Monetary Policy Credibility and Inflation Risk Premium: a model with application to Brazilian data*

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Abstract

We derive a simple asset pricing-Taylor rule model and propose a new approach to investigate monetary policy credibility: track the movements in inflation expectation and "inflation risk premium" separately. We conduct a case study in Brazil: we show that it is one of the few countries in which short run inflation surprises has affected medium run inflation expectations. This phenomenon leads to a less effective monetary policy, as its output cost is higher. This is a symptom of at least one of two problems: (i) Inflation inertia due to indexation of the economy; and/or (ii) Lack of credibility of the monetary authority. The remedy depends on the cause. For instance, if the reason is simply indexation, central bank independence will not solve it. Our model argues that we can identify if credibility is one of the causes by looking at comovements in inflation risk premium. By doing so, we confirm that this is the case in Brazil and, thus, central bank independence should helps monetary policy to be less costly.

1 Introduction

When monetary policy lacks credibility, central banks have to impose a higher interest rate than otherwise in order to control inflation. The recognition of this phenomenon is probably one of the responsibles for the adoption of inflation targeting (IT) by many countries across the globe. Following the spread of inflation target as the most fashionable monetary policy arrangement across the globe, the literature on

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monetary policy credibility have flourished. Empirically, the extent of the credibility usually is evaluated in two ways[1]: (i) by running regressions on inflation expectations, as in Cerisola and Gelos (2005) or (ii) by looking at the inflation implicit in nominal and real bonds, the "market inflation" as in Svensson (1993), Laxton and N'Diaye (2002) and Gürkaynak et al (2005).

We argue that the information contained in this data can be better explored. The difference between the nominal and real yields, referred to as "break even inflation " or "market inflation" is not explained only by the expected inflation: it include a risk premium as well. Differently from the aforementioned papers, to investigate the credibility of monetary policy we separate the "market inflation" into two components: the expected inflation and the inflation risk premium. We present an asset pricing model with a Taylor rule and an equation for inflation dynamics which allow us to interpret this "inflation risk premium". We apply its results to investigate monetary policy credibility in Brazil.

A very rich data-set, containing inflation expectation for many horizons, allow us to use the methodology proposed to analyze the recent Brazilian experience. An extra reason for choosing this country is that one of the most popular subjects among macroeconomist these days in Brazil is the inflation resilience to the high interest rate. Many possible reasons have been raised: fiscal dominance, subsidized credit[2] with interest rate not sensitive to the short rate determined by the monetary authority, fiscal policy not being tight enough, the short run expansionary effect of the expansion of the credit to consumers and so on. On this paper we will point out that credibility of the monetary authority has been also an important factor clogging the transmission channels of monetary policy.

On an international comparison, we show that Brazil is one of the few countries in which short run inflation surprises affect medium run inflation expectations. This is a symptom of at least one of two problems: (i) Inflation inertia / indexation of the economy; and/or (ii) Lack of credibility of the monetary authority. The remedy depends on the cause. For instance, if the reason is simply indexation, central bank independence will not solve it.

Our model suggests that we can identify if credibility is one of the causes by looking at the inflation risk premium. By doing so, we show that this is the case in Brazil. Thus, central bank independence should helps monetary policy to be significantly less costly. Other evidences points in this direction as only bad news (positive inflation shocks) seems to have some effect on both medium run inflation expectation and inflation risk premium.

Section 2 present the empirical evidence with a regression analysis of the effects of short run inflation surprises in 12 month inflation expectations on Brazil and the world. The theoretical model is presented

[1] Some other methods: Rossi and Rebucci (2004) that studies the credibility of the disinflation program in Turkey using a Bayesian approach and Agénor and Taylor (1993) that use the difference between exchange rate quoted in official and black market.

[2] National Development Bank's (BNDES) loans constitute approxematelly 40% of the total availble credit to private sector.

Year	Setting Date	Target		CPI Inflation	GDP Growth
1999	30/6/1999	8.00%	± 2,00%	8.94%	0.79%
2000	30/6/1999	6.00%	± 2,00%	5.97%	4.36%
2001	30/6/1999	4.00%	± 2,00%	7.67%	1.31%
2002	28/6/2000	3.50%	± 2,00%	12.53%	1.93%
2003	28/6/2001	3.25%	± 2,00%	-	-
2003*	27/6/2002	4.00%	± 2,50%	-	-
2003*	21/1/2003	8.50%	± 2,50%	9.30%	0.54%
2004	27/6/2002	3.75%	± 2,50%	-	-
2004*	25/6/2003	5.50%	± 2,50%	7.60%	4.94%
2005	25/6/2003	4.50%	± 2,50%	-	-
2005**	23/9/2004	5.10%	-	5.69%	2.30%
2006	30/6/2004	4.50%	± 2,00%	4.53%+	3.48%+
2007	22/6/2005	4.50%	± 2,00%	4.51%+	3.65%+

* - Revised Targets.

** - Objective.

\+ - Consensus forecasts (means) on March 31, 2006

Figure 1:

in section 2. Following the results of the model Section 3 analyze the evidence that for Brazil, inflation risk premium is very sensitive to inflation surprises, indicating lack of credibility of monetary policy during the sample period analyzed. The asymmetry of positive and negative shocks is observed through all the empirical analysis. Section 4 concludes and provides some conjectures on the causes of the lack of credibility.

2 Evidence of the Effects of Short Run Surprises in Medium Run Inflation Expectations

In Brazil, the inflation target regime begun in 1999. The Central Bank target is over the consumer price index called IPCA. The targets are usually defined and announced in June[3]. The table below present the targets, objectives and results of inflation targeting in Brazil:

Since the targets are valid only for the calendar year, we calculated the 12 month ahead target by interpolating of the official calendar-year targets. Through out the paper we work with monthly data, so on the coming notation, each t represents a month. Define "Credibility Gap" as being the expected deviation of the 12 month ahead inflation form the target:

- "Credibility Gap" $= E_t \left(\sum_{s=t+1}^{t+12} CPI_s \right) -$ (Central Bank Announced Target for the next 12 months).

Twelve months ahead inflation expectations were collected from Brazilian Central Bank's expectation survey called Focus. We present below the interpolated Central Bank announced target for the next 12

[3] There has been a history of changes in this policy objectives. When a big shock hits the economy and the target is no longer credible, the CB usually announce the objective that it will aim.

