carare and Stone (2006).[11]

In addition, we form the set of the ZLB-dummy that takes value of 1 for those countries in our sample that have hit the ZLB during the sample period, and zero otherwise. The ZLB is represented by 0.5% or lower value of a central policy rate that corresponds to empirically observed values associated with the ZLB-related monetary policy of major central banks in the US, UK, Eurozone, Canada etc. (Buiter, 2009; Swanson and Williams, 2014). Eleven countries plus eurozone in our sample that have hit a ZLB during the sample period are listed in the Appendix Table A1 with starting and ending dates when their central bank's policy rate was at or below 0.5%; in case on no ending date, the ZLB was maintained until the end of our sample period.

Further, we form the variable $IT_{ct}^{EXP} \cdot Abs(Inflation - Target)_{ct}$ to capture absolute deviations of the inflation rate from the central bank's explicit inflation target. The changes in target levels over time are accounted for. In case a central bank has a target interval we use a midpoint as a reference value. In Table A1 we provide information on countries' inflation target rates as well as timing of their adoption.

Finally, for the exchange rate regime classification we employ a *de facto* regime classification that is provided by Reinhart and Rogoff (2004) until 2001. For the later period (2002-2013) a *de facto* regime classification is based on their approach and checked against information obtained from the individual central banks and empirical literature. We distinguish constraining exchange rate arrangements with respect to the U.S. dollar and the Euro (or the Deutsche mark before 1999); on one occasion we also account for a peg to the British pound.[12] The dummy variable for the exchange

[10] Since IT started to be adopted only in early 1990s, we do not consider earlier data. This makes up about 80 quarters of observations, which could be argued as being on the border of the time span for a time-varying parameter model. Still, capturing the trend can be highly valuable even when 2-sigma confidence intervals show no change. For example, there is a widespread agreement in the literature that postwar U.S. inflation persistence has decreased while Pivetta and Reis (2007; p. 1327) clearly show that one can draw a horizontal line between the 2-sigma limits and that "inflation persistence in the United States is best described as unchanged over the last three decades", that is, during 1947–2001.

[11] Eurozone countries are classified as explicitly targeting because of the declared commitment of the European Central Bank (ECB) to keep the annual inflation rate close to or below 2%, as specified by the ECB's Governing Council. In some countries we relied on expert information to classify regimes. For example, it is quite difficult to actually characterize Russian monetary policy since 1998, as there have been many targets at the same time (Korhonen and Mehrotra, 2010). However, by the end of 2014 the Russian central bank has not adopted explicit IT yet.

[12] Eurozone countries are classified as floaters because since its introduction the euro freely floats. During our sample period only Israel used the British pound as a reserve currency in its constraining exchange rate regime, when the British pound was part of a basket with the U.S. dollar. Prior to the beginning of our research period sample, eight more

rate regime with respect to a specific currency takes a value of one during periods when such a regime was in power and zero otherwise. We account for a peg to a reserve currency along with constraining intermediate regimes. In the case of a currency basket peg or its crawling version, more than one reserve currency is involved and the dummy variables are coded to reflect this link. In Table A1 we provide information on when constraining exchange rate regimes were in power in the countries in our sample.

6. Empirical results

Our empirical results are presented in both quantitative and graphical form. Due to the sizeable panel data set comprising 68 countries all over the world, some of the detailed results are excessively large when presented in tables. For that we present only a summary in the text and leave the details in the Appendix.

6.1 Inflation persistence dynamics

We assess the stability of the estimated inflation persistence equation within the class of I(0) series by using two break point tests - Chow test and Quandt-Andrews test. For the Chow-test we assume the break point to be exogenous because the date of the IT adoption is known. Depending on the type of the statistics used (indicated in parentheses), the Chow test rejects the null of no change in 3 (F-stat.), 5 (LR stat.) and 9 (Wald type) cases at 5% statistical significance and under 10% trimming, out of 31 countries which adopted explicit IT during our sample period. With the Quandt-Andrews test we tested for stability changes at unknown break points to account for potential instabilities due to other reasons than IT adoption. At 5% statistical significance (under 10% trimming) the test rejects the null of no change in 6 to 39 cases, depending on the type of the statistics used.[13] When comparing results of both tests we conclude that instabilities in persistence equation exist and number of them materializes for reasons in excess of IT adoption.

In the second step we describe the essential facts related to the panel estimation.[14] The key results are obtained based on our primary measure of inflation persistence: the sum of the autoregressive coefficients (SUM) defined in equation (3); they are presented in Table 1. Supplementary results are obtained based on alternative measures of inflation persistence: LAR (Table 1), HLF (Table 1), and RJT (Table 2). Since all four measures of persistence are constructed differently, the persistence estimates derived from the measures are not directly comparable. Recall that the explained variable in panel regression (13) is the sequence of inflation persistence country by country. On the right-hand side of the regression we aim to reproduce the persistence series using the dummy variables for constraining exchange rate arrangements with a specific reserve currency ($ER_{ct}^{USD}$and ER_{ct}^{EUR}), dummy variables for specific inflation targeting strategy (IT_{ct}^{IMP} and IT_{ct}^{EXP}), plus constant and country-specific fixed effects and time (period) fixed effects.

In our panel set-up a constant is the same for all countries and represents the average persistence of all countries under the condition that the exchange rate and IT regime-dependent

countries used the British pound as a reserve currency in their exchange regimes; these were Bangladesh, Egypt, India, Indonesia, Jordan, Malaysia, New Zealand, and Pakistan. For details see Table A1.

[13] The Quandt-Andrews test provides maximum (MaxF), exponential average (ExpF) and average (AveF) test statistics with non-standard distributions. The true distribution was developed by Andrews (1993) and the approximate asymptotic *p*-values were provided by Hansen (1997). In our analysis, there are 3x2=6 potential results (MaxF/ExpF/AveF x LR/Wald) on rejecting the null of no break. Specific numbers of rejections are 29, 10, 4, 39, 6, 25 (observing the order of test statistics' list in parentheses).

