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"The impact of monetary strategies on inflation persistence"

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The impact of monetary strategies on inflation persistence

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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. Regimes with the U.S. dollar as a reserve currency are less effective than those using the Euro; this effect correlates with the level of the reserve currency's inflation persistence. Further, we document the existence of structure in inflation persistence data. Our results are robust to differences in four well established inflation persistence measures and are not affected by existing structural breaks or the endogeneity of monetary strategies.

JEL-Classification: C22; C32; E31; E52; F31

Keywords: Inflation persistence; inflation targeting; exchange rate regime; flexible least squares; structural breaks

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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

[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 (2013).

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 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 and the contribution of our paper is fourfold. First, we employ the four different measures of inflation persistence that are established in the literature (see Section 3) and cover more measurement issues. Second, 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. Third, we use the flexible least squares method 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. Fourth, we identify 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.

As a complementary step, we perform a principal components analysis and provide evidence of structure in inflation persistence, since two key principal components explain 76% of the total variation in the data. We conjecture that active monetary policies and shifts in institutional arrangements are potential sources of the structure.

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

[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.

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 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. [4]

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).[5] 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

[4] An alternative to inflation targeting is price-level targeting. While inflation targeting aims at the price growth rate, price-level targeting targets the price level itself. As there is only limited evidence on price-level targeting in practice, we do not attempt to cover this issue. However, we acknowledge that, as Ruge-Murcia (2014; p. 324) shows, "there is heterogeneity in the actual application of inflation targeting across countries, and that the description of inflation targeting as a policy that systematically accommodates price-level shocks may be restrictive".

[5] "Explicit inflation targeting is characterized by the announcement of an official target for the inflation rate and by an acknowledgment that low inflation is a priority for monetary policy" (Goodfriend, 2004; p. 311). Kim (2011) argues that simple central bank's announcement of a numerical target does not necessarily imply commitment to stabilize inflation and shows that the better outcome of inflation targeting comes from "constrained discretion" rather than from commitment.

witnessed in the case of the U.S.[6] 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."

Inflation targeting, therefore, displays the central bank's capacity to alter the dynamics of inflation and inflation persistence. Williams (2006; p. 2) explicitly claims that a "change in the observed persistence of inflation may reflect the effects of a shift from poorly anchored inflation expectations in the past to well-anchored expectations today". Similarly, Roger (2010; p. 48) claims that "inflation expectations are better anchored in countries that adopt inflation targeting and that authorities in those countries place a greater emphasis on keeping inflation from surging." Hence, it is believed that truly credible IT helps to lower intrinsic persistence.

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.[7] 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

[6] Goodfriend (2004; p. 322) argues that "The manner in which the Greenspan Fed moved to restore credibility for low inflation before 1992 and pushed to price stability after 1992 demonstrates a second sense in which it may be said to have targeted inflation implicitly. It is clear that the Greenspan Fed practiced a form of flexible inflation targeting in its pursuit of price stability." A similar and concurring view is presented by Thornton (2012). On the other hand, Kuttner and Posen (2012) find no evidence suggesting that an explicit targeter (the Bank of England) fights inflation in a more aggressive manner than an implicit targeter (the Fed). In any event, our prior is that explicit IT should produce a stronger effect. Both explicit and implicit IT regimes should produce similar effects if the role of monetary strategy was similar in intended impact.

[7] The countries are: Australia, Canada, New Zealand, Sweden, and the United Kingdom.

(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).[8] 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). Finally, 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).

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.[9] 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.[10] 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).

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

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

[10] 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.

2.3 Structural breaks in inflation persistence

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 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 and robustness checks. 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:

$$y_t - y_{t-1} = \alpha g_t \tag{1a}$$
$$g_t = -\beta i_t \tag{1b}$$
$$i_t = \gamma y_t \tag{1c}$$
$$y_t = \phi y_{t-1} = \frac{1}{1+\alpha\beta\gamma} y_{t-1}. \tag{1d}$$

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:

$$y_t = \phi_{0t} + \phi_{1t} y_{t-1} + \phi_{2t} y_{t-2} + \cdots + \phi_{pt} y_{t-p} + \varepsilon_t \qquad t = 1,2,\dots,T, \tag{2}$$

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.[11]

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:

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

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 $\lambda_1, \lambda_2, \dots, \lambda_p$ are the roots of the inverse autoregressive polynomial (which may be complex but if so, they appear as conjugate pairs) and $c_1, c_2, \dots, c_p$ are constants that sum to 1

[11] 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.

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:

$$IP_t^{LAR} = \max_i |\lambda_i|. \tag{6}$$

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:

$$IP_t^{HLF} = \min_k \{ k \big| j \geq k \Rightarrow \big| IRF_j \big| < 0.5 \}. \tag{7}$$

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_{jt}^2 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.[12] 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,

$$y_t = \beta_t' x_t + \varepsilon_t \qquad t = 1,2,\dots,T. \qquad (10)$$

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:

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

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:

[12] 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).

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

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:

$$\widehat{IP}_{ct} = \alpha_0 + \alpha_1 ER_{ct}^{USD} + \alpha_2 ER_{ct}^{EUR} + \alpha_3 IT_{ct}^{IMP} + \alpha_4 IT_{ct}^{EXP} + CFE_c + TFE_t + u_{ct}. \qquad (13)$$

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 four 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 (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). Finally, IT_{ct}^{IMP} and IT_{ct}^{EXP} are mutually exclusive dummy variables.

By using the cross-section fixed effects, we account for any level differences between the countries, and by applying time fixed effects in (13) we account for any common trend among the persistence series. This ensures that the effects associated with the above-defined 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.

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.

4.3 Testable hypotheses

Our methodological approach accounts for time-varying inflation persistence and potential structural breaks. Because this is our prior we formally test for the constancy of inflation persistence and establish grounds for the employed methodology. Based on the procedure of Harvey et al. (2006), we formally test the null hypothesis H_0: {constant $I(0)$ or constant $I(1)$ process} against the alternatives H_A: {change from $I(0)$ to $I(1)$}, H_B: {change from $I(1)$ to $I(0)$}, and H_C: {change from $I(0)$ to $I(1)$ or change from $I(1)$ to $I(0)$}. When performing these tests we preset a given significance level, which affects the test statistics: we use both 10% and 5% significance values.

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.

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.

5. Data

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.[13] 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.

[13] 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.

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).[14]

The exchange rate regime classification follows the *factual* regime classification in the spirit of Reinhart and Rogoff (2004). Specific information on regime classification was obtained mainly from the individual central banks. 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.[15] The dummy variable for the exchange 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 first assess whether the inflation persistence of the countries in our sample is constant or varying over time. The time-varying IP sequences are estimated for each country by the FLS-smoother. The results of the tests are summarized in Table 1; more detailed results are presented in Table A2 in the Appendix. The null hypothesis of constant inflation persistence is tested against a change from stationarity to nonstationarity (H_A), from nonstationarity to stationarity (H_B), or either of the alternative hypotheses (H_C); see Section 3.4 for the formal definitions. For 47 countries, the null hypothesis of no change in the process is rejected based

[14] 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.

[15] 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 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.

on at least one version of the test as specified by alternative hypotheses. For 21 countries, the null hypothesis cannot be rejected, though. The same result is reached based on at least two versions of the test. Naturally, the rejection rate drops when all three tests are considered. These quite strong results indicate the existence of structural breaks in the inflation persistence of numerous countries, which supports our time-varying approach and is also fully in line with findings of Noriega et al. (2013).

In the second step we describe the essential facts related to IP estimation.[16] 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 2. Supplementary results serving as robustness check are obtained based on alternative measures of inflation persistence: LAR (Table 2), HLF (Table 2), and RJT (Table 3). 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 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 (13) 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 an ample evidence of differences in inflation persistence among countries, existence of structural breaks and a uniform effect of financial crisis as IP was rising in all three groups during 2007-2008.