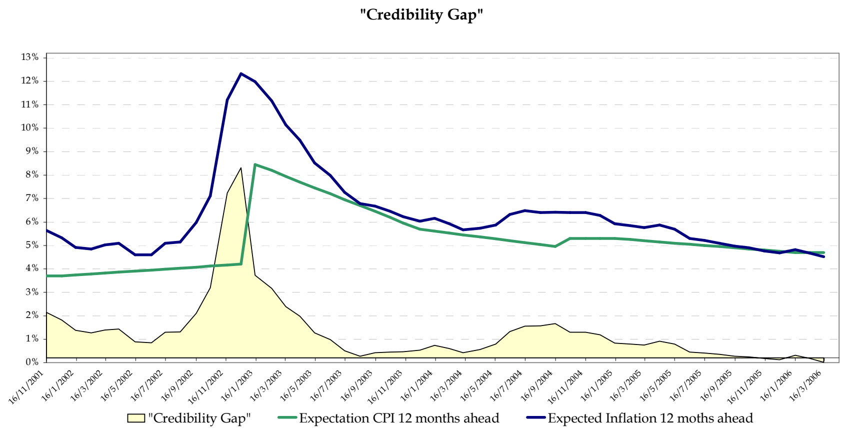


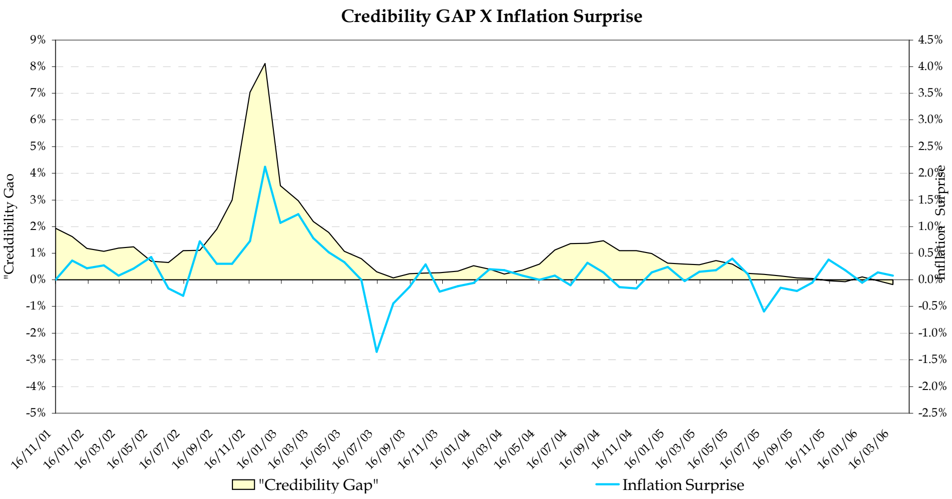
Figure 2:

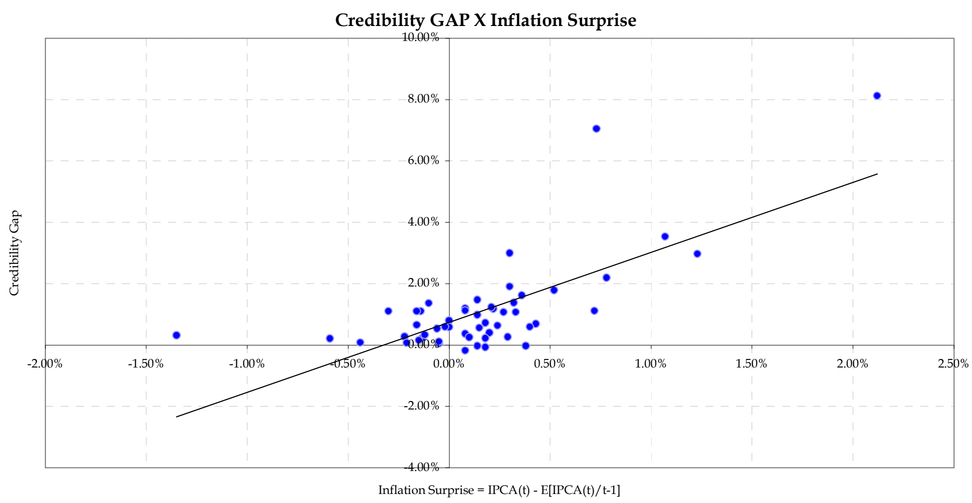
months (green line), the inflation expectation for the next 12 months (blue line) and the "credibility gap" (filled area below):

But what is the effect of short run inflation surprises on medium run inflation expectations? Or, more interestingly, what is the effect of short run inflation surprises on deviations from the announced target? We proceed in an empirical investigation to estimate this effect. Define "inflation surprise" as the actual monthly inflation minus the expected monthly inflation last month:

- "Inflation Surprise" $= CPI_t - E_{t-1}(CPI_t)$

One month ahead inflation expectation was also collected from Focus survey. On the graph and tables below, we depict the evidence of the co-movement of the inflation surprise and "credibility gap" in Brazil:





The evidence is that short run inflation surprises induce a significant variation on medium run inflation expectation in Brazil. The regressions presented below indicates that for all sub-periods analyzed, this effect is statistically significant, even controlling for exchange rate and commodity price effects. The coefficient is 0,748 for the whole sample, however, the effects is diminishing: from Jan/02 to Jun/03 a 1% inflation surprise affects the 12 month ahead inflation expectation in 2.049% while from the period from Jul/03 to Mar/06 the effect is almost 10 times smaller: 0.203%[4] but still significant. Also interesting to notice is that in this last sub-sample, exchange rate and commodity price shocks started to impact positively inflation expectations.

The tables below also highlight an interesting fact: the asymmetric effect of positive and negative

[4]The 12 month ahead inflation expectation does not take into account the actual month's inflation, which is the one that suffered the unexpected shock.

OLS estimates	Dep Variable: Credibility Gap = E(IPCA 12 month) - CB announced target 12 meses ahead					
	coefficient	coefficient	coefficient	coefficient	coefficient	coefficient
C	0.003	0.002	0.007	0.006	0.000	0.000
	(0.164)	*(0.187)*	*(0.122)*	*(0.234)*	*(0.991)*	*(0.332)*
AR_1	0.640	0.488	0.272	0.232	0.929	0.934
	(0.017)	*(0.107)*	*(0.305)*	*(0.414)*	*(0.001)*	*(0.001)*
Surprise	0.748	-	2.049	-	0.203	-
	(0.096)	-	*(0.028)*	-	*(0.022)*	-
Positive Surprise	-	1.553	-	2.312	-	-0.186
	-	*(0.087)*	-	*(0.039)*	-	*(0.490)*
Negative Surprise	-	0.023	-	-0.117	-	0.328
	-	*(0.915)*	-	*(0.967)*	-	*(0.000)*
?%XR(-1)	0.016	0.014	0.016	0.009	0.025	0.021
	(0.419)	*(0.540)*	*(0.623)*	*(0.829)*	*(0.055)*	*(0.153)*
? %Commodities(-1)	-0.024	-0.020	-0.081	-0.069	0.013	0.012
	(0.273)	*(0.289)*	*(0.170)*	*(0.303)*	*(0.076)*	*(0.047)*
Adjusted R2	0.672	0.683	0.537	0.505	0.850	0.855
Durbin-Watson stat	1.528	1.385	1.393	1.278	1.476	1.461
AIC	-6.523	-6.541	-5.414	-5.317	-9.733	-9.746
Sample	Jan/02 - Mar/06	Jan/02 - Mar/06	Jan/02 - Jun/03	Jan/02 - Jun/03	Mar/03 - Mar/06	Mar/03 - Mar/06
N. Observations	*51*	*51*	*18*	*18*	*34*	*34*

P-values are calculated with Newey-West robust standart errors

Figure 3:

shocks. On the whole sample, a 1% unexpected inflation shock leads to an increase of 1.55% on the 12 month inflation expectation above the CB's target while a negative surprise has no effect. On the second sub-sample the positive effect is insignificant, only the negative effect is relevant. To summarize, the overall evidence is that inflation expectation is very sensitive to short run surprises in Brazil.

To address how this effect has been evolving over time, we also estimated 24 month rolling regression. The graph below present the results of the 90% confidence interval of the inflation surprise coefficient. Clearly the effect of inflation surprise on deviation of inflation expectation over the target has diminished over time.

We also ran the regression with contemporaneous exchange rate devaluation but to control for endogenity of the exchange rate, we implemented two-stage-least squares regression method using the lagged exchange rate devaluation as an instrument. In this regression we also included the Embi+ (country risk) but it didn't showed up significant. The results didn't change much.

For sake of comparison, we implement similar analysis with international data. Since we do not have the same disaggregation available for Brazil in international data[5], the analysis is slightly different. Instead of using short run inflation surprises directly, we assume that the 1 month ahead inflation expectation is current month inflation, i.e., agents make projections as if monthly inflation was a random walk. We also modify the dependent variable, instead of using the "inflation gap" we simply use the 12

[5] We don't have 1 month ahead inflation to any country besides Brazil. Moreover, usually the data is for inflation expectaion for a given year, not for the following 12 months.