[14] We note that all our panel regression results largely stay the same when applying a bootstrap test to the residuals. None of the estimated coefficients' significance levels change when looking at the bootstrap distribution.

dummies do not exhibit any effect. Based on the constant coefficient (α_0) value, the average persistence is rather low. In our estimations we also account for country-specific and time fixed effects. The country-specific effect is basically an added constant for every given country and its sum with the global constant above (α_0) represents the average country persistence (again, under the condition that the exchange rate- and IT regime-dependent dummies do not exhibit any effect). Based on the SUM measure, the values of country-specific effects range from 0 to about |0.7|; this means that inflation persistence is strongly country-dependent. Since we have 68 countries, the individual fixed effect coefficients are not reported.

Time fixed effects account for a common trend in inflation persistence among countries. In Figure 1 we present a plot of those estimated period fixed effects; they are obtained from the panel specification (13a) estimated with the different measures of IP defined in (3), (6), (7) and (9). Through period fixed effects we control for the downward trend in the IP dynamics that changed into a general increase after 2001 and culminated with the financial crisis in 2008. Later this pattern is characterized by a mild decline. These features were well captured by period-specific effects, as advocated in Section 4.2.

Further, in Figure 2, we present plots of the averages of the FLS smoothed inflation persistence based on the SUM persistence measure for three country groups: low, middle and high persistence countries. The plots show (i) an ample evidence of a common pattern in inflation persistence among countries, albeit at different levels of IP, and (ii) existence of structural breaks and a uniform effect of financial crisis as IP was rising in all three groups during 2007-2008. In addition, low persistence countries exhibit even negative inflation persistence. This finding could partly be a consequence of the time-varying steady-state level of the inflation rate, but is not unusual as it is reported in other studies as well (see, among others, Benati, 2008; Meller and Nautz, 2012; Darvas and Varga, 2014). Explanation of this phenomenon can be made with the help of microeconomic price-setting models that often imply that "high persistence in the price level … translates into very low or even negative persistence in inflation" (Cecchetti and Debelle, 2006; p. 317). For example, in a canonical time-dependent price-setting model of Taylor (1980) positive persistence in the price level implies negative inflation persistence. Hence, price-level stickiness yields a plausible interpretation to the negative inflation persistence observed in some countries in our sample. From a technical point of view it is also worth considering that state space models, like the Kalman-filter or FLS, compute the optimal increment of the state variable (in our example, the AR coefficients which are directly linked to persistence), holding the variance of this increment constant (or given, as in the FLS case). This can more easily lead to negative persistence values. The key take from this is to look rather at the IP development and less at its exact levels.

Finally, in Figure 3 we present the estimated FLS smoothed sum-of-AR-coefficients (SUM) persistence series for the United States and Germany (as a proxy for the Eurozone) - their evolution is similar, although the German series is smoother than the U.S. series but they seem to change direction at the same time in most cases.[15]

[15] We use our persistence series based on the FLS/SUM persistence measures for all 68 countries and perform a principal components analysis (PCA) on them. We observe that the first two principal components explain 76% of the total variance (58% and 18%, respectively) and the influence of the remaining components is negligible. We take the result of the PCA as evidence of the existence of a factor structure in inflation persistence across countries. Since we are unable to directly interpret the principal components, as a conjecture we offer two possibilities along the arguments of Cogley et al. (2010) and Benati and Surico (2007), who emphasize that policy factors account for changes in inflation persistence. One possibility is the effect of monetary policy measures that are being adopted to counteract inflation persistence (Dornbusch, 1982; Davig and Doh, 2014), The second possible explanation is that a large part of the decline in inflation persistence is due to shifts in institutional arrangements, particularly changes in wage bargaining and wage indexation

6.2 Exchange rate regime and inflation persistence

The link between a constraining exchange arrangement and IP is captured by the coefficients α_1 and α_2, which represent the marginal effects of dummy variables ER^{USD} and ER^{EUR} on inflation persistence as an average for all countries. Relatively small and negative values of the α_1 coefficient based on the SUM measure (Table 1) suggest that the USD-based constraining regime is mildly linked to persistence decrease. Results based on the LAR and HLF persistence measures are not available as the estimate coefficients are statistically insignificant (Table 1). Results based on the RJT measure produce very small positive coefficients, but half of them is statistically insignificant (Table 2). All results, taken together, point at limited but contributing link between the U.S. dollar-based constraining exchange regime and inflation persistence.

Regimes using the Euro (or Deutsche mark) exhibit an order of magnitude larger and contributing effect towards persistence decrease as the SUM-based α_2 coefficients are negative and relatively large (Table 1). Results obtained by using three other measures of inflation persistence are also negative and proportionally similar (Tables 2 and 3), given the differences in measure construction. Low German inflation and reasonably low inflation pursued by the ECB under the Maastricht stability criterion along with prudent monetary policies of both institutions have led to low or moderate inflation persistence (Altissimo et al., 2006; Meller and Nautz, 2012) as documented for much of the span of our sample. Based on such IP dynamics the negative α_2 coefficients come as a sensible outcome and the estimates provide consistent findings: the effect of constraining exchange regimes using the Euro (or Deutsche mark) is relatively strong and uniformly point at a link to a decrease in inflation persistence. The effect is also in accord with the dramatic decrease in inflation persistence following the Euro introduction that is documented by Lopez and Papell (2012).

The above results indicate some difference between the effects of exchange rate regimes using different reserve currencies. Such dissimilarity materialized despite the strong constraints on domestic policy actions imposed by a commitment to a constraining exchange rate regime and limitations on how the monetary authorities can react to the persistence of inflation shocks (Bleaney, 2001). As a complement, in Figure 3 we provide a plot of inflation persistence for the U.S. and Germany. Inflation persistence in the U.S. was relatively high for the initial two thirds of the period under research and, in fact, was rising prior to financial crisis. Then it experienced a marked decline during 2006–2008. This pattern is quite different from the global picture (Figure 2) where a major increase in IP coincides with the crisis period in 2008. The sharpest decline of the U.S. inflation persistence occurs from the mid-2007 and correlates with the sequence of the cuts in the Fed Funds Rate initiated in August 2007. Increase in the post-crisis IP is soon transformed into a subsequent decline that coincides with the adoption of explicit inflation targeting by the Fed in 2012. The fact is that after the crisis the US inflation persistence has been remarkably low. The German IP exhibits a different pattern: it is low for most of the period and declines in a stable manner. A notable difference between U.S. and German inflation persistence is visible with respect to the 2008 crisis, though. During the crisis, German IP rises, albeit marginally, then declines and levels off. The difference between the patterns in the U.S. and German IP likely stems from the fact that post-crisis ECB interest rate cuts were not that drastic as those of the Fed.