[16] 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.

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 2) suggest that the USD-based constraining regime is only 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 2). However, results based on the RJT measure produce relatively small and positive coefficients (Table 3). All the results taken together point at the rather limited link between a constraining exchange regime, with the U.S. dollar as a reserve currency, and inflation persistence.

On the other hand, regimes using the Euro (or Deutsche mark) exhibit an order of magnitude larger and contributing effect towards persistence decrease as the α_2 coefficients are negative and relatively large (Table 2). Robustness 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 a marked divide between the effects of exchange rate regimes using different reserve currencies. Such a 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 (as a proxy for the Eurozone). 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 inflation targeting by the Fed in 2012. On the other hand, German IP exhibits a different pattern: it is lower 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.

Despite the difference between the above 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 does not necessarily need to suppress inflation persistence dramatically if the U.S. inflation persistence itself is not low. The evidence of high U.S. inflation persistence brought by Pivetta and Reis (2007) further supports the above result and explanation.

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 some contribution of a constraining exchange rate regime to pacify inflation persistence.

6.3 Inflation targeting and inflation persistence

In Table 2 we present the key results based on the SUM measure; robustness checks are shown in Tables 2 and 3. Coefficients α_3 and α_4 exhibit marginal effects of two forms of IT on inflation persistence. Negative values of coefficients in both Tables 2 and 3 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_4) than those (α_3) of a less formal monetary strategy represented by implicit inflation targeting (Table 2; 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 2) 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 2), 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 3) 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 2) and those based on the HLF (Table 2) and RJT measures (Table 3) are not entirely incompatible and provide a qualitatively similar inference.

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 robust effect when related to the financial crisis.

7. Structure in inflation persistence

In the Introduction, we stressed that in this paper our goal is not to uncover the structural sources of IP but to explore reduced form persistence. Still, we aim to deliver at least a suggestion for whether there is a factor structure in inflation persistence across countries. Earlier, in Figure 3, we presented the estimated FLS smoothed sum-of-AR-coefficients (SUM) persistence series for the United States and Germany. It is quite striking how similar their evolution is, although the German series is smoother than the U.S. series: specifically, the IP series seem to change direction at the same time in most cases. Similarities in IP behavior may be detected in other countries as well, as we showed in Figure 2. Therefore, we explore these patterns more.

We use our 78-quarters-long persistence series based on the FLS/SUM persistence measures for all 68 countries and perform a principal components analysis (PCA) on them. This procedure delivers 68 uncorrelated linear components ordered from highest to lowest variance. We observe that the first two principal components explain 76% of the total variance. The first and second principal components explain 58% and 18% of the variance, respectively, the influence of the remaining components is negligible. In this way we are also able to reduce the dimensionality degree from 68 to 2 and lose only 24% of the total variance.

We take the result of the PCA as evidence of the existence of a factor structure in inflation persistence across countries. The PCA has its limits, though. We are unable to directly interpret the principal components or translate them into factors of influence. 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. For example, Davig and Doh (2014) show that monetary policy can reduce inflation persistence when the nominal interest rate is adjusted more aggressively in response to inflation. Or, according to Dornbusch (1982), monetary policy responding to price shocks in a less accommodative manner is likely to produce less persistent inflation. 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. The reasoning behind this explanation comes from the argument shown by Christoffel and Linzert (2010) that more rigid wages translate into more persistent movements of aggregate inflation but efficient bargaining generates lower degrees of inflation persistence. Du Caju et al. (2009) show that in the EU, U.S., and Japan wage bargaining at the sectoral level is the most dominant, with an increasingly important role for bargaining at the firm level. Wage adjustments also have some direct bearing on monetary policy: the empirically documented presence of a time variation in the degree of wage indexation (automatic wage adjustment procedures) implies that, for example, 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, 2015). Thus, both possibilities behind the existence of a factor structure in inflation persistence seem to have some connections.

Another phenomenon which may cause a common factor in our series is the self-fulfilling nature of inflation persistence purely due to the time series properties of the inflation data. We can identify two extreme cases. In the first case, persistence is high (thus, inflation follows a random walk) and the optimal forecast of inflation in period t+1 is the same as in period t. For example, if firms form their expectations in this way, when firms set their prices, their expectations will induce a high level of inflation persistence. However, in the second case, if inflation is stationary, meaning that persistence is low, inflation forecasting is relatively straightforward. If inflation is unexpectedly high in period t, then it is likely to be lower in period t+1 to ensure that the inflation rate does not diverge from its long-run average value. If firms forecast this way, then their pricing decisions will lead to a relatively low level of aggregate persistence in the observed data.[17]

Thus, the above concept indicates that both steady high and low inflation persistence may be self-fulfilling. In actual time series data this may induce long periods of high persistence, long periods of small persistence, not too many sudden moves, long and slow changes, and even correlation in the cross-section of countries. In fact all these stylized facts can be seen in our persistence series, which underpins our concept and gives credit to our time-varying parameter estimation method.

Despite the fact that we are unable to say more about the structure in inflation persistence, we hope to have shed some light on the reduction in inflation persistence that seems to be happening in most countries around the world.

8. 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

[17] The above concept is based on a loose analogy to Ball and Mankiw (1995), who discuss the implications of firms' menu costs for the predictability of prices.

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. Further, regimes with the U.S. dollar as a reserve currency are less effective than those using the Euro (or Deutsche mark). Hence, our evidence shows that the effect of the exchange rate arrangement on inflation persistence is reserve currency-dependent and correlates with the level of inflation persistence in the country of the reserve currency.

Our results are robust to differences in four inflation persistence measures; these represent well established and suitable measures used in the literature. The results are also derived by a methodology that effectively accounts for existing structural breaks in inflation persistence series as well as for the endogeneity of policy strategies with respect to persistence itself.

Further, via principal components analysis we uncover the existence of a structure in inflation persistence. The evidence is quite strong as two key principal components account for 76% of the total variance in the data. A dramatic reduction of the dimensionality degree from 68 to 2 hints at the importance of two factors underlying the IP structure. Due to the limitations of the PCA, we offer some conjectures on potential sources of the structure: active monetary policy and shifts in institutional arrangements (changes in wage bargaining and wage indexation).

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. Finally, IT seems to be a robust 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.

References:

Alogoskoufis, G. S., 1992. "Monetary accommodation, exchange rate regimes, and inflation persistence," *Economic Journal*, 102(412), 461-480.

Alogoskoufis, G. S., and Smith, R. P., 1991. "The Phillips curve, the persistence of inflation, and the Lucas critique: evidence from exchange rate regimes," *American Economic Review*, 81(6), 1254-1275.

Altissimo, F., Ehrmann, M. and Smets, F., 2006. Inflation persistence and price setting behaviour in the Euro area – a summary of the IPN evidence, ECB Occasional Paper No. 46.

Anderton, R.,1997, Did the Underlying Behaviour of Inflation Change in the 1980s? A Study of 17 Countries. *Weltwirtschaftliches Archiv*, 133, pp. 22-38.

Ascari, G., and Sbordone, A.M., 2014. The Macroeconomics of Trend Inflation. *Journal of Economic Literature*, 52(3), 679–739.

Ascari, G., Ropele, T., 2012. Sacrifice Ratio in a Medium-Scale New Keynesian Model. *Journal of Money, Credit and Banking*, 44(2-3), 457-467.

Attey, J.A., 2015. Time Varying Wage Indexation and the New Keynesian Wage Phillips Curve. Mimeo, Erasmus School of Economics, Erasmus University Rotterdam.

Baxa, J., Horváth, R., Vašíček, B., 2014. How does monetary policy change? Evidence on inflation-targeting countries. *Macroeconomic Dynamics* 18, 593-630.

