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Abstract

This paper investigates the forward-lookingness of monetary policy related to stabilising inflation over time under different degrees of central bank credibility in the four largest Latin American economies, which experienced a different transition path to the full-fledged inflation targeting regime. The analysis is based on an interest rate-based hybrid monetary policy rule with time-varying coefficients, which captures possible shifts from a backward-looking to a forward-looking monetary policy rule related to inflation stabilisation. The main results show that monetary policy is fully forward-looking and exclusively reacts to expected inflation under nearly perfect central bank credibility. Under a partially credible central bank, monetary policy is both backward-looking and forward-looking in terms of stabilising inflation. Moreover, monetary authorities put increasingly more priority on stabilising expected inflation relative to actual inflation if central bank credibility tends to improve over time.

Keywords: forward-lookingness, central bank credibility, inflation targeting, hybrid monetary policy rule, time-varying coefficients

JEL classification: C32, E42, E58

1 Introduction

In the two decades before the 2000's, Latin American economies were characterized by several periods of high or even hyperinflation, large currency devaluations, overall weak economic growth, and several economic and financial crisis which was considered to be the result of a lack of discipline of monetary and fiscal policy. In turn, this resulted in a low degree of central bank credibility to contain inflation low and stable. In the 1990's, the Latin American economies implemented a considerable change in the conduct of monetary policy and introduced price stability as a main monetary policy objective. Subsequently, inflation rates of Latin American economies decreased substantially and remained at a low and stable level thereafter at least compared to previous historical inflation dynamics. At the end of 1990's and early 2000's, most of the largest Latin American economies abandoned the exchange rate targeting regime and almost simultaneously adopted a full-fledged inflation targeting regime[1] with a single nominal anchor of price stability and with a free or managed floating exchange rate.

In the largest Latin American economies, central banks are supposed to have different degrees of credibility at the time point of the adoption of the full-fledged inflation targeting regime and thereafter since the countries experienced different historical inflation dynamics and different transition paths to the new regime, respectively. The incentive of policy-makers to shift to a full-fledged inflation targeting regime was to further build up central bank credibility by enhancing transparency and thus accountability, which allows monetary policy to anchor expected inflation to the announced inflation target. Hence, in the analysis of this paper, the degree of central bank credibility is supposed to depend on the degree of anchoring of expected inflation to the inflation target. In turn, under a high degree of central bank credibility, monetary authorities are supposed to react to expected inflation since it is more effective and requires less of a change of the policy instrument to achieve the same stabilizing impact on actual inflation compared to the case when monetary authorities directly

[1] Mishkin and Savastano (2001), Svensson (1999) and Svensson (2010) provide criteria of a full-fledged inflation targeting regime (1) Announcement of medium-term inflation targets; (2) Institutional commitment to price stability as primary objective of monetary policy; (3) Full responsibility to implement monetary policy decisions necessary to attain the inflation target (4) Transparency of monetary policy strategy and communication of plans, objectives and rational behind decisions; (5) Mechanisms that make monetary policy accountable for economic agents in terms of how to attain its inflation objective.

react to actual inflation. Hence, the degree of forward-lookingness of monetary policy related to stabilizing inflation is supposed to depend on the degree of central bank credibility. This implies that monetary policy of Latin American economies possibly build up credibility and intend to transit from a backward-looking to a rather forward-looking monetary policy.

The objective of this paper is to analyze the evolution of the conduct of monetary policy of open Latin American economies over time for the time period after the full-fledged inflation targeting regime was adopted. The selected countries are Brazil, Chile, Colombia and Mexico which are the four largest Latin American economies and cover over 70% of overall GDP and about 60% of the overall population of Latin American and Caribbean countries in the 2002 to 2017 period.

The core research objective addresses the evolution of the conduct of monetary policy in terms of stabilizing inflation over time under a changing degree of central bank credibility. For this purpose, the empirical analysis refers to an interest rate-based hybrid monetary policy rule with time-varying coefficients which consists of the future expected inflation gap and the actual lagged inflation gap beside the real output gap and other control variables. This policy rule allows to study a possible shift in the degree of forward-lookingness of monetary policy over time. In a preliminary empirical analysis, the degree of central bank credibility is estimated for the respective country in order to evaluate the forward-lookingness of monetary policy under the country-specific degree of central bank credibility.

The main empirical results provide evidence that the degree of forward-lookingness depends on the degree of anchoring of expected inflation to the announced inflation target and thus on the degree of central bank credibility. If the central bank has nearly perfect credibility, monetary policy turns out to be fully forward-looking and exclusively reacts to expected inflation. In case of a partially credible central bank, monetary policy reacts to both expected and actual inflation dynamics and thus monetary authorities are simultaneously backward-looking and forward-looking in terms of stabilizing inflation. Furthermore, it turns out that monetary authorities put increasingly more priority on stabilizing expected inflation under an increasing degree of central bank credibility over time.

2 Central Bank Credibility

In the considered Latin American economies, the incentive of the shift to a full-fledged inflation targeting regime was the support of the respective country's disinflationary path and to use the new monetary policy regime as a means of building up central bank credibility. Recent literature define credibility as "*A central bank is credible if people believe it will do what it says*" (Blinder, 2000). Demertzis et al. (2012) and Svensson (2012) define central bank credibility as the degree how closely expected inflation match the central bank's announced inflation target. A credible monetary policy implies that the private sector is confident in the ability of monetary authorities to react decisively and to achieve the announced inflation target within a specified time horizon. Hence, a high degree of credibility refers to the ability of monetary policy to anchor expected inflation to the inflation target for sustained periods of time, which induces actual inflation to follow expected inflation with some lags. In case of well anchored expected inflation, monetary authorities rather react to expected inflation in order to stabilize actual inflation close to the inflation target since a reaction to expected inflation requires less of a change of the policy instrument to achieve the announced policy objective. Thus, monetary policy refers to a forward-looking policy rule if the degree of credibility and thus the degree of anchoring is sufficiently large given that a forward-looking monetary policy is more effective. In turn, a low degree of credibility implies that expected inflation is de-anchored for sustained periods of time from the inflation target and expected inflation follows rather actual inflation dynamics. In case of low credibility and a low degree of anchoring, monetary authorities are supposed to directly react to actual lagged inflation and thus to refer to a backward-looking monetary policy rule in terms of stabilizing inflation. Under a low degree of credibility, monetary policy is less effective since monetary authorities have to react more aggressively with a change of the policy instrument to volatile actual inflation in order to have the same stabilizing impact on actual inflation as in the case when monetary policy is highly credible and forward-looking.

The way of implementing the inflation targeting regime differs among advanced and emerging market economies. In several advanced economies, central banks have built up full credibility over a long time horizon and reached a high degree of anchoring of long-run expected inflation to the inflation target where short-run expected inflation and actual inflation dynamics follow long-run ex-

pected inflation with some lags. Hence, the inflation targets are implemented as long-run objectives and central banks are considered to be credible if long-run expected inflation is anchored to the inflation target. As a consequence, monetary policy only reacts to long-run expected inflation dynamics. In contrast to them, central banks in emerging market economies have historically rather low credibility which applies especially to central banks in Latin American economies due to the bad inflation performance in the recent history. The central banks provide rather short-run inflation targets under imperfect credibility since the public is expected to evaluate the performance of monetary policy related to the inflation stabilization policy and is further assumed to adjust its inflation expectations for the short time horizon. Hence, monetary policy stabilizes short-run expected inflation under imperfect credibility and in the process of building up credibility. Once short-run expected inflation is well anchored to the inflation target, central banks may turn to interpret their respective inflation target as a medium to long-run objective as this is the case for central banks in most advanced economies.

In the literature there does not exist any consensus about how to appropriately measure central bank credibility. There exists a number of different measures which relate long-term expected inflation to the inflation target and actual inflation. The approach of Bomfim and Rudebusch (2000) and Rosenblatt-Wisch and Scheufele (2015) refer long-run expected inflation as a weighted average of the announced inflation target and lagged actual inflation.

In the subsequent preliminary analysis, the model of central bank credibility of Bomfim and Rudebusch (2000) is estimated by means of a constant coefficient model and is applied for the full sample as well as for two sub-samples which allow to evaluate the degree of credibility over time for the central banks of the four considered countries. However, in contrast to Bomfim and Rudebusch (2000), this model is modified and refers to short-run expected inflation defined as a weighted average of the inflation target and actual lagged inflation since the inflation target refers to the short horizon of 12 months. This modification takes account of the conditions in Latin American economies where monetary policy addresses short-run expected inflation in the process of building up central bank credibility:

$$E_t(\pi_{t+h}) = \theta_1 \pi_t^* + \theta_2 \pi_{t-1} + u_t \tag{2.1}$$

$$u_t = \alpha_p u_{t-p} + \xi_t \tag{2.2}$$

where the residual term u_t follows an AR(p) process and p refers to the number of lags which are required to get rid of serial correlations in the residuals. The coefficient θ_1 ($\in$ [0,1]) measures the degree of anchoring of expected inflation ($E_t(\pi_{t+h})$ with h periods ahead) to the announced inflation target (π_t^*) and thus reflects the degree of central bank credibility. If $\theta_1 = 1$, expected inflation is perfectly anchored to the inflation target and monetary policy is fully credible. The coefficient θ_2 is defined as $(1 - \theta_1)$ and captures the extent to which expected inflation is affected by actual lagged inflation dynamics (π_{t-1}). If $\theta_2 = 1$, expected inflation is de-anchored from the inflation target and entirely follows actual inflation dynamics which implies that monetary policy has no credibility at all. In this case the inflation target is entirely disregarded in the formation of expected inflation. An intermediate case of the previous two extreme cases refers to $0 < \theta_1 < 1$ which means that expected inflation is partially anchored to the inflation target and central bank credibility is imperfect.

This model is estimated with constant coefficients and by means of Bayesian regressions. This model accounts for serial correlation in the residuals. The Gibbs sampler is used to estimate the conditional posterior distribution by means of 15000 draws. The empirical results are outlined together with the results of the coefficients of the monetary policy reaction functions of the respective country.

3 Empirical Analysis

3.1 Short Review of Monetary Policy Rules

This short review of monetary policy rules serves as a theoretical background for the interest rate-based monetary policy rule which is specified in the next chapter and applied in the subsequent empirical analysis of this paper.

