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Keywords: inflation targeting, exchange-rate targeting, monetary regime switch, developing economies

JEL classification: F41, E42

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1. Introduction and motivation

"Throughout the world, monetary-policy regimes have changed dramatically over the decade of the 1990s. … The biggest transformation has been the move away from focusing on intermediate objectives, such as money and exchange rates, toward the direct targeting of inflation." (Cecchetti and Ehrmann, 1999, p.1). Inflation targeting (IT) as a monetary regime is relatively new, dating back to the beginning of the 1990s when New Zealand was the first to adopt an official inflation target. The first several years of the IT era were marked by the adoption by advanced countries (see Table 1). Though, many subsequent ITers either targeted inflation implicitly, i.e. only as a benchmark against which outcomes are measured, or followed several explicit targets (Morandé and Schmidt-Hebbel, 2000). IT is a regime based on rules and objectives that have to be achieved and which is freed of any other monetary policy target. Judging according to this specification, there are 26 inflation targeters in the world today (plus three that have left IT to join the Euro zone).

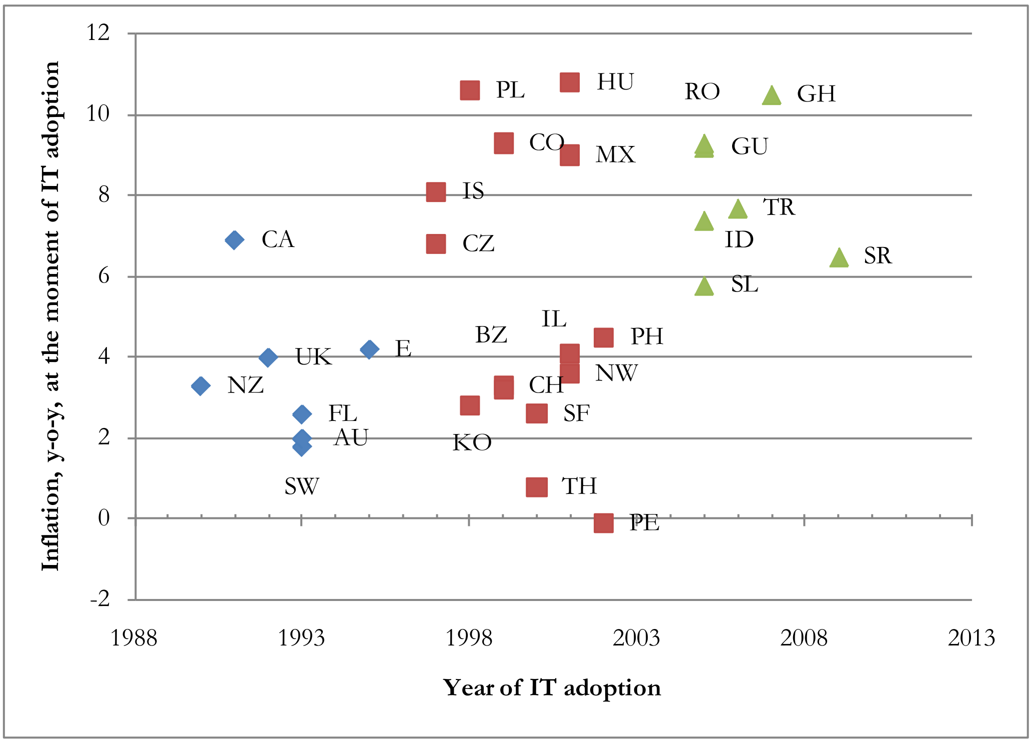
As a monetary regime, IT appeared and grew in the developed world. We denote the adoption of IT by the advanced economies as the first wave which terminated in the mid 1990s (Figure 1; blue points). The majority of the quantitative studies are conducted on datasets for those countries. The initial results of the application of the new monetary regime were satisfactory: Although inflation reduction started before the introduction of IT, "inflation did not bounce back up afterwards as expected" (Mishkin and Posen, 1998, p.90). However, there is no overwhelming evidence that the new regime in the adopting countries significantly affected inflation expectations nor that it significantly reduced output volatility. It is perhaps important to note that these countries enjoy acquired credibility of their central bank, which is important for this monetary regime.

After the positive experience of the first ITers, in terms of a low inflation level, a new wave of ITers commenced at the end of the decade: many developing economies started to target inflation, explicitly or implicitly (Figure 1; red points). In the same time, a growing body of studies emerged around IT in emerging economies, but the review in Petreski (2009a) finds that these studies are merely descriptive. Many of the implicit nominal targeters embarked on explicit IT; the majority of developing economies did that because of facing pressures on the foreign exchange market, or even a demise of the fixed exchange rate. Petreski (2008) elaborated on the challenge to sustain the peg against a background of foreign disturbances and increased capital mobility. For instance, after its real exchange-rate crisis in early 1999, Brazil abandoned the peg, embarked on a floating regime and officially adopted IT (Bogdanski *et al.* 2000). Following the Asian financial crisis in 1997 and the demise of the Thai baht exchange-rate system, a floating rate was introduced alongside a money-base target in Thailand. The latter suffered from the weak link between money and prices and ultimately the Central Bank adopted an IT framework (Agenor, 2000). After the boom of capital inflows in Hungary in the late 1990s, the pressures on the foreign exchange market resulted in a widening of the exchange-rate band to ±15% in 2001 and some months later in abandoning the target as "the exchange rate no longer served a useful function as a focal point for inflationary expectations" (Siklos and Abel, 2002, p.310). Jonas and Mishkin (2003) report the cases of the Czech Republic and Poland, which also introduced IT after exchange-rate regime turbulence, albeit the establishment of the new regime in Poland was more gradual.

A third wave of IT adoption is underway with developing countries (Figure 1; green points) which mostly relied on alternative strategies, but embark on IT with the persuasion of improved benefits for their economies. A growing number of economies are currently examining the introduction of targets and several have already launched preparations for formally adopting them. These include the developing and emerging economies of Albania, Armenia and Kazakhstan, which already have price stability as a stated objective but have yet to adopt a formal IT. The world economic crisis might postpone any such plan; they do not dominate the agenda in these countries currently.

As many countries decided to abandon any preannounced peg, they faced the need to adopt new nominal anchor. Fourteen exchange-rate peggers embarked on a new monetary strategy – inflation targeting. Nine out of those were developing economies (see Table 1). These are the spotlight of the analysis in this paper.

Figure 1. Three waves of inflation targeters



Source: Table 1

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The argumentation and empirical evidence (summarized and empirically explored in Petreski, 2009b; 2010) suggest that exchange-rate pegging, albeit not important in affecting the long-term growth performance of the economy, is important in stabilizing output fluctuations. However, when large real shocks hit, it might spur output volatility. It is argued that as the economy gets more involved in the international financial market, real shocks become likely. Further, the argumentation in Petreski (2009a; forthcoming) suggested that the exit from an exchange-rate peg will provide the economy with more flexibility in buffering real shocks, but the economy will still need a monetary anchor. IT along with a managed-floating exchange rate is argued to provide a nominal anchor and to take into consideration the need to reduce output- and exchange-rate volatility (Goldstein, 2002). Yet, opinions in the literature as to the effectiveness with which such a policy affects output fluctuations remain divided. Moreover, the role of the exchange rate has been neglected for advanced economies, but gains importance for developing economies – because of: i) the exchange-rate being the core transmission channel for monetary policy; ii) because of its complex macro-relationships, like the level of euroization; and iii) because of these economies' exposure to capital inflows reversals and sudden stops (Amato and Gerlach, 2002; Eichengreen *et al.* 1999; Chang and Velasco, 2000).

The aim of this paper is to empirically examine the effect of a regime switch, from exchange-rate targeting (ERT; fixed exchange rate) to inflation targeting (IT) in nine developing economies, on monetary policy, hence adding to evidence on whether IT along with a managed float provides a better monetary policy compared to ERT.

The paper is organized as follows. Section 2 discusses the data and sample and sets out the model to be estimated. Section 3 establishes the switching-regression method as our empirical strategy. Section 4 examines the results, while Section 5 gives some discussion, robustness analysis and a critique of the applied methodology. Section 6 offers the Markov-switching regression as an alternative modelling approach. Section 7 reports the findings of this approach and presents further discussion. The last section concludes the paper.

2. Data, sample and model

Given that the objective of the paper is to investigate monetary-policy responses under a regime switch from exchange-rate targeting to inflation targeting, *the first step* to achieve this is to establish a representation of the monetary policy. A large strand of the monetary-economics literature suggests the interest-rate rule as a neat way to represent monetary policy: some review papers include: Boivin and Giannoni (2006); Primiceri (2006); Lubik and Schorfheide (2004); Weerapana (2000); Svensson and Woodford (2003); King (1999); McCallum (1997); Cristiano and Gust (1999); and Woodford (1999). However, Clarida *et al.* (2000) remains probably the most cited piece of work over the preceding decade; they estimate a Taylor-type policy rule for the US whereby the federal funds rate is a function of inflation and output gap as final targets. In general, the monetary-policy reaction function, a-la Taylor (1993; 2001), explains reactions of the central bank to the macro-variables (like the output gap and inflation), which at the same time is consistent with the description of the IT regime (see, for instance, Svensson, 2000). The economic model is therefore as follows:

$$r_t = \alpha + \rho r_{t-1} + \beta_1 E_t \pi_{t+n} + \beta_2 (y_t - y_t^*) + \beta_3 \Delta e_t + u_t \qquad (1)$$

where r_t, π_{t+n}, $(y_t - y_t^*)$, and e_t denote respectively the nominal interest rate, expected inflation, the output gap and the nominal exchange rate (direct quote) at time t (or plus n periods into the future for expected inflation); E_t is the expectations operator conditional on information available at time t; Δ is the first difference operator; ρ is the smoothing parameter to be estimated; β s are coefficients to be estimated, measuring the central-bank response to the changes in these variables, which can partly reflect authorities' preferences in designing monetary policy; and u_t is the error term. This is a forward-looking interest-rate rule augmented with the exchange rate. Some papers including the exchange rate in the interest rule include: Ball (1999), Mishkin and Savastano (2002), Minella *et al.* (2003) Mohanty and Klau (2005) and De Mello and Moccero (2008). There is some controversy over the inclusion of the exchange rate in the interest-rate rule, but this is done for three reasons, the latter two being largely present in the existing literature (see Frankel, 1979): i) our control-group countries (described below in this section) target and our ITers formerly targeted the exchange rate, hence it is/was the main intermediate objective and might be considered as a high-frequency indicator of the external sector that guides monetary policy; ii) there may still be more complex interactions between movements in the exchange rate and macroeconomic performance in developing ITers (like their "fear of floating" [Calvo and Reinhart, 2004]; or the relevance of the exchange-rate pass-through, discussed in Petreski, 2008); and iii) financial imperfections such as a large amount of external debt or large foreign currency substitution might make the case for monetary intervention on exchange-rate movements stronger.

In addition to this, interest-rate smoothing is allowed in the equation, by adding a lagged endogenous variable (see Sack and Wieland, 1999; and Lowe and Ellis, 1997, for a documentation of this strand of the literature). Mohanty and Klau (2005) offer several reasons for smoothing: i) to reduce the risk of policy mistakes, when uncertainty about model parameters is high and when policymakers have to act on partial information; ii) the authorities' concern about the implications of their actions for the financial system: if markets have limited capacity to hedge interest-rate risk, a sudden and large change in the interest rate could expose market participants to capital losses and might raise systemic financial risks; iii) to avoid reputation risks to central banks from sudden reversals of interest-rate directions; and so on.

As a robustness check, later other variables are added that might have an importance in our analytical framework:

i) Lagged inflation, to check if monetary policy was backward- instead of forward-looking (Taylor, 1993);

ii) Reserves growth, in order to serve the same purposes as the inclusion of the nominal exchange rate, but also to reflect pressures on the foreign-exchange market more tightly. It is argued that for the periods under pegged exchange rate, the nominal rate might not fully reflect these pressures;

iii) Net-foreign assets (NFA) of the banking system to GDP, as a measure of euroization, hence making a separate case to address the concern of how it might have affected the conduct of monetary policy;

iv) Monetary-aggregate growth, to capture its potential observation as an intermediate target of monetary policy (Sims and Zha, 2006). However, many studies argue that the inclusion of a monetary aggregate is contestable due to the weakened link between money and prices.

Bernanke and Gertler (2001); Bordo and Jeanne (2002) and Mohanty and Klau (2005) argue to include asset prices, in order to capture the potential role of the central bank in combating asset bubbles or as a potential source of risk to financial stability. However, several arguments lead us not to explore this aspect here: i) asset-prices role in monetary policy became of increased interest just after the crisis of 2008 emerged, i.e. only at the end of our data period; ii) the effect of asset prices on the economy was not as dramatic in the developing economies as in advanced ones; and iii) good data-series for the stock market, and particularly for the housing market, are lacking for the majority of countries of interest.

As mentioned in the introductory section, the research interest of the paper is the nine developing countries that have historically experienced a switch from exchange-rate targeting to inflation targeting. The developing-countries switchers or the "treatment" group (henceforth referred to as simply "switchers") is: Brazil, Chile, Colombia, the Czech Republic, Hungary, Israel, Philippines, Poland and Thailand. Albeit that an official target has been announced, the de-facto behaviour of the exchange rate matters. Hence, the de-facto exchange-rate regime is reported to stand for the strength of the commitment to the exchange-rate target (Table 1; column 6), which might appear crucial for our empirical analysis hereafter. We notice that although an official target was announced in Chile, Israel, Poland and Colombia, the de-facto behaviour of the exchange rate was considerably lax. Hence, we might need to recall this later. The rest of the group is relatively homogenous in terms of the de-facto exchange-rate regime prior to the adoption of IT - all did have a de-facto tight exchange rate, which gives grounds for comparisons of the results.

Against the small group of switchers, the total number of exchange-rate targeters in the world is large. Given our methodological approach I (section 3), we need comparison countries that in the same period continued to target the exchange rate and can act as a suitable control group (henceforth referred to as "non-switchers") that do not include implicit ITers. The control group for developing countries is taken from the neighbouring developing countries to the switchers and/or countries with which these have trading and financial relationships, and have had the exchange-rate strategy for a prolonged period and did not move to IT. These countries are likely to have been subject to the same common regional shocks because of the proximity and the economic relations. These are: Argentina, Bulgaria, China, Ecuador, El Salvador, Estonia, Latvia, Lithuania, Macedonia and Uruguay.

< insert Table 1 here >

For the estimation monthly data from 1991:1 to 2009:12 are used. The usage of monthly data is justified by the fact that almost all central banks decide on the interest rate at a fortnightly frequency. Based on common sense and similar literature (like Clarida *et al.* 1998), a horizon of a year (12 months) is chosen for inflation (inflation enters with expectation in [1], being the reason why the interest rule is forward-looking). We are aware that central bankers are not concerned with the month-to-month movements in inflation, but rather with its medium-term trend.