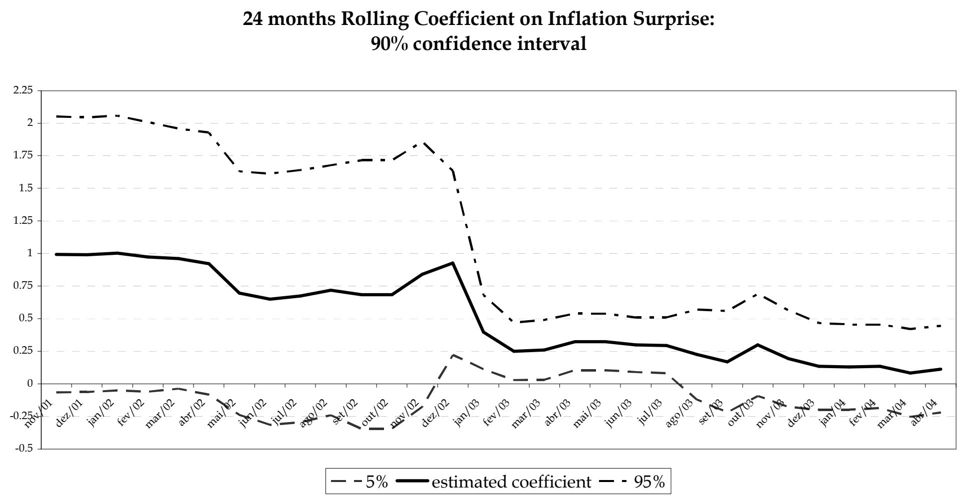


Figure 4:

2SLS estimates	Dep Variable: Credibility Gap = E(IPCA 12 month) - CB announced target 12 meses ahead					
	coefficient	coefficient	coefficient	coefficient	coefficient	coefficient
C	0.0045	0.0040	0.0019	0.0026	0.0003	0.001
	(0.0003)	*(0.2218)*	*0.0000*	*(0.8375)*	*(0.8367)*	*(0.630)*
AR_1	0.2913	0.1729	0.0803	0.0672	0.6906	0.801
	(0.6906)	*(0.3371)*	*0.0000*	*(0.8512)*	*(0.0002)*	*(0.000)*
Surprise	0.7299	-	1.7267	-	0.2674	-
	(0.0382)	-	*(0.1366)*	-	*(0.0448)*	-
Positive Surprise	-	1.3734	-	1.8894	-	-0.444
	-	*-0.0231*	-	*-0.1507*	-	*(0.151)*
Negative Surprise	-	0.1373	-	0.2641	-	0.469
	-	*-0.8053*	-	*-0.9657*	-	*(0.001)*
d%XR	0.0948	0.0959	0.1004	0.0979	0.0332	0.015
	(0.2321)	*(0.0238)*	*(0.2411)*	*(0.2503)*	*(0.0263)*	*(0.549)*
d%Commodities	-0.0340	-0.0305	-0.0358	-0.0367	-0.0174	-0.017
	(0.1068)	*(0.2484)*	*(0.6203)*	*(0.6218)*	*(0.1989)*	*(0.068)*
Embi+ Brazil	0.0004	0.0003	0.0005	0.0004	0.0005	0.0004
	(0.1352)	*(0.2857)*	*(0.5241)*	*(0.7015)*	*(0.2218)*	*(0.1615)*
Adjusted R2	*0.710*	*0.714*	*0.559*	*0.530*	*0.787*	*0.849*
Sample	Jan/02 - Mar/06	Jan/02 - Mar/06	Jan/02 - Jun/03	Jan/02 - Jun/03	Jun/03 - Mar/06	Jun/03 - Mar/06
N. Observations	*51*	*51*	*18*	*18*	*34*	*34*

P-values are calculated with Newey-West robust standart errors

Figure 5:

OLS estimates	Dep Variable: E(CPI 12 month/t) - E(CPI 12 month/t-1)					
	CHILE	BRAZIL	TURKEY	UK	MÉXICO	ISRAEL
	coefficient	coefficient	coefficient	coefficient	coefficient	coefficient
C	0.000	0.024	-0.858	-0.006	-0.086	-0.139
	(0.990)	*(0.885)*	*(0.011)*	*(0.729)*	*(0.054)*	*(0.397)*
?Monthly Inflation	0.028	0.501	0.333	0.027	-0.016	-0.359
	(0.479)	*(0.062)*	*(0.084)*	*(0.416)*	*(0.846)*	*(0.061)*
?%XR(-1)	2.583	2.701	8.221	-1.416	2.308	15.905
	(0.015)	*(0.136)*	*(0.072)*	*(0.178)*	*(0.200)*	*(0.012)*
? %Commodities(-1)	-1.494	-0.790	-13.870	0.650	1.162	-7.472
	(0.041)	*(0.792)*	*(0.226)*	*(0.177)*	*(0.269)*	*(0.503)*
R2	0.219	0.178	0.219	0.064	0.096	0.123
Durbin-Watson stat	1.342	1.324	1.342	2.029	1.870	1.113
AIC	3.632	2.266	3.632	-0.846	-0.432	2.694
Sample	Oct/2001 - Oct/2004	Jan/2002 - Mar/2005	Oct/2001 - Nov/2004	Oct/1997 - Dec/2003	Jun/2001 - Sep/2004	Feb/1992 - Jan/1996
N. Observations	*37*	*39*	*38*	*75*	*40*	*48*

P-values are calculated with Newey-West robust standart errors

Figure 6:

OLS estimates	Dep Variable: E(CPI 12 month/t) - E(CPI 12 month/t-1)					
	CHILE	BRAZIL	TURKEY	UK	MÉXICO	ISRAEL
	coefficient	coefficient	coefficient	coefficient	coefficient	coefficient
C	0.000	0.037	-0.903	-0.004	-0.086	-0.164
	(0.992)	*(0.824)*	*(0.012)*	*(0.840)*	*(0.052)*	*(0.322)*
?Monthly Inflation(-1)	0.063	0.521	-0.044	-0.002	-0.052	0.143
	(0.325)	*(0.022)*	*(0.866)*	*(0.935)*	*(0.420)*	*(0.492)*
?%XR(-1)	2.141	3.428	8.830	-1.200	2.488	15.979
	(0.027)	*(0.108)*	*(0.059)*	*(0.128)*	*(0.158)*	*(0.029)*
? %Commodities(-1)	-1.611	-1.760	-13.070	1.554	1.073	-3.590
	(0.020)	*(0.628)*	*(0.161)*	*(0.112)*	*(0.329)*	*(0.734)*
R2	0.256	0.189	0.166	0.101	0.105	0.083
Durbin-Watson stat	1.438	1.146	1.394	2.075	1.832	1.111
AIC	-0.662	2.252	3.697	-0.887	-0.443	2.739
Sample	Oct/2001 - Oct/2004	Jan/2002 - Mar/2005	Oct/2001 - Nov/2004	Oct/1997 - Dec/2003	Jun/2001 - Sep/2004	Feb/1992 - Jan/1996
N. Observations	*37*	*39*	*38*	*75*	*40*	*48*

P-values are calculated with Newey-West robust standart errors

Figure 7:

month ahead inflation expectation, since some of the countries didn't have an announced target on our sample. We used are the market expectations survey and their sources are each country's central bank. We also run an instrumental variable regression where we use the lagged first difference of inflation as an instrument to the inflation surprise. The results are shown below:

The results shown on the tables above suggest that in Brazil and Turkey[6] this effect is positive while in Chile, UK, Mexico and Israel there is no effect at all.