A starting point of this review is the well-known Taylor rule proposed by Taylor (1993) which has been extensively used in the literature as a monetary policy reaction function in order to analyze how a central bank adjusts its monetary policy interest rate based on its policy objectives and economic conditions. This simple interest rate rule reflects monetary policy in a closed economy which is not subject to any external economic constraints:

$$i_t^{TR} = \gamma_0 + \gamma_1 \pi_t + \gamma_2 y_t \tag{3.1}$$

where i_t^{TR} is the target nominal interest rate implied by the Taylor rule and describes the level at which the short-term nominal interest rate should be set according to the inflation gap (π_t) and output gap (y_t). The constant term is defined as the long-term equilibrium nominal interest rate which itself is defined as the sum of the long-term equilibrium real interest rate and the inflation target rate ($\gamma_0 = i^* = r^* + \pi^*$). The coefficients γ_1 and γ_2 measure the responsiveness of monetary policy to a change in the inflation gap and output gap, respectively. In a closed economy, the coefficient for the inflation gap γ_1 is required to be larger than one in order to ensure determinacy and thus a stable inflation path (Taylor principle).[2]

The original Taylor rule has been modified and expanded for several reasons for instance in order to address monetary policy in an open economy. For this purpose, Clarida et al. (1998) expand the Taylor rule by additional variables such as exchange rates in order to address external factors from abroad which are expected to have an impact on domestic inflation dynamics. Furthermore, Clarida et al. (1998), Clarida et al. (2000) and Orphanides (2004) among others modify the Taylor rule and replace actual inflation by expected inflation in order to address recent developments in the conduct of monetary policy where central banks intend to control expected inflation. Girardin et al. (2017) apply a hybrid monetary policy rule for an emerging market economy with a backward-looking and forward-looking inflation gap. This rule allows to capture the reaction of monetary authorities to both actual and expected inflation and addresses a possible transition from a backward-looking to a forward-looking monetary policy. This often applies to central banks in emerging market economies who intend to build up credibility and anchor expected inflation to the announced inflation target by means of a transition from a discretionary to a more rule-based conduct of monetary policy:

$$i_t^{TR} = \gamma_0 + \gamma_1 E_t(\pi_{t+h}) + \gamma_2 \pi_{t-1} + \gamma_3 y_{t-1} + \gamma_4 \zeta_{t-1} \tag{3.2}$$

where ζ_{t-1} represents a vector of additional external variables such as for instance the exchange rate. $E_t(\pi_{t+h})$ represents expected inflation for h periods ahead and π_{t-1} and y_{t-1} are the lagged inflation gap and the lagged output

[2] A large number of authors have proven in their models that the Taylor principle ensures determinacy for the inflation path in a closed economy setting: Bernanke and Woodford (1997), Benhabib et al. (2001), Clarida et al. (2000), Carlstrom and Fuerst (2001), Carlstrom et al. (2006), Woodford (2001), Taylor (1999), McCallum (2003) or Walsh (2010) among others

gap, respectively. In this context, Linnemann and Schabert (2006) address the Taylor principle in an open economy case and indicate that there is a lack of a clear-cut result for the Taylor principle for the open economy case since the literature yields contradicting results about the determinacy issue under the Taylor principle (Galí and Monacelli (2005), De Fiore and Liu (2005) and Leith and Wren-Lewis (2009)). Nevertheless, the model analysis of Linnemann and Schabert (2006) turns out, that a strong reaction to current consumer price inflation and thus satisfying the Taylor principle ensures determinacy also in the open economy case. In case of a forward-looking policy rule, a severe interest rate adjustment to expected future consumer price inflation may induce an unstable inflation path if the degree of trade openness is high and the import share of the country is sufficiently large. Hence, a possible clear-cut value for the Taylor principle is country-specific in the open economy case. The indeterminacy results from the fact that a rise in the interest rate leads to an immediate appreciation and a subsequent future expected depreciation of the country's currency which finally leads to a rise in expected inflation rates via the expected increase of future import prices.

Moreover, recent literature (e.g. Judd et al. (1998) and Clarida et al. (1998)) extend the monetary policy rule by introducing interest rate smoothing behavior in order to capture the preferences of central banks to gradually adjust the monetary policy interest rate to the target level i_t^{TR}:

$$i_t = \rho i_{t-1} + (1-\rho) i_t^{TR} \quad with \quad 0 \leq \rho \leq 1 \tag{3.3}$$

Inserting equation 3.2 in equation 3.3 yields:

$$i_t = \rho i_{t-1} + (1-\rho)[\gamma_0 + \gamma_1 E_t(\pi_{t+h}) + \gamma_2 \pi_{t-1} + \gamma_3 y_{t-1} + \gamma_4 \zeta_{t-1}] \tag{3.4}$$

where $(1-\rho)\gamma_0$ and $(1-\rho)\gamma_i$ are the short-run coefficients which describe the immediate reaction of monetary policy to the underlying variables of the policy rule. Accordingly, the long-run coefficients γ_i represent the reaction of monetary policy to the respective underlying variable when monetary policy has finally adjusted the short-term nominal interest rate to the desired interest rate. They are derived by dividing the short-run coefficients by the speed of adjustment coefficient: $\frac{(1-\rho)\gamma}{(1-\rho)}$ and $\frac{(1-\rho)\gamma_i}{(1-\rho)}$.

3.2 Empirical Model

The empirical analysis of this paper applies an interest rate-based monetary policy rule with time-varying coefficients which was applied first by Kim and Nelson (2006), Boivin (2006) and later by Aragón and de Medeiros (2015). This model is capable to capture both smoothed structural changes over a long time horizon as well as abrupt changes in the reaction of monetary policy to the underlying variables of the policy rule. The empirical model of the subsequent analysis refers to the model in equation 3.4 and is extended by time-varying coefficients:

$$i_t = \rho_t i_{t-1} + (1-\rho_t)[\gamma_{0,t} + \gamma_{1,t} E_t(\pi_{t+h}) + \gamma_{2,t}\pi_{t-1} + \gamma_{3,t} y_{t-1} + \gamma_{4,t}\zeta_{t-1}] + e_t \quad (3.5)$$

$$\gamma_{j,t} = \gamma_{j,t-1} + \epsilon_{jt} \quad \text{with} \quad \epsilon_{jt} \overset{iid}{\sim} N(0, \sigma^2_{j,\epsilon}) \quad j = 0,1,2,3,4 \quad (3.6)$$

$$\rho_t = \rho_{t-1} + \psi_t \quad \text{with} \quad \psi_t \overset{iid}{\sim} N(0, \sigma^2_{\psi}) \quad (3.7)$$

The time-varying coefficient model to be estimated consists of a measurement equation 3.5 and refers to the monetary policy rule which is based on the lagged interest rate, a time-varying intercept, the output gap and the gap for actual and future expected inflation (with time horizon h). Moreover, the monetary policy rule consists of further control variables such as the exchange rate, commodity returns and the US monetary policy rate which are covered in the vector ζ_{t-1}. Hence, the coefficient vector $\gamma_{4,t}$ consists of the corresponding coefficients of the control variables. Finally, this monetary policy rule includes a residual term which covers random exogenous shocks and the impact of further possible variables on monetary policy decisions which are not included in the policy rule. The residuals of this equation are i.i.d. normally distributed ($e_t \overset{iid}{\sim} N(0, \sigma^2_e)$). The equations 3.6 and 3.7 are the transition or state equations which describe the random walk dynamics of the time-varying coefficients. Except for expected inflation, all independent variables are included as lagged variables in order to diminish the potential of reverse causality.

As described already by Clarida et al. (1998), the use of future expected inflation in the Taylor rule induces an endogeneity problem since future expected inflation is correlated with the residual term e_t. The analysis of this paper follows closely the lines of Kim and Nelson (2006) and Kim and Kim

(2011) who suggest an instrumental equation approach in order to cope with the endogeneity problem in a time-varying coefficient model framework. In the previous two papers the residual term e_t is decomposed into an endogenous term ($\lambda^{'}\nu_t^*$) and an exogenous term ω_t, where ω_t is now uncorrelated with future expected inflation and $\lambda^{'}\nu_t^*$ is the endogeneity bias correlation term. In order to solve for endogeneity, the ν_t^* is obtained from the following instrumental equation approach which assumes a time-varying relation between future expected inflation (regressand) and the used instrumental variable (regressor):

$$E_t(\pi_{t+h}) = Z_t^{'}\delta_t + \nu_t \quad \text{with} \quad \nu_t \overset{iid}{\sim} N(0, \sigma_\nu^2) \tag{3.8}$$

$$\delta_t = \delta_{t-1} + \xi_t \quad \text{with} \quad \xi_t \overset{iid}{\sim} N(0, \sigma_\xi^2) \tag{3.9}$$

where Z_t is the instrumental variable which refers to future expected inflation with lags of 10 months ($E_{t-10}(\pi_{t+h-10})$). The equation 3.8 represents the measurement equation and future expected inflation is regressed on the instrumental variable which in turn includes ten lags of the future expected inflation variable. In equation 3.9 the transition equation describes the random walk dynamics of the time-varying coefficient which measures the time-varying impact of the instrumental variable on future expected inflation.

The outlined time-varying coefficient model is estimated in a two-step estimation procedure as suggested by Kim and Kim (2011). In contrast to them, the analysis of this paper applies the Bayesian regression method in order to obtain unbiased coefficient estimates under a relatively small sample with a limited number of observations. In the first step, the instrumental equation 3.8 and the transition equation 3.9 are used to estimate time-varying coefficients by means of the Kalman filter in a Gibbs sampling algorithm where 15000 draws are applied to estimate the conditional posterior distribution of the respective coefficient. From the estimation result, the standardized residuals ($\nu_t^* = \frac{\nu_t}{\sigma_\nu}$) are derived and used as the endogeneity bias correction term in the second estimation step.

In the second step, the standardized residuals from the first step are introduced to estimate the model of equation 3.5 to 3.7. The residual term of equation 3.5 can be replaced by $e_t = \lambda^{'}\nu_t^* + \omega_t$ where $\omega_t \overset{iid}{\sim} N(0, \sigma_\omega^2)$ is not correlated with future expected inflation. Hence, equation 3.5 is corrected by the endogeneity bias correction term ($\lambda^{'}\nu_t^*$) and the residual term ω_t as expressed

in the following equation:

$$i_t = \rho_t i_{t-1} + (1-\rho_t)[\gamma_{0,t} + \gamma_{1,t} E_t(\pi_{t+h}) + \gamma_{2,t}\pi_{t-1} + \gamma_{3,t} y_{t-1} + \gamma_{4,t}\zeta_{t-1}] + \lambda^{'}\nu_t^* + \omega_t \tag{3.10}$$

The regression of the second step is conducted by means of equations 3.6, 3.7 and 3.10 and the regression steps are the same as in the first step. Hence, equation 3.10 consists of equation 3.5 augmented with the endogeneity bias correction term and the residual term ω_t is now uncorrelated with future expected inflation. The time-varying coefficients are estimated by means of an extended Kalman filter in a Gibbs sampling algorithm where 15000 draws are applied to estimate the conditional posterior distribution of the respective coefficients.

4 Data Description

The empirical analysis of the previous chapter is mainly based on data sources which are provided by the respective country's central bank. A detailed description of the data and the data sources are provided in table 9 in Appendix A. The time length of the data sample varies among the considered countries and depends on the data availability. The variable with limited data availability is short-run expected inflation such that the empirical analysis for the four countries starts at different years. For Brazil, Chile and Colombia, the analysis starts in June 2002, August 2001 and May 2004, respectively, and ends in December 2017. Mexico started to use the short-term nominal interest rate as a primary monetary policy instrument in 2008 such that the data sample is restricted and the analysis starts in January 2008 and ends in December 2017. The analysis uses data of monthly frequency since monetary authorities of the considered countries conduct monetary policy decisions on a monthly basis or at least eight times a year such that the conduct of monetary policy and thus interest rate decisions are better captured as in the case of using quarterly data.

The used data refers to ex-post data since real-time data appears not to be available, especially for monthly output measures for the set of considered countries. Actual lagged inflation and future expected inflation refer to year-on-year measures and are introduced as gap variables which are defined as percentage deviation of inflation from the announced inflation target. The expected inflation gap refers to 12-months ahead expected inflation and is used

as a contemporaneous variable. The output gap is defined as the percentage deviation of the respective output measure from its respective trend and is used with a lag of one month. The use of lagged inflation and lagged output measures are motivated by monetary policy practice since monetary authorities are subject to information delays since contemporaneous observations for output and inflation are not available at the time point of decision making (McCallum, 1993). The use of future expected output gap would be a further relevant additional variable which has been used in the estimation of monetary policy rules for industrialized countries in recent literature (e.g. Boivin (2006)) but its use has been discarded in the analysis of this paper since reliable future expected output measures on a monthly frequency appear not to be available for the set of considered countries.

As a further control variable, the real exchange rate is introduced into the policy rule and is defined as the country's currency in terms of US dollar expressed in year-on-year percentage growth rates. For a central bank with an inflation targeting regime, it is plausible to add the exchange rate dynamics to the monetary policy rule since countries are exposed to external shocks and exchange rate dynamics might have an impact on domestic consumer price inflation through changing prices of imported goods. The impact of the exchange rate on consumer price inflation depends on size of the exchange rate shock and on the share of import prices in the consumer price index.