(Christoffel and Linzert, 2010; Du Caju et al., 2009). Moreover, both examples can be connected - the empirically documented presence of a time variation in automatic wage adjustment procedures implies that a monetary policy conducted along a Taylor rule necessitates the response of the interest rate to shocks stemming from the degree of wage indexation (Attey, 2016).

Despite some difference between the effects, the results can be reasonably explained. Bleaney (2001; p. 393) develops a model of inflation persistence under a constraining exchange rate regime and argues that “more constraining exchange rate regime tends to reduce the variance of inflation persistence across countries, because all countries take on the inflation persistence of the reserve currency in proportion to the degree of exchange rate constraint”, but the inflation persistence is not necessarily lower in a more constraining arrangement. According to his model the coincidence of low inflation persistence under a more constraining regime would emerge “if the exchange rate regime constrains the reserve currency to have low inflation persistence, or if it happened to have low inflation persistence by chance”. The above arguments imply that under a constraining exchange rate regime—linked to a specific reserve currency—lower inflation persistence can be potentially imported under the condition that the persistence is low in the reserve currency country and its dynamics is stable in the first place. From this it follows that a constraining exchange arrangement with the U.S. dollar as a reserve currency might suppress inflation persistence somewhat less than the one based on the euro/Deutsche mark. Pivetta and Reis (2007) bring evidence of high U.S. inflation after the WWII until late 1990’s but Beechey and Österholm (2012) argue that the U.S. inflation persistence decreased during recent decades, partly thanks to the Fed that have accentuated price stability in its monetary policy – this claim resonates well with our evidence on high U/S. persistence before the crisis and particularly low IP afterwards (Figure 3).

The above findings and interpretation are further supplemented by complementary testing the exchange rate channel of IP. We proceed by including the IP of Germany and of the U.S. separately in the equation (13a; not shown formally) and at the same time removing IP of each country from a panel of dependent variables. Statistically significant results are limited to the SUM measure and positive coefficients associated with IP of the U.S. and Germany amount to 0.4 for the U.S. IP, and 2.6 for the German IP (not reported, available upon request). These marginal effects from the IP of the reserve country mean that increase in the U.S. persistence is associated with disproportionally lower increase of IP in another country. On other hand, increase in the German persistence is associated with disproportionally larger increase of IP in another country. We have to note that including the persistence of reserve countries in the equation (13a) did not change statistical significance of the key coefficients. Hence, our original inference remains same. The strong positive coefficients associated with IP of the U.S. and Germany also show that there is a common factor in the persistence series of individual countries (see footnote 15).

We complement our regression results with a graphical presentation in Figure 4, where we show the persistence dynamics in countries with and without constraining exchange regimes. Figure 4 is divided into two panels. The *solid lines* show the mean and two standard error bands of inflation persistence in countries that did not have any exchange rate arrangement at a given time. As the FLS estimator is distribution-free, the error bands are calculated using the distribution of the by-country FLS point-estimate sequences. The *dashed lines* in both left and right panels show the same information for countries that exercised dollar-based or Euro/Deutsche mark-based arrangements at a given time. The persistence in countries using a dollar-based regime was decreasing until 2002 and increased afterwards, reaching the highest value in 2008 crisis (Figure 4; left panel). Increasing persistence before the world financial crisis signals worsening monetary conditions in countries with tight exchange arrangements potentially transferred via the USD. A temporal drop in persistence after 2008 was quickly replaced by an increase of persistence to new level, even slightly higher than that prior to the crisis. Inflation persistence in countries with floating exchange rates was mostly somewhat lower than that of those with dollar-based regimes and exhibits a more stable decreasing pattern. Persistence in countries using the Euro (Deutsche mark) as a reserve currency experienced a continuous decrease until 2000 and after stabilization, began to marginally rise during the 2005–2008 period (Figure 4; right panel). After the financial crisis, inflation persistence began to decrease. In general, it was also slightly lower and exhibited a more stable pattern than persistence in floating countries. The dynamics of persistence in both panels indirectly supports our quantitative results presented in Table 2 about certain contribution of a constraining exchange rate regime to pacify inflation persistence.

6.3 Inflation targeting and inflation persistence

In Table 1 we present the key results based on the SUM measure and those based on the LAR and HLF IP measures. Results based on the RJT measure are shown in Table 2. Coefficients α_3 and α_{4a} exhibit marginal effects of two forms of IT on inflation persistence. Negative values of coefficients in both Tables 1 and 2 provide consistent outcomes with respect to a decrease in inflation persistence. The stronger commitment of explicit inflation targeting is witnessed by almost twice-larger coefficients (α_{4a}) than those (α_3) of a less formal monetary strategy represented by implicit inflation targeting (Table 1; SUM). This is a quite strong result in two senses as our sample contains 68 countries, out of which 42 have practiced some type of IT during the time span. First, it shows that inflation targeting contributes to lower inflation persistence. Second, it shows that even its less strict version (IIT) possesses the power to tame persistence.

The results based on the LAR persistence measure also show a contributing effect to lower inflation persistence (Table 1) but the estimate for the explicit version is statistically insignificant. The results from the HLF measure point at implicit IT being more contributive than explicit IT (Table 1), at least by the values of respective coefficients. This finding might stem from differences in the construction of the persistence measures. Recall that the HLF measure represents the number of periods in which inflation remains above 0.5 after a unit shock. Hence, a smaller value of the half-life estimate for explicit IT indicates that this strategy is seemingly less conducive to helping lower persistence below 0.5 than implicit IT. However, since inflation is usually higher under implicit IT than under explicit IT, it is also more likely that individual persistence will be above the 0.5 threshold after a shock more often than under explicit IT. Hence, explicit IT provides less room for improvement of the half-life persistence measure than implicit IT. Further, results based on RJT measures (Table 2) show that the effect of implicit IT on inflation persistence seems to be also larger than that of explicit IT. However, the coefficients show that effect of explicit IT is rather stable but that of implicit IT diminishes with the time over which the specific RJT measure is computed. Thus, after all, results from the SUM measure (Table 1) and those based on the HLF (Table 1) and RJT measures (Table 2) are not entirely incompatible and provide a qualitatively similar inference.