So the evidence so far is that short run inflation surprises induce a significant variation on medium run inflation expectation in Brazil, differently from most other countries. We conjecture that this phenomenon can be happening for two (non mutually exclusive) reasons:

[6] In Turkey the effect is not observed when we run the instrumental variable regression.

- Indexation of the economy.
- Lack of credibility of the Central Bank.

It would be hard to argue that there is no remaining indexation in Brazil. If one checks the concession contracts of telephony and energy services, will be convinced that inflation indexation is quite alive[7]. What we are interested in is in figuring out if the lack of credibility is also present. If this is the case, the benefit of an independent Central Bank would be clear.

What we propose in the next section is a methodology to identify if the phenomenon itself is somehow related to the lack of credibility of the Central Bank and then, in the fourth section, we apply it to the Brazilian data. The idea is to look at the *"Inflation Risk Premium"*[8], which is the difference between the inflation implicit in financial securities, the *"Market Inflation"* and the inflation expectation given by market participants.

3 The Model

Let us start by defining what is "market inflation" (or break even inflation) and "inflation risk premium:

- "Market Inflation" = (1+Nominal Rate)/(1+ Real Rate)-1
- Inflation Risk Premium = (Market Inflation) - (Expected inflation reported by market participants)

The main message of the model is the following: If the cause of the effect of short run inflation surprise on 12 month inflation expectation is solely indexation, there is no reason for an increase in the uncertainty when the economy is hit by a positive inflation shock: we know that the prices will be re-adjusted in the future with certainty. However, if there is lack of credibility on monetary policy, there will be an increase in the uncertainty on future responses to inflation, leading to an increase in the uncertainty on inflation itself. This will be capture by the inflation risk premium. We now formalize this argument.

3.1 Asset Pricing and the Inflation Risk Premium

Take an economy with two assets: a nominal bond ($P_t^{\$}$) and a real bond (P_t). These bonds will be freely traded in the market. In order to price them, we will suppose absence of arbitrage. This will imply that there is a strictly positive stochastic discount factor M_{t+1} such that for any stochastic *nominal payoff* X_{t+1} to be realized in $t+1$, its price in time t will be given by $P_t = E_t\left[M_{t+1}X_{t+1}\right]$. If markets were complete, the stochastic discount factor used to price any asset in this economy would be the same. We

[7] These contracts are re-adjusted annualy by the 12 month accumulated IGP-M.

[8] Inflation risk premium is also known by the term break even inflation.

don't need that much, we can have incomplete markets since the M_{t+1} used to price the real bond can also be one of the stochastic discount factors used to price the nominal bond.

If the *nominal payoff of the real bond is* Π_{t+1}, i.e., (1+inflation%), and the *nominal payoff of the nominal bond is* $1, their prices will be:

- Real Bond: $P_t = E_t\left[M_{t+1}\Pi_{t+1}\right]$
- Nominal Bond: $P_t^{\$} = E_t\left[M_{t+1}\$1\right]$

If an investor buys a nominal bond he will not be hedged against inflation, so a nominal bond needs to compensate investors for inflation risk. Notice that if $E_t\Pi_{t+1} > 1$, then $P_t^{\$} < P_t$ or, in other words, the real rate will be smaller than the nominal rate.

The log real rate is $r_t \equiv -\ln P_t$ and the log-nominal rate is $r_t^{\$} \equiv -\ln P_t^{\$}$. We can specify the process of the short rate and the prices of risk which is equivalent to specifying a process for the stochastic discount factor. Our main hypothesis is that this short rate process is defined by the Central Bank and can be characterized by a state-dependent "Taylor rule". This is also done in Ang and Piazzesi (2003), Ang et al (2005) and Rudebusch and Wu (2004). Define the Taylor rule as:

$$r_t = \delta^0 + \delta_t^1 X_t \tag{1}$$

In (1) X_t are the state variables of the economy that affects the decision of the Central Bank, such as current inflation and output. Notice that we allow the Central Bank response to vary to state variable shocks to be time-varying[9]. Let the dynamic of the state variables be driven by a VAR process:

$$X_t = \mu + \Phi X_{t-1} + \varepsilon_t$$

We also suppose that the sources of uncertainty on the economy are associated with a vector λ containing the prices of risk of each state variable of the economy. We follow Vasicek (1977) and suppose that the prices of risk are not time varying[10]. To use the pricing formulas above, we must get the stochastic discount factor and the connection is given by the Radon-Nikodym[11] derivative ξ_{t+1} that changes the probability measure to a martingale equivalent one:

$$\xi_{t+1} = \xi_t \exp\left(-\frac{1}{2}\lambda'\lambda - \lambda'\varepsilon_{t+1}\right) \tag{2}$$

[9] Think of that in an monetary policy framework where the Central Bank is not independent: there is a possibility that, for electoral reasons, the cuntry's president can change the staff of the Central Bank, generating a change in its Taylor rule.

[10] Later, we will discuss what would be the implications of relaxing this hypothesis. We will argue that, for our purpuses, it wouldn't make much difference.

[11] Radon-Nikodym derivative changes the probability measure to a maringale equivalent one. However, to price assets, it is equivalent to work with the present value of the expected payoff under the martingale equivalent measure or the expected payoff multiplied by the stochastic discount factor.

Recall that ε_{t+1} is the vector of uncertainties affecting the state variables X_{t+1}.

The stochastic discount factor (or pricing kernel) will be given by:

$$M_{t+1} = \exp\left(-r_t\right)\frac{\xi_{t+1}}{\xi_t} \tag{3}$$

Substituting 1 and 2 in 3:

$$m_{t+1} \equiv \ln M_{t+1} = -\frac{1}{2}\lambda'\lambda - \delta^0 - \delta_t^{1'}X_t - \lambda'\varepsilon_{t+1} \tag{4}$$

Now we can calculate the prices of the relevant securities. Our task is to understand what affect the inflation risk premium, which is defined by the difference between the log "market inflation" ($\log \Pi_{t+1}^{market}$), and the agent's log expected inflation ($\log E_t(\Pi_{t+1})$). The "market inflation" is simply the inflation rate implicit on the financial securities, and it can be measured by the nominal forward rate minus the forward real rate $\log \Pi_{t+1}^{market} = f_{t+1}^{\$} - f_{t+1}$. So, these are the securities that we are interested in to calculate the inflation risk premium.

Define $m_{t+1} \equiv \ln M_{t+1}$, $\pi_{t+1} \equiv \ln \Pi_{t+1}$ and suppose that M_t and Π_{t+1} are jointly lognormally distributed. The price of the 1 period nominal bond will be given by:

$$p_t^{1\$} = E_t\left(m_{t+1}\right) + \frac{1}{2}Var_t\left(m_{t+1}\right) \tag{5}$$

And the price of the real bond will be given by:

$$p_t^1 = E_t\left(m_{t+1}\right) + E_t(\pi_{t+1}) + \frac{1}{2}Var_t\left(m_{t+1}\right) + \frac{1}{2}Var_t(\pi_{t+1}) + Cov_t(m_{t+1}, \pi_{t+1}) \tag{6}$$