The data are from the IFS database; whenever a series was missing, the central-bank and statistical-office web sites have been used as the source. Data are further described in Appendix B. The policy interest rate is represented through the money-market rate, as it best mimics the stance of the monetary policy; though where this was not available, the discount rate was used. Inflation is taken as year-on-year monthly percentage change of the consumer price index. Output volatility is defined through an HP filter, from the industrial production index, since GDP is not available on a monthly basis. The difference in the exchange rate is approximated through the year-on-year monthly percentage change of the nominal exchange rate of the national currency to the special drawing rights, since other series, like the nominal effective exchange rate was missing for a major part of our sample. Reserves growth is taken to be the year-on-year monthly percentage growth of the official reserves minus gold. Euroization in the economy is measured through the ratio of the absolute value of the net foreign assets in the banking system to GDP. Money growth is the year-on-year monthly percentage change of the broad money M2.

3. Method I

3.1. Designing a switching regression

Given that the objective of the paper is to investigate if and how monetary-policy responses change under a regime switch from exchange-rate targeting to inflation targeting, *the second step* is to design a switching regression (hereafter SR), whereby a subset of the population is subjected to an exogenous variation in variables, which may have been caused by a policy shift (Cameron and Trivedi, 2005). To be consistent with the jargon of this paper, henceforth treatment will be referred as "monetary-regime switching" or, in brief, "switching". A traditional way to design a regime-switching regression is to incorporate a dummy variable, taking a value of zero for the one regime (pre-switching) and one for the other regime (post-switching). In this way, the policy shift will be incorporated into the estimation. Further to this, an object of interest is a comparison of the two outcomes for the same unit when exposed, and when not exposed, to the regime switch. This approach is straightforward and enables an assessment of whether the switch to a new monetary regime is significant or not.

In a SR, we would like to measure the impact of the policy-switch variable on the economic outcome of a continuous variable labelled as y_i. The policy-switch variable is discrete and observable, labelled as D, where D takes value of 1 if the switch is applied and 0 otherwise. A simple SR can be designed by writing the following:

$$y_1 = E[y_1 \mid X] + u_1 \quad \text{- for the switching group} \tag{2}$$

$$y_0 = E[y_0 \mid X] + u_0 \quad \text{- for the non-switching group} \tag{3}$$

Whereby the policy-outcome variable for each group depends on its mean conditional on a set of exogenous regressors, X, and an error term, u_i. It is crucial that both groups share the same characteristics, captured by the same regressors X. This is a SR, because switching and non-switching groups have different conditional mean functions, $\mu_i(X)$, i.e.

$$E[y_1 \mid X] = \mu_1(X) \tag{4}$$

$$E[y_0 \mid X] = \mu_0(X) \tag{5}$$

The observed outcome is written:

$$y_i = Dy_1 + (1-D)y_0 \tag{6}$$

D being the switching variable and i indexes countries. Substituting (3) and (5) into (2) and (3), respectively, and then the latter two in (6), yields:

$$\begin{aligned} y_i &= D(\mu_1(X) + u_1) + (1-D)(\mu_0(X) + u_0) \\ &= D\mu_1(X) + Du_1 + \mu_0(X) + u_0 - D\mu_0(X) - Du_0 \\ &= \mu_0(X) + D[\mu_1(X) - \mu_0(X) + u_1 - u_0] + u_0 \end{aligned} \tag{7}$$

Since D can take values of 0 or 1, the term $D[\mu_1(X) - \mu_0(X) + u_1 - u_0]$ switches between the switching and the non-switching group. It measures the effect of the new monetary regime; the component $\mu_1(X) - \mu_0(X)$ measures the average change to switchers with characteristics X, randomly drawn from the population (often referred to as the average treatment effect), while $u_1 - u_0$ is the random error (often referred to as country-specific gain from treatment) (Wooldridge, 2002).

If the switching and non-switching group are observed over time, then a panel is obtained. In this way, we can make use of the increased variability of the data and along with observing switchers versus non-switchers we can exploit the 'before-switch' versus 'after-switch' variability (Blundel and MaCurdy, 2000). Now, equations (6) and (7) can be advanced in the following manner:

$$y_{it} = \beta X_{it} + \phi D_{it} + \gamma D_{it} X_{it} + \delta_t + \alpha_i + u_{it} \quad (8)$$

whereby y_{it} is the outcome variable for the unit (country) i in period t; D_{it} takes value of 1 if country i switched to the new regime in period t, and 0 otherwise; X_{it} is a vector of explanatory variables; $D_{it} X_{it}$ captures the switching parameters of the explanatory variables ; δ_t is a time-specific fixed effect; α_i is a country-specific fixed effect; and u_{it} is the usual i.i.d. error term. Certainly, all or some of the explanatory variables can be allowed to switch, based on economic theory and intuition. Given that the X_{it} variables are exogenous, (8) can be consistently estimated by the fixed-effects estimator, given that some underlying assumptions are satisfied. Namely, as Cameron and Trivedi (2005) and Meyer (1995) explain, the extent to which SR can give credible econometric evidence crucially depends on:

1. The outcome of the non-switching group does not determine switching to the new regime, i.e. the mean of the non-switching group conditional on X_{it} does not depend on the value of D_{it} (the so called conditional-mean independence assumption); and
2. The decision to switch does not depend on the outcomes, after controlling for the variation in them induced by the differences in X_{it} variables (the so called exogeneity assumption).

While the decision to establish formal IT aims to be exogenous, as these assumptions require, still policymakers might be forced to, i.e. endogenously embark on a new regime. Hence, the switch-exogeneity assumption might be violated; this is discussed in the next section.

3.2. Endogeneity in a switching regression

It follows that despite its simplicity, the SR approach has a disadvantage. Meyer (1995) argues that good natural experiments are those where there is a transparent exogenous source of variation in the explanatory variables that determine the treatment assignment, like policy changes or financial crises. This can be achieved by selecting a random sample. However,

> Randomization of treatment [switch, *n.b*] is often infeasible… In most cases, individuals [countries, *n.b*] at least partly determine whether they receive treatment [whether they switch, *n.b*], and their decisions may be related to the benefits of the treatment, $y_1 - y_0$. In other words, there is **self-selection** into treatment (Wooldridge, 2002, p.606).

As an intuitive explanation, although the switch to IT might be considered as an exogenous policy shift, there might be reasons for it not being independent (i.e. exogenous) of former high levels of inflation or increased output and exchange-rate volatility under shocks. For example, countries might have been trapped in high inflation or devaluation pressures over a prolonged period of time (as the examples reviewed in Section 1), which forced them to exit a peg and switch to IT. Hence, ITers might be self-selected. In econometric terms, the selection bias arises when D_{it} (the switch) is correlated with the error in the outcome equation (8). According to Cameron and Trivedi (2005), this can be induced by omitted variables that determine both D_{it} and y_{it}, or by some unobserved factors. To examine the former, (8) can be rewritten as follows:

$$E[y_{it} \mid X_{it}, D_{it}, z_{it}] = \beta X_{it} + \phi D_{it} + \gamma D_{it} X_{it} + \delta_t + \alpha_i + E[u_{it} \mid X_{it}, z_{it}] \quad (9)$$

Whereby z_{it} denotes a set of observable variables that determine D_{it} and may be correlated to the outcome and $E[u_{it} \mid z_{it}] \neq 0$. Hence, to overcome this potential endogenous switching, we need to introduce in the equation all observable variables that could be possibly correlated with u_{it}, but also determine y_{it} i.e.:

$$y_{it} = \beta C_{it}^{'} + \phi D_{it} + \gamma D_{it} C_{it} + \delta_t + \alpha_i + u_{it} \qquad (10)$$

whereby $C_{it}^{'}$ includes all exogenous (X_{it}) and variables related to the switching (z_{it}). By doing so, the observed information contained in $C_{it}^{'}$ that determines the switch, will remove any correlation between y_{it} and D_{it}. This so-called selection by observables will eliminate any endogeneity of the switch coming from observable information (see further in Barnow *et al.* 1980; Heckman and Hotz, 1989; and Moffitt, 1996).

However, $E[u_{it} \mid X_{it}, D_{it}] \neq 0$ may still be different from zero if there are common unobservable factors that affect both D_{it} and u_{it}, in which case D_{it} is still endogenous. If there exists only a component of the z_{it} vector to determine D_{it}, then it may be used as an instrumental variable to correct the endogeneity of D_{it} (because it is correlated with D_{it} but not with the outcome y_{it}, except through D_{it}). According to Wooldridge (2002), this means that this component of z_{it} will not appear in (10), because it affects y_{it} only indirectly; this is the part of the identification to overcome endogeneity stemming from the selection of unobservables and it can be tested only indirectly through an over-identification test.

4. Empirical results I

4.1. Model in estimable form and technique

Linking our economic model in equation (1) and our sample defined in Section 2, with our primary objective to discover if and how the reaction of the monetary policy has changed when regime switched (Section 3), the following estimable form of the model can be written:

$$\begin{aligned} r_{it} = {} & \beta_0 + \rho r_{it-1} + \beta_1 after + \beta_2 switch + \beta_3 after\_switch + \\ & + \sum \gamma_i COVAR_{ijt} + \sum \eta_i COVAR_{ijt} * after + \sum \kappa_i COVAR_{ijt} * switch + \\ & + \sum \vartheta_i COVAR_{ijt} * after\_switch + \alpha_i + \delta_t + u_{it} \end{aligned} \qquad (11)$$

Whereby, r_{it} is the nominal reference interest rate; $after$ is a dummy variable equal to unity for the period after the date of the switch for switchers and after 2000 for the non-switchers (taken as a median year when most of the switchers switched), and zero otherwise; $switch$ is a time-invariant dummy variable equal to unity over the whole period for the countries in the sample that switched to IT (switchers) and zero otherwise. The period-dummy $after$ captures unobserved but systematic influences on the interest rate during the after period in the same way for both switchers and non-switchers. The presence of $switch$ by itself captures possible differences between switchers and non-switchers that are independent of the switch. $after$ and $switch$ control for period- and group-specific level effects on the interest rate, respectively. $after\_switch$ is a dummy variable equal to unity for those observations in the switching group after these countries switched to IT, and is the variable of primary interest: it identifies the difference to the interest rate associated with switching after controlling for both group-specific variations (*switch*) and period-specific variations (*after*). $COVAR_{ijt}$ consists of our covariates explained in Section 2: inflation, π_{it+n}; output gap, gap_{it}; and changes of the nominal exchange rate, Δer_{it}. The terms $COVAR_{ijt} * after; COVAR_{ijt} * switch$; and $COVAR_{ijt} * after\_switch$ multiply those covariates with $after; switch$; and $after\_switch$, respectively. ϑ_is are the coefficients of interest which capture differences in monetary-policy reaction in the switchers after they switched, which in the presence of controls for both group-specific and period-specific variation identifies the effects of switching. η_i and κ_i are used as coefficients to control for period- and group-specific responses, respectively. The lagged interest rate is not interacted, since there are no intuitive grounds to claim that the way in which the authorities smooth the interest-rate path has to do with the regime in operation. δ_t s are annual time dummies, which are suggested as a way to remove the common influence of any global shocks from the errors (Sarafidis *et al.* 2006; Roodman 2008a). Annual and not monthly dummies are used because of the large time dimension. α_i s are country-specific dummies, and u_{it} is the usual disturbance.

With the selection of observables that might have forced a switch (inflation, output gap and exchange-rate changes) one part of the endogeneity of the switching dummy $after\_switch$ was addressed. Moreover, since intermediate and final targets of policy enter the interest rule, we cannot claim that the right-hand side variables should be treated as exogenous themselves. Hence, our estimable model (11) needs to be estimated using IVs, whereby lagged values of the potentially endogenous variables are used as instruments. In addition, since our model is dynamic, dynamic panel IV estimation is needed. However, this type of estimation is appropriate for panels with a short time and a wide cross-section dimension (Baltagi, 2008). On the other hand, since we have a narrow but long panel of 19 countries (N=19) and monthly data over 19 years (T=228), we refer to Nickell (1981) who derived an expression for the bias of the coefficient on the lagged dependent variable (ρ in [1]) when there are no exogenous regressors, showing that the bias approaches zero as T approaches infinity. Judson and Owen (1996) document that the bias ranges from 3% to 20% of the true value of the coefficient when T=30. Thus, non-dynamic IV estimators will perform well under a fairly large time dimension (T=228) and these are ones applied here.

Before proceeding to addressing the issue of endogeneity arising from unobservables, we draw attention to an issue which is ignored in the empirical literature in this area: the difference between the standard IV estimator and the GMM estimator. The difference lies in the way of addressing heteroskedasticity, which is often present in empirical work. Baum *et al.* (2003) argue that the presence of heteroskedasticity does not affect the consistency of the IV-coefficient estimates, but the estimates of the standard errors will be inconsistent and diagnostic tests invalid. A way to partially resolve this issue is to use heteroskedasticity-consistent ("robust") standard errors. Unfortunately, the Pagan-Hall (1983) test for detecting heteroskedasticity in IV estimation has not been developed for panel data. Hence, we rely on the advice of Stock and Watson (2006, p.166) that, when using the standard IV estimator:

> Economic theory rarely gives any reason to believe that the errors are homoskedastic. It therefore is prudent to assume that the errors might be heteroskedastic unless you have compelling reasons to believe otherwise. [...] If the homoskedasticity-only and heteroskedasticity-robust standard errors are the same, nothing is lost by using the heteroskedasticity-robust standard errors; if they differ, however, then you should use the more reliable ones that allow for heteroskedasticity. The simplest thing, then, is always to use the heteroskedasticity-robust standard errors.

However, it should be noted that this applies as long as the sample is large enough, which is arguably the case here.

A more advanced way of dealing with heteroskedasticity of unknown form is to use GMM, introduced by Hansen (1982). "Efficient GMM brings with it the advantage of consistency in the presence of arbitrary heteroskedasticity, but at a cost of possibly poor finite sample performance." (Baum *et al.* 2003, p.2). If heteroskedasticity is not present, the GMM estimator is asymptotically no worse than the IV estimator. However, the optimal weighting matrix in the GMM estimation is a function of fourth moments and obtaining reasonable estimates for these requires very large sample sizes. Hence, an efficient GMM estimator can have poor small-sample properties (Hayashi, 2000).