As a complementary check we performed a formal test for the statistical significance of the difference between explicit and implicit inflation targeters. For all IP measures the effects of the EIT and IIT were found to be statistically different at 1% significance level; not reported but available upon request.

Our results also contribute to the debate on how the zero lower bound (ZLB) has affected inflation persistence due to its constraint that it imposes on the conventional monetary policy (Buiter, 2009; Swanson and Williams, 2014). The coefficients of the ZLB-dummy (α_5) are relatively small but negative and statistically significant when measured by the LAR (Table 1) and RJT (Table 2) IP measures; they are also negative but statistically insignificant in case of the SUM and HLF measure (Table 1). The negative marginal effect of the ZLB means that, ceteris paribus, once a country hits the ZLB its inflation persistence mildly decreases. This result should not be taken as an advice to lower interest rate to achieve lower IP, though. Under the ZLB the inflation is low anyway. Plus, the limited fraction of our research time-span, during which some countries entered the ZLB, suggests that we take the ZLB effect with a grain of salt.

Further, we show how deviations of the inflation rate from the central bank's explicit inflation target impact inflation persistence. The result is limited to the SUM measure (Table 1) as other measures produce statistically insignificant coefficients. However, negative coefficient (α_{4b}) associated with the variable $IT_{ct}^{EXP} \cdot Abs(Inflation - Target)_{ct}$ means that as a central bank moves from its inflation target, there exist a pull to return to inflation persistence mean, ceteris paribus. The extent of this impact should not be overstated, though. For the whole sample, an average marginal effect of the pull translates in to about 0.1% lower persistence when inflation is 1% from its target.

Finally, one has to note that the number of countries practicing any form of IT has been growing during the time. Concurrently, from our IP estimates we witness a mostly decreasing pattern of IP over time (Figure 5). These two phenomena might produce an inverse relationship. In order to rule out the possibility of such a spurious link, we repeated the estimation with the difference of IP as our explanatory variable in (13). This robustness check (using FLS estimation) produced negative and statistically significant coefficients (α_3 and α_4; not reported, available upon request) and confirmed the contributive effect of IT on inflation persistence.

Similarly as before, we bring forth a graphical presentation of the persistence dynamics in Figure 5 that is divided into two panels. The *solid lines* show the mean and two standard error bands of inflation persistence in countries that did not practice any form of inflation targeting at the given time. The *dashed lines* in the left panel show the same information for countries that implicitly (and only implicitly) exercised inflation targeting at the given time. The *dashed lines* in the right panel show the inflation persistence in countries with explicit inflation targeting. Persistence in countries practicing any form of IT shows a very stable pattern of gradual decline that is not interrupted even by the 2008 financial crisis. The key difference between both panels is the dramatically larger pattern of decrease in persistence for countries with implicit IT. After 2002, the paths of the persistence of implicitly IT and non-IT countries even diverge. During most of the period under research, the persistence in explicitly targeting countries is low and stable, and exhibits a mild decreasing pattern that is interrupted only by temporary and marginal increases around 2000 and in 2008. Further, confidence bands around the persistence of the explicit-IT countries are visibly narrower that those related to the persistence of non-IT countries. The IP pattern in countries without IT is quite different. A gradual decline during the 1990s is in 2002 replaced by an upward trend and IP sharply rises prior to and during the 2008 financial crisis. A post-crisis drop is then replaced by an increase in IP to a new level that is higher than the low IP in 2002. In general, persistence dynamics is in line with our quantitative results and supports the favorable effect of IT with respect to inflation persistence and even its unaltered effect when related to the financial crisis.

7. Conclusions

In this paper, we provide a comprehensive analysis of the link between price stability-oriented monetary strategies and inflation persistence. We analyze the dynamics of inflation persistence in a panel of 68 countries all over the world by employing quarterly inflation rates for the period from 1993:Q1 to 2013:Q4. The panel data set contains both developed countries and those falling into the category of emerging markets (according to the Dow Jones list). This exceptionally wide coverage enables us to provide a truly "big picture" of the analyzed phenomenon.

Recall that in the first stage we use the time-varying coefficients approach to derive four different measures of inflation persistence for each individual country in our sizeable data set. The time-varying persistence approach helps us to account for structural breaks in persistence that in fact exist in a majority of the countries in our sample. In the second stage, we estimate links between inflation persistence and two policy strategies that possess a potential to affect inflation persistence. The strategies are inflation targeting and a constraining exchange rate arrangement. We distinguish between implicit and explicit inflation targeting strategies of central banks, and also identify constraining exchange rate arrangements with respect to the U.S. dollar and Euro (or Deutsche mark).

Based on our results we show a contributing effect of inflation targeting with respect to inflation persistence. The effect of explicit IT is stronger than that of implicit targeting. However, even the less strict version (IIT) possesses the power to tame persistence. The link between inflation persistence and constraining exchange rate regimes is, in general, less pronounced than that of IT and the effect is statistically significant across all IP measures. Our results also contribute to the debate on how the zero lower bound (ZLB) has affected inflation persistence due to its constraint that it imposes on the conventional monetary policy: we show that once a country hits the ZLB its inflation persistence mildly decreases. Finally, we assess how deviations of the inflation rate from the central bank's explicit inflation target impact inflation persistence. We show that there exists a mild pull to return to inflation persistence mean once a central bank moves away from its inflation target.

Further, regimes with the U.S. dollar as a reserve currency are less effective than those using the Euro (or Deutsche mark). On other hand, the U.S. persistence transfers via dollar disproportionately lower effect on other countries' persistence than the IP of Germany. Hence, our evidence shows that the effect of the exchange rate arrangement on inflation persistence is reserve currency-dependent and correlates with the characteristics of inflation persistence in the country of the reserve currency.