The next variable is based on real commodity price returns and are expressed as the year-on-year percentage growth rate of a country-specific commodity price index. Commodity prices are added to the monetary policy rule since imported commodities are raw material for the production of final goods of consumption and the impact of commodity prices on the consumer price index is large if the share of such commodity-based consumption goods is sufficiently large in the consumer price index.

Both real exchange rates and real commodity prices are introduced into the policy rule as lagged variables based on a lag of one month. Under the inflation targeting regime, monetary authorities need to distinguish between transitory and permanent shocks in order to appraise the impact of an exchange rate shock and commodity price shock on actual and expected inflation. Monetary authorities should only react to permanent shocks since they are expected to have an impact on future inflation dynamics whereas transitory shocks are not expected to have such an impact. Hence. it makes sense to use both variables

as lagged values instead of contemporaneous values since the detection of a permanent shock needs some time and cannot be observed instantaneously.

Finally, the U.S. effective federal funds rate is inserted into the monetary policy rule as a control variable and serves as a proxy for global monetary conditions. The use of the U.S. federal funds rate in the policy rule is motivated by the literature, which stresses the existence of a global financial cycle. This cycle is largely driven by U.S. monetary policy decisions (Miranda-Agrippino and Rey (2015) and Bruno and Shin (2015) and affects financial and monetary conditions of emerging market economies through portfolio flows and the international credit and risk channel (Passari and Rey (2015), Rey (2015) and Rey (2016)) such that U.S. interest rate decisions influence the conduct of monetary policy in emerging market economies. Empirical evidence of international monetary spillovers to several emerging market economies is also shown by Anaya et al. (2017) who show that portfolio flows induce these international monetary spillovers from the U.S. to the conduct of monetary policy in emerging market economies.

5 Empirical Results

This chapter discusses the empirical results of the hybrid monetary policy reaction functions of Brazil, Chile, Colombia and Mexico which refer to the long-run time-varying reaction coefficients of the actual and expected inflation gap. The reported results for inflation are depicted together with both underlying variables in this chapter and refer to the time period when the country's central bank operates under a full-fledged inflation targeting regime. The empirical results of the coefficients for the control variables such as the coefficients of speed of adjustment of the policy rate and the long-run reaction coefficients of the real output gap, real exchange rate, real commodity price index and the U.S. effective federal funds rate are depicted together with the respective underlying variable in the figures 5 to 8 which are shifted to Appendix B.

5.1 Monetary Policy in Brazil

The central bank in Brazil adopted the full-fledged inflation targeting regime in 1999 in an ad-hoc policy action within a few months in response to the balance of payment crisis and the subsequent sharp depreciation of the currency. Brazil

abandoned the exchange rate targeting regime and directly shifted to a full-fledged inflation targeting regime combined with a dirty float of the exchange rate and an independently operating monetary policy with price stability as a primary policy objective. This ad-hoc adoption was accompanied with restrictive monetary policy stance in order to reverse the devaluation of the currency and to stop surging inflation. The adoption of the new monetary policy regime occurred within a very short time period under severe economic conditions such that monetary authorities had a lack of time to build up perfect central bank credibility. Furthermore, Brazil was exposed to extreme high inflation rates before 1999 which further undermined a quick build-up of credibility. Hence, monetary policy in Brazil is rather supposed to be partially credible where expected inflation is not fully anchored to the announced inflation target in the first years after the adoption of the new regime and rather follows to some extent actual inflation dynamics. Under these conditions, monetary authorities announced an explicit short-run inflation target for a 12-month horizon in the process of building up central bank credibility since the public is assumed to evaluate the performance of the inflation stabilization policy for the short time horizon. Moreover, monetary authorities started to use the short-term nominal interest rate as a primary monetary policy instrument.

Table 1 reports the descriptive inflation measures for year-on-year actual inflation and 12-month ahead expected inflation of Brazil and refers to the 2002 to 2017 period as well as to two different sub-samples. These inflation measures describe the dynamics of actual and expected inflation and allow to roughly appraise the degree of central bank credibility. Brazil has been exposed to the largest actual inflation rates before and after the adoption of the full-fledged inflation targeting regime among the considered set of countries. Moreover, the central bank of Brazil announces the largest inflation target (range). The actual and expected inflation rate are within the target range in 58.76% and 88.66% of the months within the 2002 to 2017 period whereas this result is benefited by the large inflation target range of 4%. This means that expected inflation is anchored with a high degree within the target range and does not entirely follow actual inflation dynamics.

The average actual inflation rate of 6.64% is substantially above the inflation target and its variance of 7.95 shows that actual inflation repeatedly deviates with a large amplitude from the average inflation rate. The average expected inflation rate of 5.46% is about one percentage point above the inflation tar-

Table 1: Descriptive Inflation Measures for Brazil

Inflation Measures	**2002 - 2017**	**2002 - 2009**	**2010 - 2017**
Inflation Targets	3.5% - 5.5%	3.5% - 5.5%	4.5%
Inflation Target Range	± 2% - 2.5%	± 2% - 2.5%	± 2%
Actual Inflation:			
Within Target Range	58.76%	67.01%	50.00%
Within Upper Target Range	42.78%	39.18%	46.88%
Average Inflation	6.64%	6.91%	6.36%
Variance of Inflation	7.95	12.13	3.56
Average Inflation Gap	2.17%	2.50%	1.86%
Expected Inflation:			
Within Target Range	88.66%	87.76%	89.58%
Within Upper Target Range	64.43%	48.98%	80.21%
Average Inflation	5.46%	5.36%	5.57%
Variance of Inflation	1.93	3.27	0.55
Average Inflation Gap	1.00 %	0.93%	1.07%

Note: Descriptive inflation measures of actual and expected inflation dynamics in Brazil from 2002 to 2017. The inflation measures refer to this entire period and to two sub-samples which refer from 2002 to 2009 (first sub-sample) and from 2010 to 2017 (second sub-sample). The announced inflation target (range) changed several times over the sample.
Source: Authors' calculations.

get and the low variance of 1.93 implies that expected inflation deviates less severely from its average value and fluctuates with a much smaller variability as compared to actual inflation. This confirms the view that expected inflation does not fully follow actual inflation dynamics. Table 2 shows the results from the preliminary empirical analysis which refers to the estimation of the degree of central bank credibility in Brazil by means of equation 3.1. The estimation results show that expected inflation is largely anchored to the inflation target with a coefficient value of 0.7703. Nevertheless, expected inflation is also to some degree driven by actual inflation dynamics with a coefficient value of 0.2845, which is line with the conclusions obtained from the descriptive inflation measures. Hence, expected inflation is partially anchored to the inflation target and thus monetary policy in Brazil turns out to be partially credible to contain inflation at a low and stable level.

Figure 1 depicts the results from the empirical analysis of the hybrid monetary policy reaction function of Brazil and shows the time-varying reaction

Table 2: Empirical Results of Credibility Measures for Brazil

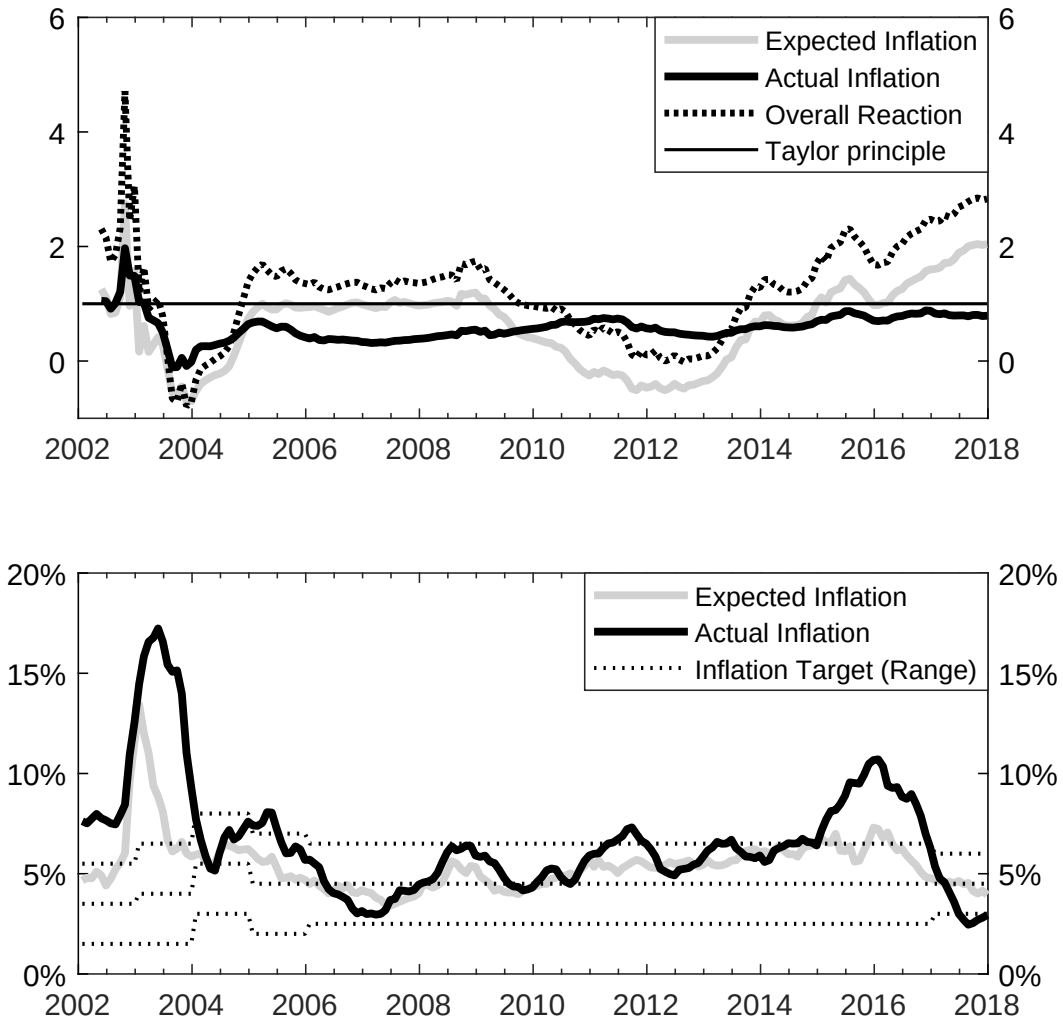
Coefficients	**Actual Inflation**	**Explicit Inflation Target**
2002 - 2017	0.2845	0.7703
	(0.0562)	(0.1261)
2002 - 2009	0.2992	0.6464
	(0.0792)	(0.1864)
2010 - 2017	0.1925	0.8078
	(0.0731)	(0.4570)

Note: Dependence of expected inflation on actual inflation and the announced inflation target in Brazil for the 2002 to 2017 period and two sub-periods. The coefficients are obtained from Bayesian estimation with correction of autocorrelated residuals. Numbers in parenthesis below the estimated coefficients are standard deviations.
Source: Authors' calculations.

coefficients of the expected and actual inflation gap together with the overall reaction coefficients and the Taylor principle in the upper figure. The corresponding expected and actual inflation rates are depicted together with the inflation target (range) in the lower figure. The empirical results point out that monetary authorities respond to both expected and actual inflation rates such that monetary policy is simultaneously backward-looking and forward-looking for most of the considered time period under a partially anchored expected inflation rate. Hence, a limited degree of forward-lookingness is linked to a partially credible central bank. For most of the months, the reaction to actual lagged inflation is accommodative whereas the reaction to expected inflation is almost restrictive except for 2003/04 and the time episode after the global financial crisis. Moreover, the sum of the reaction coefficients of actual and expected inflation indicates the overall reaction of monetary policy to inflation, which turns out to be restrictive since the sum of the coefficient values exceeds one for most of the time which implies that Brazil possibly fulfills the Taylor principle for most of the time.