In the same way, we can also calculate the price of the 2 period nominal and real bond[12]. Using these formulas, we calculate the 1 period real forward rate, which is given by $f_t = p_t^1 - p_t^2$ and the 1 period nominal forward rate, given by $f_t^{\$} = p_t^{1,\$} - p_t^{2,\$}$:

$$f_t^{\$} = -E_t\left(m_{t+2}\right) - \frac{1}{2}Var_t\left(m_{t+2}\right) - Cov(m_{t+1}, m_{t+2}) \tag{7}$$

$$\begin{aligned} f_t &= -E_t\left(m_{t+2}\right) - E_t(\pi_{t+2}) - \frac{1}{2}Var_t\left(m_{t+2}\right) - \frac{1}{2}Var_t(\pi_{t+2}) - \\ &\quad -Cov(m_{t+1}, m_{t+2}) - Cov(\pi_{t+1}, \pi_{t+2}) - \\ &\quad -Cov_t(m_{t+1}, \pi_{t+2}) - Cov_t(m_{t+2}, \pi_{t+1}) - Cov_t(m_{t+2}, \pi_{t+2}) \end{aligned} \tag{8}$$

To calculate the inflation risk premium we also need the expected log inflation that under the log-normality assumption is given by:

[12] This calculation is shown in the appendix.

$$\log E_t(\Pi_{t+1}) = E_t(\pi_{t+1}) + \frac{1}{2}Var_t(\pi_{t+1})$$

The formula of the 2 period inflation $\Pi_{t+2} = e^{\pi_{t+1}+\pi_{t+2}}$ is given by:

$$\log E_t(\Pi_{t+2}) = E_t(\pi_{t+2}) + E_t(\pi_{t+1}) + \frac{1}{2}Var_t(\pi_{t+1}) + \frac{1}{2}Var_t(\pi_{t+2}) + Cov(\pi_{t+1}, \pi_{t+2})$$

In turn, the expectation of the log 1 period inflation in $t+2$ will be:

$$\log E_t(\Pi_{t+2}/\Pi_{t+1}) = E_t(\pi_{t+2}) + \frac{1}{2}Var_t(\pi_{t+2}) + Cov(\pi_{t+1}, \pi_{t+2}) \tag{9}$$

Now we are ready to calculate the inflation risk premium substituting out the equations (7), (8) and (9) on the following definition:

$$\begin{aligned} \textit{Inflation Risk Premium}_t &\equiv \log \Pi_{t+1}^{market} - \log E_t(\Pi_{t+2}/\Pi_{t+1}) \\ &= f_t^{\$} - f_t - E_t(\pi_{t+2}^f) \\ &= Cov_t(m_{t+1}, \pi_{t+2}) + Cov_t(m_{t+2}, \pi_{t+1}) + Cov_t(m_{t+2}, \pi_{t+2}) \end{aligned} \tag{10}$$

To relate the Taylor rule with inflation risk premium, we still need to substitute the s.d.f. equation (4). We also get rid of constant terms, the irrelevant for the covariance, and arrive at:

$$\textit{Inflation Risk Premium}_t \equiv Cov_t(-\delta_t^{1'} X_t - \lambda' \varepsilon_{t+1}, \pi_{t+2}) + Cov_t(-\delta_t^{1'} X_{t+1} - \lambda' \varepsilon_{t+2}, \pi_{t+1}) + Cov_t(-\delta_1' X_{t+1} - \lambda' \varepsilon_{t+2}, \pi_{t+2}) \tag{11}$$

Now we can already figure it out what could be causing variations in the inflation risk premium. One of the state variables in the vector X_t is the inflation π_t, so, there are basically possibilities[13] to explain the phenomenon: (1) variations in the conditional expected volatility of future inflation σ_{t+1}^{π}; (2) variations in the price of risk of inflation λ; (3) variations in the expected central bank response to future inflation shocks δ_{t+1}^1. Notice that here we have even relaxed the hypothesis that market price of risks are constant. Therefore, these are the only three possibilities without imposing any further assumption[14].

We will focus on the third possible explanation: variations in the expected CB responses to inflation. For the endeavor, in the next section we will impose some further restrictions to get a more tractable formulation. But the basic insight is already in equation (11): consider two types of Central Bank, a tougher one that responds aggressively to a contemporaneous inflation shock (high δ^1) and a second type, that has a loose monetary policy and do not respond so much to contemporaneous inflation shock (low δ^1). The tight monetary authority type will be associated with a lower inflation risk premium.

[13] Actually, if there are contemporaneous covariance between π_t and other state variables to which the Central Bank, through its Taylor rule, responds to, there may be other possibilities.

[14] The only necessary hypothesis are: (i) absence of arbitrage, (ii) linear Taylor rule and (iii) linear price of risk and (iv) the contemporaneous covariance of inflation with other variables entering the Taylor rule is negligible.

3.2 Taylor Rule, Inflation Dynamics and Prices of Risk

3.3 What is the responsible for the correlation of inflation surprises with risk premium: Inflation inertia (indexation) or Monetary Policy Credibility?

Let us recall the main motivation of the paper. The empirical evidence presented in Section 2 was that short run inflation surprises induce a significant variation on medium run inflation expectation in Brazil, differently from most other countries. We conjecture that this phenomenon could be happening for two (non mutually exclusive) reasons:

- Indexation of the economy.
- Lack of credibility of the Central Bank.

As said before, it would be hard to argue that there is no remaining indexation in Brazil. What we are interested in is in figuring out if the lack of credibility is also present. The strategy that we are suggesting is to look at the effects of inflation surprises inflation in risk premium, which brings information about future responses to inflation shocks. For the endeavor of having this clear interpretation of inflation risk premium, we will further parametrize the model.

We start with the inflation dynamic equation. A question that can arise is if inflation inertia could be the responsible for variations in inflation risk premium. For this reason, in the model we will allow for inflation inertia. Assume that the log inflation is given by:

$$\pi_t = (1 - \phi_\pi)\mu_\pi + \phi_\pi \pi_{t-1} - \phi_r(r_{t-k} - \overline{r}) + \varepsilon_t^\pi \tag{12}$$

Where, μ_π is the long-run "natural inflation"; ϕ_π is the inflation inertia (degree of indexation of the economy); ϕ_r is the inflation sensitivity to monetary policy, $\varepsilon_t^\pi \sim N(0, \sigma)$ is the inflation shock at time t and; k is the lag with which the monetary policy affects the economy.

Now we turn to the Taylor rule. We permit for central bank's response to be time varying. Think of that as the possibility of changes in the board of the Central Bank. Without Central Bank independence, the president can appoint the CB board according to his will.

Since we already know that all that matters for inflation risk premium is the covariance of inflation to the stochastic risk premium, we can worry only with the Central Bank responses to inflation shocks without any loss to the final result. Recall that ε_t^π is the unexpected inflation shock at time t. We will allow the central bank to respond to contemporaneous or any past shock, with different elasticities of response. The state-dependent Taylor Rule will be given by:

$$r_t = \overline{r} + \delta_0^\theta \varepsilon_t^\pi + \delta_1^\theta \varepsilon_{t-1}^\pi + \delta_2^\theta \varepsilon_{t-2}^\pi + ... \tag{13}$$

Where $\overline{r}$ is the long run "natural" interest rate. δ_t^θ is the type θ monetary authority policy response[15] to inflation shock at time t.

For sake of simplicity, suppose that there can be two types of Central Bank: (i) one more committed to fight inflation, i.e, with a higher interest rate response to inflation shock δ^H; and (ii) one less committed to fight inflation, i.e, with a lower interest rate response to inflation shock δ^L. Moreover, let p_t denote the conditional probability at time t of the type of monetary authority in $t+1$ being L and $(1-p_t)$ the the conditional probability at time t of the type of monetary authority in $t+1$ being H.