In terms of inflation persistence, Ascari and Sbordone (2014; p. 682) note that "knowing the time it takes for inflation to approach a new equilibrium after a shock is crucial for determining how to adjust monetary policy tools to reach desired objectives." Our findings then convey a strong message that price stability-oriented policy strategies possess the ability to help reduce inflation persistence; e.g., these strategies contribute to reducing the time it takes for inflation to approach a new equilibrium after a shock. This is a positive policy implication: both monetary strategies, albeit to a different extent, provide central banks with enlarged "policy space" to deal with temporary price shocks. This is in line with argument voiced by Siklos (2017; p.42) that "low and stable inflation continues to represent an essential ingredient of good practice in monetary policy". Finally, IT seems to be a good monetary strategy as inflation persistence in countries practicing any form of IT exhibits a stable pattern of gradual decline that is not interrupted even by the 2008 financial crisis and remains on the track afterwards.

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Tables and Figures

Table 1. Panel least squares estimation results with SUM, LAR, and HLF persistence measures

Dependent Variable		SUM persistence estimate		LAR persistence estimate		HLF persistence estimate	
Equation Setup		With ITEXP dummy	With IT diffference	With ITEXP dummy	With IT diffference	With ITEXP dummy	With IT diffference
Constant	α_0	0.289 (18.46) ***	0.147 (14.35) ***	0.859 (243.54) ***	0.855 (371.91) ***	6.621 (10.50) ***	5.122 (12.45) ***
US dollar regime (ERUSD)	α_1	-0.060 (-3.20) ***	-0.041 (-2.20) **	0.004 (0.85)	0.004 (0.98)	0.137 (0.18)	0.339 (0.45)
Euro (Deutsche Mark) regime (EREUR)	α_2	-0.405 (-19.29) ***	-0.251 (-13.77) ***	-0.019 (-4.00) ***	-0.016 (-3.97) ***	-4.082 (-4.83) ***	-2.812 (-3.85) ***
Implicit inflation targeting (ITIMP)	α_3	-0.215 (-9.01) ***	-0.130 (-5.87) ***	-0.024 (-4.43) ***	-0.020 (-3.97) ***	-6.925 (-7.21) ***	-5.597 (-6.28) ***
Explicit inflation targeting (ITEXP)	α_{4a}	-0.443 (-18.84) ***		-0.005 (-0.85)		-2.865 (-3.02) ***	
ITEXP*ABS(Inflation - IT midpoint)	α_{4b}		-0.122 (-17.14) ***		0.001 (0.80)		-0.168 (-0.59)
Zero lower bound dummy (DZLB50BP)	α_5	-0.031 (-1.06)	-0.029 (-1.00)	-0.014 (-2.10) **	-0.013 (-2.00) **	-1.713 (-1.46)	-1.553 (-1.33)
R-squared		60.9%	60.5%	59.0%	59.0%	21.5%	21.4%

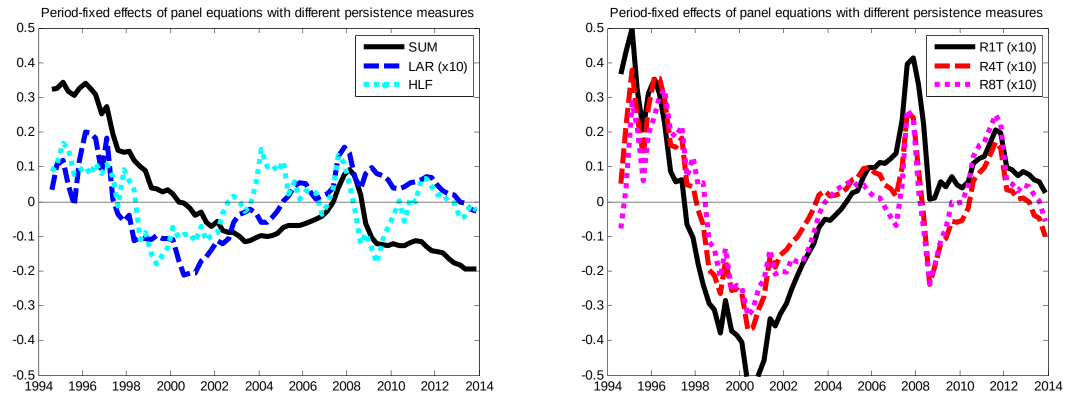
Notes: The persistence measures are the sum of autoregressive coefficients (SUM), largest autoregressive root (LAR), and half-life in quarters (HLF). The table shows regression coefficients with *t*-statistics in parentheses. * indicates a rejection of insignificance at the 10% level, ** at the 5% level, and *** at the 1% level. Cross-section and period fixed effects (dummy variables) are included in all specifications, the number of periods is 78 and the number of cross-sections is 68.

Table 2. Panel least squares estimation results with RJT persistence measures

Dependent Variable		R1T persistence estimate		R4T persistence estimate		R8T persistence estimate	
Equation Setup		With ITEXP dummy	With IT diffference	With ITEXP dummy	With IT diffference	With ITEXP dummy	With IT diffference
Constant	α_0	0.350 (49.54) ***	0.344 (74.74) ***	0.256 (34.33) ***	0.244 (50.31) ***	0.156 (20.99) ***	0.145 (29.99) ***
US dollar regime (ERUSD)	α_1	0.025 (2.93) ***	0.025 (3.04) ***	0.015 (1.64)	0.016 (1.81) *	0.009 (1.06)	0.011 (1.22)
Euro (Deutsche Mark) regime (EREUR)	α_2	0.000 (0.03)	0.006 (0.75)	-0.004 (-0.41)	0.006 (0.75)	-0.026 (-2.66) ***	-0.017 (-2.02) **
Implicit inflation targeting (ITIMP)	α_3	-0.132 (-12.22) ***	-0.128 (-12.79) ***	-0.115 (-10.14) ***	-0.106 (-10.10) ***	-0.115 (-10.22) ***	-0.106 (-10.15) ***
Explicit inflation targeting (ITEXP)	α_{4a}	-0.016 (-1.48)		-0.027 (-2.38) **		-0.021 (-1.89) *	
ITEXP*ABS(Inflation - IT midpoint)	α_{4b}		-0.004 (-1.12)		-0.004 (-1.29)		-0.002 (-0.50)
Zero lower bound dummy (DZLB50BP)	α_5	-0.046 (-3.48) ***	-0.045 (-3.46) ***	-0.053 (-3.81) ***	-0.052 (-3.75) ***	-0.043 (-3.15) ***	-0.042 (-3.07) ***
R-squared		56.7%	56.7%	56.2%	56.1%	47.8%	47.8%