Ball, L., Mankiw, G., 1995. Relative-price changes as aggregate supply shocks. *Quarterly Journal of Economics*, 110, 162-193.

Banerjee, A., Lumsdaine, R., Stock, J., 1992. Recursive and sequential tests of the unit-root and trend-break hypotheses: theory and international evidence. *Journal of Business and Economic Statistics* 10 (3), 271–288.

Beechey, M., and Osterholm, P., 2012. "The rise and fall of U. S. inflation persistence," *International Journal of Central Banking*, 8(3), 55-86.

Benati, Luca, 2008. Investigating Inflation Persistence Across Monetary Regimes. *Quarterly Journal of Economics*, 123 (3), 1005-1060.

Benati, L., and Surico, P., 2007. Evolving U.S. Monetary Policy and the Decline of Inflation Predictability. *Journal of the European Economic Association*, 6, 634-646.

Bernanke, B.S., Laubach, T., Mishkin, F.S., Posen, A.S., 2001. *Inflation Targeting: Lessons from the International Experience*. Princeton University Press.

Bleaney, M. F., 2001. Exchange rate regimes and inflation persistence. *IMF Staff Papers*, 47(3), 387-402.

Bleaney, M. F., and Francisco, M. 2005. "Inflation persistence and exchange rate regimes: evidence from developing countries". *Economics Bulletin*, 6(2), 1-15.

Bofinger, P., 2001. *Monetary Policy. Goals, Institutions, Strategies, and Instruments*. Oxford University Press.

Burdekin, R. C. K., and Siklos, P. L., 1999. Exchange rate regimes and shifts in inflation persistence: does nothing else matter? *Journal of Money, Credit and Banking*, 31(2), 234-247.

Busetti, F. and Taylor, A. M. R., 2004. Tests of stationarity against a change in persistence, *Journal of Econometrics*, 123, 33-66.

Carare, A, Stone, M.R., 2006. Inflation targeting regimes. *European Economic Review* 50, 1297–1315.

Cecchetti, S. G., Debelle, G., 2006. Has the Inflation Process Changed? *Economic Policy*, 21(46), 311–352.

Christoffel, K., Linzert, T., 2010. The Role of Real Wage Rigidity and Labor Market Rigidities for Inflation Persistence. *Journal of Money, Credit, and Banking*, 42(7), 1435-1446.

Cogley, T., Primiceri, G.E., Sargent. T.J., 2010. Inflation-Gap Persistence in the US. *American Economic Journal: Macroeconomics* 2 (1), 43–69.

Cogley, T., Sargent, T. J., 2001. Evolving Post-World War II U.S. Inflation Dynamics, in NBER Macroeconomics Annual 2001, 331-372.

Darvas, Z., Varga, B., 2012. Uncovering Time-Varying Parameters with the Kalman-Filter and the Flexible Least Squares: a Monte Carlo Study. Working Paper 12/04, Department of Mathematical Economics and Economic Analysis, Corvinus University of Budapest.

Darvas, Z., Varga, B., 2014. Inflation persistence in central and eastern European countries. *Applied Economics*, 46(13), 1437-1448.

Doh, T., 2012. What does the yield curve tell us about the Federal Reserve's implicit inflation target? *Journal of Money, Credit and Banking*, 44(2-3), 469–486.

Du Caju, P., Gautier, E., Momferatou, D., Ward-Warmedinger, M. 2009. Institutional features of wage bargaining in 23 European countries, the U.S. and Japan. *Ekonomia*, 12(2):57-108.

Edwards, S., 2006. "The Relationship between Exchange Rates and Inflation Targeting Revisited," NBER Working Papers 12163

Edwards, S., 2011. Exchange-Rate Policies in Emerging Countries: Eleven Empirical Regularities from Latin America and East Asia. *Open Economies Review* 22, 533–563.

ECB, 2004. *The Monetary Policy of the ECB*, 2nd ed. European Central Bank, Frankfurt.

Filardo, A., Genberg, H. (2010). Targeting inflation in Asia and the Pacific: Lessons from the recent past. The international financial crisis and policy challenges in Asia and the Pacific. BIS Papers No. 52, Bank for International Settlements.

Franta, M., Saxa, B., Šmídková, K., 2010. The Role of Inflation Persistence in the Inflation Process in the New EU Member States. *Czech Journal of Economics and Finance*, 60(6), 480-500.

Fuhrer, J. C., 1994. Optimal monetary policy and the sacrifice ratio. Conference Series; [Proceedings], Federal Reserve Bank of Boston, 38, 43-84.

Fuhrer, J. C., 2006. Intrinsic and inherited inflation persistence. *Journal of Money, Credit and Banking*, 27(6), 975-984.

Fuhrer, J.C., 2011. Inflation Persistence. In Friedman, B.M. and Woodford, M. (eds.), *Handbook of Monetary Economics*, vol. 3A, ch. 9, pp. 423-486. Elsevier.

Gerlach, S., Tillmann, P., 2012. Inflation targeting and inflation persistence in Asia–Pacific. *Journal of Asian Economics* 23, 360–373.

Goodfriend, M., 2004. Inflation Targeting in the United States? In B.S. Bernanke and M. Woodford (eds.): *The Inflation-Targeting Debate*, NBER Book Series Studies in Business Cycles, p. 311 - 352, 2004, University of Chicago Press.

Greenwood-Nimmo, M., 2014. Inflation targeting monetary and fiscal policies in a two-country stock–flow-consistent model. *Cambridge Journal of Economics*, 38, 839–867.

Harvey, D. I., Leybourne, S. J., Taylor, A. M. R., 2006. Modified tests for a change in persistence, *Journal of Econometrics*, 134, 441-469.

Heenan, G. Peter, M., Roger, S., 2006. Implementing Inflation Targeting: Institutional Arrangements, Target Design, and Communication. IMF Working Paper 06/278.

Husain, A., Mody, A., Rogoff, K., 2004. Exchange rate regime durability and performance in developing versus advanced economies. *Journal of Monetary Economics*, 52, 35-64

Jiranyakul, K., Exchange Rate Regimes and Persistence of Inflation in Thailand (June 11, 2014). Available at SSRN: http://dx.doi.org/10.2139/ssrn.2448663

