Market expectations and inflationary bias in inflation targeting regimes

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Abstract

In inflation targeting regimes agents may influence the monetary policy through market expectations reported to the central bank. Monetary authority, in its turn, should formulate the monetary policy considering that influence may be used for the benefit of agents themselves. We model this strategic relationship as a sequential game between a representative financial institution and the central bank. We show that when the monetary authority chooses only the level of interest rates, there is a potential inflationary bias in the economy. This bias is overcome when the money supply becomes a second instrument of policy.

Keywords: inflation expectation; central bank; inflationary bias.
JEL: E52; E58; E59.

1 Introduction

Since the seminal paper of Taylor (1993), policymakers around the world have been knowing the importance of inflation expectation in their choices. Indeed, several studies have reported empirical evidences[1] of the expected price's level influence on the monetary authority's decision, mostly on the interest rate level's definition process. The so called Taylor rule indicates generally that stabilization policies should reply to both higher current inflation and higher expected inflation by increasing the basic interest rate of the economy.

As inflation targeting regimes have spread around the world, the importance of monitoring future prices' expectations has raised even more. Based on the rational expectations theory, central banks have tried to eliminate the economy's inflationary bias through "anchoring" the agents' expectations. This process consists basically in trying to make the inflation expectation converge to the target. In order to do so, the central bank may

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[1] For a survey of these studies as well as for history of the Taylor rule, see Asson et al. (2010).

create reputation of intolerant to inflation or to be independet, for example. The monitoring process may have such a major role that the central bank may adopt intermediate targets for the inflation expectation (Svensson, 1997).

The need of monitoring expectations has made several central banks create a system to collect periodically expected values of a set of macroeconomic indicators (prices, output, exchange rate, interest rate, among others)[2]. A set of agents, usually composed by financial institutions which have technical departments specialized in forecasting, reports to the monetary authority its expectations for many differents time horizons (daily, monthly, annual, among others). With that data, the policymaker has more information and may decide what monetary instrument to use as well as its optimal level.

Because central banks consider agents' expectations in their monetary policy's formulation, they give power to affect the economy's basic interest rate to those institutions which are part of market expectation system. This paper is based on the conjecture that those institutions have incentives to use such power for the benefit of themselves. To understand how that can happen, consider, for instance, an influent commercial bank that has a portfolio composed by assets indexed to the basic interest rate. Given that the bank knows the monetary authority's behavior, it may decide to report inflation expectation higher than that it really forecasts and so to impact positively inflation. This process makes the central bank replies with higher interest rate, benefiting the commercial bank.

Another reason for financial institutions prefer higher interest rates is that environments of low interest rate coupled with fierce banking competition may limit possibilities of loans and deposits' precification, putting pressure on the operating margin and negatively affecting banks' profitability (Trujillo-Ponce, 2013). In fact, empirical literature provides evidences of positive impact of the basic interest rate on commercial banks' profits. Examples are studies of Bourke (1989) for Europe, North America and Australia, Claeys and Vennet (2008), Molyneux and Thornton (1992) and Staikouras and Wood (2003) for Western and Central Europe, and García-Herrero et al. (2009) for China. In a broader research, including countries from all continents and of different levels of economic development, Demirguç-Kunt and Huizinga (1999) found the same evidence. The positive relationship between interest rate and banking profitability is also found in Brazil, according Rover et al. (2011) and Vinhado and Divino (2011).

The interest rate is not the only channel through which financial institutions may affect its own profit by choosing what inflation expectation to report. Higher inflation rate is generally positively correlated to higher banking profits. Revell (1979) provides one of the first reasons for that relationship by estabilishing that inflation's effects on profits depend on how both wages and other operational costs are affected. Further, Perry (1992) concludes that inflation's impact on profits depends on how price increases are antecipated by banks. So, with completely antecipated inflation, financial institutions may adjust suitably their interest rate, such that their revenue raises faster than their costs.