Returning to the endogeneity issue, because of the potential endogeneity arising from unobservables, $after\_switch$ will be instrumented by including variable(s) that do not enter the interest-rate rule *per se*, but might be important for the switch. For finding suitable instruments, we refer to Siklos and Abel (2002) for the necessary preconditions for establishing an IT: an independent, transparent, accountable and technically-capable central bank; absence of fiscal dominance; and a sufficiently developed financial system. We believe these are suitable candidates for instruments for $after\_switch$, as they do not enter the model directly, i.e. they affect the interest rate only through $after\_switch$. However, while a measure of the financial-system development and fiscal dominance can be easily obtained (the most frequently used measure for the first being bank assets-to-GDP and credits-to-GDP; and for the second the amount of monetary financing of the public deficit-to-GDP), measures for central-bank independence are usually calculated on an annual basis and will thus lack variability. Hence, we proceed by addressing the selection of unobservables by adding the ratio of domestic credit-to-GDP and the central-bank claims on central government-to-GDP as instruments. In addition to these, Leiderman *et al.* (2006) and Armas and Grippa (2005) discuss the role of euroization in the IT economies. Although they do not find arguments for euroization playing an important role under IT, it may still be the case that highly-euroized ERTers might be deterred from switching to IT, because a larger amount of bank assets would become exposed to exchange-rate risk. Hence the ratio of net-foreign assets of the banking sector to GDP is used as a third instrument for the switching variable.[1]

Finally, a note on serial correlation. In order to take into account any serial correlation in the residual, autocorrelation-robust standard errors are calculated (which along the heteroskedasticity-robust standard errors are known as HAC – heteroskedasticity and autocorrelation corrected standard errors; Newey and West, 1987b). HAC estimates are calculated with the kernel function's bandwidth which is chosen at one[2]. Though, this correction does not eliminate any violation of the *i.i.d.* assumption, but we believe if serial correlation is still in the residual, it will be indicated by the overidentifying-restrictions test.

4.2. Results from the switching regression

We turn to empirical results. Table 2 reports the results of the basic switching FE regression. First, both standard IV estimators (homoskedastic-only and HAC) and GMM are reported. We firstly compare the standard errors of the homoskedasticity-only (column 1) and HAC (column 2) IV estimators and conclude that there are notable differences, which leads us to conclude that heteroskedasticity and autocorrelation should be accounted for in making statistical inferences. Then, the GMM estimator is utilized whereby estimates and standard errors are robust to arbitrary heteroskedasticity and autocorrelation (column 3). In the Stock and Yogo (2005) test the critical values are devised only up to three endogenous variables, but we do have more than three endogenous variables in all cases, and these cannot be omitted, simply because we work with interactions, which are among our variables of interest. However, in all specifications we investigated, the weak identification test did not exceed an F-value of 5. The "rule of thumb" of 10 (Staiger and Stock, 1997) is thus never attained. Yet the critical values required to interpret the F-stat depend on the number of endogenous variables and instruments and also differ between estimators, and there is a lack of studies testing for weak instruments in the presence of non-i.i.d. errors (Stock and Yogo, 2005; Baum *et al.* 2007, p.24). Nevertheless, we do have sufficient empirical grounds to suspect that our estimates might suffer from weak identification.

The problem of weak identification arises, even when the sample is large, when the correlation between the endogenous regressors and the excluded instruments is nonzero but small (Baum *et al.* 2007). Unfortunately, the Stock-Yogo (2005) test has critical values devised only up to three endogenous variables, making investigation of the problem more problematic in our case. However, not all estimators are equally affected by weak instruments. Hansen *et al.* (1996) proposed the continuous updating GMM estimator (CUE), whereby estimation of the covariance matrix of orthogonality conditions and of coefficients is done simultaneously, i.e. information is "continuously updated". The limited-information likelihood estimator (LIML) dates back to Anderson and Rubin (1949), but Davidson and MacKinnon

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[1] There are arguments for including this variable in the main specification to explore the role of euroization under the two monetary strategies. We do this in the robustness checking in Table 4. However, we find there that the NFA-to-GDP is generally insignificant in explaining the interest rate (and, hence, has no significant role in monetary policy in the investigated countries), which supports our approach in using it as an excluded instrument for correcting 'after-switch' endogeneity due to unobservables.

2 Unfortunately, the optimal choice of the bandwidth by using the automatic bandwidth selection criterion of Newey and West (1994) is not provided under xtivreg2. Setting the bandwidth at one has both economic and technical reasoning: i) the interest rate is often decided at frequent intervals of two weeks, lending support to the idea that if autocorrelation exists in the model, it would be mostly first-order; ii) estimating the model with larger bandwidth caused computational difficulties.

(1993, p.644-649) derived it by solving an eigenvalue problem. Both CUE and LIML are argued to perform better in the presence of weak instruments (see: Baum *et al.* 2007). Hahn *et al.* (2004) offer some evidence in favour of this. A possible drawback of CUE could be that it requires numerical optimization; on the other hand, LIML requires the strong assumption of normally distributed disturbances (Baum *et al.* 2007). Given this, in our estimations, CUE is preferred – this is reported in columns (4) and (5) and LIML in column (6) of Table 2. Column (4) reports CUE for homoskedasticity only, while (5) reports HAC errors. We again observe notable differences and conclude that heteroskedasticity and autocorrelation should be accounted for. LIML estimates are efficient for homoskedasticity only, while CUE estimates are efficient for arbitrary heteroskedasticity. Consequently, our preferred estimator is CUE (HAC errors), and henceforth our discussion and further robustness tests are based on it.

< insert Table 2 here >

In all regressions the null that the model is under-specified can be rejected and the null that the instruments are valid (the over-identification test) cannot be rejected. Considering the possibility of weak identification within CUE, it is observed that coefficients' magnitude remained largely similar to other estimation methods. The endogeneity test for the switching variable rejects the null of it being exogenous, which supports our approach of using instrumental estimation. Note that given our specification, estimated coefficients approximate short-run relationships. However, these are the coefficients of interest, given that the monetary-policy reactions are of a short-run nature.

Given the complexity of the estimable model, in what follows we explain each panel of Table 2. Because of the issues related to weak identification discussed above, attention is focused on column (5) – CUE (HAC s.e.). A note on the lagged interest rate first: it has a very plausible magnitude, suggesting on a high smoothing, and is highly significant. Hence, it is doing a lot of explanation of the significance of the other coefficients. Without observing separate groups (panel A), we find that expected inflation and the change of the nominal exchange rate are insignificant at conventional levels, while the output gap is significant only at 10%. It suggests a very mild reaction of the central bank - an increase of output gap by 1 p.p. (economy overheating) leads to an increase of the nominal interest rate by 0.07 p.p.

Panels B and C of Table 2 control for the period- and group-specific effects, respectively. Recall that the 'after' dummy is equal to one for all countries after their official switch (for switchers) and after 2000 (for non-switchers), and zero otherwise. The coefficient in front of 'after' dummy (Table 2, Column 5) suggests that in the later period interest rates have been, on average and other things equal, lower by 0.6 p.p. It could be that this is a reflection of the characteristic of this period - an increased growth and shock-free macroeconomic environment; this is also reflected in the time dummies (available on request). However, the ceteris paribus effect is very strict here, given that we know that the average macroeconomic indicators changed between periods. Results suggest that in the "after" period, countries toughen monetary policy reaction to the inflation and the exchange rate, but these are significant only at the 10% level. The 'switch' dummy is equal to one for all switchers over the whole examined period, and zero otherwise; however, because FE regression is estimated, 'switch', as a time-invariant variable is dropped. This does not mean that 'switch' was not controlled for in the specifications (it is subsumed within the FE), but we were not able to obtain a separate estimate of its value.

What is of importance here is the case when the estimated monetary-policy responses in the switchers during the period under IT are considered. Recall that the 'after-switch' dummy is equal to one for switchers after they switched to IT, and zero otherwise. The coefficient on the intercept dummy (which is combined coefficient of 'after' and 'after-switch' dummies in Table 2) suggests that interest rates in switchers have been, on average and other things equal, higher by 0.8 p.p. (given the caution regarding the strictness of the ceteris paribus principle here). The policy-reaction coefficients are with negative signs and suggest that switchers, after they switched to IT, were able to moderate their reactions to macroeconomic developments. However, only expected inflation is statistically significant (at the 1% level) in affecting interest rates: an increase of expected inflation by 1 p.p. leads to a lower change in the nominal interest rate - by 0.18 p.p. - as compared to the period before and to the control group of countries. Also, the Wald test (not shown but available on request) suggests that inflation coefficient in the switchers is systematically different from the period before and from the control group. Consequently, these results suggest that IT represented a real switch in the investigated countries. Under

IT, the results suggest that these countries became more concerned in combating inflation (given statistical significance), but their reaction moderated compared to the period before and to the control group (given the change in the interest rate). Still, the price they paid for this is the higher level of interest rates, as compared to the period before and to the control group (as suggested by the intercept dummy). Although the coefficients on the output gap and the change in the exchange rate seem plausible and also suggest moderation in the policy reaction, they remain neither significant nor systematically different from the period before and from the control group. This suggests that these countries were concerned with inflation only and not the output gap and exchange rate, i.e. that they ran a monetary policy geared towards strict IT. This can be reconciled with reality: many of these countries were suffering periods of high inflation in the past (and this is the primary reason why they established ERT in the former period), so that even after they switched to IT, inflation remained their primary focus. This can be also reconciled with the observation that inflation should remain the main focus of IT policymakers until credibility is acquired, which is particularly the case in developing economies. On the other hand, the insignificance of the exchange rate might be a result of the relaxation of the exchange rate (whose price to pay was the higher level of interest rates, picked up by 'after-switch' dummy).

Overall, the conclusion runs counter to the idea that monetary policy has not undergone any change in the 2000s. Once it is controlled for, the estimates suggest that the switch to a new monetary regime explains these results. Also, the results oppose the usual statement in the literature that central banks under IT react strongly to inflation deviations from the target - compared to the period before and to the control group, these reactions moderate under IT. Taken together, the potential reason is that interest rates were maintained at a higher level than would otherwise be the case. On the other hand, no statistical significance was established for the output and the exchange rate, suggesting that these countries ran policy geared toward strict IT, i.e. policy not accounting for the real-economy developments. Also, the significance of the expected inflation effect in the switchers after they switched, might suggest that the switch could be more thought of as a switch toward more independent monetary policy, which afforded a space to account for domestic objectives. However, this is yet very limited evidence, given the insignificance of the reaction to the output gap.

5. Further discussion on the switching regression

5.1. Robustness tests

The general conclusion of the above discussion is that the switch to IT was a real switch to a newly-designed monetary policy, focused on inflation. Here, some robustness checks are performed, to test the stability of these results; CUE (HAC s.e.) only is used. Results are presented in Table 3 and Table 4 which are presented in the same way as in Table 2. In Table 3, three kinds of robustness check are done: i) dropping 'after' and 'switch' intercept and slope dummies; ii) allow for the switching variable to be exogenous; and iii) cut sample size.

< insert Table 3 here >

Combining intercept and slope dummies is often associated with multi-collinearity and hence, unstable estimates, as model specification and sample is changed. To investigate this, 'after' and 'switch' intercept and slope dummies are dropped in column 1. All diagnostics seem acceptable, including the weak identification test, given our earlier discussion. The estimated coefficients in the 'quadrant' of interest again suggest moderation of the policy responses under IT, but the output gap, while has similar magnitude as in the basic regression, now has statistical significance at the 1% level. This might lend some support to the notion that investigated countries were not 'inflation nutters' that much, but their policymaking afforded some space for pursuing real objectives.

Columns (2) and (3) of Table 3 treat the switching dummy as being exogenous, the difference being that the latter column has a gap-period implemented. The gap period refers to exclusion of the period around the official switch to IT: this is done in order to avoid the potential endogeneity of the switch. We allow a gap period of three years, symmetrically shared around the switch. Arguably this gives sufficient time to capture any macro-performance that might have forced a switch (pre-switch) and/or period when IT was declared but not (fully) adhered to (post-switch). The results (column 2) are insignificant in the quadrant of interest and the exogeneity of the switching variable is rejected, which renders the specification questionable and supports our approach in dealing with the endogeneity followed before. When the gap-period is included (column 3), we note that the estimated response coefficients of the central bank switch sign, but are insignificant at conventional levels. Also, the appropriate test cannot reject the null of exogeneity, which is expected, given that the period around the switch is ruled out of the estimation. A feature of this specification is that the 'after' dummy becomes positive, but insignificant, while the composed coefficient in front of the after-switch dummy ('after' + 'after-switch') is positive, but its magnitude is lower than in the other specifications. This might suggest that the period around the switch is very important in terms of macroeconomic developments, and although this specification (column 3) supports acknowledging switch endogeneity in the other specifications, it still excludes this important period, which is not what we opt for in this paper.

In column (4) the sample size is cut to 15 countries: Chile, Israel, Poland and Colombia are excluded from the switchers group, given the concern raised in Section 2 - although an official exchange-rate target was announced, the de-facto behaviour of the exchange rate remained considerably lax. Estimates are robust to reducing the sample size; the output-gap effect is of similar magnitude, but is significant at the 10%.

In Table 4 robustness testing is pursued forward by considering possible additional variables. Firstly, we check if the interest rule has a backward-looking component; in column (1) the 12^{th} lag of inflation and the interactions are added; since these are lagged values, they enter as exogenous in the regression. Lagged inflation is insignificant in all groups, suggesting that the forward-looking specification of the interest rule might be more appropriate. The remaining coefficients remain stable. Column (2) explores the potential role of euroization in the economy. Euroization is insignificant in all groups; hence, it is in line with the observations of Leiderman *et al.* (2006) and Armas and Grippa (2005) that financial euroization does not preclude an independent monetary policy oriented at maintaining low and stable inflation rate and lends justification for its usage as an excluded instrument in the previous regressions. Other coefficients remain stable.

Column (3) includes reserves. They are significant throughout the sample, suggesting that they play a strong role for these small, open economies. Estimated coefficients of other variables are of comparable magnitude as in our basic specification. An exception is the expected inflation in the 'after-switch' group, which becomes insignificant and wrongly signed, but the output gap is significant at the 10%. Given the exchange rate peg in a major part of the sample, the pressure on the foreign exchange market cannot be fully felt on the nominal exchange rate but reserves should capture this effect. The positive sign could be odd, though, since it is expected that growing reserves will leave more space for an easier monetary policy. However, it might be that the central bank, in such conditions, sterilizes money inflow from abroad (fearing of inflation) and hence the interest rate increases. In the switchers after they switched, the response to reserves' changes moderates.

Money growth is added in column (4) and is significant at 5%, except in the base group. An increase of money in the economy increases interest rates in the 'after' and switching group, but, in line to the overall conclusion from before, the reaction in the 'after-switch' group moderates. Its inclusion in the regression does not change the remaining coefficients and conclusions remain largely the same.