Kalaba, R. and Tesfatsion, L., 1988. The Flexible Least Squares Approach to Time-varying Linear Regression. *Journal of Economic Dynamics and Control*, 12, 43-48.
Kalaba, R. and Tesfatsion, L., 1990. Flexible least squares for approximately linear systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 20, 978–89.
Kalman, R. E., 1960. A new approach to linear filtering and prediction problems. *Transaction of the ASME-Journal of Basic Engineering*, 82, 35–45.
Kim, J., 2011. Inflation Targeting as Constrained Discretion. *Journal of Money, Credit and Banking*. 43(7), 1505–1522.
Kim, J-Y., 2000. Detection of Change in Persistence of a Linear Time Series, *Journal of Econometrics*, 95, 97-116.
Kim, J-Y., J. Belaire-Franch and R. B. Amador, 2002. Corrigendum to "Detection of Change in Persistence of a Linear Time Series", *Journal of Econometrics*, 109, 389-392.
Kočenda, E., Papell, D. H., 1997. Inflation Convergence within the European Union: A Panel Data Analysis. *International Journal of Finance and Economics*, 2(3), 189-198.
Korhonen, I. and Mehrotra, A., 2010. Money demand in post-crisis Russia: Dedollarization and Remonetization, *Emerging Markets Finance and Trade*, 46:2, 5-19.
Kuttner, K.N. and Posen, A.S., 2012. How Flexible Can Inflation Targeting Be and Still Work? *International Journal of Central Banking*, 8(S1), 65-99.
Levin, A.T., Piger, J.M. 2004. Is Inflation Persistence Intrinsic in Industrial Economies? European Central Bank Working Paper 334.
Lopez, C., Papell., D., 2012. Convergence of Euro area inflation rates. *Journal of International Money and Finance*, 31, 1440-1458.
Meller, B., Nautz, D., 2012. Inflation persistence in the Euro area before and after the European Monetary Union. *Economic Modelling*, 29(4), 1170–1176.
Mishkin, Frederic S. and Klaus Schmidt-Hebbel, 2007, "Does Inflation Targeting Make a Difference?" in *Monetary Policy under Inflation Targeting*, Edited by Frederic S. Miskin, Klaus Schmidt-Hebbel, and Norman Loayz, Edition 1, Volume 11, Chapter 9, Central Bank of Chile.
Mishkin, F., 2008. Can Inflation Targeting Work in Emerging Market Countries? In Reinhart, C., Vegh, C., Velasco, A. (Eds.), *Money, Crises, and Transition: Essays in Honor of Guillermo Calvo*, pp. 74-91. MIT Press.
Montana, G., Triantafyllopoulos, K., Tsagaris, T., 2009. Flexible Least Squares for Temporal Data Mining and Statistical Arbitrage, *Expert Systems with Applications*, 36, 2819–2830.
Morón, E., Winkelried, D., 2005. Monetary Policy Rules for Financially Vulnerable Economies. *Journal of Development Economics*, 76(1), 23–51.
Nguyen, T.-P., Nguyen D.T., Su, J.J., Singh, T., 2014. Shifts in Exchange Rate Regimes and Inflation Persistence in Vietnam, 1992–2010. *Journal of Southeast Asian Economies*, 31(2), 256-275.
Noriega, A. E., Capistrán, C., Ramos-Francia, M., 2013. On the dynamics of inflation persistence around the world, *Empirical Economics*, 44(3), 1243-1265.
Obstfeld, M., 1995, International Currency Experience: New Lessons and Lessons Relearned. *Brookings Papers on Economic Activity*, 1995, pp. 119-220.
Pivetta, F., Reis, R., 2007. The persistence of inflation in the United States, *Journal of Economic Dynamics and Control*, 31, 1326-1358.
Reinhart, C.M., Rogoff, K.S., 2004. The Modern History of Exchange Rate Arrangements: A Reinterpretation. *Quarterly Journal of Economics*, 119(1): 1-48.
Roache, S.K., 2014. Inflation Persistence in Brazil - A Cross Country Comparison. IMF Working Paper WP/14/55
Roger, S., 2010. Inflation targeting turns 20. *Finance and Development*, 47(1), 46-49.

Ruge-Murcia, F., 2014. Do Inflation-Targeting Central Banks Implicitly Target the Price Level? *International Journal of Central Banking*, 10(2), 301-326.
Siklos, P. L., 1999. Inflation-Target Design: Changing Inflation Performance and Persistence in Industrial Countries. *Federal Bank of St. Louis Review*, March/April 1999, 47-58.
Siklos, P. L., 2008. Inflation targeting around the world. *Emerging Markets Finance and Trade*, 44, 17–37.
Stock, J.H., Watson, M., 2007. Has inflation become harder to forecast? *Journal of Money, Credit and Banking*, 39, 3–34.
Svensson, L., 1997, Inflation forecast targeting: implementing and monitoring inflation targets, *European Economic Review* 41, 1111-1146.
Svensson, L., 2002. Inflation targeting: should it be modeled as in instrument rule or a targeting rule? *European Economic Review* 46, 771-780. How Did We Get to Inflation Targeting and
Thornton, D.L., 2012. Where Do We Need to Go to Now? A Perspective from the U.S. Experience. *Federal Reserve Bank of St. Louis Review*, January/February 2012, 94(1), 65-81.
Watson, M.W., 2014. Inflation Persistence, the NAIRU, and the Great Recession. *American Economic Review: Papers & Proceedings*, 104(5): 31–36.
Wheeler, G., 2015. Reflections on 25 Years of Inflation Targeting. *International Journal of Central Banking*, 11(S1), 3-17.
Williams, J.C., 2006. Inflation Persistence in an Era of Well-Anchored Inflation Expectations. *FRBSF Economic Letter*, 2006-27, 1-3.

Tables and Figures

Table 1. Summarized results of persistence change tests: total number of rejections

Direction	I(0) to I(1)		I(1) to I(0)		Either	
Significance level	10%	5%	10%	5%	10%	5%
All 3 tests rejected	9	6	34	30	35	26
At least 2 out of 3 rejected	14	10	42	37	44	33
At least 1 out of 3 rejected	15	12	44	39	47	36

Notes: The table shows the number of countries out of 68 where a given number of test rejections appears. There are 3 tests for each persistence change direction; all of them have the null hypothesis of no persistence change.

Table 2. Panel least squares estimation results with SUM, LAR, and HLF persistence measures

Dependent Variable		SUM persistence estimate			LAR persistence estimate			HLF persistence estimate		
Constant	α_0	0.273	(18.83)	***	0.860	(261.90)	***	6.654	(11.32)	***
US dollar regime (ERUSD)	α_1	-0.061	(-3.30)	***	0.005	(1.14)		0.326	(0.44)	
Euro (Deutsche Mark) regime (EREUR)	α_2	-0.383	(-19.63)	***	-0.022	(-5.00)	***	-4.637	(-5.86)	***
Implicit inflation targeting (ITIMP)	α_3	-0.230	(-8.99)	***	-0.030	(-5.17)	***	-6.971	(-6.73)	***
Explicit inflation targeting (ITEXP)	α_4	-0.431	(-19.47)	***	-0.007	(-1.39)		-3.165	(-3.53)	***
R-squared		61.3%			59.1%			21.5%		
Number of periods		78			78			78		
Number of cross-sections		68			68			68		

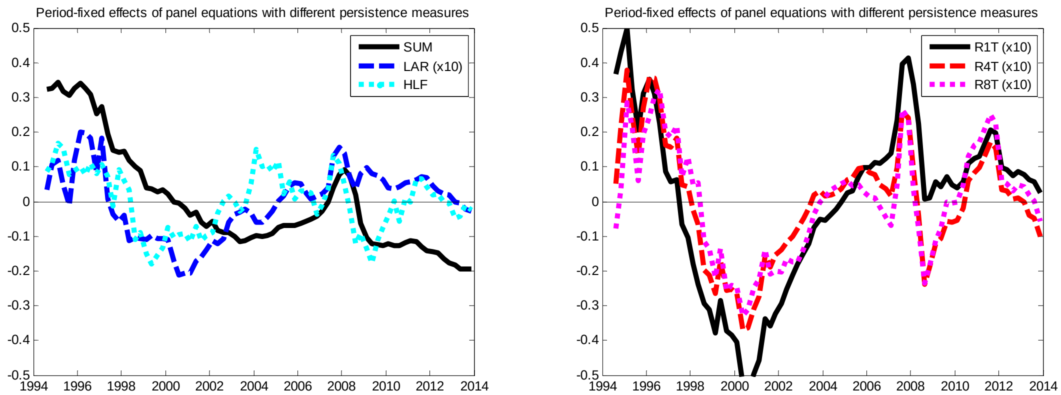
Notes: The persistence measures are the sum of autoregressive coefficients (SUM), largest autoregressive root (LAR), and half-life in quarters (HLF). The table shows regression coefficients with *t*-statistics in parentheses. * indicates a rejection of insignificance at the 10% level, ** at the 5% level,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