The positive relationship between inflation and banking profitability is also confirmed by empirical literature. Alexiou and Sofoklis (2009) and Athanasoglou et al. (2008) found such relationship by analysing the Greek banking sector. Moreover, Kasman et al. (2010) analyzes that sector in all European Union - including new members and candidates for future positions - and found the same positive association between those two variable.

[2]See, for example, the Brazilian system (https://www3.bcb.gov.br/expectativas/publico/consulta/serieestatisticas). Henceforth, based on names adopted by several central banks, we call such systems as market expectation systems.

That result confirms evidences already found by Claeys and Vennet (2008) and Pasiouras and Kosmidou (2007). Such a pattern also emerges when study object is the Brazilian banking sector, according Rover et al. (2011) and Vinhado and Divino (2011), and Chinese, according García-Herrero et al. (2009).

Finally, financial institutions also benefit from output growth. Low level of economic activity may make loans portfolio worse off, bringing credit losses, increasing banks reserves and so decreasing the sector's profitability. On the other hand, a good economic performance increases the demand for credit by households and firms as well as improves the solvency of borrowers, such that there exists a positive impact on banking profit (Athanasoglou et al., 2008; Trujillo-Ponce, 2013). In this regard, Albertazzi and Gambacorta (2009) concludes that pro-cyclical nature of the sector's profit is result of the net effect that economic growth causes in the interest revenue (via loans) and in the decrease of reserves (via improvement in the quality of credit's portfolio).

Besides Albertazzi and Gambacorta (2009), several studies observe the pro-cyclical behavior of the financial institutions' profitability. Demirguç-Kunt and Huizinga (1999) found such relationship as significant in a sample with countries of different phases of development, while Biker and Hu (2002) uses only industrialized countries and obtains the same result. Furthermore, it is noteworthy that relationship also arises in researches for Greece (Athanasoglou et al., 2008) and for Switzerland (Dietrich and Wanzenried, 2011). The Brazilian banking profitability, as Rover et al. (2011); Vinhado and Divino (2011) show, presents the same pro-cyclical pattern.

The aim of this paper is to model the strategic relationship between financial institutions and the central bank which is implicit in the above discussion. On the one hand, institutions wish to maximize their profit by choosing the level of inflation expectation to report to the monetary authority. On the other hand, the central bank aims to stabilize the economy - to minimize deviations both of inflation from its target and of output from its potential level - by choosing the level of monetary policy's instrument. Given that there exists the possibility of the reported expectation to be greater than true one, one of the critical points for the central bank is to give incentives to institutions in order to anchor expectations.

We present two sequential games of perfect and complete information involving the central bank and financial institutions. In the basic model of two periods, we allow that financial institutions choose what inflation expectation to report and then the central bank observes that move and decides the economy's interest rate. The equilibrium of this game results in inflationary bias and output below its potential level. That bias is overcome in the second model, in which we introduce in the basic game the possibility of the central bank to play before financial institutions by choosing the economy's money supply. Such modification coupled with an assumption about the equilibrium in bond market implies in inflation and output completely stabilized.

Since we obtain conclusions about inflationary bias, our paper relates to literature represented, for example, by the seminal study of Barro and Gordon (1983)[3]. However, unlike that paper, in our model the source of bias is not the dynamic inconsistency of the monetary policy, rather it is the possibility that agents use reported inflation expectation to affect the monetary authority's decision of interest rate. Furthermore, given that we obtain suitable mechanisms for overcoming the bias, our results are in line with other

[3]Papers cited in this paragraph are a small part of the large literature about that subject. For a good survey about inflationary bias and attempts to overcome this problem, see Persson and Tabellini (1990) and Walsh (2010).

works which suggest different ways to solve such problem. Known examples in literature are Rogoff (1985), Alesina (1987), Chari and Kehoe (1990), García de Paso (1993) and Walsh (1995).