Now we can have a clearer expression to equations (10) and (11):

$$\begin{aligned} \textit{Inflation Risk Premium}_t &= \left[p_t(-\lambda - \delta_o^L) + (1-p_t)(-\lambda - \delta_o^H)\right](1+\phi_r)\sigma_{t+1}^\pi \quad \text{if k=0} \\ &= \left[p_t(-\lambda - \delta_o^L) + (1-p_t)(-\lambda - \delta_o^H)\right]\sigma_{t+1}^\pi \qquad \text{if k>0} \end{aligned} \tag{14}$$

This is enough to see that indexed economy does not provoke a positive relation between inflation surprises and inflation risk premium, since the indexation parameter ϕ_π does not appear in equation (14).

According to our formulation what happens is that positive inflation shocks can induce an increase in the perceived probability p_t that that the monetary policy next period will be more loose than the current one.

What could induce that perception? Recall that we suppose that we do not have Central Bank independence, so the president can choose to change the board according to his will. Although we didn't included output gap in the analysis, let suppose that there is a short run trade off between inflation and output gap as in a Phillips curve. If output gap affects voters evaluation of the incumbent government negatively, we can think as in an "opportunistic"[16] model in the spirit of Persson and Tabellini (1990) and Rogoff and Silbert (1988) in which politicians care only about being elected. These models have a non-observable competence term. The voters don't know if the better outcome was achieved by exploiting the Phillips curve or by a higher competence of the government. To reconcile that with our result that some agents are predicting future Taylor rule, suppose that the agent that trade in the financial market and determine prices is not the *median voter*. This hypothesis is done in Mankiw and Zeldes (1991). They observe that only a fraction of the families invest on the financial market in the USA and use that to try to solve the equity premium puzzle[17]. Our claim is that this observation legitimizes the use of

[15] Should the monetary authority react to current inflation shocks ε_t^π raising interest rates if it wants to diminish inflation, i.e., should $\delta > 0$? If the $k = 0$ the answer is clearly yes. But it is also easy to see that even if the monetary policy affect the economy with some lag ($k > 0$), the central bank will want to have $\delta > 0$ if we have some inflation inertia ($\phi_\pi > 0$).

[16] Nordhaus (1975) and Lindbecck (1976) introduced this approach but in their model, voters are naïve and the agents do not have rational expectations.

[17] The volatitlity of consumption of equity investors is much higher than the average US resident, so in a CCAPM model the s.d.f. is more volatile, requiring a muxh smaller risk aversion to calibrate for the data on equity returns.

different representative agents: one to price the assets and the other to elect the government.

In other words, a positive relation between unexpected inflation shocks and inflation risk premium reflects financial agents expecting a change in the conduction of monetary policy towards a not so tight one, since the scenario is not so benign to the incumbent government. This happens because due to electoral concerns, the president can change the board of the Central Bank if the state of the nature is not in his favour. If Central Bank were independent this effect wouldn't appear.

Another possibility for time-varying risk premium is the presence of heteroskedasticity in inflation. But even if the stochastic process of inflation were heteroskedastic (for example an EGARCH process), we should not observe a correlation between inflation surprises and inflation risk premium. What should matter is not if the shock is unexpected, but only its magnitude and sign. We will show latter in the empirical part that the surprise is what is significant, not the total size of the shock. We believe that this would be a second order effect.

The third and last possibility would be a time varying market price of risk for inflation λ. We don't really know how to rationalize that and why it would be associated to an unexpected shock. Nonetheless, in the following empirical part we allow for the inflation risk premium to depend on EMBI+ Brazil - which is the usual measure of risk aversion in Brazil - and show that its effect on inflation risk premium is not economically important.

Therefore, if inflation risk premium is changing in the presence of positive unexpected inflation shocks agents are fearing that the "type" of the monetary policy can change. Precisely, agents are fearing a loosening of monetary policy $\delta^L < \delta^H$ when the economy is hit by a positive inflation shock, causing an increase in inflation risk premium. This fact has a deleterious effect on economy since the inflation expectations should also increase in the presence of this shock, what makes monetary more costly in terms of output loss. It should be clear that we are not saying that lack of credibility of the monetary policy is the only factor: inflation indexation can be important too[18]. Thus, if the the empirical pattern indicate this positive relation – as indeed it is the case in Brazil as will be shown in the next section – there would room to reduce the cost of monetary policy by promoting Central Bank independence.

4 Inflation Risk Premium in Brazil

What could be causing the positive relation between short run inflation surprise and medium run inflation expectation as identified in Brazil in section 2? Does monetary policy credibility plays a role in that? The methodology proposed in this paper to identify if the phenomenon is somehow related to the lack of credibility of the Central Bank is to look at the relation between inflation surprise and inflation risk

[18] And as said before, we think it is as the examples of the public services contracts such as telephones and energy points out.

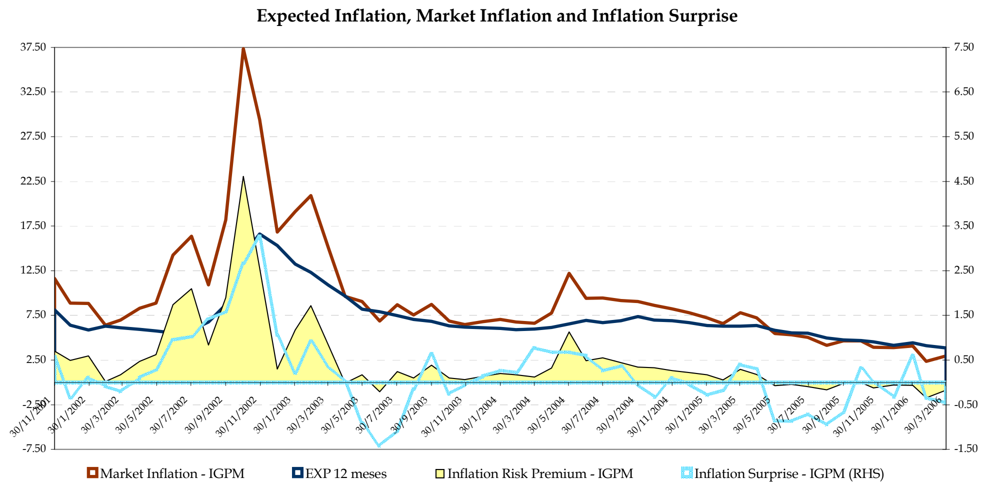


Figure 8:

premium. In this section we investigate if this is Brazilian data.

The intuition of the model was that if the cause of the effect of short run inflation surprise on 12 month inflation expectation is solely indexation, there would be no reason for an increase in uncertainty when the economy is hit by a positive inflation shock: we know that the prices will be readjusted in the future with certainty. However, if there is lack of credibility on monetary policy, there would be an increase in the uncertainty on future responses to inflation, leading to an increase in the uncertainty on inflation itself. This will be capture by the inflation risk premium.

Now we look at the empirical relation between inflation risk premia and inflation surprises in Brazil. There was no liquid market for bonds indexed to IPCA until recently, so we had to resort to a different inflation index: IGPM[19]. All over the time frame analyzed, there was a liquid market for government bonds indexed to this inflation indexed, the NTN-Cs. The data used in the analysis is the interpolated 1 year real rate and 1 year nominal rate[20], both provided by , provided by Brazil's Future and Mercatile Exchange (BM&F) and the survey of market expectation for IGPM 1 year inflation was obtained in Brazilian Central Bank's Focus. Below, we present graphs of the evolutions of these series. Brown line is the market inflation, dark blue line is the 12 month expected inflation. The difference between these two is the Inflation risk premium, represented in the shaded area. The short run inflation surprise is the light blue line. We also present scatter plot:

There is a clear pattern of positive relation between inflation surprise and inflation risk premium. We continue to investigate that in a series of regressions presented below:

[19] This is a general price index, basically an average of producer price index and consumer price index.
[20] Swap DI-pré 1 year.