Table 3. Panel least squares estimation results with RJT persistence measures

Dependent Variable		R1T persistence estimate			R4T persistence estimate			R8T persistence estimate		
Constant	α_0	0.354	(53.47)	***	0.254	(36.45)	***	0.147	(21.19)	***
US dollar regime (ERUSD)	α_1	0.027	(3.27)	***	0.022	(2.53)	**	0.017	(1.93)	*
Euro (Deutsche Mark) regime (EREUR)	α_2	-0.023	(-2.57)	**	-0.027	(-2.90)	***	-0.041	(-4.41)	***
Implicit inflation targeting (ITIMP)	α_3	-0.124	(-10.64)	***	-0.101	(-8.20)	***	-0.085	(-6.97)	***
Explicit inflation targeting (ITEXP)	α_4	-0.026	(-2.57)	**	-0.028	(-2.63)	***	-0.010	(-0.96)	
R-squared		56.2%			55.8%			47.3%		
Number of periods		78			78			78		
Number of cross-sections		68			68			68		

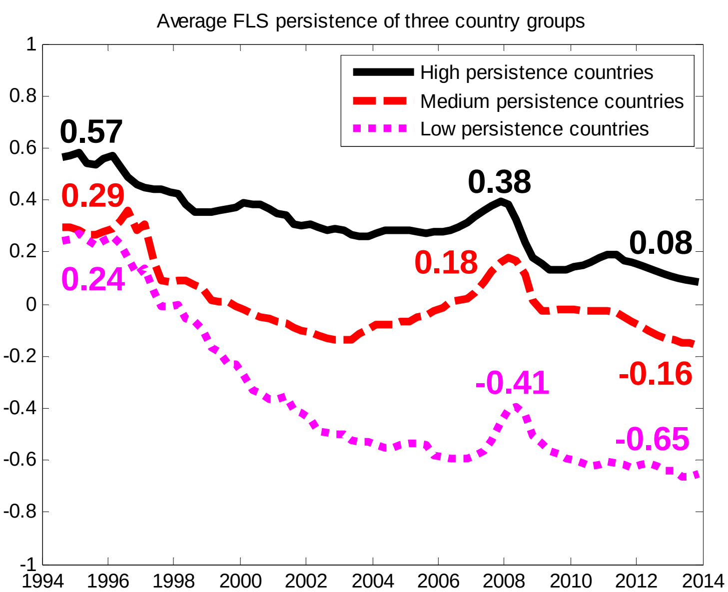
Notes: The persistence measures are the R^2_{jt} statistics for $j = 1$ (R1T), $j = 4$ (R4T), and $j = 8$ periods (R8T). The table shows regression coefficients with *t*-statistics in parentheses. * indicates a rejection of insignificance at the 10% level, ** at the 5% level, and *** at the 1% level.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

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



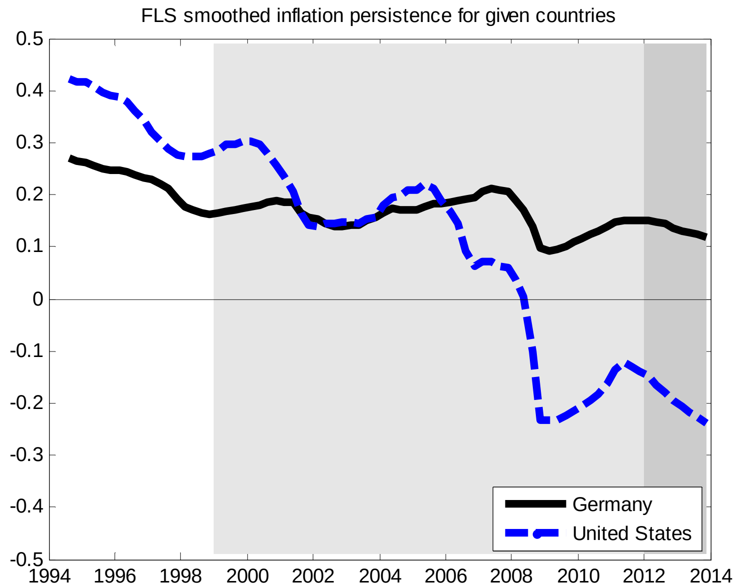
Notes: The graphs show the time fixed effects for the FLS smoothed persistence equations, with all six persistence measures. Some measures are multiplied by a factor of 10 to make a similar range.

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



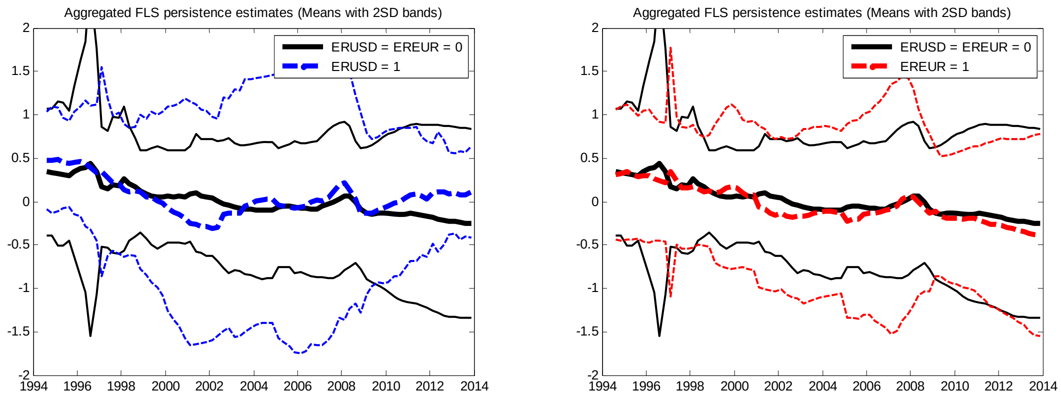
Notes: The three lines show the estimated FLS smoothed sum-of-AR-coefficients (SUM) persistence series for the three country groups based on average persistence throughout the sample. High persistence means the highest one-third of the countries, low persistence means the lowest one-third of the countries, 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



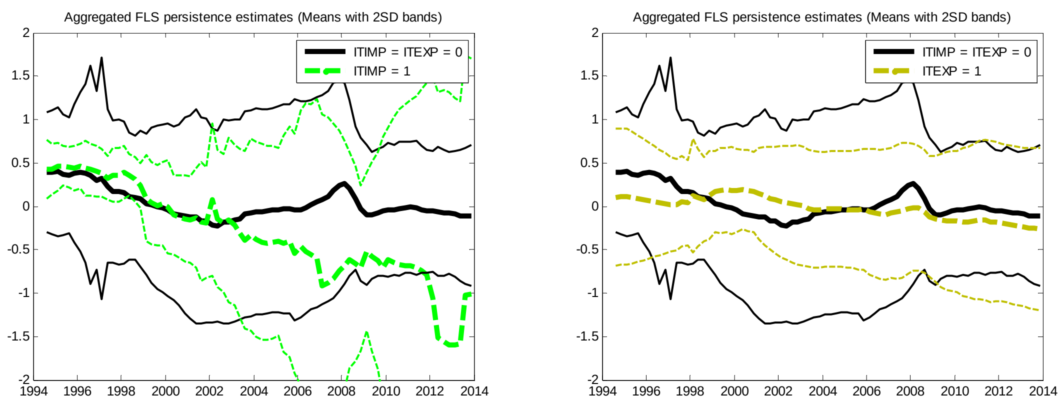
Notes: The two lines show the estimated FLS smoothed sum-of-AR-coefficients (SUM) persistence series for the United States and Germany. The beginning of the light grey background shows when the Euro was adopted. The dark grey background depicts when the U.S. adopted explicit inflation targeting.

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. Countries and the timings of inflation targeting and exchange rate regimes.