< insert Table 4 here >

Overall, with the basic specification and the robustness checks, the conclusions are: i) there is supporting evidence that the switch to IT represented a real switch in the investigated countries, i.e. that monetary policy is responsible for the changing results in the 'after' period; ii) central bankers in the 'after-switch' react to inflation, but the reaction becomes moderate in comparison to the control group and the period before; iii) although, in general, we concluded that these countries embarked on a policy geared towards strict IT (i.e. without considering output fluctuations), still there was limited evidence in some of the regressions that real fluctuations were taken into account and suggested that the reaction there moderated as well, but this finding is far from being robust; and iv) the exchange rate remained largely insignificant in affecting monetary-policy conduct.

5.2. A critique

Designed in this way, the switching regression suffers some drawbacks; three are discussed here; the last two are important for the further investigation. Firstly, some shortcomings are associated with the usage of the FE estimator. Namely, it precluded the 'classic' natural experiment identification strategy, i.e. a comparison of 'before' and 'after' effects in both 'switch' and 'non-switch' groups. This cannot be done in FE estimation, because the four dummy variables, each representing one of the four 'quadrants' sum to an overall constant, as do the country fixed effects. Similar to this limitation, in our estimation, the 'switch' dummy, as time-invariant variable, cannot be included, given that it is a fixed effect. However, this does not mean that 'switch' was not controlled for in the specifications, but we were not able to obtain a separate estimate of its value. Interactions of 'switch' with the covariates were possible, though.

Secondly, the technique is originally designed to capture a switch with exogenous variation. However, we argued and provided a statistical support that the switch to IT should be treated as endogenous. This was resolved by addressing both endogeneity stemming from the selection of observables and of unobservables. The overidentifying restrictions of the switching variable were tested and suggested it being endogenous. This is not problematic approach if countries that experienced increased inflation volatility and exchange-rate pressures ultimately abandoned the existing regime and explicitly embarked on another. However, a potential problem is that some of the countries might have started to target the medium-term inflation well before they officially introduced it (like Israel), or the opposite, they officially introduced it, but continued to tightly target the exchange rate for some intermediate period (like Hungary). The SR approach cannot potentially capture these developments.

Thirdly, this approach enables intercept and slope switches, but not variance switches. This cannot facilitate the need to observe if and how the monetary environment under IT changed, i.e. if, under IT the economy achieved both lower inflation- and output variance. To address the second and the third drawback, we proceed with an alternative modelling strategy, which is described as the paper proceeds.

6. Method II

6.1. Nonlinear switching regression

Given above drawbacks of the SR approach, other methods are available in the literature designed to capture the sources of non-linearities in the data. The last two decades marked a substantial increase in the application of non-linear methods to macroeconomic and financial data. These are largely classified into two broad areas: threshold autoregressive (hereafter TAR) and Markov-switching (hereafter MS) methods. The application of the regime-switching methods has been particularly common in analysing economic cycles (e.g. Garcia, 1998, Kim *et al.* 2008); stock markets (Ang and Bekaert, 2002b; Dai *et al.* 2003) and interest rates (Ang and Bekaert, 2002a; Garcia and Perron, 1996). However, no study, to our knowledge, uses those methods to analyse monetary policy in a context of monetary-regime switch.

The threshold autoregression models the behaviour of a variable in a relation to a threshold value (Tong, 1983; Potter, 2002). Originally, this class of methods was proposed by Tong (1978) and further developed by Tong and Lim (1980) and Tong (1983). The value that changes (the interest rate, in our case) depending on the values of an independent variable (say, inflation) is within the space of the threshold variable (which could also be inflation) but not linear in time. When the threshold variable is taken as a lagged value of the time-series itself, the method is known as a self-exciting threshold autoregressive (SETAR) method (Tong, 1993; Hansen, 1996; 1997; 2000). Designed in this way, the TAR method crucially depends on two factors: i) the choice of the threshold variable; and ii) the information about the official switch. Although some of our right-hand-side variables might be good candidates for a threshold variable, and although the official date of the switch to IT is known, our understanding is that the approach to the problem is similar to the SR approach (Section 3), which is not helpful given its potential drawbacks in light of our research question (as discussed in section 5.2).

In contrast to the TAR approach (and apparently to the SR approach), the structural break in the Markov switching approach is the outcome of an unobserved, discrete, random variable, which is assumed to follow a Markov process[3] (Goldfeld and Quandt, 1973; Cosslett and Lee, 1985; Hamilton, 1989). This strand of the literature was steered by the seminal contributions of Hamilton (1989; 1994), although the work was motivated by the earlier contribution of Goldfeld and Quandt (1973). Textbook exposition of the MS models can be found in Maddala and Kim (1998); Brooks (2002); and Doornik and Hendry (2009). Hamilton's (1989) model explores the quarterly percentage change in US real GNP from 1953 to 1984 as a function of its own lagged values in the previous four quarters and allows the conditional mean to switch between two states: expansion and recession. Since this seminal contribution, a growing literature on regime switching in applied macroeconomic time-series analysis has emerged. An indicative list includes: Cecchetti *et al.* (1990), Diebold and Rudebusch (1996), Garcia and Perron (1996), Ravn and Sola (1995), Sola and Driffill (1994). However, these applications are still largely limited to business-cycle analysis. A small part of the literature (Ang and Bekaert, 2002b; Vasquez, 2008; Sims and Zha, 2006; Valente, 2003) analyses monetary policy, but frequently try to capture different styles of monetary policy under different central-bank governors. Also, these studies are largely limited to developed countries.

What advantages would the MS approach have over the SR approach? Although we obtained in Section 4 some evidence in favour of IT, still our discussion there and in Ball and Sheridan (2005) poses the contra-argument that this evidence is still open to the identification-strategy problem (i.e. how good a comparative group is the control group). Moreover, Creel and Hubert (2009) point out that contrary to SR and TAR methods, MS methods will circumvent the task of predefining a switch or a threshold and will simply reveal if and when different regimes occurred in the switching economies. Moreover, letting data speak freely will address our earlier concern (Section 5.2) that investigating the presence of distinct regimes, rather than assuming a strict break, would enable us to check if anti-inflation policies existed in the past (i.e. authorities might have started to target medium-term inflation before they officially announced a switch) or if the exchange-rate target was not fully abandoned even after the official switch to IT (i.e. authorities continued to target the exchange rate for a certain period after they officially switched). Finally, by allowing for the variance in the regression to differ in both regimes, MS methods allow for investigation of whether the economic environment changed due to monetary policy. Given that this method will potentially overcome our concerns within Section 5.2, we proceed with an MS framework, which is further explained in the next subsection.

6.2. Designing a Markov-switching regression

In an MS regression, explanatory power is assigned to the existence of a few "states" (regimes) among which the economy shifts:

$$y_t - \mu_{S_t} = \sum_{i=1}^{4} \varphi_i (y_{t-i} - \mu_{S_{t-i}}) + \varepsilon_t; \qquad (12)$$

where y_t is a univariate time series to be explained; s_t is a latent dummy variable taking the value of 0 or 1 and representing two states in which the economy could fit; and ε_t is Gaussian white noise ($\varepsilon_t \mid S_t \approx NID(0, \Sigma(S_t))$; Hamilton, 1989). μ is a mean term conditional upon the state in which the economy belongs; the state is assumed to be unobservable and has to be inferred from the data. In his work, Hamilton (1989) sets the autoregressive order equal to four. In cases where the null of $\mu = 0$ cannot be rejected, only one state governs the process and this could be represented by the standard AR(4) model.

To complete the description of the dynamics of (12), we need to define a probability rule of how y_t changes between regimes. A Markov chain is the simplest time-series method for a discrete-valued

[3] A Markov process is a stochastic process in which only the present value of the variable is relevant to predict its future behaviour, i.e. its past values and the way in which the present value has emerged from the past are irrelevant. Hence, Markov processes are not path-dependent.

random variable, such as the regime variable s_t. s_t is assumed to follow an ergodic[4] first-order Markov process (and is, hence, serially correlated) and is characterised by the matrix Π, consisting of the transition probabilities p_{ij} from state *i* to state *j*:

$$\Pi = \begin{bmatrix} p_{11}\ p_{21} \cdots p_{N1} \\ p_{12}\ p_{22} \cdots p_{N2} \\ . \quad . \quad \cdots \ . \\ p_{1N}\ p_{2N} \cdots p_{NN} \end{bmatrix} \tag{13}$$

$$p_{ij} = p(S_t = j \mid S_{t-1} = i, S_{t-2} = k, ...) = p(S_t = j \mid S_{t-1} = i)$$

$$\sum_{j=1}^{N} p_{ij} = 1; i = 1,2,3....N; 0 \leq p_{ij} \leq 1$$

For a two-regime state-space, transition probabilities can be expressed as follows:

$$\begin{aligned} p[S_t = 0 \mid S_{t-1} = 0] &= p \\ p[S_t = 1 \mid S_{t-1} = 0] &= 1 - p \\ p[S_t = 1 \mid S_{t-1} = 1] &= q \\ p[S_t = 0 \mid S_{t-1} = 1] &= 1 - q \end{aligned} \tag{14}$$

whereby the probability that the economy has been in regime 0 and will stay in the same regime is p; the probability that it was in regime 0, but it is now in regime 1 is 1-p, and so on. With these transition probabilities the regime switch is dependent only on the state before the switch, while the expected duration of each regime is constant (Misas and Ramirez, 2007; Kim *et al*. 2008). In other words, Hamilton's (1989) approach does not require any prior information to characterize the current state of the economic series (see also in Medeiros and Sobral, 2008; Moolman, 2004). Hence, the evolution of the regime switch occurs exogenously. However, this specification appears very restrictive in the description of regime-changes.

6.3. Endogeneity in a Markov-switching regression

As argued above, Hamilton's (1989) model is a univariate framework that assumes regime shift being exogenous to all realizations of the regression disturbance. Since Hamilton (1989), many applications used MS models that included additional explanatory variables (see Maddala and Kim, 1998, pp.463, for a review). In these, though: i) independent variables, as in every other form of regression, might be endogenous; and ii) the switch might evolve endogenously. However, neither source of endogeneity in the MS regression was resolved until Krolzig (1998) developed the MS methods in the area of vector auto-regressions (hereafter MS-VAR; see Krolzig, 1998; Krolzig and Toro, 1999). These are standard VAR models, whereby some or all of the parameters are allowed to switch when regime changes. In its most general form, the MS-VAR process has the following form:

$$y_t = \nu(S_t) + \sum_{i=1}^{p} A_i(S_t) y_{t-i} + \varepsilon_t; \tag{15}$$

where $y_t = (y_{1t}, ..., y_{nt})$ is an n-dimensional transposed vector, ν is the vector of intercepts, $A_1, ..., A_p$ are the matrices with the autoregressive parameters and ε_t is the white noise vector process

[4] Similarly, a stochastic process is said to be ergodic if no sample helps meaningfully to predict values that are very far away in time from that sample. Another way to say that is that the time path of the stochastic process is not sensitive to initial conditions.

($\varepsilon_t \mid S_t \approx NID(0, \Sigma(S_t))$) and all can be dependent on the switching variable S_t. Hence, MS-VARs appear in a variety of specifications, whereby different facets are allowed to be regime-dependent; Krolzig (1998) gives an overview, which is reproduced here, for convenience:

< insert Table 5 here >

Since MS-VARs represent a system of equations whereby each potentially endogenous variable is regressed on all other potentially endogenous and exogenous variable subject to switch, the first source of endogeneity in the MS regression is addressed. In turn, the switch, the second aspect of endogeneity in an MS regression, could be endogenous to one or more of:

i) Observed variables, like inflation or exchange rate;

ii) Unobserved variables, like macroeconomic shocks to the VAR that correlate to the monetary regime in operation (Kim *et al*. 2008); and

iii) Duration of the regime in operation (Durland and McCurdy, 1994).

By allowing the potential determinants of the switch to interact in a dynamic framework, the issue discussed in Section 3.2, of endogeneity arising from the selection of observables is addressed. However, given that transition probabilities are constant, one still might be concerned about switch endogeneity stemming from unobservables. The literature approached to this issue in a similar fashion as in the SR approach: transition probabilities can be allowed to change, depending on the value of a variable that does not enter the system, but might be correlated with the latent switch. Filardo (1994) and Diebold *et al.* (1999) argue that an MS model whereby economic fundamentals are allowed to affect transition probabilities can recognize systematic changes in them before and after switching; capture more complex temporal persistence and allow expected duration to vary across time. Hence, allowing for time-varying transition probability (TVTP) will capture some of the remaining endogeneity, if any, from the switching variable. Unfortunately, at present: i) the MSVAR package does not allow for TVTP; and ii) MS-VARs with TVTP do not allow duration-dependence, which suggests that being able to account for all potential source of endogeneity in a single MS model awaits further theoretical advance(s). Given this, the possible presence of remaining switch endogeneity could be checked only indirectly, by observing if transition probabilities change when MS-VAR specification changes. Namely, Vázquez (2008) argues that there would be a cause for concern if estimated probabilities differ under alternative MS-VAR specifications - that is, the switching variable would be exhibiting endogeneity stemming from unobservables if the smoothed probabilities depended on the MS-VAR specification.

We need guidance on how large the bias can be if endogeneity remains in the switching variable. Kim *et al.* (2008) performed a Monte Carlo analysis to check for the bias. Their results suggest that there is a bias in the estimated coefficients under the first regime and in the obtained regimes' volatility, but that the bias is lower for larger transition probabilities and for lower correlation of the switching variable with the economic fundamentals. For illustration, we specifically refer here to Kim *et al.*'s (2008) results related to the characteristics of our case – T=200 and high persistence, p_{11}=0.9 and p_{22}=0.9. First, they obtained that allowing for TVTP when the true switching is exogenous does not yield any efficiency gain. When the true switching process is endogenous, though, the estimated coefficients in the first regime are found to be upwardly biased by 6% to 11% for the case when the correlation between the switch and the economic fundamentals is moderate, 0.5; and by 10% to 20% for the case when the correlation is high, 0.9. Estimated coefficients in the second regime are found to be unbiased. Regimes' volatilities are found to be downward biased by 3% (for moderate correlation, 0.5) and by 6% (for high correlation, 0.9).