Preliminary estimation results from table 2 show that the degree of anchoring increases from the first to the second sub-sample while expected inflation is less affected by actual inflation dynamics. The descriptive inflation measures in table 1 show a slight increase of average expected inflation over time but a large drop of volatility of expected inflation from 3.27 to 0.55 which in this

Figure 1: Long-Run Reaction Coefficients for Brazil – Actual Lagged Inflation Gap & Expected Inflation Gap



Note: **Upper Figure:** Time-varying long-run reaction coefficients of the actual and expected inflation gap for Brazil together with the overall reaction coefficients to inflation and the Taylor principle; **Lower Figure:** Actual inflation rate and expected inflation rate 12-months ahead together with the announced inflation target (range) from 2002 to 2017.

present case might be a hint of an increased degree of anchoring to the inflation target since expected inflation fluctuates less around its average value and less around the inflation target. These facts are confirmed by visual inspection of the lower figure in figure 1. In each of the two sub-samples Brazil is exposed to one time episode of a large surge in the actual and expected inflation rate. The two episodes differ considerably in terms of the inflation dynamics and in terms of the reaction of monetary policy. In 2002/03 expected inflation follows

actual inflation dynamics and both exceed substantially the upper bound of the inflation target range, which implies that inflation is not well anchored to the inflation target. In this context, monetary policy reacts decisively to actual and expected inflation with reaction coefficients larger than two, respectively. In 2015 actual inflation exceeds considerably the upper bound of the inflation target range but expected inflation apparently does not follow actual inflation dynamics and remains mostly below the upper bound of the inflation target range which in turn could be a hint of an increased degree of central bank credibility over time. Interestingly, monetary authorities continue to react accommodatively to actual inflation and reacts more decisively to expected inflation with reaction coefficients far above one. Hence, under improved credibility, monetary policy in Brazil put increasingly more priority on stabilizing expected inflation as compared to actual lagged inflation especially when actual inflation jumps above the upper bound of the inflation target. Apparently, monetary authorities assume actual inflation to follow expected inflation dynamics with a lag of a few months which results in a larger degree of forward-lookingness such that monetary policy increasingly becomes more forward-looking over time under improved central bank credibility. However, the conduct of monetary policy in Brazil does not shift to a fully forward-looking policy rule since monetary authorities continue to partly react to lagged actual inflation dynamics. This certainly results from the fact that expected inflation is not sufficiently well anchored to the inflation target on average even though the results from table 2 show that the degree of anchoring improves from 0.6464 to 0.8078 but the dependence on actual inflation only slightly declines from 0.2992 to 0.1925 from the first to the second sub-sample.

5.2 Monetary Policy in Chile

After Chile had implemented price stability as a main monetary policy objective in 1990, the central bank of Chile also obtained full legal, political and operational independence from the government in the same year and was thus able to freely choose the monetary policy regime. The central bank in Chile pursued a dual nominal anchor in the 1990's and followed an exchange rate targeting regime between 1984 and 1999 but the inflation target was the dominant target throughout the 1990's. In 1999 the exchange rate regime was entirely abandoned and the full-fledged inflation targeting regime was adopted with a single

Table 3: Descriptive Inflation Measures for Chile

Inflation Measures	**2002 - 2017**	**2002 - 2009**	**2010 - 2017**
Inflation Targets	3%	3%	3%
Inflation Target Range	± 1%	± 1%	± 1%
Actual Inflation:			
Within Target Range	50.52%	52.04%	48.96%
Within Upper Target Range	20.10%	20.41%	19.79%
Average Inflation	3.18%	3.29%	3.07%
Variance of Inflation	4.66	7.68	1.57
Average Inflation Gap	0.18%	0.29%	0.07%
Expected Inflation:			
Within Target Range	92.27%	89.80%	96.88%
Within Upper Target Range	29.90%	21.43%	38.54%
Average Inflation	3.09%	3.09%	3.10%
Variance of Inflation	0.31	0.52	0.10
Average Inflation Gap	0.09 %	0.08%	0.10%

Note: Descriptive inflation measures of actual and expected inflation dynamics in Chile from 2002 to 2017. The inflation measures refer to this entire period and to two sub-samples which refer from 2002 to 2009 (first sub-sample) and from 2010 to 2017 (second sub-sample).
Source: Authors' calculations.

nominal anchor of inflation stabilization which in turn was accompanied with a rather free floating exchange rate. Moreover, monetary authorities started to use the short-term nominal interest rate as a primary monetary policy instrument. In Chile, monetary policy pursued a gradual transition to a full-fledged inflation targeting regime which resulted in the opportunity to gradually build up central bank credibility over a long time horizon even before the adoption of the new regime. Moreover, Chile was exposed to low inflation rates during this episode which certainly further supported the build-up of central bank credibility. Hence, the central bank in Chile is supposed to have already a high degree of credibility and thus well anchored expected inflation in the first years after the adoption of the new regime. The explicit inflation target refers to a 12-month horizon as a short-run objective such that monetary policy is supposed to target the stabilization of expected inflation in the short-run.

The descriptive inflation measures for Chile are reported in table 3 and show the most relevant descriptive measures of expected and actual inflation.

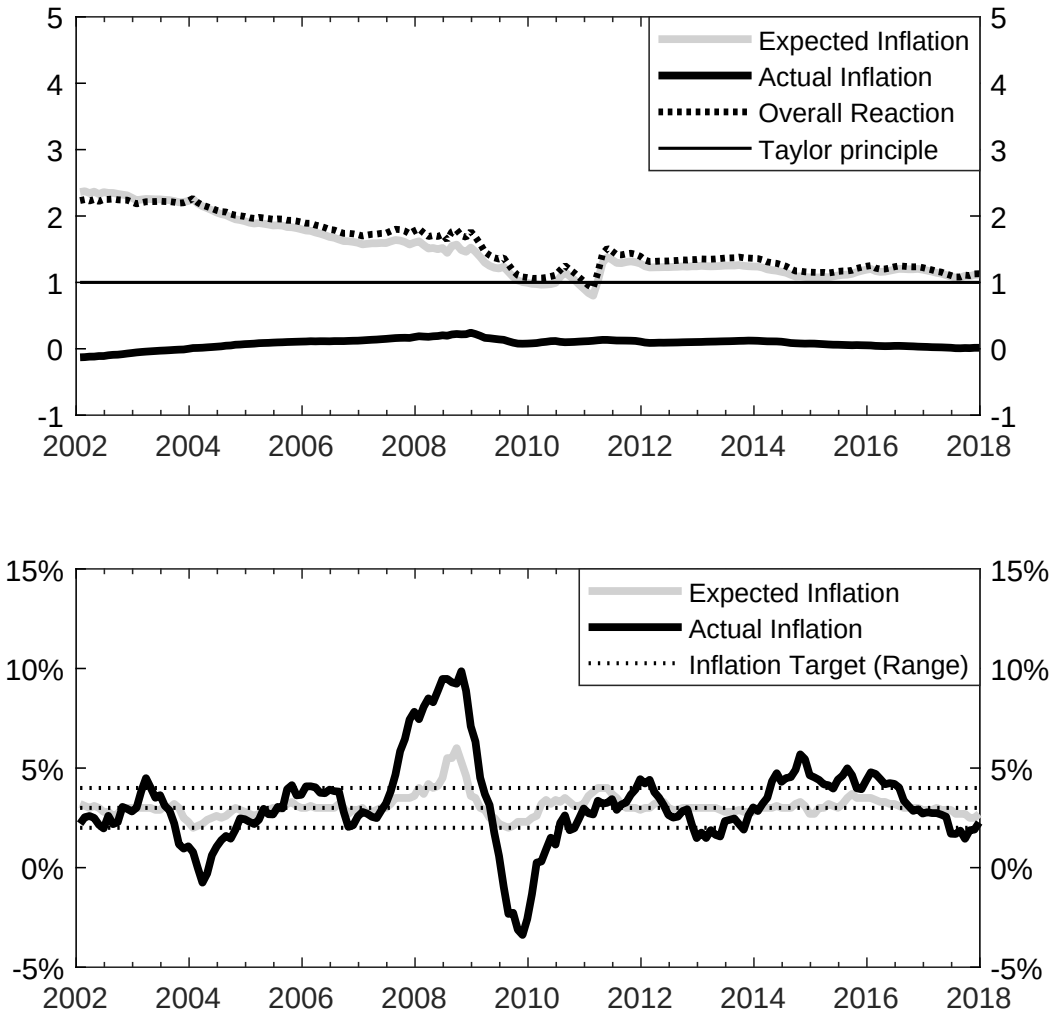
Table 4: Empirical Results of Credibility Measures for Chile

Coefficients	Actual Inflation	Explicit Inflation Target
2002 - 2017	0.1479	0.8599
	(0.0253)	(0.0710)
2002 - 2009	0.1562	0.8242
	(0.0369)	(0.1913)
2010 - 2017	0.1083	0.8105
	(0.0363)	(0.3142)

Note: Dependence of expected inflation on actual inflation and the announced inflation target in Chile for the 2002 to 2017 period and two sub-periods. The coefficients are obtained from Bayesian estimation with correction of autocorrelated residuals. Numbers in parenthesis below the estimated coefficients are standard deviations.
Source: Authors' calculations.

The inflation target amounts to 3% for the entire 2002 to 2017 period. The table shows that actual inflation is within the inflation target range in 50.52% of the months of the considered period under a rather tight target range of 2%. The average actual inflation rate of 3.18% is very close to the inflation target. Nevertheless, actual inflation is relatively volatile and has a variance of 4.66, which implies that actual inflation deviates temporarily to a large degree from average inflation and the inflation target. The expected inflation rate is within the inflation target in 92.27% of the months between 2002 and 2017 such that expected inflation is well anchored within the inflation target range. The average expected inflation of 3.09% is very close to the inflation target of 3%. Moreover, the variance of expected inflation of 0.31 is relatively low compared to actual inflation, which implies that expected inflation is much less volatile as actual inflation and fluctuates closely around its average value. Hence, expected inflation is well anchored to the inflation target and thus monetary policy has nearly perfect credibility to contain inflation close to the inflation target. Table 4 refers to the preliminary analysis of estimating the degree of central bank credibility and provides evidence that expected inflation dynamics are largely affected by the inflation target (0.8599) and that expected inflation is rather weakly affected by actual inflation dynamics (0.1479). This empirical evidence confirms the previous conclusions from the descriptive inflation measures that expected inflation is well anchored to the inflation target.

Figure 2: Long-Run Reaction Coefficients for Chile – Actual Lagged Inflation Gap & Expected Inflation Gap



Note: **Upper Figure:** Time-varying long-run reaction coefficients of the actual and expected inflation gap for Chile together with the overall reaction coefficients to inflation and the Taylor principle; **Lower Figure:** Actual inflation rate and expected inflation rate 12-months ahead together with the announced inflation target (range) from 2002 to 2017.

Figure 2 depicts the results from the empirical analysis of the hybrid monetary policy reaction function of Chile and shows the time-varying reaction coefficients of the actual and expected inflation gap together with the overall reaction coefficients and the Taylor principle in the upper figure. The corresponding expected and actual inflation rate are depicted together with the inflation target (range) in the lower figure. This analysis provides evidence that monetary policy in Chile exclusively responds to expected inflation and totally

omits to react to actual inflation between 2002 and 2017. Hence, monetary policy is fully forward-looking under nearly perfect central bank credibility. Moreover, monetary authorities mostly respond decisively to expected inflation since the reaction coefficients exceed almost always the value of one such that the Taylor principle is supposed to be fulfilled and thus the condition for a stable inflation path.