Notes: Explicit inflation targeting (EIT) and implicit inflation targeting (ITT) have only starting dates (no IT regime has ended yet). We report these with monthly precision. At some EIT starting dates, [ea] marks that the given country adopted EIT because it entered the euro area. 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	ER intervals	ER types
1	Argentina	–	–	1964 – 1971 1985 – 1986 1991Q2 – 2002Q3	USD USD USD
2	Australia	Jan 1990	Apr 1993	1972 – 1987	USD
3	Austria	–	Jan 1999 [ea]	1954 – 1959 1960 – 1998	USD DEM
4	Bangladesh	Jul 2013	–	(1972) – 1982 1983 – 2002	GBP USD
5	Belgium	–	Jan 1999 [ea]	1954 – 1955 1956 – 1998	USD DEM
6	Brazil	–	Jun 1999	(1945) – 1950 1967 – 1998	USD USD
7	Bulgaria	–	–	(1945) – 1989 1997 –	USD DEM / EUR
8	Canada	–	Mar 1991	(1945) – 1950 1963 – 1969	USD USD
9	Chile	Sep 1990	Sep 1999	1960 – 1962 1973Q2 – 1999Q3 1982 – 1983	USD USD DEM
10	China	–	–	1974 – 2005Q4 –	USD EUR
11	China / Hong Kong	–	–	(1945) – 1972 1983Q4 –	USD USD
12	Colombia	Jan 1991	Sep 1999	(1945) – 1983 1985 – 1998	USD USD
13	Czech Republic	–	Dec 1997	(1991) – 1997Q2 (1991) – 1997Q2	USD DEM
14	Denmark	–	–	(1945) – 1951 1952 –	USD DEM / EUR
15	Egypt	–	–	(1945) – 1950 1963 – 2002	GBP USD
16	Estonia	–	Jan 2011 [ea]	1992 – 2010	DEM / EUR
17	Finland	–	Feb 1993	1949 – 1972 1973 – 1998	USD DEM
18	France	–	Jan 1999 [ea]	1949 – 1971 1972 – 1998	USD DEM
19	Germany	–	Jan 1999 [ea]	(1945) – 1970 1971 1972 1973 – 1998	USD (DEM) USD (DEM)
20	Greece	–	Jan 2001 [ea]	1950 – 1981 1985 – 2000	USD DEM / EUR
21	Hungary	–	Jun 2001	(1945) – 1990 – 1999	DEM USD
22	Iceland	–	Mar 2001	1947 – 1977 1984 – 2000	USD DEM / EUR
23	India	–	–	(1945) – 1969	GBP

				1970 1971 – 1978 1980 – 2007	USD GBP USD
24	Indonesia	May 1999	Jul 2005 +	(1945) – 1949 1969 – 1997	GBP USD
25	Iran	–	–	1954 – 1976	USD
26	Ireland	–	–	1980 – 1998	DEM
27	Israel	Jun 1992	Jun 1997	(1948) – 1950 1962 – 1970 1971 – 1975 1980 – 1998 1986 – 1998	GBP GBP USD GBP USD
28	Italy	–	Jan 1999 [ea]	1952 – 1975 1979Q2 – 1998	USD DEM
29	Japan	Jan 2010	Feb 2012	1949 – 1977	USD
30	Jordan	–	–	(1945) – 1971 1972 – 1975 – 1988	GBP USD SDR
31	Korea (South)	Apr 1998	Jan 2001	(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 [ea]	(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	(1945) – 1976Q3 1982Q3 – 1994	USD USD
39	Morocco	–	–	(1945) –	DEM
40	Netherlands	–	Jan 1999 [ea]	1951 – 1970 1971 – 1998	USD DEM
41	New Zealand	–	Mar 1990	(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 +	(1945) – 1972 1973 – 1992	USD DEM
44	Pakistan	–	–	(1945) – 1971 1972 – 2007	GBP USD
45	Peru	–	Jan 2002	(1945) – 1971 1994 – 2007	USD USD
46	Philippines	Jul 1993	Jan 2002	1952 – 1956 1962 – 1968 1973 – 1982 1986 – 1990	USD USD USD USD
47	Poland	Aug 1997	Oct 1998	1990 – 2000 1991 – 2000	USD DEM / EUR
48	Portugal	–	Jan 1999 [ea]	(1945) – 1972 1973 – 1998	USD DEM
49	Romania	Jan 2002	Aug 2005	1990 – 2002	USD

				1990 – 1993 2009 –	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	–	–	(1945) – 1971 1972 – 1998	DEM USD
53	Slovak Republic	–	Jan 2005 [ea]	(1991) – 1997 (1991) – 1997 1999 – 2008	USD DEM EUR
54	Slovenia	Nov 2003	Jan 2007 [ea]	1993 – 2006	DEM / EUR
55	South Africa	Jan 1990	Feb 2000	(1945) – 1973	DEM
56	Spain	Jan 1995	Jan 1999 [ea]	(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	1946 – 1972 1973 – 1992	USD DEM
60	Switzerland	Jan 1975	Jan 2000	(1945) – 1972 1982 –	USD DEM / EUR
61	Taiwan	–	–	–	–
62	Thailand	–	May 2000	(1945) – 1947 1948 – 1997	DEM USD
63	Tunisia	–	–	(1945) –	DEM
64	Turkey	Jan 2002	Jan 2006	1946 – 1953 1961 – 1980 1998 – 2000	USD USD DEM / EUR
65	Ukraine	–	–	1997 – 2006	USD
66	United Kingdom	–	Oct 1993	(1945) – 1971 1991 – 1992	USD DEM
67	United States	1992	Jan 2012	(1945) –	(USD)
68	Venezuela	–	–	(1945) – 1982 1994 –	USD USD

Table A2. Detailed results of persistence change tests for all countries.

Notes: The first three data columns show the test statistics on the basis of Kim (2000) and Kim et al. (2002), testing for a change from I(0) to I(1): MS=mean score, ME=mean exponential, and MX=maximum score. The next three data columns show test statistics on the basis of Busetti and Taylor (2004) testing for a change from I(1) to I(0): MS^R=mean score / reciprocal, ME^R=mean exponential / reciprocal, and MX^R= maximum score / reciprocal. The final three data columns are based on the test statistics of Busetti and Taylor (2004) for testing when the direction of change is unknown: MS^M=mean score / maximum = max(MS, MS^R), ME^M=mean exponential / maximum = max(ME, ME^R), and MX^M=maximum score / maximum = max(MX, MX^R). There are two lines for each country: the first shows the modified tests at the 10% level (* indicates a rejection) and the second the modified tests at the 5% level (** indicates a rejection), as in Harvey et al. (2006). The test outcome can only be analyzed at the pre-set significance level.