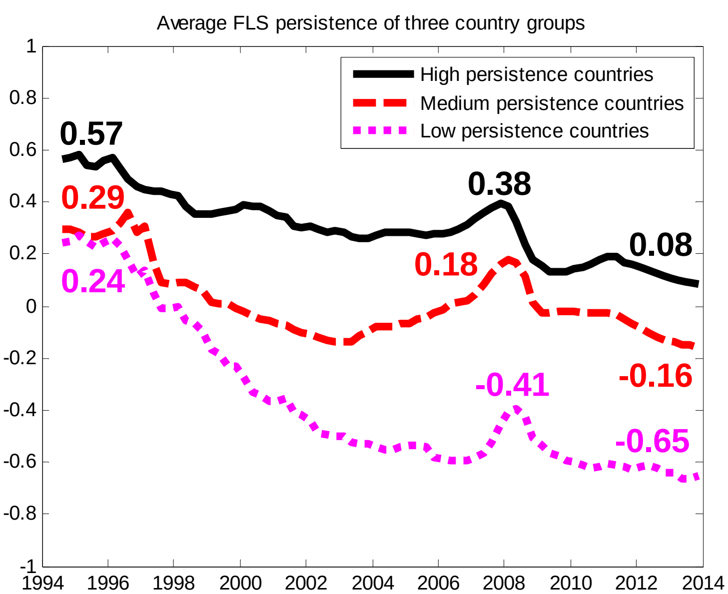
Notes: The persistence measures are the R_{jt}^2 statistics for $j = 1$ (R1T), $j = 4$ (R4T), and $j = 8$ periods (R8T). The table shows regression coefficients with *t*-statistics in parentheses. * indicates a rejection of insignificance at the 10% level, ** at the 5% level, and *** at the 1% level. Cross-section and period fixed effects (dummy variables) are included in all specifications, the number of periods is 78 and the number of cross-sections is 68.

Figure 1. Estimated period-fixed effects of the panel equations



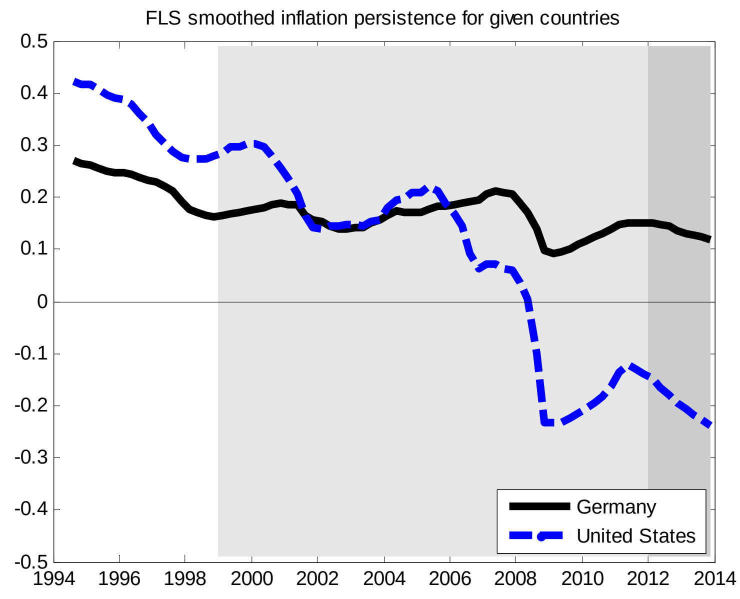
Notes: The graphs show the time fixed effects for the FLS smoothed persistence equations, with all six persistence measures. Some measures are multiplied by a factor of 10 to make a similar range.

Figure 2. Average FLS smoothed inflation persistence of three country groups



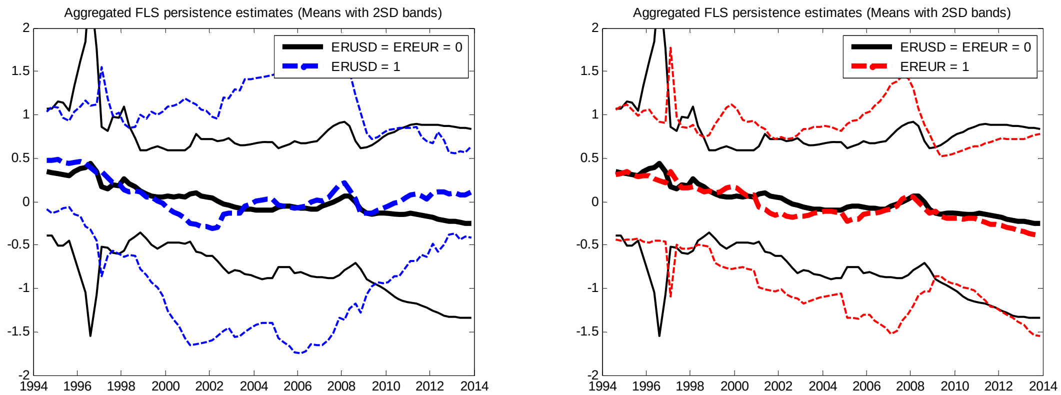
Notes: The three lines show the estimated FLS smoothed sum-of-AR-coefficients (SUM) persistence series for the three country groups based on average persistence throughout the sample. High persistence means the highest one-third of the countries, low persistence means the lowest one-third of the countries, while medium means the middle one-third. The numbers show the values of the series at the beginning of sample (1994Q3), the financial crisis (2008Q1), and the end of sample (2013Q4).