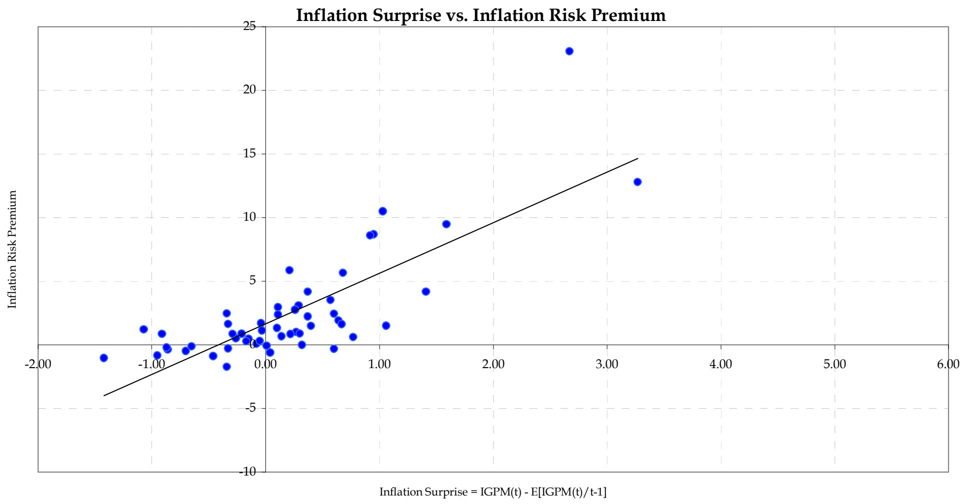


Figure 9:

OLS estimation	Dep Variable: IGPM Inflation Risk Premium					
	coefficient	coefficient	coefficient	coefficient	coefficient	coefficient
C	-0.8302	-0.7907	2.4220	2.0862	-1.0940	-1.097
	(0.2631)	*(0.3247)*	*(0.5081)*	*(0.5217)*	*(0.0567)*	*(0.059)*
AR_1	-0.1304	-0.2648	-0.4619	-0.6031	0.2792	0.275
	(0.3145)	*(0.1407)*	*(0.1373)*	*(0.0687)*	*(0.0432)*	*(0.021)*
Surprise	2.6801	-	5.4791	-	1.1021	-
	(0.0156)	-	*(0.0544)*	-	*(0.0031)*	-
Positive Surprise	-	4.7407	-	7.4750	-	1.038
	-	*(0.0025)*	-	*(0.0124)*	-	*(0.233)*
Negative Surprise	-	0.6852	-	2.1872	-	1.144
	-	*(0.2253)*	-	*(0.0112)*	-	*(0.026)*
d%XR	11.1806	9.6535	9.5944	3.2863	-2.3169	-2.250
	(0.0457)	*(0.2029)*	*(0.2633)*	*(0.6784)*	*(0.6631)*	*(0.671)*
d%Commodities	3.1230	0.7135	3.3838	8.3628	-3.1701	-3.133
	(0.5783)	*(0.9198)*	*(0.7708)*	*(0.4988)*	*(0.3303)*	*(0.338)*
Embi+ Brazil/100	0.3963	0.2930	0.1498	0.0849	0.3539	0.3598
	0.0000	*(0.0065)*	*(0.6113)*	*(0.7790)*	*(0.0096)*	*(0.0124)*
Adjusted R2	*0.731*	*0.783*	*0.688*	*0.750*	*0.557*	*0.541*
Sample	Jan/02 - Mar/06	Jan/02 - Mar/06		Jan/02 - Jun/03	Jun/03 - Mar/06	Jun/03 - Mar/06
N. Observations	*51*	*51*		*18*	*34*	*34*

P-values are calculated with Newey-West robust standart errors

Figure 10:

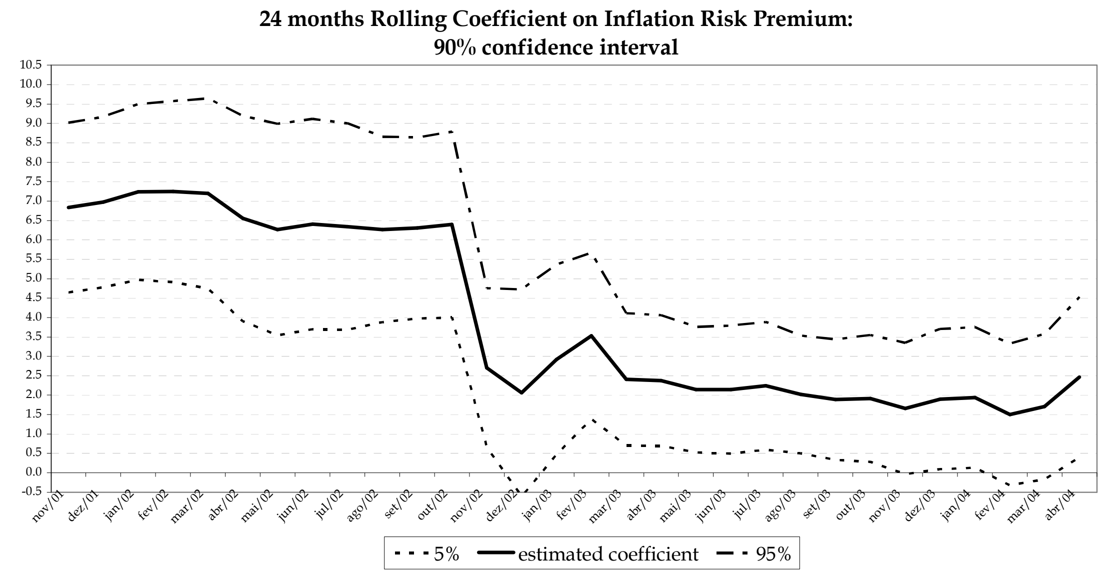


Figure 11:

The coefficient on inflation surprises is positive and significant in all specifications. The magnitude is much greater than the ones in inflation expectation regressions. Asymmetric effects are also present: positive surprises have a much larger effect than a negative one in the whole sample. On average a 1% inflation surprise increase inflation risk premium in 2.68%. We notice the EMBI spread also have a positive effect in inflation risk premium, but its inclusion don't change the significance of inflation surprises[21].

As on the previous analysis, the effect has clearly been diminishing in recent time. This can be seen in the regressions on more recent time frame and on the graph below, where we plot the result of 24 month rolling regression.

5 Conclusion

We propose a new approach to investigate monetary policy credibility: track the movements in inflation expectation and "inflation risk premium" separately. This is done through an asset pricing model with a Taylor rule and an equation for inflation dynamics which allow us to interpret this "inflation risk premium". We apply its results to investigate monetary policy credibility in Brazil.

[21] Recall that earlier we said that one of the possible causes of the time variation in inflation risk premium is a time varying price of risk. Embi is the usually the best instrument for risk aversion in Brazil and its inclusion does not change the significance of short run inflation surprises. Thus, we believe that the effect that we are focusing in, namely the expected change in Taylor rule, is indeed present.

We argue that an additional factor that can helps to explain the low efficiency of monetary policy in Brazil is the credibility. Although interest rates are very high in the present, what determines the agent's price setting is the expectation of what is going to happen in the future. If people think that the current tight monetary policy can be relaxed in the future, they will resist setting their prices according to the announced targets.

In fact, first we show that Brazil is one of the few countries in which short run inflation surprises affect medium run inflation expectations. This phenomenon leads to a less effective monetary policy, as its output cost is higher. We conjecture that this is a symptom of at least one of two problems: (i) Inflation inertia / indexation of the economy; and/or (ii) Lack of credibility of the monetary authority.