Additionally, the descriptive inflation measures show that the average actual and expected inflation rate as well as the corresponding variances decrease from the first to the second sub-sample (table 3) which means that both inflation measures fluctuate closer to the respective average inflation value and the inflation target. This is also confirmed by the visual inspection of the lower figure in figure 2 where expected and actual inflation are apparently larger on average and more volatile from the 2002 to 2009 period as compared to the second sub-sample from the 2010 to 2017 period. The preliminary empirical analysis of central bank credibility shows that the degree of anchoring remained unchanged while the degree of dependence of expected inflation on actual inflation dynamics slightly decreases over time from 0.1562 to a very low value of 0.1083. This improved degree of anchoring of expected inflation and the simultaneous drop of dependence lead to an obvious decline of the reaction coefficients close to but above the value of one. Thus, monetary policy apparently became more effective since a lower reaction is required to contain expected inflation close to the announced inflation target. Moreover, it is interesting to see within the first sub-sample between 2007 and 2009 that monetary policy solely reacts to expected inflation and omits to react to actual inflation even though actual inflation first largely exceeds and later undercuts the inflation target range while expected inflation is within the target range except for a few months. Apparently, monetary authorities fully trust in stabilizing actual inflation dynamics by reacting exclusively to expected inflation in the conduct of monetary policy assuming that actual inflation will follow expected inflation with a lag of a few months.

5.3 Monetary Policy in Colombia

In 1991 the central bank in Colombia implemented price stability as a main monetary policy objective in terms of maintaining the value of the national currency. Moreover, monetary policy obtained greater political and operational

independence from the government due to a new constitution and the mandate of price stability was performed by means of an exchange rate targeting regime. In 1999 the full-fledged inflation targeting regime was adopted after monetary policy was forced to abandon the exchange rate targeting regime under the specific economic condition of a large devaluation of the domestic currency. The legal changes in the early 1990's and the economic circumstances in terms of large volatility of capital flows at the end of the 1990's smoothed the way for a rather gradual transition to a full-fledged inflation targeting. Hence, monetary policy had the opportunity to gradually build up central bank credibility in terms of stabilizing inflation. However, Colombia was exposed to large inflation rates before 1999 which undermined the build-up of perfect central bank credibility. Monetary policy is assumed to be partially credible and is supposed to be in a process of building up a credible central bank. The inflation target is announced for a 12-month horizon and serves as a short-run objective where monetary authorities address the stabilization of short-run expected inflation. In 1999, monetary policy started to use the short-term nominal interest rate as a primary monetary policy instrument.

The descriptive inflation measures for Colombia are reported in table 5 and refer to both expected and actual inflation dynamics. In Colombia the inflation target was steadily declined from 5.5% in 2003 to 3% in 2010 and remained at 3% from 2010 to 2017. The actual inflation rate is within the target range in 50.58% of the months of the considered time period while expected inflation is within the target range in 76.74% of the considered months which means that expected inflation does not entirely follow actual inflation dynamics. The average actual inflation rate amounts to 4.52% which is substantially above the inflation target in the 2003 to 2017 period. This is also confirmed by the average actual inflation gap of 0.77% which reflects the average deviation of actual inflation from the target. The variance of actual inflation is 3.06 and thus much lower as in Brazil and even as in Chile which implies that actual inflation is less volatile and fluctuates closer around the average actual inflation rate as in the previous two countries. The average expected inflation rate is 4.07% and is much closer to the inflation target as compared to actual inflation which confirms the previous conclusion that expected inflation does not fully follow actual inflation dynamics and is partially anchored to the inflation target. The volatility of expected inflation is moderate with 0.67 such that expected inflation fluctuates with a rather low amplitude around the average

Table 5: Descriptive Inflation Measures for Colombia

Inflation Measures	**2003 - 2017**	**2003 - 2009**	**2010 - 2017**
Inflation Targets	3% - 5.5%	4% - 5.5%	3%
Inflation Target Range	± 0.5% - 1%	± 0.5%	± 1%
Actual Inflation:			
Within Target Range	50.58%	40.79%	58.33%
Within Upper Target Range	26.16%	19.74%	31.25%
Average Inflation	4.52%	5.75%	3.83%
Variance of Inflation	3.06	1.58	3.16
Average Inflation Gap	0.77%	0.69%	0.83%
Expected Inflation:			
Within Target Range	76.74%	77.63%	83.33%
Within Upper Target Range	54.65%	27.63%	76.04%
Average Inflation	4.07%	4.82%	3.47%
Variance of Inflation	0.67	0.29	0.17
Average Inflation Gap	0.31 %	0.11%	0.47%

Note: Descriptive inflation measures of actual and expected inflation dynamics in Colombia from 2003 to 2017. The inflation measures refer to this entire period and to two sub-samples which refer from 2003 to 2009 (first sub-sample) and from 2010 to 2017 (second sub-sample). The inflation target (range) changed several times over the sample.
Source: Authors' calculations.

expected inflation rate. This aspect is confirmed by the empirical results of the preliminary analysis where the degree of central bank credibility is estimated. The results are reported in table 6 and provide evidence that expected inflation is anchored to the inflation target (0.7346) but in comparison to Chile, expected inflation follows with a larger degree actual inflation dynamics (0.2717) in the 2003 to 2017 period. This implies that expected inflation is not fully anchored to the inflation target and thus that the central bank is partially credible to contain inflation at a low and stable level.

Figure 3 presents the empirical results of the hybrid monetary policy reaction function of Colombia and shows the time-varying coefficients of the actual and expected inflation gap together with the overall reaction coefficients and the Taylor principle in the upper figure. The corresponding expected and actual inflation rate are depicted together with the announced inflation target (range) in the lower figure. The empirical analysis turns out that monetary policy responds to both actual and expected inflation while monetary authorities to-

Table 6: Empirical Results of Credibility Measures for Colombia

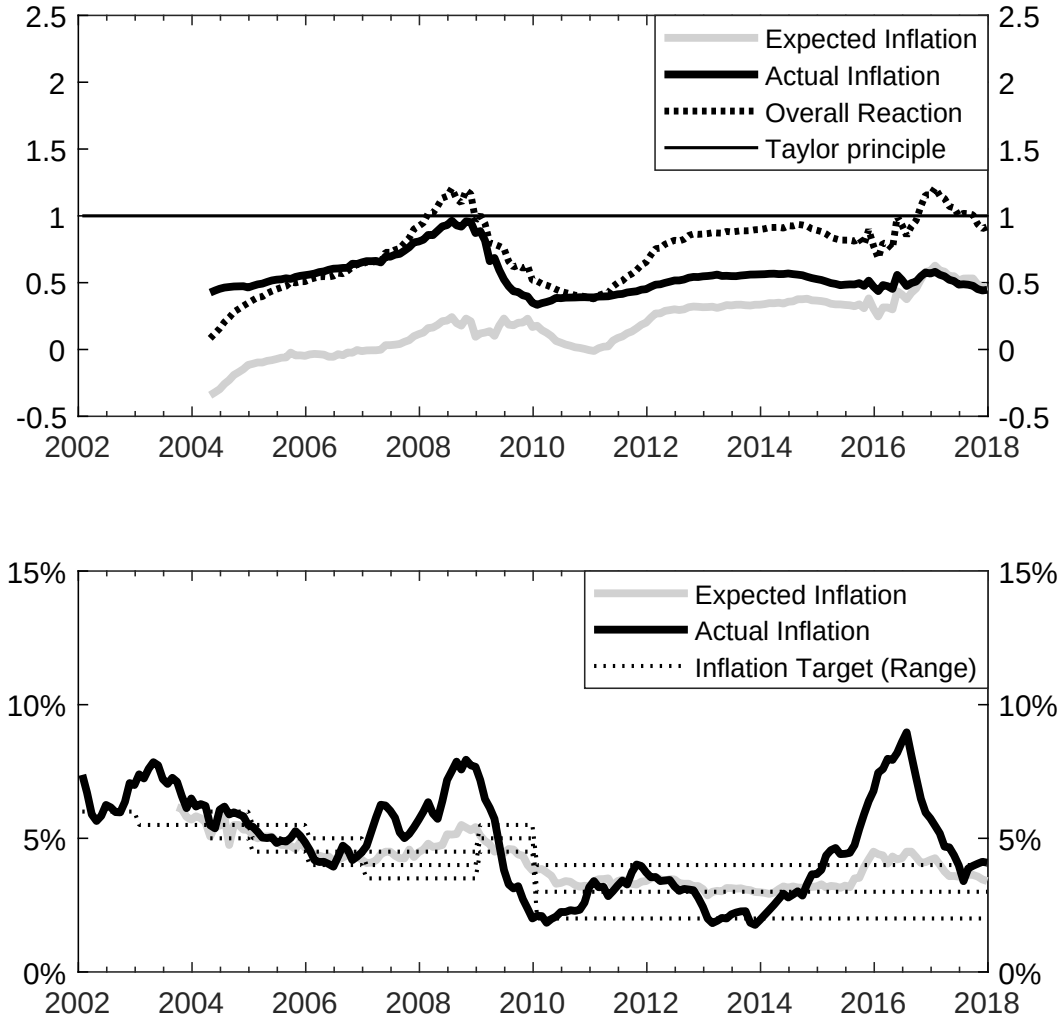
Coefficients	Actual Inflation	Explicit Inflation Target
2002 - 2017	0.2717	0.7346
	(0.0193)	(0.0253)
2002 - 2009	0.3214	0.6484
	(0.0264)	(0.0309)
2010 - 2017	0.2183	0.8686
	(0.0116)	(0.0167)

Note: Dependence of expected inflation on actual inflation and the announced inflation target in Colombia for the 2003 to 2017 period and two sub-periods. The coefficients are obtained from Bayesian estimation with correction of autocorrelated residuals. Numbers in parenthesis below the estimated coefficients are standard deviations.
Source: Authors' calculations.

tally omit to react to expected inflation in the first years of the considered time period. After 2007 monetary policy is backward-looking and forward-looking under a partially credible monetary policy regime. The reaction to actual inflation is always accommodative with reaction coefficients below one except for the episode of the global financial crisis where monetary authorities react decisively to a jump of actual inflation. The reaction to expected inflation is always accommodative with coefficients below one such that monetary authorities put priority on reacting to actual lagged inflation dynamics. The overall reaction to actual and expected inflation is mostly below but close to one, which means that monetary policy does not fulfill the Taylor principle for most of the time such that the inflation dynamics are certainly not always on a stable inflation path.

The descriptive inflation measures of Colombia show that the average actual and expected inflation decrease from the first to the second sub-sample (table 5) which means that the degree of anchoring of expected inflation is improved over time and the decreased variance implies that expected inflation fluctuates closer around their average values in the second sub-sample. The preliminary empirical analysis (table 6) shows that the degree of anchoring of expected inflation to the inflation target is substantially improved over time with a change in the coefficient value from 0.6484 to 0.8686 from the first to the second sub-sample. Simultaneously, the expected inflation rate follows less

Figure 3: Long-Run Reaction Coefficients for Colombia – Actual Lagged Inflation Gap & Expected Inflation Gap



Note: **Upper Figure:** Time-varying long-run reaction coefficients of the actual and expected inflation gap for Colombia together with the overall reaction coefficients to inflation and the Taylor principle; **Lower Figure:** Actual inflation rate and expected inflation rate 12-months ahead together with the announced inflation target (range) from 2002 to 2017.

actual inflation dynamics which results from the decline of the corresponding coefficient value from 0.3214 to 0.2183 from the first to the second sub-sample which in turn indicates improved central bank credibility. This conclusion is confirmed by visual inspection of the inflation dynamics from 2010 to 2017 in the lower figure of figure 3 where actual inflation deviates substantially from the target from time to time and exceeds or undercuts the inflation target range. At the same time expected inflation does not follow actual inflation dynamics

and remains within the target range and close to the inflation target. Interestingly, the responsiveness of monetary policy to expected inflation increases over this period with a simultaneous increase of the degree of anchoring of expected inflation. Hence, the degree of forward-lookingness of monetary policy related to stabilizing inflation increases under improved central bank credibility. In 2016 and 2017 monetary authorities react equally in magnitude to actual and expected inflation and thus monetary policy becomes equally backward- and forward-looking in terms of stabilizing inflation.