Our paper also has similarities with the research area which models the game between the central bank and the public as a problem of asymmetric information. Although we adopt perfect and complete information, the use of game theory's tools makes our study close to Backus and Driffill (1985), Canzoneri (1985), Cukierman and Liviatan (1991), Ball (1995), among others. Further, our result about combination of monetary policy's instruments for anchoring inflation expectation is related to the discussion of optimal instruments and intermediate targets, surveyed in Friedman (1990) and, more recently in a context of inflation targeting, in Svensson (1997). In short, the main difference between our model and those in literature also is our major contribution: the possibility that agents affect the economy (inflation, output and interest rate) through their inflation expectation and the resulting inflationary bias.

This paper is divided in three sections. After this introduction, in the section 2 we study the strategic relationship between the central bank and financial institutions through two above cited games. Section 3 concludes and provides some ideas for future works. Ommited proofs are in appendix A.

2 Strategic relationship between central bank and financial institutions

2.1 The basic model: a game of two periods

Consider a game with two players, the central bank and a representative financial institution - a commercial bank is a good example. Our goal is to model how the strategic relationship between these two agents affects inflation and output. In order to do so, lets start defining current inflation and output functions:

$$\pi = \pi_0 \Delta m - \pi_1 i + \pi_2 \theta \tag{2.1}$$

and

$$y = y^* + a(\pi - \theta), \tag{2.2}$$

where π is the current inflation, Δm is the money supply change, i is the basic interest rate of the economy, θ is the inflation expectation reported by agents to the central bank, y is the current output, y^* is the potential output and π_0, π_1, π_2 and a are non-negatives exogenous parameters. Observe that, for the sake of simplicity, we are assuming the economy's structure is deterministic, given that there is no shock on π and y.

Equation (2.1) is based on the Taylor rule of monetary policy, cited in introduction. It is possible to note that (2.1) is just a rearrangement of terms in a simple linear rule, in which only the current inflation, its expectation and the money supply are considered in the interest rate decision. The important thing to notice is that i affects negatively π, such that the central bank has possibility to use such instrument in order to control price instability. On the other hand, θ impacts positively inflation. Further, (2.2) is a Lucas supply curve, used in several studies, such as Backus and Driffill (1985) and Ball (1995), for example. Observe that, according (2.2), output will be above its potential level only if there is inflation surprise.

Our first model is a two period sequential game with perfect and complete information, where the representative financial institution is the first to play. This agent decides what inflation expectation θ to report to the central bank[4]. The monetary authority observes the first player's choice, and then decides the level of the basic interest rate of the economy i. Next we will allow that the central bank also chooses the money supply. Therefore, we seek a subgame perfect equilibruim (SPE) in the form of strategy profile $\{\theta, i(\theta)\}$, what will allow us to replace the optimal values of θ e i in equations (2.1) and (2.2) and to find the current inflation and output of the economy.

Since it is a dynamic game, we must use backward induction in order to obtain the SPE. Thus, we start solving the central bank's problem, the last to play. Its aim is to stabilize the economy, minimizing deviations of inflation from its target and of output from its potential level. Formally, we represent its loss function by

$$U_{CB} = \frac{\lambda}{2}\left(y - y^*\right)^2 + \frac{1}{2}(\pi - \pi^*)^2, \tag{2.3}$$

where π^* is the inflation target, assumed as exogenous, and λ is a non-negative parameter that measures the weight given by the monetary authority to output stabilization relative to price stabilization. Expression (2.3) is standard in literature and it has been used, with some modifications, since the original version proposed by Barro and Gordon (1983)[5].