Figure 3. FLS smoothed inflation persistence



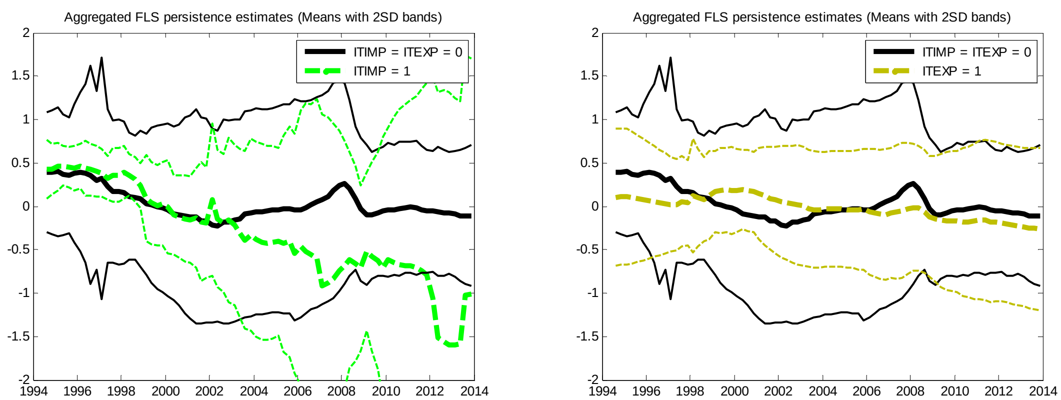
Notes: The two lines show the estimated FLS smoothed sum-of-AR-coefficients (SUM) persistence series for the United States and Germany. The beginning of the light grey background shows when the Euro was adopted. The dark grey background depicts when the U.S. adopted explicit inflation targeting.

Figure 4. Aggregated FLS smoothed SUM persistence estimates by exchange rate regime



Notes: The solid lines show the mean of IP (and bands of 2 standard errors) in countries that did not have any exchange rate arrangement at a given time. The dashed lines on the left show the same for countries that exercised a USD regime at given time, the dashed lines on the right show the same with EUR (and DEM earlier). Because ER^{USD} and ER^{EUR} are not mutually exclusive dummies by our definition, the three groups do have intersections.

Figure 5. Aggregated FLS smoothed SUM persistence estimates by inflation targeting



Notes: The solid lines show the mean of IP (and bands of 2 standard errors) in countries that did not have inflation targeting at a given time. The dashed lines on the left show the same for countries that implicitly (and only implicitly) exercised inflation targeting at a given time; the dashed lines on the right show the same with explicit inflation targeting. Because IT^{IMP} and IT^{EXP} are mutually exclusive dummies by our definition, the three groups are disjunctive and their union gives all the countries at every time point.

Appendix

Table A1. Timings of inflation targeting, exchange rate and zero lower bound regimes.

Notes: Implicit (IIT) and explicit (EIT) inflation targeting and zero lower bound (ZLB) regimes have mostly starting dates (no IT regime has ended yet, only two ZLB regimes have ended within our sample time span). We report these with monthly precision. Annual inflation target values or bands are always converted to a midpoint plus-minus a half range (zero in case of exact target rate), and are reported in percentage points; the conversion was done for convenience of estimation irrespective of whether a central bank has a specific rate or band as a target. For Eurozone we use values of 1.75±0.25; this solution reflects a slightly vague commitment of the European Central Bank (ECB) to keep the annual inflation rate close to or below 2% (different target value options reflecting the commitment do not yield materially different results). For some IT values (EIT and ZLB starting dates) shaded background marks that the specific country adopted given regime because of its euro area membership. The exchange rate regime (ER) intervals are reported with quarterly precision. The Q1 notations at starting dates and Q4 notations at ending dates are omitted. The starting dates in parentheses indicate the approximate starting point of a given ER regime, but this does not affect our analysis as our data sample starts later on. In case of a variant of currency basket pegs, the exchange rate regime involves a peg to more than one currency during the specific period.

No	Country	IIT start	EIT start	IT Value	ZLB start (end)	ER intervals	ER types
1	Argentina					1964 – 1971 1985 – 1986 1991Q2 – 2002Q3	USD USD USD
2	Australia	Jan 1990	Apr 1993	2.50±0.50		1972 – 1987	USD
3	Austria		Jan 1999	1.75±0.25	May 2013	1954 – 1959 1960 – 1998	USD DEM
4	Bangladesh	Jul 2013				(1972) – 1982 1983 – 2002	GBP USD
5	Belgium		Jan 1999	1.75±0.25	May 2013	1954 – 1955 1956 – 1998	USD DEM
6	Brazil		Jun 1999	4.50±2.00		(1945) – 1950 1967 – 1998	USD USD
7	Bulgaria				Jan 2010	(1945) – 1989 1997 –	USD DEM/EUR
8	Canada		Mar 1991	2.00±1.00	Mar 2009 (Jul 2010)	(1945) – 1950 1963 – 1969	USD USD
9	Chile	Sep 1990	Sep 1999 Jan 2001	4.00±0.00 3.00±1.00		1960 – 1962 1973Q2 – 1999Q3 1982 – 1983	USD USD DEM
10	China	Jan 2003				1994 –	USD
11	Colombia	Jan 1991	Sep 1999	3.00±1.00		(1945) – 1983 1985 – 1998	USD USD
12	Czech Republic		Dec 1997	2.00±1.00	Jul 2012	(1991) – 1997Q2 (1991) – 1997Q2	USD DEM
13	Denmark				Jun 2012	(1945) – 1951 1952 –	USD DEM/EUR
14	Egypt					(1945) – 1950 1963 – 2002	GBP USD
15	Estonia		Jan 2011	1.75±0.25	May 2013	1992 – 2010	DEM/EUR
16	Finland		Feb 1993 Jan 1999	2.00±0.00 1.75±0.25	May 2013	1949 – 1972 1973 – 1998	USD DEM
17	France		Jan 1999	1.75±0.25	May 2013	1949 – 1971 1972 – 1998	USD DEM
18	Germany	Jan 1975	Jan 1999	1.75±0.25	May 2013	(1945) – 1970 1971 1972 1973 – 1998	USD (DEM) USD (DEM)
19	Greece		Jan 2001	1.75±0.25	May 2013	1950 – 1981 1985 – 2000	USD DEM/EUR