Series T = 83	MS MS_m (10%) MS_m (5%)	ME ME_m (10%) ME_m (5%)	MX MX_m (10%) MX_m (5%)	MS^R MS^R_m (10%) MS^R_m (5%)	ME^R ME^R_m (10%) ME^R_m (5%)	MX^R MX^R_m (10%) MX^R_m (5%)	MS^M MS^M_m (10%) MS^M_m (5%)	ME^M ME^M_m (10%) ME^M_m (5%)	MX^M MX^M_m (10%) MX^M_m (5%)
Argentina	0.01	0.00	0.02	61.50 *	76.95 *	163.90 *	59.33 *	73.49 *	156.98 *
	0.01	0.00	0.01	59.32 **	73.48 **	156.93 **	56.87 **	69.66 **	149.17 **
Australia	0.26	0.13	0.93	6.02 *	5.73 *	17.91 *	5.95 *	5.65 *	17.68 *
	0.26	0.13	0.92	5.95 **	5.65 **	17.68 **	5.88	5.56	17.40
Austria	0.66	0.36	2.38	3.26	4.50 *	15.02 *	3.24	4.45	14.88
	0.65	0.35	2.32	3.24	4.45	14.88	3.21	4.40	14.71
Bangladesh	0.76	0.53	3.67	4.51 *	7.23 *	21.45 *	4.50	7.22 *	21.40 *
	0.71	0.49	3.41	4.50	7.22 **	21.40 **	4.49	7.20	21.35
Belgium	2.43	2.07	9.88	0.74	0.44	3.27	2.40	2.03	9.72
	2.40	2.03	9.73	0.72	0.43	3.18	2.36	1.99	9.54
Brazil	0.00	0.00	0.00	23743.35 *	42909.54 *	86983.96 *	23226.12 *	41712.93 *	84712.53 *
	0.00	0.00	0.00	23223.29 **	41710.39 **	84697.09 **	22631.29 **	40367.78 **	82102.87 **
Bulgaria	0.00	0.00	0.01	498.57 *	1165.58 *	2416.06 *	472.30 *	1087.32 *	2263.95 *
	0.00	0.00	0.01	472.16 **	1087.16 **	2262.94 **	443.13 **	1003.17 **	2096.39 **
Canada	1.33	1.02	6.22	1.46	0.89	5.25	1.42	1.01	6.11
	1.29	0.98	6.00	1.42	0.86	5.09	1.38	0.97	5.90
Chile	0.04	0.01	0.11	15.41 *	50.05 *	108.53 *	15.19 *	49.15 *	106.71 *
	0.03	0.01	0.07	15.19 **	49.15 **	106.69 **	14.94 **	48.13 **	104.59 **
China	0.00	0.00	0.02	81.12 *	127.54 *	263.37 *	80.83 *	126.97 *	262.27 *
	0.00	0.00	0.01	80.83 **	126.97 **	262.27 **	80.50 **	126.31 **	260.98 **
Colombia	1.82	10.43 *	28.62 *	46.65 *	168.74 *	361.29 *	53.05 *	207.18 *	424.84 *
	1.81	10.30 **	28.28 **	42.93 **	151.72 **	326.92 **	52.41 **	204.05 **	418.71 **
Czech Republic	0.51	1.01	7.23	19.24 *	29.93 *	67.93 *	18.88 *	29.21 *	66.40 *
	0.49	0.96	6.93	18.88 **	29.21 **	66.39 **	18.47 **	28.40 **	64.65 **
Denmark	4.42 *	4.34 *	15.06 *	0.36	0.18	1.49	4.41	4.32	14.99
	4.41	4.32	14.99	0.34	0.17	1.42	4.39	4.29	14.90
Egypt	0.79	0.54	4.20	2.68	6.61 *	20.54 *	2.55	6.21 *	19.37 *
	0.65	0.41	3.27	2.55	6.21 **	19.37 **	2.41	5.78	18.08
Estonia	0.00	0.00	0.01	133.77 *	148.77 *	310.68 *	129.51 *	142.71 *	298.84 *
	0.00	0.00	0.00	129.49 **	142.70 **	298.76 **	124.67 **	136.00 **	285.41 **
Finland	1.58	0.98	5.47	0.76	0.37	1.25	1.56	0.97	5.39
	1.56	0.97	5.39	0.73	0.35	1.19	1.54	0.95	5.30
France	1.23	0.67	3.93	0.98	0.53	2.75	1.21	0.66	3.88
	1.19	0.64	3.77	0.96	0.51	2.67	1.18	0.64	3.74
Germany	0.44	0.23	1.93	4.51 *	5.67 *	18.00 *	4.50	5.66 *	17.96 *
	0.42	0.22	1.81	4.50	5.66 **	17.96 **	4.49	5.64	17.91
Greece	0.20	0.10	0.67	4.70 *	2.42	6.29	4.57	2.34	6.08
	0.19	0.09	0.63	4.57	2.34	6.07	4.42	2.24	5.84
Hong Kong	0.89	1.83	7.38	10.22 *	11.43 *	30.37 *	10.07 *	11.21 *	29.84 *
	0.67	1.24	5.11	10.07 **	11.21 **	29.83 **	9.89 **	10.97 **	29.21 **
Hungary	0.22	0.13	1.78	22.71 *	25.42 *	59.81 *	20.92 *	22.89 *	54.21 *
	0.17	0.10	1.34	20.91 **	22.88 **	54.18 **	19.00 **	20.27 **	48.27 **

Table A2. Detailed results of persistence change tests for all countries. *Continued.*