5.4 Monetary Policy in Mexico

In Mexico the central bank abandoned the exchange rate targeting regime in the wake of the balance of payment crisis and the financial crisis in 1995 which was accompanied with a surge in inflation. At the same time, monetary policy adopted a managed float of the exchange rate and started to announce inflation targets. In 1998 monetary policy started to transit gradually towards a full-fledged inflation targeting regime by reinforcing the role of inflation targets. In 2001 monetary policy adopted the full-fledged inflation targeting regime and monetary authorities set price stability as the main objective of monetary policy. The central bank in Mexico experienced a rather long transition path towards a full-fledged inflation targeting regime with the opportunity of a gradual build-up of central bank credibility. However, monetary policy were exposed to large inflation rates during this episode which undermined the build-up of prefect central bank credibility such that monetary authorities are supposed to be partially credible at the time point when the new regime was adopted. The announced inflation target is interpreted as short-run to medium-run objective such that monetary policy is assumed to target the stabilization of short-run expected inflation. Moreover, monetary authorities started to use the short-term nominal interest rate not until 2008 such that the subsequent analysis starts in this year.

The descriptive inflation measures of Mexico are reported in table 7 and illustrate the dynamics of both actual and expected inflation rates of the 2008 to 2017 period. After the adoption of the new monetary policy regime, the central bank announced different inflation targets over time and the target was declined over time from 4.5% in 2002 to 3% in 2003 and remained at this level thereafter. The actual and expected inflation rates are within the

Table 7: Descriptive Inflation Measures for Mexico

Inflation Measures	**2008 - 2017**	**2008 - 2012**	**2013 - 2017**
Inflation Targets	3%	3%	3%
Inflation Target Range	± 1%	± 1%	± 1%
Actual Inflation:			
Within Target Range	51.67%	43.33%	60.00%
Within Upper Target Range	37.50%	43.33%	31.67%
Average Inflation	4.15%	4.42%	3.88%
Variance of Inflation	1.34	0.91	1.65
Average Inflation Gap	1.15%	1.42%	0.88%
Expected Inflation:			
Within Target Range	72.50%	50.00%	95.00%
Within Upper Target Range	72.50%	50.00%	95.00%
Average Inflation	3.87%	4.07%	3.66%
Variance of Inflation	0.12	0.10	0.05
Average Inflation Gap	0.87%	1.07%	0.66%

Note: Descriptive inflation measures of actual and expected inflation dynamics in Mexico from 2008 to 2017. The inflation measures refer to this entire period and to two sub-samples which refer from 2008 to 2012 (first sub-sample) and from 2013 to 2017 (second sub-sample). *Source:* Authors' calculations.

target range in 51.67% and 72.50% of the months in the 2008 to 2017 period, respectively. This implies that expected inflation is mostly within the inflation target range and does not fully follow actual inflation dynamics. The average actual inflation rate of 4.15% is over 1% above the inflation target and the variance of 1.34 is relatively low compared to the other considered countries such that actual inflation deviates substantially from the target on average but inflation fluctuates with a low amplitude. The average expected inflation of 3.88% deviates to some degree from the inflation target but has low volatility since the variance is small and only amounts to 0.12 over the 2008 to 2017 period. Hence, the descriptive measures show that the degree of anchoring of expected inflation to the inflation target is limited such that monetary policy in Mexico is partially credible to contain inflation at a low level and close to the announced inflation target.

The visual inspection of figure 4 (lower figure) supports these conclusions but provides further insights about the inflation dynamics. This figure reveals

Table 8: Empirical Results of Credibility Measures for Mexico

Coefficients	Actual Inflation	Implicit Inflation Target
2008 - 2017	0.2363	0.6848
	(0.0303)	(0.0315)
2008 - 2012	0.6160	0.2604
	(0.0642)	(0.0665)
2013 - 2017	0.0643	0.8956
	(0.0317)	(0.0354)

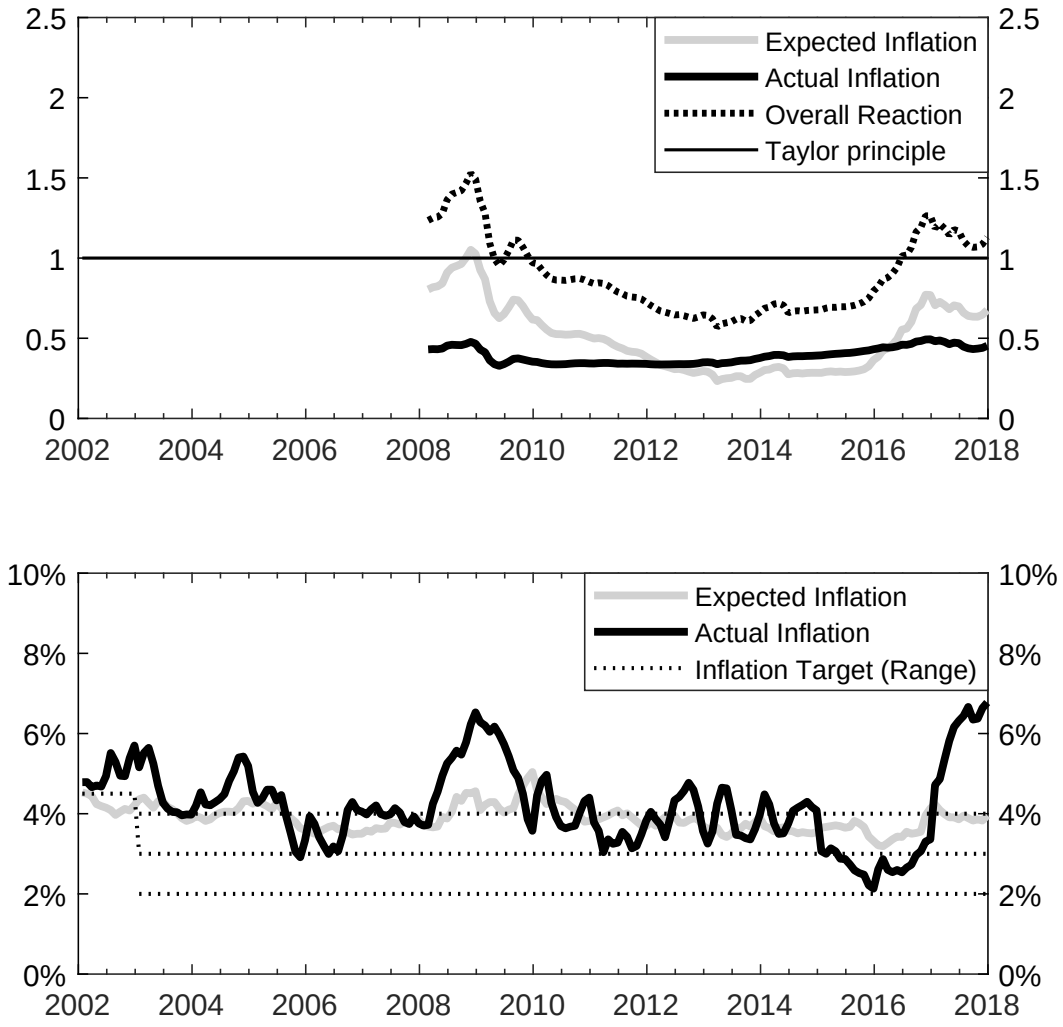
Note: Dependence of expected inflation on actual inflation and an assumed implicit inflation target in Mexico for the 2008 to 2017 period and sub-periods. The coefficients are obtained from Bayesian estimation with correction of autocorrelated residuals. Numbers in parenthesis below the estimated coefficients are standard deviations.
Source: Authors' calculations.

that expected inflation always exceeds the announced explicit inflation target and fluctuates closely to the upper bound of the inflation target which also applies to actual inflation dynamics for most of the time until 2015. This raises the question whether the public supposes monetary policy to have an implicit unknown inflation target which exceeds the officially announced inflation target. The preliminary analysis of central bank credibility confirms this impression since the empirical results show no plausible coefficient values for the degree of anchoring of expected inflation and for the coefficient of actual lagged inflation when the analysis is based on the officially announced 3% explicit inflation target. In contrast, these coefficient values turn out to be plausible and are within the defined range as outlined in chapter 2 when the announced inflation target is replaced by an implicit inflation target which is assumed to be the upper bound of the announced inflation target of 4%. The empirical results are reported in table 8 and provide plausible coefficient values and show evidence that expected inflation is partially anchored to the upper bound of the inflation target (0.6848) but still follows actual inflation dynamics (0.2363).

Figure 4 (upper figure) depicts the empirical results of the hybrid monetary policy reaction function for Mexico and shows the time-varying reaction coefficients of the actual and expected inflation gap together with the overall reaction coefficients and the Taylor principle. The empirical results point out that monetary authorities react to both the actual and expected inflation

gap such that monetary authorities are simultaneously backward-looking and forward-looking under a partially credible central bank.

Figure 4: Long-Run Reaction Coefficients for Mexico – Actual Lagged Inflation Gap & Expected Inflation Gap



Note: **Upper Figure:** Time-varying long-run reaction coefficients of the actual and expected inflation gap for Mexico together with the overall reaction coefficients to inflation and the Taylor principle; **Lower Figure:** Actual inflation rate and expected inflation rate 12-months ahead together with the announced inflation target (range) from 2002 to 2017.

Mexico is exposed to two major inflationary events in the 2008 to 2017 period. The first jump of actual inflation occurs in 2008 during the global financial crisis and after monetary authorities adopted the short-term nominal interest rate as a main monetary policy instrument. Actual inflation exceeds the upper bound of the inflation target by up to 2% and also expected inflation

exceeds the upper bound and follows partly actual inflation dynamics. The reaction to expected inflation is restrictive for a very short time period during the global financial crisis but declined thereafter which results in coefficient values below one. The reaction to actual inflation is always accommodative and results in coefficients below one independent of the current level actual inflation. The second jump of actual inflation occurs in 2016/17 when actual inflation exceeds the upper bound of the inflation target by up to 2.5%. At the same time, expected inflation is well anchored since expected inflation remains within the target range and decouples from actual inflation dynamics, which implies that the degree of anchoring of expected inflation improved over time. This confirms the improved forward-lookingness under a higher degree of central bank credibility. This conclusion is confirmed by the descriptive inflation measures since average actual and expected inflation decline from the first to the second sub-sample (table 7) and volatility of inflation measures decrease and inflation is closer to the respective average inflation rate. Moreover, the results of the preliminary analysis of table 8 shows that the degree of anchoring of expected inflation to the implicit inflation target increases from the first to the second sub-sample which is illustrated by the change of the coefficient from 0.2604 to 0.8956. At the same time expected inflation turns out to be less affected by actual inflation dynamics since the coefficient declines from 0.6160 to 0.0643. Except for the financial crisis period, the overall reaction to inflation is accommodative in the first sub-sample but the improved credibility increases the degree of forward-lookingness of monetary policy in the second sub-sample. Apparently, monetary authorities react decisively in time episodes of high inflationary pressure and conduct an accommodative monetary policy in times of rather low inflationary pressure where actual and expected inflation are mostly within the target range.

6 Conclusion

This paper empirically investigates the evolution of the forward-lookingness of monetary policy in terms of stabilizing inflation under different degrees of central bank credibility for the four largest Latin American economies, which adopted the full-fledged inflation targeting regime. This analysis applies a hybrid monetary policy reaction function with time-varying coefficients which allows to estimate the changing reaction to both the expected inflation gap

and the lagged actual inflation gap over time. Hence, this model allows to capture a possible transition from a backward-looking to a forward-looking monetary policy regime in terms of stabilizing inflation which might occur under a changing degree of central bank credibility.