Given that its choice variable is i, we must replace (2.1) and (2.2) in (2.3) and then optimize the central bank's behavior. By doing that, we may write the monetary authority's problem as

$$\min_i \frac{\lambda}{2}\left[a\left(\pi_0\Delta m - \pi_1 i + (\pi_2 - 1)\theta\right)\right]^2 + \frac{1}{2}\left(\pi_0\Delta m - \pi_1 i + \pi_2\theta - \pi^*\right)^2.$$

Its first order condition is given by

$$-\pi_1\lambda a^2\left(\pi_0\Delta m - \pi_1 i + (\pi_2 - 1)\theta\right) - \pi_1\left(\pi_0\Delta m - \pi_1 i + \pi_2\theta - \pi^*\right) = 0, \tag{2.4}$$

which provides the following central bank's best response function[6]:

$$i(\theta) = \frac{1}{\pi_1}\left[(\pi_o\Delta m) - \frac{\pi^*}{(1+\lambda a^2)}\right] + \frac{\theta}{\pi_1}\frac{\left[\pi_2(1+\lambda a^2) - \lambda a^2\right]}{(1+\lambda a^2)}. \tag{2.5}$$

What (2.5) says is that the central bank will respond in a linear way to the inflation expectation reported by agents. However, notice that the slope of line defined by (2.5) depends on parameters' values of our model. Proposition 2.1 below deals with that subject.

Proposition 2.1 *Consider the central bank's best response function given by (2.5). Then:*

(i) if $\pi_2 > \frac{\lambda a^2}{(1+\lambda a^2)}$, then $\frac{\partial i}{\partial \theta} > 0$, that is, the monetary authority responds to increases in the reported inflation expectation with increases in the basic interest rate;

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[4]Our model does not concern about how *true* expectations are formed by agents - rationals or adaptatives, for example. In fact, our findings are independent of any assumption made about that process, because we consider only *reported* expectation.

[5]Walsh (2010) provides a good survey of monetary policy models which use (2.3).

[6]Because the central bank's loss function is strictly convex in i, (2.4) is a sufficient condition to minimum. Convexity is guaranteed by $\frac{\partial^2 U_{CB}}{\partial i^2} = \pi_1^2(1+\lambda a^2) > 0$.

(ii) if $\pi_2 < \frac{\lambda a^2}{(1+\lambda a^2)}$, then $\frac{\partial i}{\partial \theta} < 0$, that is, the monetary authority responds to increases in the reported inflation expectation with decreases in the basic interest rate;

(iii) and if $\pi_2 = \frac{\lambda a^2}{(1+\lambda a^2)}$, then the basic interest rate is independent of the reported inflation expectation.

What one may conclude from the proposition 2.1 is that, if condition $\pi_2 > \frac{\lambda a^2}{(1+\lambda a^2)}$ is satisfied, so the financial institution has power to affect positively the basic interest rate through their choice of what inflation expectation to report. In order to understand the condition above, lets define $M = \frac{\lambda a^2}{(1+\lambda a^2)}$. Given that π_2 measures the sensitiveness of the current inflation to the reported inflation expectation, we have that the financial institution will have (indirect) power of increasing i only if the effect of their reported expectation is greater than the bound M. Intuitively, if the effect of θ on π is large enough, thus the central bank will respond to increases in expectation with higher levels of interest rate, because one of its goals is to stabilize prices. On the other hand, if $\pi_2 < M$, so increases in θ will have small impact in π, such that the best response is to decrease i and to stimulate output.

Observe also that $M = \frac{\lambda a^2}{(1+\lambda a^2)} \leq 1$, because, for fixed λ, $\lim_{a\to\infty} M = 1$ and $\lim_{a\to 0} M = 0$, and for fixed a, $\lim_{\lambda\to\infty} M = 1$ and $\lim_{\lambda\to 0} M = 0$. Therefore, to ensure that higher expectations are replied by higher levels of the interest rate, one may think in imposing the condition $\pi_2 > 1$. Yet, it is not likely that in the Taylor rule of any economy, the effect of the inflation expectation on the current inflation is larger than unity. An assumption like that will imply in inertial inflation in the long run. In addition, it is not intuitive to assume large values for λ and a - case in which the central bank would give much more weight to the output stabilization relative to inflation, and that inflation surprise would affect substantially output, respectively. Then, given above reasoning and the fact of our paper focuses in the strategic relationship between financial institutions and the central bank, we make the following assumption.