In the empirical comparisons, these findings were roughly confirmed. Some are given here for illustration. In Turner *et al.*'s (1989) model of equity returns, volatilities' bias was found between 0% and 1.4%, but the largest bias was documented for the coefficient measuring the volatility feedback - one third smaller when endogeneity is allowed than when it is ignored. Correlation was estimated to be modest, -0.4, but different from zero only at the 10% level. Misas and Ramirez (2007) estimated a MS regression for economic growth in Colombia. Under a very high correlation of 0.98, the bias found for volatilities was again very low and ranged from 1.5% to 3.3%, but the bias for the means increased from 0.7% up to one fifth of the value when endogeneity was accounted for. However, no evidence was provided if these means were statistically different from zero or comparatives for the estimated coefficients. Cerra and Saxena (2000) evaluated the relative merits of fundamentals versus contagion in determining financial crisis in Indonesia in the late 1990s, via MS methods. They obtained a bias of 15.3% for the mean; 2.4% for the variance; and 24% for the only significant coefficient. Chen (2006) used an MS specification of the nominal exchange rate to investigate its nexus with the interest rate for six developing countries. The bias ranged from 2.7 to 8.3% for the means and from 0.5% to 12.6% for variances (although statistically insignificant). However, this paper also does not provide evidence on whether TVTP models are preferred (i.e. if the correlation mentioned above is different from zero). Overall, identified biases in the empirical investigations are in line with Kim *et al.*'s (2008) Monte Carlo simulation and, although not negligible, they are argued not to be of such a magnitude as to affect the qualitative interpretation of results or any corresponding policy implications.

In relation to the possibility that a regime's duration can itself inflict a switch and hence be a source of endogeneity, it was argued in Petreski (2008) that longer pegs could be detrimental to output volatility, especially in times of large shocks. In Petreski (2010), some evidence was provided suggesting that pegs longer than five years transmit real shocks larger than 11% onto output volatility and can lead to crisis and, thus, to a peg exit. Hence, the exit of a peg might be duration-dependent, i.e. it is reasonably to believe that the probability of peg exit is not the same at the very beginning of the phase as after several years. However, no such argumentation, practical or quantitative evidence exists for IT, at least not yet. Given this, the switch to a new monetary strategy might evolve endogenously because of duration.

Krolzig's models cannot possibly capture this source of endogeneity. In order to face this limitation, Durland and McCurdy (1994) introduced the duration-dependent MS autoregression, designing an alternative filter for the latent switching variable. Pelagatti (2003; 2008) generalized the model in a multivariate framework – the duration-dependent MS-VAR (DD-MS-VAR). He applied his model to the US business cycle (Pelagatti, 2002; 2008) and found it being sufficiently capable of discerning recession and expansions. Pelagatti's (2003) model has the usual MSM-VAR specification (see Table 5), whereby in order the switch variable S_t to become duration dependence, a Markov chain is built for the pair $(S_t; D_t)$, D_t being regime duration, defined as follows:

$$D_t = \begin{cases} D_{t-1} + 1 & \text{if } S_t = S_{t-1} \\ 1 & \text{if } S_t \neq S_{t-1} \end{cases} \qquad (16)$$

A maximum value for the duration variable D_t must be fixed so that the Markov chain $(S_t; D_t)$ is defined in a finite state space. Then, a transition matrix of the Markov chain S_t is defined; given that it is rather sparse, a more parsimonious probit specification of S_t is used. Pelagatti's contribution consists in the introduction of the multi-move Gibbs sampler to estimate the model. However, given that we use Pelagatti's model only at the margin in this exposition, for a more technical exposition we refer to Pelagatti (2003). Moreover, the DD-MS-VAR has the shortcoming that only the mean can switch between two regimes; however, with these attributes, it has been sufficient to analyse business cycles (Durland and McCurdy, 1994; Lam, 2004); here, it will be used only as an additional indirect vehicle to check for remaining endogeneity in the switching variable due to duration.

Designed in this manner, the MS-VAR approach includes all the 'time-series' features of the switching regression (Section 3) and is designed to overcome the indentified drawbacks (Section 5.2). Although powerful, Krolzig's MS-VAR suffers some potential shortcomings, though. First, a great disadvantage of it, at present, seems to be the apparently non-comprehensive approach to dealing switch endogeneity. By allowing a multivariate framework and, thus, by allowing potential determinants of the switch to enter the MS regression, MS-VAR can address one part of switch endogeneity – coming from observables. However, the potential endogeneity stemming from unobservables or from regime duration is not directly addressed at present. Vázquez (2008) and Pelagatti (2003) offered indirect ways to check for these, although Pelagatti's model has its own shortcomings. Secondly, many variables (and many lags) cannot be included in the MS-VAR, because computation becomes cumbersome and frequently the system does not converge. A not-so-recent literature (Asea, 1996; Asea and Bloomberg, 1998) proposed a Markov-switching panel (MSP) model. Yet, since that time, this type of MS model has not evoked much interest nor has it been further advanced. Because of this, the current stage of MSP undergoes, at least, two main shortcomings: i) it potentially suffers from not addressing the possible cross-sectional dependence among units, which is a considerably debated issue in recent years in a panel context; and ii) it does not advance the issue for the switch being endogenous more than MS-VAR nor does it allow for endogenous regressors. These considerations render estimation of MSP inappropriate for our case. Finally, as compared to the SR approach, the MS-VAR has the disadvantage that results have only time comparability and not group comparability, which was apparently an advantage of the former.

6.4. Solving algorithm

To solve an MS-VAR model, an algorithm consisting of two steps is used: expectation and maximization. The expectation-maximization (EM) algorithm (Dempster *et al.* 1977) is an efficient iterative procedure to compute the Maximum Likelihood (ML) estimate of model parameters in the presence of an unobserved latent variable. In ML estimation, we wish to estimate the model parameter(s) for which the observed data are the most likely. Each iteration of the EM algorithm consists of two processes: The E-step, and the M-step. In the E-step, the latent variable is estimated given the observed variables and the current estimate of the model parameters. This is achieved using the expectation, conditional on the entire sample of observations. In the M-step, the likelihood function is maximized under the assumption that the latent variable is known. The estimate of the latent variable from the E-step is used in place of the actual latent variable. These parameter-estimates are then used to determine the distribution of the latent variables in the next E-step. Convergence is assured since the algorithm is guaranteed to increase the likelihood at each iteration.[5]

7. Empirical results and discussion II

7.1. Basic findings

In order to proceed with estimating an MS-VAR model, our economic model (1) needs to be defined in a reduced vector-autoregressive form, as follows:

$$y_t = \nu(S_t) + \sum_{i=1}^{p} A_i(S_t) y_{t-i} + \sum_{i=0}^{p} B_i(S_t) x_{t-i} + \varepsilon_t; \qquad (17)$$

where y_t is our four-dimensional vector comprised of: nominal interest rate, r_t; inflation, π_t; output gap, gap_t; and changes of the nominal exchange rate, Δer_t; x_t is a vector of exogenous variables which could enter contemporaneously or with a lag, but is not mandatory; ν is the vector of intercepts, $A_1,....,A_p$ and $B_0,....,B_p$ are the matrices containing the autoregressive parameters and ε_t is the white noise vector process ($\varepsilon_t \mid S_t \approx NID(0, \Sigma(S_t))$). The same data for switchers as before are used, described in Appendix B. Estimations were performed with MS-VAR in OxMetrics, which utilizes the EM algorithm, following the guidelines of Krolzig (1998) and others. The model is set as MSIAH(2)-VAR(p), allowing the intercept, autoregressive terms and the variance to switch between two regimes. Based on the statistical properties of the identified regimes, we will argue later if these can be reconciled with the switch to IT. No exogenous regressors are included in the basic specification. Intercept and regressors were allowed to switch within the SR approach, but additionally, by allowing the overall variance of the vectors to change here and be part of the regime switching identification, we may check if the monetary environment changed between the two regimes (i.e. address what was identified as a drawback in SR). *p* denotes the number of lags, which is chosen by appeal to the Schwarz information criterion (SIC), after serial correlation has been eliminated. Some authors (for instance, Clarida *et al.* 2000; Rudebusch, 2002) suggest and estimate empirical Taylor-rule versions which are based on lagged variables only, which is the case with any VAR framework, including MS-VAR.

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5 A technical exposition on the EM algorithm is given in Borman (2009).

The results for each country are reported in Table 6; only the vector for the interest rate is reported because it is here representing our economic model (1). We note the linearity test, given in the last row in Table 6. This test is based on the likelihood-ratio statistic between the estimated model and the derived linear model and under the null hypothesis the linear model is preferred (Doornik and Hendry, 2009). The first p-value is based on the conventional Chi-squared distribution, while the second is derived by Davies (1987). In all cases, the linearity test suggests that the model is significantly non-linear and that parameters switch between regimes. The remaining diagnostics is available only through visual checks which are available on request. These suggest that the errors can be considered normally and independently distributed, while the model is stable. All the remaining vectors are similarly well specified; they are also available on request.

< insert Table 6 here >

After checking diagnostics, attention is focussed on four aspects in explicating the results in Table 6: i) persistence of the system in each regime; ii) volatility of innovations in each regime; iii) estimates of the model in each regime; and iv) the date of switching inferred from the data. Note that since we have not yet related the identified regimes to ERT or IT, the reporting in Table 6 and the explication henceforth is set so that regime 1 corresponds to the earlier regime in time and regime 2 to the later one.

Transition probabilities p_{11} and p_{22} are given in a lower panel of Table 6; they refer to the probability that the regime which was prevailing in the previous period will continue to operate in the current period and, in that way, are an indication of regime persistence. Reported transition probabilities suggest that regimes are highly persistent, i.e. there are no "short" and frequent switches between regimes. Brazil and Hungary might be considered as slight exceptions, since regime 1 is not as persistent as regime 2. This point is returned to. Standard error of the interest-rate equation in each regime, approximating its volatility, is reported within each regime's panel in Table 6. The volatility of innovations is much higher in regime 1 than in regime 2. Therefore, regime 2 can be identified as the regime with lower volatility when compared to regime 1.

Estimated coefficients are given in the panels headed 'Regime 1' and 'Regime 2' in Table 6. Whenever more than one lag was used, the sum of the lags for each variable is reported, along with the Wald test of their joint significance. Results suggest that the coefficient associated with the lagged interest rate generally ranges above 0.9 in the regime 2, suggesting a high degree of interest-rate smoothing. Contrary to our thought that smoothing might not be regime-dependent, here we observe considerably smaller estimated smoothing parameters of about 0.6 to 0.7 in regime 1.

The estimated coefficients suggest that central banks responded significantly to inflation in regime 2 (asterisks indicating significance are largely present in the regime-2 panel of Table 6), while the response in regime 1 remains generally insignificant. In regime 2, the central-bank response to inflation-change of 1 p.p. ranges from very mild in Israel (0.004 p.p) to considerable in Columbia (0.26 p.p), with the median being a 0.03 p.p increase of the interest rate (in Chile). Still, if coefficients between the two regimes are compared, we observe that the reaction to inflation in regime 2 has moderated.

The output gap effect in both regimes is significant in half of the countries and frequently only at the 10% level. Estimated responses suggest that the policy reaction to output fluctuations in regime 2 has moderated as well. Moreover, when compared to the response to inflation, the response to the output gap in regime 2 is found to be even milder, ranging from 0.002 p.p in Philippines to 0.03 p.p in Brazil, with the median being 0.007 p.p in Israel. But, can this be interpreted as evidence that these central banks were less concerned with the level of economic activity than with inflation? The answer is no, because of Svensson's (1997) argument that the size of the estimated coefficient on the output gap does not necessarily reflect the importance of that variable in the central-bank loss function, but that the weight and the coefficient are related in a non-linear fashion. The objective here is not to find out the weight, because the obtained information that the central bank started to take into consideration, albeit partially, the movements in the real economy, besides inflation, is sufficient for our purpose.

At last, responses to the exchange-rate movements are largely insignificant under both regimes. To check for the earlier concern that this might be due to the fact that pressures on the foreign-exchange market do not fully reflect onto the nominal rate, which, at least in regime 1 was pegged, a robustness analysis with reserves is carried out in Section 7.2.

Given the above discussion, it is argued that regime 1 could be reconciled with ERT and regime 2 with IT, because of, at least, six reasons:

1) Volatility of regime 2 is considerably lower than volatility of regime 1 (reported in each regime's panel in Table 6). Stevens and Debelle (1995) argue that IT is designed to allow moving not only along the (inflation-output volatility) trade-off curve, but also to the left on a new lower-volatility curve. Also, by allowing for a discretion constrained by a pre-set inflation target and a horizon to achieve it, the central bank is able to manage a multitude of objectives (nominal and real), which potentially gives the lowest possible macroeconomic volatility;

2) The persistence of both regimes is high in almost all cases (reported transition probabilities in the lower panel of Table 6), which suggests long-lasting and continuous regimes, not regimes which appear sporadically and with frequent interchanges;

3) The macroeconomic variables are considerably more often statistically significant in regime 2, compared to in regime 1. This is as expected given the substance of the two regimes: under ERT, monetary policy is largely dependent on the monetary policy in the anchoring economy, i.e. the space for monetary policy aimed at domestic goals is restricted (and hence, the estimated effects of variables such as inflation and output gap are statistically insignificant); on the other hand, IT is a "constrained-discretion" strategy, whereby the policy can be geared toward achieving domestic objectives, *per se* (and hence, variables such as inflation and output gap are statistically significant);

4) The significance and magnitude of the coefficient on inflation in regime 2 suggests that these countries embarked on a policy geared toward strict IT, whereby large weight is put on inflation. This is expected, given that in the early phases of IT in developing countries, credibility needs to be acquired through tight observation of inflation;

5) The sporadically-appearing significance and magnitude of the coefficient on economic activity might still suggest that although these economies geared policy towards strict IT, still they avoided being 'inflation nutters' that much and did to some extent consider short-run output movements, which is an attribute of the IT design;

6) The date of the switch inferred from the data is close to the official date of switch. The inferred timing of each regime and, hence, the inferred switch date, is given last in each regime's panel in Table 6. Given the argument about the potential endogeneity of the switch, we expected that the real switch, if can be inferred from the data, will fall around the official switch (i.e. can be just equal to the official switch only by chance). More thorough discussion on the switch date follows.

In all cases except Hungary, the inferred switch is close to the official switch to IT. In Brazil, Philippines and Thailand, it is found to precede the official switch, while in all remaining countries it followed the official switch. The distance between the official and the inferred switch ranges from as small as in Colombia and Poland (7 months) to as large as in Philippines (30 months). These findings suggest that Brazil, Philippines and Thailand embarked on a regime geared toward IT (i.e. started to target inflation forecast) before they officially announced IT, while all the others officially embarked on the new regime (as a firm way to anchor inflation expectations), but most likely continued to closely target the exchange rate for some time after the official switch. In order to pursue these suggestions, in the robustness checks a three-regime specification is estimated, in order to check whether some intermediate regime (between ERT and IT) governed monetary policy (which could be either a mix of both or an arrangement undertaken to constrain the excessive exchange-rate volatility that emerged in some of the countries, like the Czech Republic, Poland or Thailand). Hungary is probably an exception in these considerations, since the inferred switch to regime 2 is too early before the official switch to IT, but regime 1 appears rather sporadically, hence rendering the conclusion that regime 2 is IT invalid. The reason might be that Hungary as of 2001 announced both targets for inflation and the exchange rate, which is not picked up as a regime switch, but suggests that Hungary continued with a strategy geared toward ERT.