The main empirical results provide evidence that the forward-lookingness of monetary policy in terms of stabilizing inflation depends on the degree of central bank credibility and thus on the ability of policy-makers to anchor expected inflation to the announced inflation target. If the central bank has nearly perfect credibility, monetary policy is fully forward-looking and exclusively reacts to expected inflation dynamics. Moreover, the reaction to expected inflation is always restrictive such that inflation apparently follows a stable inflation path. If the central bank is partially credible, monetary policy reacts to both expected and actual inflation dynamics and thus is simultaneously backward-looking and forward-looking in terms of stabilizing inflation but the overall reaction to inflation is repeatedly accommodative. Furthermore, central banks gradually transit from a backward-looking to a rather forward-looking monetary policy if central bank credibility tends to improve over time.

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Appendix A: Data Description and Data Sources

Table 9: Description and Sources of Variables

Variables for Brazil	Description	Source
Nominal Interest Rate	SELIC rate (overnight interest rate) as key monetary policy instrument	Banco Central do Brazil
Real Output Gap	The real output gap is defined as the percentage deviation of actual real GDP from its potential value. The output gap is based on monthly real GDP which is calculated from monthly nominal GDP which is provided by the Central Bank of Brazil. Potential real GDP is calculated by means of the asymmetric band-pass filter of Christiano and Fitzgerald (2003)	Banco Central do Brazil and author's calculation.
Actual Inflation Gap	The actual inflation gap is defined as the percentage deviation of actual inflation from the target inflation rate and is used on a monthly frequency. The inflation rate is based on the Headline Broad National Consumer Price Index (IPCA) and is calculated on a year-on-year basis. The inflation target refers to a 12-month horizon	Banco Central do Brazil
Expected Inflation Gap	The future expected inflation gap is defined as the percentage deviation of expected inflation from the target inflation rate and is used on a monthly frequency. The expected inflation rate refers to 12-month ahead expectations	Banco Central do Brazil
Real Exchange Rate	The real exchange rate is defined as a ratio of Brazilian Real relative to the U.S. dollar and is used as a year-on-year growth rate	Banco Central do Brazil

Variables for Chile	Description	Source
Nominal Interest Rate	Monetary policy interest rate (MPR) which is an overnight interbank rate	Banco Central de Chile
Real Output Gap	The real output gap is defined as the percentage deviation of actual real output from its potential value. The output gap is based on a monthly economic activity index (Indicator Mensual de Actividad Económica en Chile (IMACEC)) which covers about 90 % of total GDP in Chile. Potential real output is calculated with the asymmetric band-pass filter of Christiano and Fitzgerald (2003)	Banco Central de Chile and author's calculation.
Actual Inflation Gap	The actual inflation gap is defined as the percentage deviation of actual inflation from the target inflation rates and is used on a monthly frequency. The inflation rate is based on the Headline Consumer Price Index and is calculated on a year-on-year basis. The inflation target refers to a 12-month horizon	Banco Central de Chile
Expected Inflation Gap	The future expected inflation gap is defined as the percentage deviation of expected inflation from the target inflation rates and is used on a monthly frequency. The expected inflation rate refers to 12-month ahead expectations	Banco Central de Chile
Real Exchange Rate	The real exchange rate is defined as a ratio of Chilean Peso relative to the U.S. dollar and is used as a year-on-year growth rate	Banco Central de Chile

Variables for Colombia	Description	Source
Nominal Interest Rate	Intervention interest rate as a key monetary policy rate (but other instruments are also used)	Banco de la República, Colombia
Real Output Gap	The real output gap is defined as the percentage deviation of actual real output from its potential value. The output gap is based on a monthly industrial production index. Potential real output is calculated with the asymmetric band-pass filter of Christiano and Fitzgerald (2003)	Banco de la República, Colombia and author's calculation

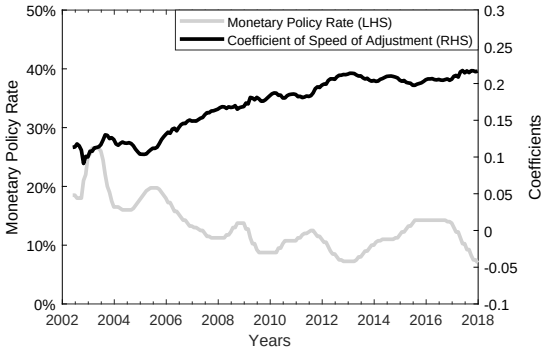
Table 9: Description and Sources of Variables

Actual Inflation Gap	The actual inflation gap is defined as the percentage deviation of actual inflation from the target inflation rates and is used on a monthly frequency. The inflation rate is based on the Headline Consumer Price Index and is calculated on a year-on-year basis. The inflation target refers to a 12-month horizon	Banco de la República, Colombia
Expected Inflation Gap	The future expected inflation gap is defined as the percentage deviation of expected inflation from the target inflation rates and is used on a monthly frequency. The expected inflation rate refers to 12-month ahead expectations	Banco de la República, Colombia
Real Exchange Rate	The real exchange rate is defined as a ratio of Colombian Peso relative to the U.S. dollar and is used as a year-on-year growth rate	Banco de la República, Colombia
Variables for Mexico	**Description**	**Source**
Nominal Interest Rate	Monetary policy rate (Tasa de fondeo bancario) is used since Jan. 2008. Before 2008: Level of commercial banks' current account balances at the Central Bank used as monetary policy instrument (corto mechanism)	Banco Central de México
Real Output Gap	The real output gap is defined as the percentage deviation of actual real output from its potential value. The output gap is based on a monthly economic activity index (Indicator Global de la Actividad Económica (IGAE)) which covers about 90 % of total GDP in Mexico. Potential real output is calculated with the asymmetric band-pass filter of Christiano and Fitzgerald (2003)	Banco Central de México
Actual Inflation Gap	The actual inflation gap is defined as the percentage deviation of actual inflation from the target inflation rates and is used on a monthly frequency. The inflation rate is based on the Headline CPI and is calculated on a year-on-year basis. The inflation target refers to a 12-month horizon	Banco Central de México
Expected Inflation Gap	The future expected inflation gap is defined as the percentage deviation of expected inflation from the target inflation rates and is used on a monthly frequency. The expected inflation rate refers to 12-month ahead expectations	Banco Central de México
Real Exchange Rate	The real exchange rate is defined as a ratio of Mexican Peso relative to the U.S. dollar and is used as a year-on-year growth rate	Banco Central de México
Additional Variable	**Description**	**Source**
Real Commodity Returns	Real commodity returns are based on a country-specific commodity price index which reflects the price dynamics of the main imported commodities and might have an impact on domestic inflation dynamics. The returns are calculated as growth rates on a year-on-year basis	Author's calculation, commodity prices are from Goldman Sachs (GSCI) and the index weights are commodity imports from UN Comtrade
U.S. Effective Federal Funds Rate	U.S. monetary policy interest rate. From January 2009 to December 2015 the U.S. federal funds rate is replaced by the shadow rate provided by Wu and Xia (2016) in order to account for the Quantitative Easing program of the U.S. Federal Reserve Bank	U.S. Federal Reserve Bank

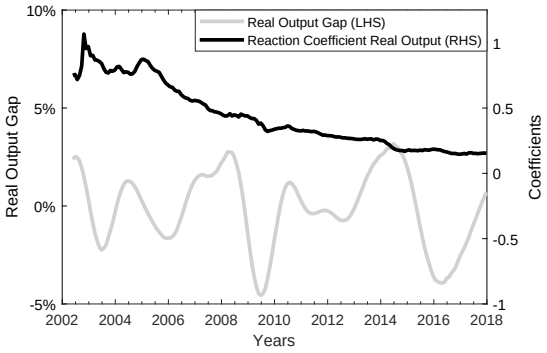
Appendix B: Empirical Results of the Control Variables

Figure 5: Long-Run Reaction Coefficients for Brazil

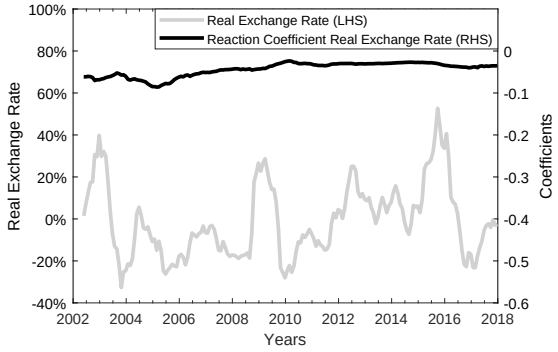
(a) Speed of Adjustment



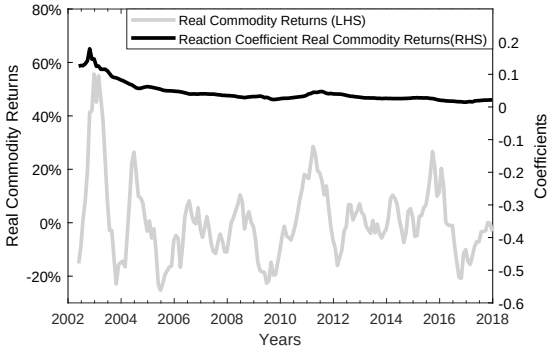
(b) Real Output Gap



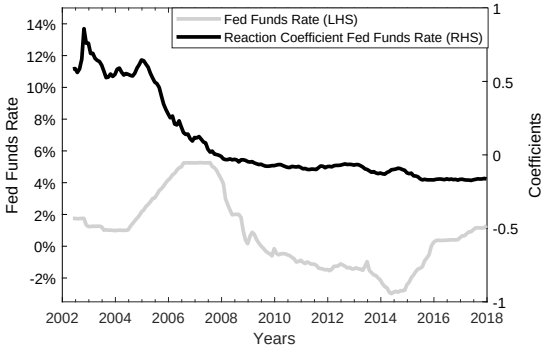
(c) Real Exchange Rate



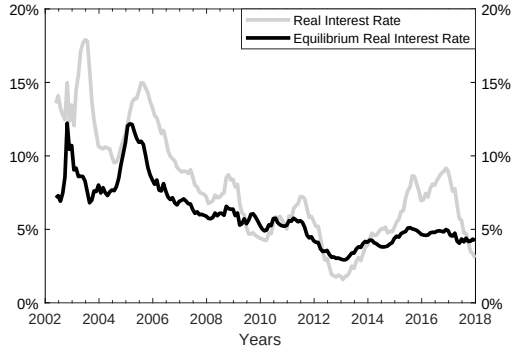
(d) Real Commodity Price Returns



(e) U.S. Effective Federal Funds Rate



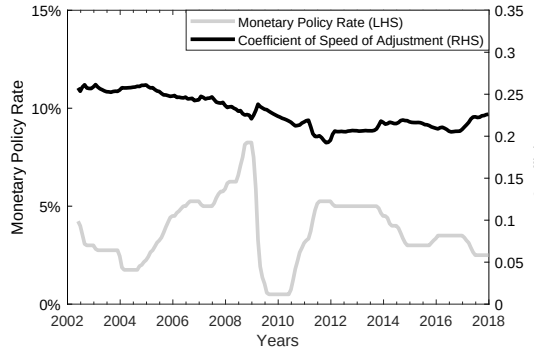
(f) Real Interest Rate



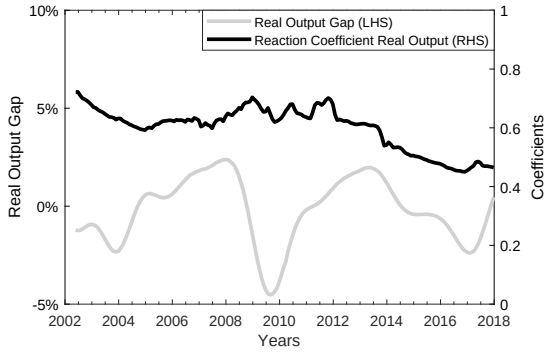
Note: Time-varying long-run reaction coefficients for the control variables of the monetary policy rule of Brazil: Black line – time-varying coefficient values of the respective variable (right scale); gray line – respective underlying variables (left scale).