Assumption 2.2 *$\pi_2 > M$.*

Now that we have the central bank's best response, we must solve the financial institution's problem. Based on the reasoning presented in the section 1, we model the profit function[7] of a commercial bank by

$$U_{IF} = \beta i + \phi\pi + \psi \ln(y + 1), \tag{2.6}$$

where β, ϕ and ψ are exogenous parameters. We assume that ϕ and ψ are non-negatives: financial institutions, in general, increase their profits with higher inflation rates and with higher economy's level of activity. For the sake of simplicity, and based on empirical observation above cited, we adopt a form linear both in i and π. However, we also assume that the demand for financial services does not increase at the same speed of output, such that the institution's profit is a logarithmic function of y[8].

Parameter β deserves some attention. Since it measures the sensitiveness of the institution's profit to changes in i, we consider this parameter as an indicator of the financial institution's position in bonds with yields indexed to the basic interest rate. Then, $\beta > 0$ indicates a creditor position in such bonds, what implies that increases in

[7] We adopt the implicit assumption that operational costs of financial institutions are constant.

[8] The functional form $\ln(y + 1)$ allows that output assumes negative values. Moreover, if output is zero, its contribuition to profit is null.

the interest rate increase the profit. On the other hand, if $\beta < 0$, the profit is negatively affected by i, because the institution is in debtor position. Finally, when $\beta = 0$, the institution is in balanced position, such that its profit is not affected by changes in i. It is noteworthy that we are considering just the direct effect of i on U_{FI}, but given that π and y are functions of i, there exist indirect effects to account as well.

In the continuation of backward induction process, now we have to find the financial institution's best response. That agent chooses what inflation expectation to report θ by foreshadowing the central bank's reply. Thus, we must to replace (2.1), (2.2), (2.5) in (2.6) before optimization, which yields

$$\begin{aligned} U_{FI} &= \beta \left\{ \frac{1}{\pi_1} \left(\pi_o \Delta m - \frac{\pi^*}{1+\lambda a^2} \right) + \frac{\theta}{\pi_1} \frac{[\pi_2(1+\lambda a^2) - \lambda a^2]}{1+\lambda a^2} \right\} + \phi \left(\frac{\pi^* + \lambda a^2 \theta}{1+\lambda a^2} \right) \\ &\quad + \psi \ln \left[y^* + a \left(\frac{\pi^* - \theta}{1+\lambda a^2} \right) + 1 \right]. \end{aligned}$$

The first order condition of $\max_\theta U_{FI}$ is given by

$$\frac{\beta}{\pi_1} \frac{[\pi_2(1+\lambda a^2) - \lambda a^2]}{1+\lambda a^2} + \frac{\phi \lambda a^2}{1+\lambda a^2} - \frac{\psi a}{(y^*+1)(1+\lambda a^2) + a(\pi^* - \theta)} = 0,$$

which yields

$$\theta^I = \pi^* + \frac{(y^*+1)(1+\lambda a^2)}{a} - \frac{\pi_1 \psi (1+\lambda a^2)}{\beta[\pi_2(1+\lambda a^2) - \lambda a^2] + \pi_1 \phi \lambda a^2}, \tag{2.7}$$

where the index I in θ indicates the solution of our first model[9]. Hence, we have that the SPE of our initial model is given by equations (2.5) and (2.7), $\{\theta^I, i(\theta)\}$.

An important question of comparative static - and that next we will see having a major role in the determination of inflation and output's level - is how the reported expectation is affected by changes in financial institution's assets (bonds) indexed to the basic interest rate. Proposition below presents this result.