Iceland	4.74 *	8.27 *	22.38 *	1.80	11.13 *	29.80 *	4.83 *	9.86 *	26.62 *
	4.13	6.86 **	18.77 **	1.64	9.86 **	26.60 **	4.32	8.57 **	23.29 **
India	2.61	4.30 *	14.87 *	4.24 *	7.18 *	21.13 *	4.17	7.02 *	20.69 *
	2.56	4.19	14.51	4.16	7.02 **	20.69 **	4.08	6.84	20.19
Indonesia	7.10 *	80.82 *	173.72 *	13.66 *	19.55 *	46.06 *	13.06 *	77.80 *	167.14 *
	6.77 **	75.80 **	163.51 **	13.06 **	18.46 **	43.63 **	12.39 **	72.78 **	156.84 **
Iran	0.11	0.07	1.86	38.61 *	66.02 *	141.05 *	37.88 *	64.42 *	137.85 *
	0.11	0.07	1.79	37.87 **	64.42 **	137.83 **	37.04 **	62.62 **	134.17 **
Ireland	20.34 *	58.12 *	125.70 *	0.44	0.27	3.48	19.72 *	55.73 *	120.86 *
	19.76 **	55.87 **	121.11 **	0.40	0.24	3.12	18.99 **	53.15 **	115.51 **
Israel	0.12	0.07	1.87	38.48 *	65.22 *	139.44 *	37.75 *	63.63 *	136.26 *
	0.11	0.07	1.80	37.75 **	63.63 **	136.24 **	36.91 **	61.84 **	132.60 **
Italy	0.09	0.03	0.26	6.52 *	3.40	9.49	6.07 *	3.11	8.71
	0.07	0.02	0.19	6.07 **	3.10	8.71	5.58	2.79	7.87
Japan	0.68	0.40	3.14	2.55	1.96	8.67	2.55	1.99	8.71
	0.66	0.38	2.99	2.39	1.81	8.02	2.43	1.87	8.21
Jordan	2.20	1.83	8.45	1.79	6.66 *	20.81 *	2.19	6.73 *	20.97 *
	2.19	1.82	8.41	1.78	6.59 **	20.60 **	2.18	6.69	20.87
Korea	0.39	0.21	1.97	3.00	1.52	4.13	3.09	1.61	4.30
	0.38	0.20	1.90	2.81	1.40	3.82	2.98	1.53	4.11
Kuwait	5.91 *	8.82 *	25.29 *	1.83	5.18 *	16.03 *	5.79 *	8.57 *	24.61 *
	5.80 **	8.58 **	24.64 **	1.68	4.63	14.44	5.64	8.29 **	23.85 **
Latvia	0.05	0.02	0.09	10.14 *	15.17 *	38.96 *	7.92 *	11.04 *	28.95 *
	0.04	0.01	0.06	7.91 **	11.04 **	28.89 **	5.92 **	7.64 **	20.38
Lithuania	0.00	0.00	0.00	192.65 *	269.88 *	601.50 *	163.58 *	218.74 *	494.17 *
	0.00	0.00	0.00	163.43 **	218.64 **	493.50 **	134.90 **	171.47 **	391.68 **
Luxembourg	0.47	0.23	0.96	2.41	1.41	6.05	2.40	1.40	6.01
	0.45	0.22	0.91	2.40	1.40	6.01	2.38	1.38	5.96
Malaysia	0.91	0.60	4.13	2.48	1.93	8.48	2.45	1.90	8.35
	0.88	0.57	3.95	2.45	1.90	8.35	2.41	1.86	8.19
Mauritius	2.05	1.06	3.76	0.58	0.32	2.58	1.95	1.00	3.54
	1.95	0.99	3.52	0.55	0.29	2.42	1.84	0.92	3.29
Mexico	0.04	0.01	0.24	331.82 *	564.58 *	1137.67 *	331.48 *	563.83 *	1136.26 *
	0.03	0.01	0.17	331.48 **	563.83 **	1136.25 **	331.08 **	562.96 **	1134.59 **
Morocco	0.09	0.04	0.20	12.21 *	9.03 *	23.24 *	12.10 *	8.92 *	22.99 *
	0.08	0.04	0.18	12.10 **	8.92 **	22.99 **	11.97 **	8.80 **	22.69 **
Netherlands	1.72	1.36	6.39	1.25	0.76	3.64	1.81	1.47	6.76
	1.63	1.26	5.96	1.23	0.73	3.54	1.76	1.42	6.54
New Zealand	1.42	0.78	3.48	1.01	0.63	3.92	1.40	0.77	3.72
	1.35	0.73	3.26	0.97	0.60	3.72	1.33	0.73	3.51
Nigeria	0.00	0.00	0.01	118.43 *	113.42 *	235.60 *	117.51 *	112.29 *	233.40 *
	0.00	0.00	0.00	117.50 **	112.29 **	233.39 **	116.43 **	111.00 **	230.83 **
Norway	1.50	0.90	4.78	0.93	0.51	3.02	1.50	0.91	4.79
	1.49	0.89	4.74	0.92	0.51	3.00	1.49	0.90	4.75
Pakistan	3.32	30.20 *	68.83 *	2.37	1.84	7.45	3.22	28.96 *	66.17 *
	3.22	29.03 **	66.31 **	2.11	1.58	6.45	3.10	27.62 **	63.25 **
Peru	0.00	0.00	0.00	193.00 *	196.88 *	404.21 *	190.61 *	193.76 *	398.20 *
	0.00	0.00	0.00	190.59 **	193.75 **	398.16 **	187.83 **	190.19 **	391.21 **
Philippines	0.67	0.34	1.53	2.37	3.68 *	13.68 *	2.30	3.54	13.17
	0.65	0.33	1.47	2.30	3.54	13.16	2.21	3.37	12.59
Poland	0.01	0.00	0.16	182.07 *	176.34 *	375.80 *	168.38 *	159.51 *	342.12 *
	0.01	0.00	0.09	168.31 **	159.47 **	341.90 **	153.57 **	141.99 **	306.17 **
Portugal	0.74	0.35	1.62	1.15	0.57	2.54	1.10	0.54	2.41
	0.68	0.31	1.45	1.10	0.54	2.41	1.04	0.51	2.26
Romania	0.05	0.01	0.19	222.77 *	356.84 *	782.36 *	193.81 *	298.42 *	661.85 *
	0.03	0.01	0.09	193.66 **	298.30 **	661.09 **	164.50 **	242.57 **	543.07 **
Russian Federation	0.00	0.00	0.00	953.78 *	5061.11 *	10200.00 *	943.01 *	4987.83 *	10061.77 *
	0.00	0.00	0.00	942.95 **	4987.67 **	10060.83 **	930.48 **	4904.23 **	9900.72 **
Saudi Arabia	2.98	6.03 *	18.83 *	1.81	6.15 *	19.08 *	2.75	6.15 *	18.82 *
	2.77	5.46 **	17.14	1.61	5.30 **	16.60	2.50	5.46	16.79
Singapore	3.70 *	12.11 *	30.92 *	0.59	0.30	1.43	4.06	14.06 *	34.55 *
	3.35	10.59 **	27.25 **	0.56	0.29	1.36	3.87	13.24 **	32.63 **

Table A2. Detailed results of persistence change tests for all countries. *Continued.*

Slovakia	0.79	0.45	2.02	6.94 *	9.76 *	25.81 *	6.51 *	9.05 *	23.95 *
	0.74	0.40	1.84	6.34 **	8.70 **	23.15 **	5.92 **	8.03 **	21.36
Slovenia	0.07	0.02	0.25	39.34 *	115.01 *	238.32 *	38.87 *	113.24 *	234.88 *
	0.04	0.01	0.12	38.87 **	113.23 **	234.86 **	38.32 **	111.21 **	230.87 **
South Africa	0.68	0.46	3.67	6.10 *	15.75 *	38.59 *	5.93 *	15.17 *	37.25 *
	0.64	0.43	3.39	5.93 **	15.17 **	37.24 **	5.72	14.52 **	35.72 **
Spain	1.05	0.55	2.90	1.07	0.56	2.41	1.07	0.57	2.97
	1.02	0.53	2.81	1.06	0.55	2.37	1.05	0.55	2.92
Sri Lanka	4.87 *	6.16 *	18.52 *	1.24	2.13	10.17	4.85 *	6.12 *	18.41 *
	4.85 **	6.12 **	18.41 **	1.17	1.97	9.45	4.82	6.07	18.28
Sudan	0.10	0.05	0.61	8.51 *	7.67 *	21.85 *	7.34 *	6.34 *	18.29 *
	0.09	0.03	0.48	7.34 **	6.34 **	18.26 **	6.17 **	5.09	14.82
Sweden	1.34	0.87	4.58	1.46	0.98	5.12	1.42	0.95	4.97
	1.31	0.85	4.44	1.42	0.95	4.97	1.38	0.91	4.80
Switzerland	5.07 *	3.62 *	11.40	0.30	0.16	1.78	5.03 *	3.57	11.27
	5.03 **	3.58	11.27	0.30	0.16	1.73	4.97	3.53	11.12
Taiwan	0.18	0.09	0.67	8.16 *	7.17 *	19.49 *	8.14 *	7.16 *	19.45 *
	0.17	0.08	0.63	8.14 **	7.16 **	19.45 **	8.13 **	7.14	19.40
Thailand	0.41	0.28	3.12	6.84 *	5.61 *	16.40 *	6.75 *	5.52 *	16.15
	0.37	0.25	2.75	6.75 **	5.52 **	16.15	6.65 **	5.42	15.87
Tunisia	1.55	1.18	6.28	0.78	0.38	2.02	1.41	1.03	5.57
	1.42	1.04	5.61	0.70	0.33	1.77	1.26	0.90	4.86
Turkey	8.05 *	23.03 *	53.83 *	888.63 *	1680.48 *	3369.31 *	888.40 *	1679.93 *	3368.27 *
	7.53 **	21.04 **	49.43 **	888.40 **	1679.92 **	3368.26 **	888.13 **	1679.28 **	3367.03 **
Ukraine	0.00	0.00	0.00	349.03 *	288.19 *	634.61 *	302.27 *	239.58 *	533.90 *
	0.00	0.00	0.00	302.03 **	239.49 **	533.26 **	255.16 **	193.42 **	435.22 **
United Kingdom	2.32	3.50 *	12.21	1.28	0.79	4.09	2.35	3.59	12.40
	2.21	3.29	11.52	1.25	0.76	3.95	2.27	3.45	11.91
United States	7.25 *	7.81 *	22.75 *	0.22	0.11	0.53	7.21 *	7.75 *	22.60 *
	7.22 **	7.76 **	22.61 **	0.21	0.11	0.52	7.17 **	7.69 **	22.42 **
Venezuela	0.18	0.08	0.74	4.84 *	3.49 *	11.62	4.88 *	3.76	11.88
	0.14	0.06	0.58	3.48	2.28	7.80	3.80	2.74	8.77

Critical values

T= 100, *Mean case*	MS	ME	MX	MS^R	ME^R	MX^R	MS^M	ME^M	MX^M
10%	3.56	3.48	12.91	3.56	3.48	12.88	4.66	5.23	17.00
5%	4.67	5.31	17.24	4.64	5.25	17.00	5.91	7.38	21.72