Figure 6: Long-Run Reaction Coefficients for Chile

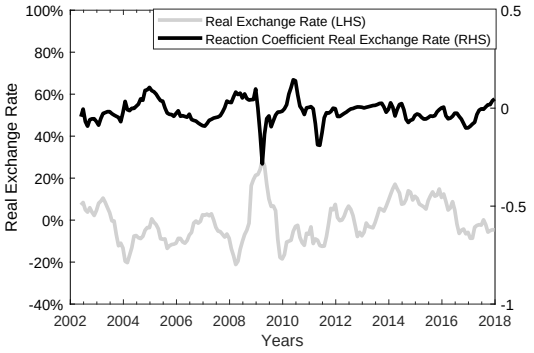
(a) Speed of Adjustment



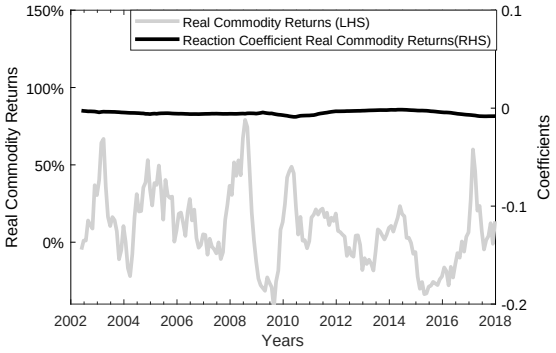
(b) Real Output Gap



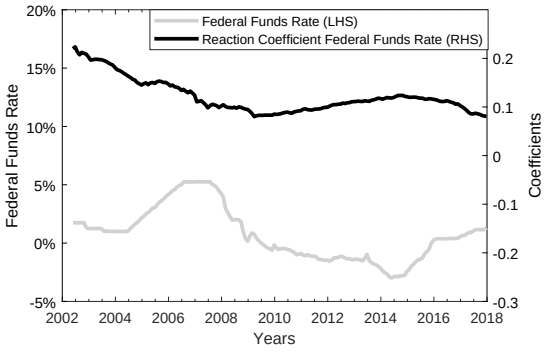
(c) Real Exchange Rate



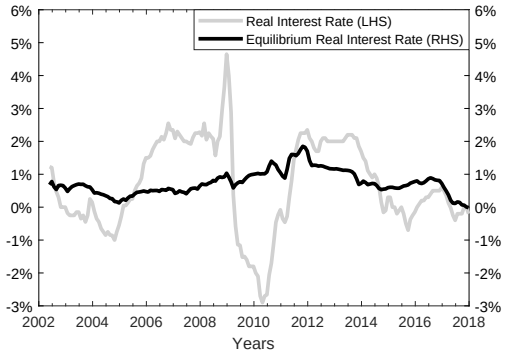
(d) Real Commodity Price Returns



(e) U.S. Effective Federal Funds Rate



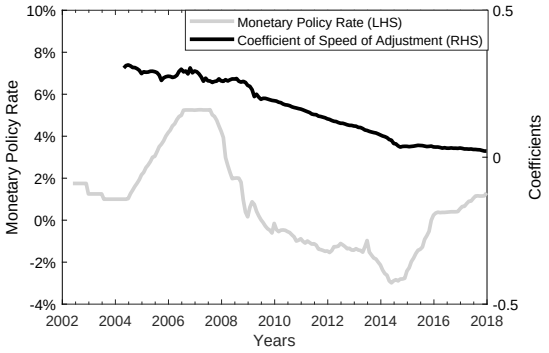
(f) Real Interest Rate



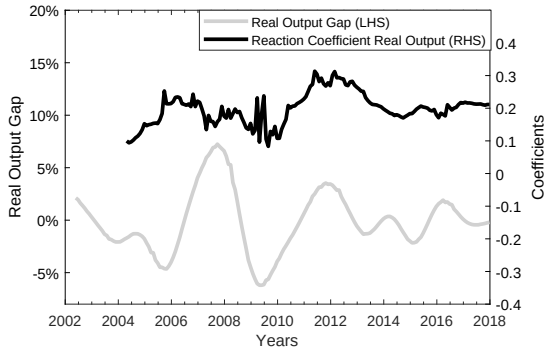
Note: Time-varying long-run reaction coefficient for the control variables of the monetary policy rule of Chile: Black line – time-varying coefficient values of the respective variable (right scale); gray line – respective underlying variables (left scale).

Figure 7: Long-Run Reaction Coefficients for Colombia

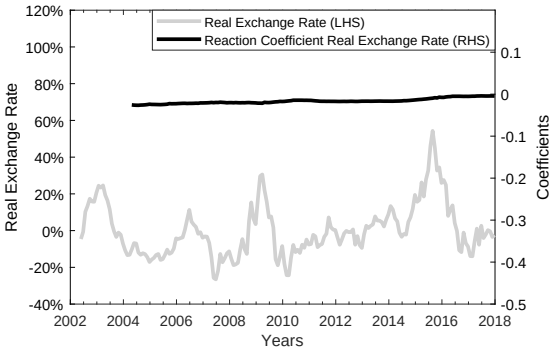
(a) Speed of Adjustment



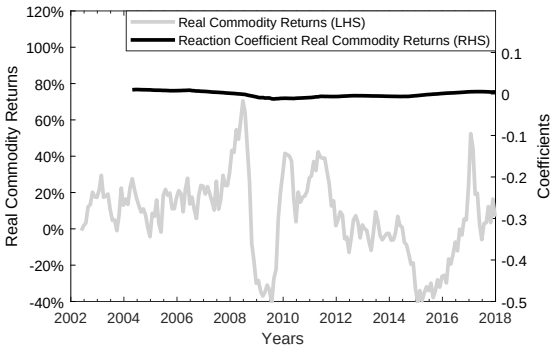
(b) Real Output Gap



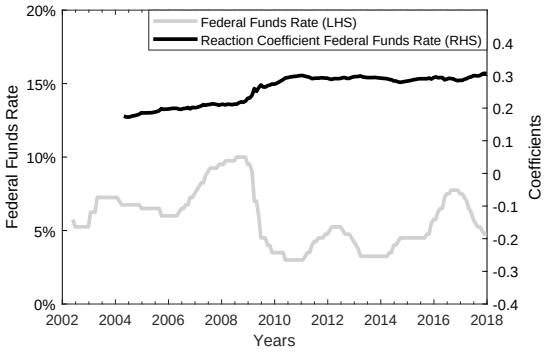
(c) Real Exchange Rate



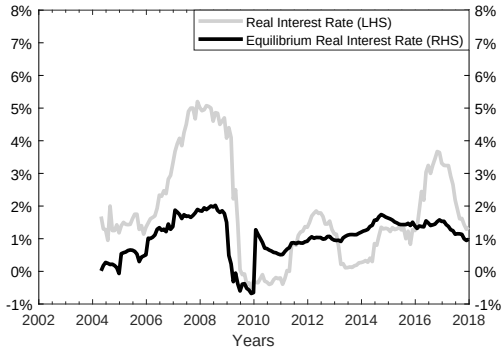
(d) Real Commodity Price Returns



(e) U.S. Effective Federal Funds Rate



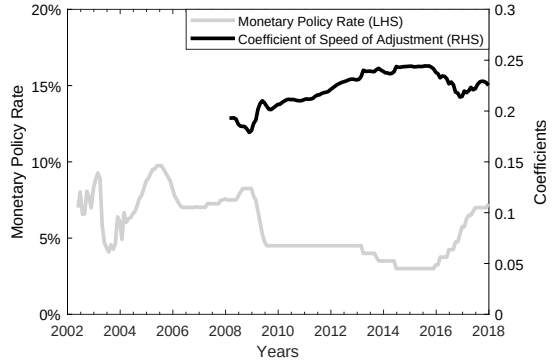
(f) Real Interest Rate



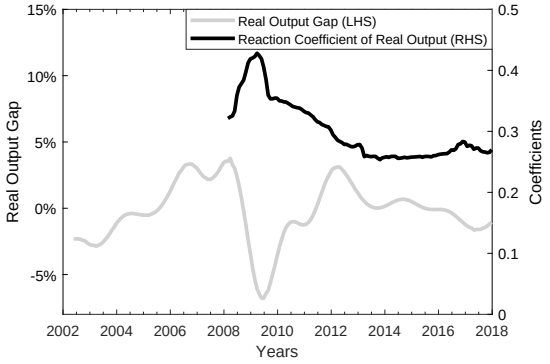
Note: Time-varying long-run reaction coefficients for the control variables of the monetary policy rule of Chile: Black line – time-varying coefficient values of the respective variable (right scale); gray line – respective underlying variables (left scale).

Figure 8: Long-Run Reaction Coefficients for Mexico

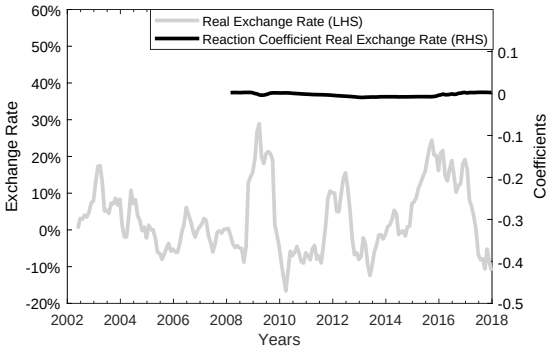
(a) Speed of Adjustment



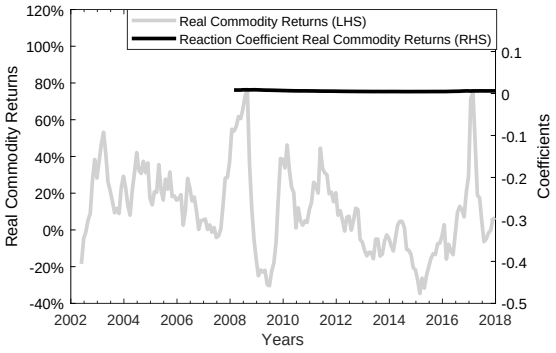
(b) Real Output Gap



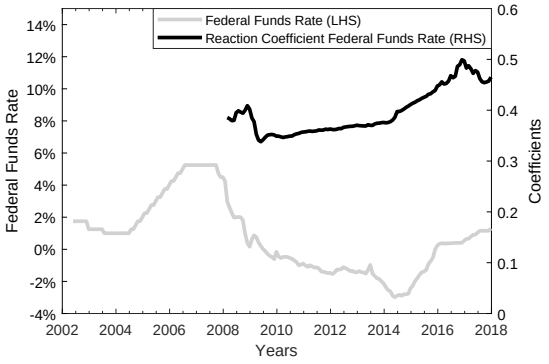
(c) Real Output Gap



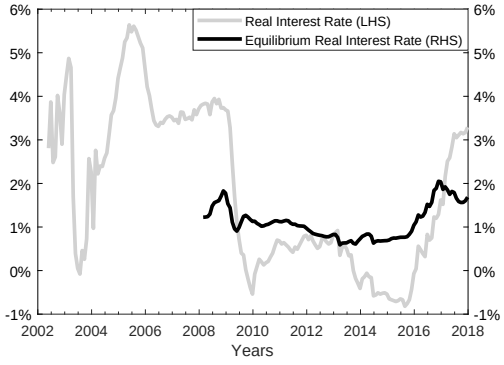
(d) Real Commodity Price Returns



(e) U.S. Effective Federal Funds Rate



(f) Real Interest Rate



Note: Time-varying long-run reaction coefficients for the control variables of the monetary policy rule of Chile: Black line – time-varying coefficient values of the respective variable (right scale); gray line – respective underlying variables (left scale).

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