20	Hong Kong				Dec 2008	(1945) – 1972 1983Q4 –	USD USD
21	Hungary		Jun 2001	3.00±0.00		(1946Q3) – 2001Q1	DEM/EUR
22	Iceland		Mar 2001	2.50±0.00		1947 – 1977 1984 – 2000	USD DEM/EUR
23	India					(1945) – 1969 1970 1971 – 1978 1980 – 2007	GBP USD GBP USD
24	Indonesia	May 1999	Jul 2005	5.00±1.00		(1945) – 1949 1969 – 1997	GBP USD
25	Iran					1954 – 1976	USD
26	Ireland		Jan 1999	1.75±0.25	May 2013	1980 – 1998	DEM
27	Israel	Jun 1992	Jun 1997 Jan 1999 Jan 2000 Jan 2001 Jan 2002 Jan 2003	8.50±1.50 4.00±0.00 3.50±0.50 3.00±0.50 2.50±0.50 2.00±1.00		(1948) – 1950 1962 – 1970 1971 – 1975 1980 – 1998 1986 – 1998	GBP GBP USD GBP USD
28	Italy		Jan 1999	1.75±0.25	May 2013	1952 – 1975 1979Q2 – 1998	USD DEM
29	Japan	Jan 2010	Feb 2012 Jan 2013	1.00±1.00 2.00±0.00	Oct 1995	1949 – 1977	USD
30	Jordan					(1945) – 1971 1972 – 1975 – 1988	GBP USD SDR
31	Korea (South)	Apr 1998	Jan 2000 Jan 2001 Jan 2004 Jan 2010 Jan 2013 Jan 2016	2.50±1.00 3.00±1.00 3.00±0.50 3.00±1.00 3.00±0.50 2.00±0.00		(1945) – 1997	USD
32	Kuwait					(1959) – 1961 1969 – 1975Q2 – 2002 2007Q3 –	DEM USD DEM/EUR EUR
33	Latvia					1995 – 2013	DEM/EUR
34	Lithuania					1995 – 2001 2002 – 2014	USD EUR
35	Luxembourg		Jan 1999	1.75±0.25	May 2013	(1945) – 1955 1956 – 1998	USD DEM
36	Malaysia					1946 – 1975 1976 – 1997 1999 – 2005	GBP USD USD
37	Mauritius					(1945) – 1975 1972Q3 1976 – 1994Q2	DEM USD USD
38	Mexico	Jan 1996	Jan 2001	3.00±1.00		(1945) – 1976Q3 1982Q3 – 1994	USD USD
39	Morocco					(1945) –	DEM
40	Netherlands		Jan 1999	1.75±0.25	May 2013	1951 – 1970 1971 – 1998	USD DEM
41	New Zealand		Mar 1990	2.00±1.00		(1945) – 1971 1972 – 1982	GBP USD peg via AUD
42	Nigeria					(1945) – 1971 1983Q3 – 1984Q2 1991Q3 – 1998	DEM USD USD
43	Norway	Feb 1999	Mar 2001	2.50±0.00		(1945) – 1972	USD

						1973 – 1992	DEM
44	Pakistan					(1945) – 1971 1972 – 2007	GBP USD
45	Peru		Jan 2002	2.00±1.00		(1945) – 1971 1994 – 2007	USD USD
46	Philippines	Jul 1993	Jan 2002	4.00±1.00		1952 – 1956 1962 – 1968 1973 – 1982 1986 – 1990	USD USD USD USD
47	Poland	Aug 1997	Oct 1998	2.50±1.00		1990 – 2000 1991 – 2000	USD DEM/EUR
48	Portugal		Jan 1999	1.75±0.25	May 2013	(1945) – 1972 1973 – 1998	USD DEM
49	Romania	Jan 2002	Aug 2005	3.00±1.00		1990 – 2002 1990 – 1993 2009 –	USD DEM EUR
50	Russia	Jan 2001				1995 – 1998 2005 – 2008 2005 – 2008	USD USD DEM/EUR
51	Saudi Arabia					(1945) – 1958 1959 –	DEM USD
52	Singapore				Jan 2009	(1945) – 1971 1972 – 1998	DEM USD
53	Slovak Republic		Jan 2009	1.75±0.25	May 2013	(1991) – 1997 (1991) – 1997 1999 – 2008	USD DEM EUR
54	Slovenia	Nov 2003	Jan 2007	1.75±0.25	May 2013	1993 – 2006	DEM/EUR
55	South Africa	Jan 1990	Feb 2000	4.50±1.50		(1945) – 1973	DEM
56	Spain	Jan 1995	Jan 1999	1.75±0.25	May 2013	(1945) – 1946 1949 – 1980 1981 – 1998	USD USD DEM
57	Sri Lanka					(1945) – 1967 1972 – 2011	DEM USD
58	Sudan					1958 – 1978 (1990) –	USD USD
59	Sweden		Jan 1993	2.00±0.00	Apr 2009 (Aug2010)	1946 – 1972 1973 – 1992	USD DEM
60	Switzerland	Jan 1975	Jan 2000	1.00±1.00	Dec 2008	(1945) – 1973 1982 –	USD DEM/EUR
61	Taiwan					–	–
62	Thailand		May 2000 Sep 2009 Jan 2015	1.75±1.75 1.75±1.25 2.50±1.50		(1945) – 1947 1948 – 1997	DEM USD
63	Tunisia					(1945) –	DEM
64	Turkey	Jan 2002	Jan 2006	5.50±0.00		1946 – 1953 1961 – 1980 1998 – 2000	USD USD DEM/EUR
65	Ukraine					1997 – 2006	USD
66	United Kingdom		Oct 1993	2.00±0.00	Mar 2009	(1945) – 1971 1991 – 1992	USD DEM
67	United States	1992	Jan 2012	2.00±0.00	Jan 2009	(1945) –	(USD)
68	Venezuela					(1945) – 1982 1994 –	USD USD