The conclusion from the above investigation is that IT represented a real switch in the investigated countries. Results suggest that monetary policy has undergone a significant change in the 2000s. The results oppose the usual statement in the literature that central banks under IT react strongly to inflation deviations from the target - compared to the period before, these reactions moderate under IT. On the other hand, the statistical significance for the effects of the output gap was found fragile, while the exchange-rate effects were found to be insignificant. The significance of the results in the regime-2 panel in Table 6, might suggest that the switch could be more thought of as a switch toward more independent monetary policy, which afforded a space to account for domestic objectives. Also, regime volatility was found lower under IT when compared to ERT, while the inferred regimes' timing can be reconciled with the switch to IT.

What could be considered as a possible critique of these conclusions? Certainly, the most striking one is that the data might be indicating a switch that is not a result of the IT strategy but, rather, of something else. For instance, the Czech Republic and Poland exhibited a transition period during regime 1, while the 2000s was a decade oriented toward economic growth. But, this is not the case in Hungary which belongs to the same group of countries, geographically and in terms of economic developments. Secondly, Thailand and Brazil exhibited financial crises during regime 1 and subsequently have had a more stable period. Yet, as we argued earlier, a financial crisis can force the country to rethink its monetary regime. Thirdly, these nine countries originate from distinct geographic regions, so the possibility that common regional shocks and potentially strong financial ties drive results is excluded.[6] However, for strengthening confidence in the results, some robustness checks are performed in Section 7.2 and some checks for endogeneity in Section 7.3.

7.2. Robustness checks

Two types of robustness analysis are performed in this section: i) allowing for three regimes, instead of two, to check if an intermediate regime between ERT and IT might have existed; and ii) adding some exogenous variables. Table 7 gives the transition probabilities and volatilities for the three regimes: the timing in the table is set regime 1 to correspond to the potential period of ERT; regime 2 to correspond to the potential period of IT; and regime 3 to stand for any other regime. Regimes' 1 and 2 persistence and timing can be reconciled with ERT and IT, respectively; also the standard errors within those regimes are similar to those in Table 6. In Brazil and Chile, regime 3 picks up some developments in the early 1990s but these cannot be attributed to any intermediate regime. In Hungary and Philippines, regime 3 appears only sporadically (has a low probability) and has probably no economic meaning; moreover, in Hungary even regime 1 has a relatively low probability, as found before (see Table 6). In Israel, regime 3 relates to the period of the mortgage crisis. However, in Colombia, the Czech Republic, Poland and Thailand, regime 3 picks up some developments between ERT and IT (bold-typed in Table 7). This can be reconciled with the evidence: all these countries embarked on IT in the aftermath of exchange-rate turbulence, so that some of them observed money target for a short period after peg exit and then started to target inflation, but this was a kind of "soft landing". Still, regime 3 is not so different from regime 2 (IT) in Colombia and the Czech Republic in terms of variance, whereas in Poland and Thailand it undeniably picks up a more turbulent period than the subsequent IT period; additionally, this intermediate regime in Poland is spread over longer period of time.

[6] Still, since this is a time-series analysis, we are limited in our ability to control for global effects (treatment-group versus control-group analysis), i.e. for trends affecting all countries at the same time. Although uncommon in the MS analysis, we still performed MS-VARs for our non-switchers (refer to Section 2): Argentina, China, Lithuania, Latvia and Macedonia. Due to the length of some of the included series - for Bulgaria, Estonia, Ecuador, El Salvador and Uruguay - these calculations were not performed for these countries. Due to space, the results are available only on request. They suggest that, in general, it cannot be established that monetary policy has been governed on a systematic basis by more than one regime over the observed period. Namely, the identified second regime, cannot be reconciled with the period of after-2000, but to other short-term 'local' events that implied different behaviour of the monetary policy; the most likely being: the currency-board crisis of 2001 in Argentina; wider exchange-rate bands (1994-1996; and possibly the wage reform in this period) in China; the easing of Latvian monetary policy in 2000-2001 and the 2008-crisis pressures on the currency board; and the easing of the Macedonian monetary policy in 2005 after the long-lasting stabilization, firstly due to the transition, then due to the internal conflict and so on.

< insert Table 7 here >

The robustness of our results is finally tested by adding some exogenous variables. Given our discussion in Section 2, reserves growth and NFA-to-GDP are added as exogenous covariates allowed to switch. The underlying specification is again MSIAH(2)-VAR(p), whereby *p* is chosen according to the Schwarz criterion after any serial correlation is eliminated. Results are given in Table 8. A similar pattern is observed as before: significant variables are largely concentrated in the second panel, i.e. inflation and output become more significant under regime 2. The exchange-rate is rarely significant. Also, the coefficients largely retain the same magnitudes. Persistence is nearly the same as before; implied volatilities under both regimes are similar; and the inferred switching times are similar to those considered in Table 6[7]. Overall, the estimates are robust to the alternative specifications.

< insert Table 8 here >

Surprisingly, reserves are generally insignificant under regime 1 (this regime being associated to ERT), albeit their magnitude and sign are as expected. However, the magnitude disappears under regime 2, while they remain insignificant. Consequently, although we believed that reserves should be more important under regime 1, we do not find strong support for this. Moreover, as expected, they are insignificant under regime 2, as is the exchange rate, suggesting that in these economies the exchange rate plays a marginal role. The level of euroization is found not to be a systematically significant influence: in some countries it matters, but in others it does not. Moreover, the sign in Brazil and Chile is not as expected. In general, the limited evidence might give support to the idea that higher exposure of bank net-assets to exchange-rate risk precludes the central bank lowering the interest rate (i.e. restricts the monetary-policy manoeuvre space), but it is very feeble.

7.3. Checks for remaining endogeneity

Given our discussion on the endogeneity of the regime switch in Section 6.3, the main shortcoming of the MS analysis seems to be the approach towards addressing this issue. Hence, although the MS analysis does address some of the shortcoming of the SR analysis pointed out in Section 5.2, this is done at the cost of introducing a possible problem of not entirely addressing potential switch endogeneity. We argued that by introducing into the empirical specification the observable variables that affect switch endogeneity, one part of it is addressed. There are intuitive grounds to believe that switch endogeneity is largely governed by the behaviour of the covariates that enter the regression: countries might be forced to switch if inflation and its volatility are threatening; if the output is volatile under a peg when a large shock hits; and if the exchange-rate peg is under constant pressure, so that reserves are leaking and threaten a peg demise. However, to be on the safe side, we need to be assured that no remaining endogeneity is left in the model, stemming from: i) unobservables; and ii) regime being duration-dependent. Unfortunately, these checks can be performed only indirectly and with considerable limitations, as is pointed out next. However, so far, the literature on MS models has not offered a complete and direct way to address entire potential endogeneity of the switch. Still, there are approaches that can help in building intuition about the problem explored.

Firstly, we rely on Vázquez's (2008) argument that if any endogeneity is left in the latent switching variable (due to unobservables, say), it will be reflected in different transition probabilities under different MS-VAR specifications (recall Table 5). Regime persistence under alternative MS-VAR specifications is checked in Table 9. The first panel is a reproduction of the persistence of Table 6, while the remaining three specify the MS-VAR forms MSI, MSIH and MSAH. All probabilities remain roughly the same which, given the argument of Vázquez (2008), do not suggest that endogeneity remains in the switching variable and that it has, instead, been picked up by the covariates. The exception is, as

[7] Hungary behaves slightly differently in this robustness checking, although the conclusion is largely the same. Here, the technique infers existence of two regimes (i.e. the regime that previously appeared only sporadically, now gains in persistence) and the timing of the switch comes closer to the official switch to IT. However, the two identified regimes are similar in their volatility, while in regime 2, inflation is only significant at the 10% level; the output gap is not significant, while the exchange rate is highly significant. This might suggest that the distinction in Hungary between the ERT and the consequent IT is hard to make, given the preserved exchange-rate target.

expected, Hungary, whereby we were not able to reconcile regime switch with IT introduction and this is further reflected here – smoothed probabilities considerably differ between specifications. Although the argument of Vázquez (2008) can be justified in a manner that if the switch still evolves endogenously, then regimes' persistence might change depending on the different characteristics of the regression allowed to change. However, this is only a rough interpretation and should be approached with caution.

< insert Table 9 here >

Duration-dependent MS-VAR (DD-MS-VAR) is compared to conventional MS-VAR in Table 10. Pelagatti's (2003; 2008) DD-MS-VAR software for OxMetrics is used. As mentioned earlier, under DD-MS-VAR, only the mean can switch between regimes. From that viewpoint, this application cannot be comparable to our earlier MS-VAR specifications nor fits our argument, since it assumes that policy responses and volatilities are equal under both regimes – the latter differ only with respect to the interest-rate mean. Given that this is rather restrictive, the results need to be interpreted with caution. However, they are helpful for providing further intuition related to switch endogeneity. Given all this, Table 10 is drafted differently from the previous tables. In the entire tabling, regime 1 is set to associate to ERT and regime 2 to IT. In the upper panel, results of the conventional MSM-VAR are presented (only mean switches – this is needed for comparability). This panel reports the same statistical properties as before (as in Table 6). In the lower panel, results of the DD-MS-VAR are reported. Lag length is only based on the autocorrelation function (ACF), as other criteria were not available. Towards the bottom of the panel, transition probabilities are reported; note that these probabilities have a different interpretation from the reported probabilities in the upper panel. While in the upper panel (MSM-VAR), probabilities indicate regime persistence, in the lower panel (DD-MS-VAR), these represent the probability that a switch to the other regime will occur, given its duration. Maximal duration is set at 10 years (approximating the average duration of the regimes in our sample), but transition probabilities are available on request for any duration up to the maximum.

< insert Table 10 here >

The estimated coefficients do not suggest that there is remaining endogeneity in the switching variable, which suggests that the covariates that entered the regression accounted for the entire endogeneity in the switching variable. Once we pass from MSM-VAR to DD-MS-VAR, the coefficients largely retain their magnitudes and levels of statistical significance. Some differences are observed in the means between the two specifications; but, in both cases, these suggest that interest rates were higher under regime 2 (the one associated to IT). Interesting insights are obtained from the transition probabilities (p_{12} and p_{21} at the very bottom of the table). The transition probability that a switch from ERT to IT will occur (p_{12}) suggests a very high probability that, at long durations, ERT will switch to IT. This is in line with the findings in Petreski (2010) that long pegs are prone to crises and exit under hard attacks. Conversely, the transition probability that a switch from IT to ERT will occur (p_{21}) ranges from 0% to 15%[8] and, as expected, suggests that even after very long duration, IT will not switch back to ERT. This is in line with the argument in Svensson (1998; 2000) and Debelle (1999) and could be ascribed to IT flexibility. However, the overall stability of the obtained results compared to those when duration dependence is not considered, suggest that duration dependence is not an important factor for the switch to evolve endogenously.

8. Conclusion

The objective of the paper was to empirically examine and analyse if the conduct of monetary policy has significantly changed with the switch from exchange-rate to inflation targeting in developing countries. Put differently, we investigated if the switch from ERT to IT represented a real switch. It was argued that the literature examining the issue for developing countries is basically descriptive. On the other hand, the available literature for the advanced economies usually suffers the identification-strategy problem, the problem of the switch being pre-determined and largely ignores the possibility that switchers were self-selected into IT, i.e. the switch emerged endogenously. To begin addressing these

[8] The exception being, again, Hungary, whereby the distinction between the two regimes is negligible, which is reflected further in the p_{12} and p_{21} probabilities.

questions, a treatment group was constructed of all developing-economy switchers from ERT to IT and a control group of comparable countries that, in the same period, continued to target the exchange rate. The economic model used is a fairly classical Taylor rule, augmented with the exchange rate, to capture its specific role for developing countries, as small, open economies. The referent period is 1991:1-2009:12.

Firstly, a panel switching regression was designed whereby the switch is observable; all covariates in the regression were allowed to switch. By including variables in the regression that potentially affected the decision to switch, one source of possible endogeneity of the switching variable was addressed. Moreover, to overcome the potential endogeneity of the switching variable stemming from unobservables, it was instrumented with variables that might have had an influence on the decision to switch, but not directly on the monetary-policy conduct. The policy-reaction coefficients suggest that switchers, after countries in the sample switched to IT, were able to moderate their reactions to macroeconomic developments, against the background of higher interest rates – ceteris paribus – for the switchers. Under IT, these countries became more concerned with combating inflation, but their reaction moderated compared to the period before and to the control group, because of the background of a more cautious monetary policy. Still, the price they paid for this is the higher level of interest rates. Coefficients on the output gap and the change in the exchange rate were found neither significant nor systematically different from the period before and the control group. This suggests that these countries were concerned with inflation only and not with the output gap and exchange rate, i.e. that they ran a monetary policy geared towards strict IT. Though, in some specifications, the output gap turned marginally significant, while the coefficient suggested moderation of central-bank reaction to real fluctuations as well. However, this modelling approach could not reveal whether the overall variability and uncertainty in the economy changed with the switch to IT. Moreover, it was argued that although countries have a date where they officially switched to IT, this does not have to be necessarily reconciled with the moment of the real switch. Hence, the real switch might be obscured.

To overcome the potential drawbacks of the switching regression, another modelling approach was employed, whereby regime switching is an outcome of an unobservable random variable – the Markov-switching regression. Our economic model was utilized in a reduced-form VAR format for each of our nine switcher countries. Intercept, autoregressive terms and variance were allowed to switch between regimes. By employing a special form of VAR, the potential endogeneity of the switch stemming from observables was addressed, but we were able to check for any remaining endogeneity only indirectly. Hence, although the MS approach addressed some of the SR's drawbacks, it potentially performed this at the cost of dealing with switch endogeneity only partially. However, regime persistence was found to be stable under alternative MS specifications, which might lend support to the idea that the only switch endogeneity was the one stemming from observables. Moreover, estimated parameters were found to be stable when transition probabilities were allowed to depend on regime duration, which is an additional if still indirect confirmation that switch endogeneity might have stemmed only from observables. In general, it was found that the inferred regimes are highly persistent; i.e. there are no "short" and frequent switches between regimes. Further, the volatility of innovations is found to be much higher in regime 1 than in regime 2. The estimation results suggest that central banks responded significantly to inflation in regime 2, while in regime 1, the response is found to be very feeble or insignificant. The estimated effect of the output gap was found to be sporadically significant but only at the 10% level. The exchange rate did not reveal any significance effects either in regime 1 or in regime 2. Finally, it was found that in all cases except Hungary, the inferred switch date is close to the official switch date. These characteristics of the inferred regimes lead to the conclusion that regime 1 can be robustly reconciled with ERT and regime 2 with IT. The estimated coefficients suggest that central-bank responses moderated under IT, while the response to a change in economic activity is found to be even milder, but with limited significance.