The remedy depends on the cause. For instance, if the reason is simply indexation, central bank independence will not solve it. The model presented argue that we can identify if credibility is one of the causes by looking at the inflation risk premium. We then show that this is the case in Brazil: we find a very strong relation between short run inflation surprises and inflation risk premium. It is also striking that the unexpected news on short run inflation seems to have effect both on 12 month inflation expectation and on inflation risk premium. Thus, we conclude that this evidence points out that central bank independence should helps monetary policy to be significantly less costly.

We conjecture that this lack of credibility cannot be understood looking at the history of very conservative decisions of the Brazilian central bank on our sample. We argued that what harms its credibility is the fear of regime switch (peso problem). This could happen either for a political reason, or by a financing constraint. The reasoning of the political economy is story goes as follows: bad news on inflation would require an even tougher monetary policy, reducing the chance of reelection of the incumbent party. In such a scenario, constantly arriving of good news would be necessary to prevent a regime switch and that's why bad news would have such a deleterious effect. Alesina, Roubini and Cohen (1999) survey this literature. Another possibility, as proposed by Blanchard (2004), is that fiscal dominance could induce to a monetization of the government debt in the future, therefore, increasing inflation. Perceiving that, agents would adjust their expectation today when a negative shock hits the economy.

6 References

Agénor, P R and M Taylor, 1993, "Analysing Credibility in High Inflation Countries: A New Approach," *Economic Journal, 103, 329-336.*

Alesina, A. and Roubini, N. with G. Cohen (1999) *Political Cycles and the Macroeconomy* The MIT Press, Cambridge, MA

Alesina, A. and Gatti, R. (1995) "Independent Central Banks: Low inflation at no costs?" *American*

Economic Review, Papers and Proceedings 196-200

Ang, A. and M. Piazzesi (2003) "A No-Arbitrage Vector Autoregression of Term Structure Dynamics with Macroeconomic and Latent Variables" *Journal of Monetary Economics* 50, 745-787

Ang, A., Dong, S. and Piazzesi, M. (2005) "No-Arbitrage Taylor Rules" working paper Columbia University

Ball, L. and D. Croushore (2005) "Expectations and The Effects of Monetary Policy" *Journal of Money Credit and Banking*, forthcoming

Barr, D. and J. Campbell (1997) "Inflation, Real Interest Rates and the Bond Market: A study of UK nominal and indexed linked government bond prices" *Journal of Monetary Economics* 39: 361-83

Bernanke, B. and Woodford, M. (1997) "Inflation Forecasts and Monetary Policy" *Journal of Money Credit and Banking 29: 653-684*

Blanchard, O. (2004) "Fiscal Dominance and Inflation Targeting: Lessons from Brazil" NBER Working Papers 10389

Campbell, J., A. Lo and C. MacKinley (1997) *The Econometrics of Financial Markets* Princeton University Press, Princeton, NJ

Campbell, J. and L. Viceira (2002) *Strategic Asset Allocation: Portfolio Choice for Long-Term Investors* Oxford University Press, Oxford

Cerisola, M. and Gelos, R. G. (2005) "What Drives Inflation Expectations in Brazil? An empirical analysis " *IMF working paper 05/109*

Cochrane, J. (2001) *Asset Pricing* Princeton University Press, Princeton, NJ

Gürkaynak, R., Levin, A. and Swanson, E. (2006) "Does Inflation Targeting Anchor Long-Run Inflation Expectations? Evidence from Long-Term Bond Yields in the U.S., U.K., and Sweden" *Federal Reserve Bank of San Francisco Working Paper 2006-09*

Laxton, Douglas, and Papa N'Diaye, 2002, "Monetary Policy Credibility and the Unemployment-Inflation Trade-Off: Some Evidence from 17 Industrial Countries," *IMF Working Paper 02/220*

Lindbeck, A. (1976) "Stabilization Policies in Open Economies with Endogenous Politicians" American Economic Review, Papers and Proceedings 1-19

Mankiw, G. and S. Zeldes (1991) "The consumption of stockholders and nonstockholders" *Journal of Financial Economics* 29: 97-112

Nordhaus, W. (1975) "The Political Business Cycle" *Review of Economic Studies* 42: 169-90

Rogoff, K. and A. Silbert (1988) "Elections and Macroeconomic Policy Cycles" *Review of Economic Studies* 55:1-16

Rossi, M. and A. Rebucci (2004) "Measuring Desinflation Credibility in Emerging Markets: A Bayesian Approach with Appliction to Turkey" *IMF Working Paper* 04/208

Persson T. and Tabellini (1990) Macroeconomic Policy, Credibility and Politics Chur, Switzerland:

Harwood Academic Publishers.

Rossi, M. and Rebucci, A. (2004) "Measuring Disinflation Credibility in Emerging Markets: A Bayesian Approach with an Application to Turkey" *IMF working paper 04/208*

Rudebusch, G. and T. Wu (2004) "A Macro-Finance Model of the Term Structure, Monetary Policy and the Economy" *Federal Reserve Bank of San Francisco Working Paper* 2003-17

Svensson, L. (1993) "The Simplest Test of Inflation Target Credibility" *NBER Working Paper* 4604

Hördal, P., O. Tristani and D. Vestin (2003) "A Joint Econometric Model of Macroeconomic and Term Structure Dynamics" *European Central Bank Manuscript*

Vasicek, O.(1977) "An Equilibrium Characterization of the Term Structure" *Journal of Financial Economics* 5, 177-188

7 Appendix

7.1 Pricing formula for 2 period bonds:

The price of a 2 period bonds:

$$p_t^{2\$} = E_t\left(m_{t+1}\right) + E_t\left(m_{t+2}\right) + \frac{1}{2}Var_t\left(m_{t+1}\right) + \frac{1}{2}Var_t\left(m_{t+2}\right) + Cov(m_{t+1}, m_{t+2})$$

$$\begin{aligned} P_t^2 &= E_t\left(m_{t+1}\right) + E_t(\pi_{t+1}) + E_t\left(m_{t+2}\right) + E_t(\pi_{t+2}) + \\ &+ \frac{1}{2}Var_t\left(m_{t+1}\right) + \frac{1}{2}Var_t(\pi_{t+1}) + \frac{1}{2}Var_t\left(m_{t+2}\right) + \frac{1}{2}Var_t(\pi_{t+2}) + \\ &+ Cov_t(m_{t+1}, m_{t+2}) + Cov_t(\pi_{t+1}, \pi_{t+2}) + \\ &+ Cov_t(m_{t+1}, \pi_{t+1}) + Cov_t(m_{t+1}, \pi_{t+2}) + \\ &+ Cov_t(m_{t+2}, \pi_{t+1}) + Cov_t(m_{t+2}, \pi_{t+2}) \end{aligned}$$

The 2 period forward rates are given by:

$$f_t = p_t^1 - p_t^2$$

$$f_t^{\$} = -E_t\left(m_{t+2}\right) - \frac{1}{2}Var_t\left(m_{t+2}\right) - Cov(m_{t+1}, m_{t+2})$$

$$\begin{aligned} f_t &= -E_t\left(m_{t+2}\right) - E_t(\pi_{t+2}) - \frac{1}{2}Var_t\left(m_{t+2}\right) - \frac{1}{2}Var_t(\pi_{t+2}) - \\ &- Cov(m_{t+1}, m_{t+2}) - Cov(\pi_{t+1}, \pi_{t+2}) - \\ &- Cov_t(m_{t+1}, \pi_{t+2}) - Cov_t(m_{t+2}, \pi_{t+1}) - Cov_t(m_{t+2}, \pi_{t+2}) \end{aligned}$$