To what extent are the conclusions from the two techniques reconcilable? The two techniques are distinct in their nature: the first is a panel technique (hence results have time and cross-section comparability) and observes the official switch; while the second is a time-series technique (hence results have time comparability only) and infers the switch from the data. As such, the obtained estimates are not directly comparable. However, they can be compared in a qualitative fashion. Firstly, both methodological approaches lead to the conclusion that there has been a statistically significant shift towards different design of monetary-policy conduct, which could be attributed to inflation targeting.

Overall, this conclusion from both approaches runs counter to the idea that monetary policy has not undergone any change in the 2000s. Estimates from both methods suggest that the switch to a new monetary regime explains these results. Also, the results challenge the usual statement in the literature that central banks under IT react strongly to inflation deviations from the target; compared to the period before and to the control group, these reactions moderate under IT. Secondly, both conclude that the period under IT was characterized by (more) independent monetary policy, with focus on inflation, which could be attributed to inflation targeting. Thirdly, the SR approach found that the policy response to the short-run output movements is significant in some specifications but far from being robust, while the MS approach found significance for some of the countries – this could be attributed to inflation targeting. Fourthly, both approaches found no significant role for the exchange rate in the IT period. In addition to this, the MS method concluded that the second regime, which could be reconciled with IT, produced generally lower macroeconomic volatility; and that the probability of a peg exit increases with the peg's duration, which is not the case with IT.

Both approaches lead to the conclusion that IT represented a real switch in developing countries and that the period of IT was characterized by a more stable economic environment, by more independent monetary-policy conduct, by strict focus on inflation and, possibly, by non-robust consideration of the short-run real objectives of the economy.

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APPENDICES

APPENDIX A – Tables

Table 1. Fully-fledged inflation targeters and switch

Country	IT introduced	Inflation rate at the beginning of IT	Inflation target / band	Prior announced monetary regime (from which the switch has been made)	DE-FACTO (RR classification)			DE-JURE (IMF classification)		
					De-facto ERR before	Duration of ERR	De-facto ERR after	De jure ERR before	Duration of ERR	De-jure ERR after
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1. New Zealand	1989M12	3.3	1–3	Implicit nominal anchor	Managed floating	5 yrs	Managed floating	Free floating	6 years	Free floating
2. Canada	1991M2	6.9	1–3	Implicit nominal anchor	Limited flexible	20 yrs	Lim-flexible and flexible (2002)	Free floating	very long	Free floating
3. UK	1992M10	4.0	2	ERM I	Fixed	Less than 2 years (ERM I)	Managed floating	Free floating	20 years	Free floating
4. Sweden	1993M1	1.8	2 (±1)	ERM I	Limited flexible	15 years	Managed floating	Fixed	16 years	Managed fl. and free fl.
5. Finland[1]	1993M1	2.6		ERM I	Limited flexible	21 years	Fixed	Fixed	22 years	Free floating
6. Australia	1993M6	2.0	2–3	Implicit nominal anchor	Free float	9 years	Free float	Free floating	9 years	Free float
7. Spain[1]	1995M1	4.2		ERM I	Fixed	2 years	Fixed	Limited flexible	6 years	Limited flexible
8. Israel	1997M6	8.1	1–3	Exchange-rate targeting	Managed floating	6 years	Managed floating	Managed floating	6 years	Managed floating
9. Czech Rep.	1997M12	6.8	3 (±1)	Exchange-rate targeting	Limited flexible	6 years	Managed fl. and lim-flexible (2002)	Fixed	6 years	Managed floating
10. Poland	1998M1	10.6	2.5 (±1)	Exchange-rate targeting	Managed floating	6 years	Managed floating	Managed floating	8 years	Free floating
11. South Korea	1998M4	2.8	3(±1)	Monetary targeting	Limited flexible	18 years	Managed floating	Managed floating	17 years	Free floating
12. Brazil	1999M6	3.3	4.5 (±2)	Exchange-rate targeting	Limited flexible	6 years	Managed floating	Managed floating	5 years	Free floating
13. Chile	1999M9	3.2	2–4	Exchange-rate targeting	Managed floating	7 years	Managed floating	Managed floating	18 years	Free floating
14. Colombia	1999M10	9.3	2-4	Exchange-rate targeting	Managed floating	16 years	Managed floating	Managed floating	20 years	Free floating
15. South Africa	2000M2	2.6	3–6	Monetary targeting	Free floating	5 years	Free floating	Free floating	17 years	Free floating
16. Thailand	2000M5	0.8	0–3.5	Exchange-rate targeting	Fixed	24 years	Managed floating	Fixed (1997) Free float (2000)	27 years	Managed floating
17. Mexico	2001M1	9.0	3 (±1)	Monetary targeting	Managed floating	5 years	Managed floating	Free floating	6 years	Free floating
18. Norway	2001M3	3.6	2.5	Implicit nominal anchor	Managed floating	55 years	Managed floating	Managed floating	6 years	Free floating
19. Iceland	2001M3	4.1	2.5	Implicit nominal anchor	Limited flexible	14 years	Managed floating	Managed floating	4 years	Free floating
20. Hungary	2001M6	10.8	3.5 (±1)	Exchange-rate targeting	Limited flexible	7 years	Limited flexible	Managed floating	5 years	Fixed
21. Peru	2002M1	-0.1	2.5 (±1)	Monetary targeting	Limited flexible	8 years	Limited flexible	Free floating	12 years	Limited flexible
22. Philippines	2002M1	4.5	4-5	Exchange-rate targeting	Limited flexible	5 years	Limited flexible	Free floating	13 years	Free floating
23. Slovak Rep.[1]	2005M1	5.8	6 (±1)	Exchange-rate targeting	Limited flexible	6 years	Limited flexible	Fixed	2 years	Managed floating
24. Guatemala	2005M1	9.2	5.5 (±1)	Monetary targeting	Limited flexible	14 years	Limited flexible	Free floating	16 years	Managed floating
25. Indonesia	2005M7	7.4	5.5 (±1)	Monetary targeting	Managed floating	6 years	Managed floating	Managed floating	4 years	Managed floating
26. Romania	2005M8	9.3	4 (±1)	Monetary targeting	Managed floating	5 years	Managed floating	Limited flexible	3 years	Managed floating
27. Turkey	2006M1	7.7	4(±2)	Monetary targeting	Free floating	3 years	Free floating	Free floating	6 years	Free floating
28. Ghana	2007M5	10.5	0-10	Monetary targeting	Limited flexible	6 years	Limited flexible	Managed floating	6 years	Managed floating
29. Serbia	2009M1	6.5	8-12	Monetary targeting	Managed floating	6 years	Managed floating	Managed floating	6 years	Managed floating

1/ Finland, Spain and Slovakia abandoned IT upon entry into the Euro zone in 1999, 1999 and 2008, respectively.

Compiled from: Reinhart and Rogoff (2004); Pétursson (2004); Hammond (2009); Roger (2009); IMF website; Central banks' websites Carmen Reinhart's web site.

Table 2. Basic switching FE regression

	Dependent variable: *Interest rate*	(1) IV homoskedas-ticity-only s.e.	(2) IV HAC s.e.	(3) GMM HAC s.e.	(4) CUE homoskedas-ticity-only s.e.	(5) CUE HAC s.e.	(6) LIML HAC s.e.
	Interest rate (-1)	0.834***	0.834***	0.834***	0.839***	0.938***	0.839***
A	**Expected inflation**	0.057	0.057	0.057	0.042	-0.016	0.042
	Output gap	0.076	0.076	0.076	0.081	0.071*	0.081
	Δ Nominal exchange rate	0.041	0.041	0.041	0.051*	-0.033	0.051
	After	-0.570	-0.570	-0.570	-0.644	-0.624*	-0.644
B	**Expected inflation_after**	-0.071**	-0.071	-0.071	-0.080*	0.085*	-0.080
	Output gap_after	-0.063	-0.063	-0.063	0.064	-0.043	0.064
	Δ Nominal exchange rate_after	-0.060**	-0.060	-0.060*	-0.071**	0.060*	-0.071
C	**Expected inflation_switch**	0.208*	0.208*	0.208***	0.242***	0.086	0.242**
	Output gap_switch	-0.012	-0.012	-0.012	-0.009	0.041	-0.009
	Δ Nominal exchange rate_switch	-0.037	-0.037	-0.037	-0.050	0.018	-0.050
					-		-
	After-switch	2.442***	2.442*	2.442***	2.901***	1.370***	2.901**
					-		-
D	**Expected inflation_after_switch**	-0.279	-0.279*	-0.279**	-0.340***	-0.183***	-0.340**
	Output gap_after_switch	-0.002*	-0.002	-0.002	-0.011	-0.063	-0.011
	Δ Nominal exchange rate_after_switch	0.074*	0.074	0.074*	0.090**	-0.029	0.090
	F-statistics H0: All regressors are insignificant	**287.39*** **	**372.38*** **	**287.39*** **	**282.59*** **	**1094.82*** **	**357.22*** **
	Under-identification test (p-value) H0: Model is under-identified	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
	Weak identification test (F-stat) H0: Model is weakly identified	**3.764**	**3.822**	**3.764**	**3.764**	**3.822**	**3.822**
	Hansen test (p-value) H0: Instruments are valid	**0.344**	**0.134**	**0.344**	**0.364**	**0.225**	**0.170**
	Endogeneity test for the switching (p-value) H0: After_switch may be treated exogenous	**0.000**	**0.011**	**0.000**	**0.000**	**0.011**	**0.012**

Note: *,**,*** indicate 10, 5 and 1% of significance, respectively. The potentially endogenous variables are instrumented by their lags, varying from the third until the 24^{th} lag at a sequence of three lags, given the monthly data. The potential endogeneity of the switching variable is addressed by using as instruments the domestic credit-to-GDP; central-bank claims on central government-to-GDP and net foreign assets in the banking system-to-GDP and their first lags; and is tested through the Wu-Hausman F-test version of the endogeneity test which is robust to various violations of conditional homoskedasticity. Reported over-identification test is Hansen *J* statistic. Reported under-identification test is Kleibergen and Paap's (2006) test. Reported weak identification test is Kleibergen-Paap rk Wald F statistics.

Table 3. Robustness checks of the switching FE regression (CUE [HAC s.e.]) I

Dependent variable: *Interest rate*		(1) Interactions with after-switch only	(2) After-switch – exogenous	(3) After-switch –gap-period	(5) Sample size
Interest rate (-1)		0.812***	0.986***	0.997***	0.948***
A	**Expected inflation**	0.193***	0.048	0.072	0.006
	Output gap	0.067***	0.107***	0.141***	0.041
	Δ Nominal exchange rate	0.013	-0.031	0.043	0.006
After		-1.404***	-0.349	0.402	-0.262*
B	**Expected inflation_after**		-0.011	-0.093	0.028
	Output gap_after		-0.082*	-0.139***	-0.017
	Δ Nominal exchange rate_after		0.041*	-0.057	0.016
C	**Expected inflation_switch**		-0.011	-0.08	0.075**
	Output gap_switch		0.042	-0.048	0.058
	Δ Nominal exchange rate_switch		0.016	-0.023	-0.035
After-switch		2.930***	0.495	-0.053	0.598**
D	**Expected inflation_after_switch**	-0.163***	-0.038	0.084	-0.128***
	Output gap_after_switch	-0.060***	-0.058	0.049	-0.077*
	Δ Nominal exchange rate_after_switch	0.013	-0.013	0.050	0.029
F-statistics		**949.68*****	**259.68*****	**956.48*****	**1360.73*****
Under-identification test (p-value) H$_0$: Model is under-identified		**0.000**	**0.000**	**0.000**	**0.000**
Weak identification test (F-stat) H$_0$: Model is weakly identified		**3.747**	**3.623**	**1.801**	**3.766**
Hansen test (p-value) H$_0$: Instruments are valid		**0.673**	**0.288**	**0.151**	**0.115**
Endogeneity test for the switching (p-value) H$_0$: After_switch may be treated exogenous		**0.003**			**0.109**
C-statistic for the switching (p-value) H$_0$: After_switch may be treated exogenous			**0.001**	**0.372**	

Note: *,**,*** indicate 10, 5 and 1% of significance, respectively. See notes on diagnostic tests in Table 2.
The C statistic (also known as difference-in-Sargan statistic) allows a test of a subset of the orthogonality conditions; i.e. of the exogeneity of one or more instruments. It is defined as the difference of the Sargan-Hansen statistic of the equation with the smaller set of instruments and the equation with the full set of instruments, i.e. including the instruments whose validity is suspect. Under the null hypothesis, both the smaller set of instruments and the additional, suspect instruments are valid.

Table 4. Robustness checks of the switching FE regression (CUE [HAC s.e.]) II

Dependent variable: *Interest rate*		Added variables			
		Lagged inflation	**|NFA| to GDP**	**Reserves growth**	**Money growth**
		(1)	(2)	(3)	(4)
Interest rate (-1)		0.964***	0.912***	0.970***	0.962***
A	**Expected inflation**	0.052	-0.014	0.167***	0.025
A	**Output gap**	0.084**	0.054	0.089***	0.069
A	**Δ Nominal exchange rate**	-0.031	-0.058**	-0.001	-0.111**
A	***Added variable***	-1.881	-0.006	0.039***	-0.072
After		-0.655	-0.622	-1.391	-2.567***
B	**Expected inflation_after**	0.016	0.118**	-0.151***	0.023
B	**Output gap_after**	-0.056	-0.029	-0.059**	-0.047
B	**Δ Nominal exchange rate_after**	0.049	0.106***	0.016	0.127**
B	***Added variable* _after**	2.894	0.014	0.044***	0.077**
C	**Expected inflation_switch**	0.047	0.094	-0.127*	0.003
C	**Output gap_switch**	0.038	0.045	0.130***	0.041
C	**Δ Nominal exchange rate_switch**	0.012	0.048*	0.023	0.105**
C	***Added variable* _switch**	-0.019	0.012	0.040***	0.082**
After-switch		1.508***	1.649*	1.992***	3.242***
D	**Expected inflation_after_switch**	-0.176**	-0.211***	0.031	-0.050
D	**Output gap_after_switch**	-0.061	-0.062	-0.144***	-0.057
D	**Δ Nominal exchange rate_after_switch**	-0.015	-0.082**	-0.026	-0.104**
D	***Added variable* _after_switch**	-0.021	-0.024	-0.047***	-0.072**
F-statistics		**932.92*** **	**752.99*** **	**1244.07*** **	**1099.59*** **
Under-identification test (p-value) H_0: Model is under-identified		**0.000**	**0.000**	**0.000**	**0.000**
Weak identification test (F-stat) H_0: Model is weakly identified		**3.504**	**3.344**	**3.208**	**3.599**
Hansen test (p-value) H_0: After_switch may be treated exogenous		**0.250**	**0.103**	**0.290**	**0.440**
Endogeneity test for the switching (p-value) H_0: After_switch may be treated exogenous		**0.013**	**0.006**	**0.009**	**0.082**

Note: *,**,*** indicate 10, 5 and 1% of significance, respectively. See notes on diagnostic tests in Table 2.

Table 5. Types of Markov-switching models

Notation	μ	ν	Σ	A_i
	mean	***intercept***	***variance***	***AR parameters***
MSM(M)-VAR(p)	varying	-	invariant	invariant
MSMH(M)-VAR(p)	varying	-	varying	invariant
MSI(M)-VAR(p)	-	varying	invariant	invariant
MSIH(M)-VAR(p)	-	varying	varying	invariant
MSIAH(M)-VAR(p)	-	varying	varying	varying

Legend: MS-Markov-switching; M-mean; (M)-number of states/regimes; (p)-order of VAR (number of lags); I-intercept; H-heteroskedasticity; A-autoregressive terms.

Source: Krolzig (1998)

Table 6. Markov-switching regression results

Dependent variable: ***Interest rate***		Brazil	Chile	Colombia	Czech	Hungary	Israel	Philippines	Poland	Thailand
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
REGIME 1										
Constant		14.862**	4.078***	-3.372	3.048***	7.007	0.311	10.565***	5.160***	2.580**
Σ Interest rate lags		0.599***	0.075	0.532***	0.695***	0.797***	0.947***	0.352***	0.672***	0.762***
Σ Inflation AR lags		-0.480	1.232*	0.801***	0.071	-0.192	0.036	-0.186	0.069*	-0.111
Σ Gap AR lags		0.575*	0.791*	0.169*	0.056	0.161*	0.058	-0.089	0.204	0.062*
Σ Exchange rate AR lags		-0.011	0.050	0.148*	0.067**	0.130	0.008***	0.018	0.021	0.053*
Regime volatility		4.399	3.705	4.805	1.636	0.685	0.556	4.003	1.857	2.356
Rough regime timing		1997:3 - 1998:8***	1993:8 - 2001:8***	1995:4 - 2000:3***	1994:4 - 1999:2***	1992:7 - 1996:10***	1992:3 - 1998:4***	1992:2 - 1999:5***	1992:5 - 1998:7***	1992:2 - 1999:1***
REGIME 2										
Constant		0.033	-0.066**	-0.433	0.052***	0.090	0.012	0.359***	0.163	0.086*
Σ Interest rate lags		0.999***	0.933***	0.828***	0.960***	0.949***	0.989***	0.954***	0.931***	0.910***
Σ Inflation AR lags		0.024***	0.031***	0.258***	0.022***	0.045***	0.004***	-0.012	0.041***	0.048***
Σ Gap AR lags		0.026*	-0.006	0.009	-0.003*	-0.009	0.007*	0.002	0.018**	0.003*
Σ Exchange rate AR lags		0.000	-0.007***	-0.001	0.000	0.004	0.006	0.006*	-0.004	-0.006*
Regime volatility		0.248	0.245	0.374	0.147	0.329	0.159	0.287	0.394	0.221
Rough regime timing		1998:9 - 2009:7***	2001:9 - 2009:9***	2000:4 - 2005:9***	1999:3 - 2009:10***	1996:11 – 2009:10***	1998:5 - 2009:10***	1999:6 - 2008:12***	1998:8 - 2009:11***	1999:2 - 2009:11***
p_{11}		0.6945	0.9693	0.9640	0.9836	0.6822	0.9711	0.9266	0.9692	0.9882
p_{22}		0.9280	0.9789	0.9835	1.0000	0.9494	0.9817	0.9594	0.9810	1.0000
Lags (based on SC)		2	4	1	2	3	2	1	4	1
Inferred switch		1998:9	2001:9	2000:4	1999:3	1996:11	1998:5	1999:6	1998:8	1999:2
Official switch (Table 1)		1999:6	1999:9	1999:10	1997:12	2001:6	1997:6	2002:1	1998:1	2000:5
Linearity test	**(chi-stat)**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(Davies)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ho: The linear model is preferred										

Note: *,**,*** indicate 10, 5 and 1% of significance, respectively. By "rough regime timing" it is meant that we do not present the identified short periods of a few months, but instead longer periods when the regime prevailed.
Whenever more than one lag was used, the sum of the lags for each variable is reported, along with the Wald test of their joint significance.

Table 7. Regimes persistence and volatility when allowed for three regimes

Country	Transition probabilities [regime volatility]			When does regime 3 ("Other") appear?
	p_{11} ERT	p_{22} IT	p_{33} Other	
Brazil	0.7677 [2167.3]	0.9461 [1.328]	0.6104 [84.636]	1992:7-1993:8
Chile	0.9083 [2.331]	0.9889 [0.151]	0.8412 [6.165]	1993:8-1994:12
Colombia	**0.9458 [2.934]**	**0.9420 [0.091]**	**0.9375 [0.700]**	**1999:4-2004:12**
Czech	**0.9825 [1.510]**	**0.9455 [0.100]**	**0.7846 [0.161]**	**1998:12-2000:4**
Hungary	0.6671 [0.553]	0.5509 [0.115]	0.1056 [1.407]	Very sporadically
Israel	0.8610 [0.892]	0.9094 [0.174]	0.8593 [0.268]	2009:1-2009:11
Philippines	0.7776 [1.070]	0.9889 [0.248]	0.6404 [4.586]	Sporadically
Poland	**0.9737 [3.154]**	**1.000 [0.295]**	**0.9888 [1.175]**	**1995:3-2002:6**
Thailand	**0.9882 [0.258]**	**0.9883 [0.143]**	**0.9458 [2.357]**	**1999:2 - 2000:10**

Note: Figures in squared brackets are regimes volatilities. Serial correlation accounted for. Bold type signifies 'other' regime that is identified between regime 1 and regime 2.

Table 8. Markov-switching regression results exogenous regressors added

Dependent variable: *Interest rate*		Brazil	Chile	Colombia	Czech	Hungary	Israel	Philippines	Poland	Thailand
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
REGIME 1										
Constant		18.746***	-8.504	25.586**	5.425***	2.136***	0.226	13.917***	11.974***	6.393***
Σ Interest rate		0.421***	0.119	0.420***	0.433***	0.897***	0.937***	0.28***	0.688***	0.564***
Σ Inflation AR terms		1.200	1.052***	0.207	0.131	-0.032	0.043	-0.212	-0.010	-0.190
Σ Gap AR terms		-0.027	0.603***	0.232**	0.032	0.033	0.051	-0.007	0.236	0.072**
Σ Exchange rate AR terms		-0.192	-0.127	0.261*	0.089**	0.008	0.013	-0.013	-0.013	0.052
Reserves growth		-0.191**	-0.051	0.047	-0.015*	0.000	0.003	-0.012	-0.002	-0.085***
NFA to GDP		-0.950	-0.167	-4.293**	0.064	0.027***	0.003	-0.399***	-0.382*	-0.074
Regime volatility		3.798	4.046	4.591	1.490	0.750	0.551	3.916	1.817	2.200
Rough regime timing		1997:3 - 1999:6***	1993:7 - 2001:8***	1995:4 - 2000:3***	1994:3 - 1999:2***	1992:2 - 1998:12***	1992:3 - 1999:8***	1992:2 -- 2001:2***	1992:5 - 1998:7***	1992:2 - 1999:1***
REGIME 2										
Constant		0.434***	0.236***	-0.549	0.093	0.690***	-0.265	0.246	-0.849	0.070
Σ Interest rate		0.962***	0.967***	0.825***	0.960***	0.911***	0.994***	0.978***	0.930***	0.916***
Σ Inflation AR terms		0.037**	0.024**	0.272***	0.020**	0.020*	0.009***	-0.020	0.055***	0.048***
Σ Gap AR terms		0.023***	0.004*	0.009**	-0.003*	0.000	0.010**	0.000*	0.020**	0.004***
Σ Exchange rate AR terms		0.000	-0.001	-0.002	0.000	0.014***	0.008***	0.001	0.004	-0.008**
Reserves growth		-0.001	-0.002	0.001	0.000	-0.011**	-0.001	-0.002	0.001	-0.004
NFA to GDP		-0.025***	-0.013**	0.004***	-0.001	0.010	0.015**	0.001	0.017**	0.002
Regime volatility		0.241	0.149	0.376	0.147	0.308	0.155	0.280	0.430	0.219
Rough regime timing		1999:7 - 2009:10***	2001:9 - 2009:3***	2000:4 - 2005:9***	1999:3 - 2009:10***	1999:1 - 2009:10***	1999:9 - 2009:8***	2001:3 - 2008:2***	1998:8 – 2009:11***	1999:2 - 2009:11***
p_{11}		0.7533	0.9804	0.9652	0.9836	0.9537	0.9706	0.8842	0.9681	0.9882
p_{22}		0.9371	0.9891	0.9849	1.0000	0.9757	0.9809	0.9275	0.9818	1.0000
Lags (based on BIC)		2	3	1	2	1	2	1	4	1
Official switch (Table 1)		1999:6	1999:9	1999:10	1997:12	2001:6	1997:6	2002:1	1998:1	2000:5
Linearity test	**(chi-stat)**	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(Davies)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ho: The linear model is preferred										

Note: *,**,*** indicate 10, 5 and 1% of significance, respectively. See other notes in Table 6.

Table 9. Regimes probabilities under different MS-VAR specifications

	Brazil	Chile	Colom-bia	Czech	Hun-gary	Israel	Philip-pines	Poland	Thai-land
MS(2)-VAR(p)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MSIAH									
p11	0.6945	0.9693	0.9640	0.9836	0.6822	0.9711	0.9266	0.9692	0.9756
p22	0.9280	0.9789	0.9835	1.0000	0.9494	0.9817	0.9594	0.9810	0.9921
MSI									
p11	0.9861	0.9889	0.9108	0.9676	0.8473	0.9792	0.9588	0.9616	0.9777
p22	0.9795	1.0000	0.9411	0.9906	0.9109	0.9890	0.9477	0.9723	0.9685
MSIH									
p11	0.6624	0.9802	0.8901	0.9834	0.2055	0.9703	0.9288	0.9919	0.9906
p22	0.9146	0.9889	0.9314	1.0000	0.7852	0.9817	0.9660	1.0000	1.0000
MSAH									
p11	0.4883	0.9685	0.9836	0.7288	0.4007	0.8673	0.9323	0.9681	0.9906
p22	0.9268	0.9756	1.0000	0.9207	0.8044	0.9104	0.9636	0.9638	1.0000

Table 10. Markov-switching VAR (MS-VAR) versus Duration-dependent Markov-switching VAR (DD-MS-VAR)

Dependent variable: *Interest rate*	Brazil	Chile	Colombia	Czech	Hungary	Israel	Philippines	Poland	Thailand
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MSM-VAR									
Mean in regime 1 (ERT)	18.254**	2.938	-6.620	1.551	5.422	7.477***	12.657***	8.492**	2.183
Mean in regime 2 (IT)	18.618**	9.114**	6.241	-0.849	6.101	9.102***	8.495***	14.430***	5.704**
Σ Interest rate	0.915***	0.980***	0.814***	0.930***	0.957***	0.942***	0.468***	0.823***	0.982***
Σ Inflation AR terms	0.076	0.920***	0.309***	0.072	0.023	0.003***	0.163**	0.067	-0.002
Σ Gap AR terms	0.091	0.188	0.038	0.023	0.014**	0.046*	0.006	0.046**	0.007*
Σ Exchange rate AR terms	0.000	0.006	0.015	0.022	0.021***	0.020***	0.017	-0.002	-0.026
Regime volatility	2.444	3.809	2.042	0.834	0.601	0.482	2.658	1.187	0.873
p_{11}	0.909	0.989	0.967	0.969	0.964	0.989	0.979	0.937	0.699
p_{22}	0.942	1.000	1.000	0.978	0.978	1.000	0.991	0.942	0.925
Lags (based on BIC)	3	1	1	4	1	2	1	2	4
Linearity test (chi-stat)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
(Davies)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ho: The linear model is preferred									
DD-MS-VAR									
Mean in regime 1 (ERT)	43.774	-58.712	487.69	90.128	73.69	7.137	-167.31	24.273	-1.538
Mean in regime 2 (IT)	44.638	-50.143***	9.673***	96.495**	74.52***	7.994***	8.184***	28.297***	1.813***
Σ Interest rate	0.921***	0.747***	0.815***	0.934***	0.984***	0.977***	0.944***	0.951***	1.015***
Σ Inflation AR terms	0.072	0.317*	0.296***	0.068*	0.018	0.018	0.038	0.028**	-0.005
Σ Gap AR terms	0.044	0.216***	0.086***	0.012	0.008	0.021	-0.038	0.021	0.009
Σ Exchange rate AR terms	0.014	0.008	0.025	0.010	0.000	0.010*	0.004	-0.001	-0.015
Lags (based on ACF of sigma)	3	3	1	1	1	2	3	1	1
p_{12} at max. duration	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
p_{21} at max. duration	0.150	0.020	0.000	0.040	1.000	0.060	0.000	0.000	0.000

Note: *,**,*** indicate 10, 5 and 1% of significance, respectively. See other notes in Table 6.

APPENDIX B – Variables

Table 11. Variables: definition and sources

Label	Description	Unit	Source	Notes
R	Money market interest rate	y-o-y % per month	IFS and national central banks	Wherever not available, the discount rate used.
CPI	Consumer prices	Index number	IFS	
INF	Inflation	y-o-y % per month	Calculated	Inflation= log(cpi)-log(cpi[-12])
IND	Industrial production	Index number	IFS and national statistics offices	
GAP	Output gap	Percentage points	Calculated	The residual series between the actual and the potential output estimated from the industrial production by HP filtering.
ER	Exchange rate	Units of national currency per SDR	IFS	
DER	Change in the exchange rate	y-o-y % per month	Calculated	DER= log(ER)-log(ER[-12])
RES	Reserves minus gold	Million of USD	IFS	
DRES	Change in the reserves	y-o-y % per month	Calculated	DRES= log(RES)-log(RES[-12])
DC	Domestic credit to nominal GDP	%	IFS	The annual GDP used for each month.
M2	Money aggregate M2	Millions/billions of national currency	IFS and national central banks	
NFA	|Net foreign assets| to GDP	Millions/billions of national currency	IFS	NFA refers to the difference between foreign assets and foreign liabilities of the banking system, taken as an absolute value. The annual GDP used for each month.