Proposition 2.3 *Consider the optimal inflation expectation reported by the financial institution, θ^I. Then:*

(i) if assumption 2.2 is satisfied, increases in the institution's creditor position make the reported expectation increase, that is, $\frac{\partial \theta^I}{\partial \beta} > 0$;

(ii) if assumption 2.2 is not satisfied, increases in the institution's creditor position make the reported expectation not increase, that is, $\frac{\partial \theta^I}{\partial \beta} \leq 0$.

Before analysing the economic intuition of the above result, observe that item (ii) may be divided in two cases: when $\pi_2 < M$, so $\frac{\partial \theta^I}{\partial \beta} < 0$ and when $\pi_2 = M$, we have $\frac{\partial \theta^I}{\partial \beta} = 0$. Proposition 2.3 is presented in that way because our main interest is in the case of the assumption 2.2 is satisfied. Regarding the result's interpretation, notice that the necessary condition for the financial institution to increase its reported inflation expectation, when its amount of bonds indexed to the basic interest rate increases, is that its expectation has a minimum effect on the current inflation, measured by π_2. That

[9]Note that U_{FI} is strictly concave in θ, such that first order condition is sufficient for maximization: $\frac{\partial^2 U_{FI}}{\partial \theta^2} = -\frac{\psi a^2}{\{\beta[\pi_2(1+\lambda a^2) - \lambda a^2] + \pi_1 \phi \lambda a^2\}^2} < 0$.

makes sense because its profit increases with both the current inflation and the interest rate, but this last variable has such positive effect only if $\pi_2 > M$. Thus, if its power to affect inflation is small, the institution may find better to increase its profit through increases in output by reporting a lower inflation expectation.

Other important point to note in (2.7) is the nonlinearity in β. Indeed, that may also be seen in the expression of $\frac{\partial \theta^I}{\partial \beta}$, which it is constant (see the proof of proposition 2.3 in appendix A). Figure 1 shows that nonlinear relationship for a set of fixed parameters[10] and three different cases: $\pi_2 > M$, $\pi_2 < M$ and $\pi_2 = M$. It is possible to see that the optimal reported inflation expectation's replies changes at increasing rates, according the amount of bonds indexed to the interest rate increases. In the case of $\pi_2 > M$, for instance, increases in β make the financial institution increase θ^I at increasing rates. That behavior avoids that large changes in β yield large changes in θ and so in π.

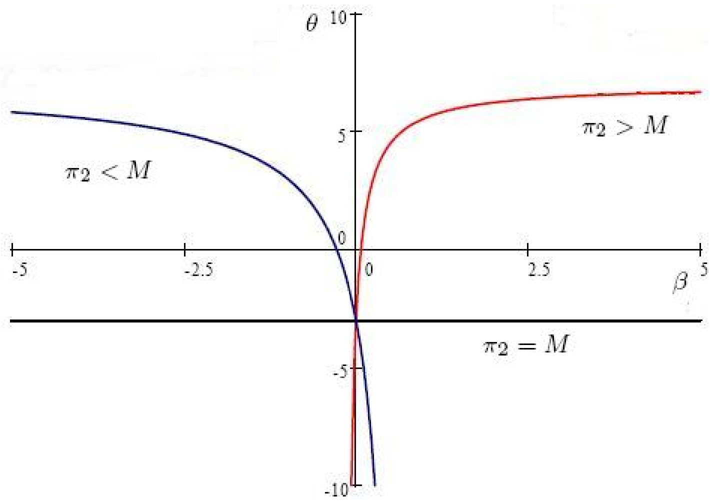

Figure 1: Inflation expectation

2.2 The potential inflationary bias

Lets investigate whether the strategic relationship modeled in the last section may result in inflationary bias. In order to do so, we start obtaining the equilibrium interest rate by using (2.7) in (2.5):

$$\begin{aligned} i^I &= i(\theta^I) = \frac{1}{\pi_1}\left[\frac{\pi_0 \Delta m(1+\lambda a^2) - \pi^*}{1+\lambda a^2}\right] + \frac{[\pi_2(1+\lambda a^2) - \lambda a^2][\pi^* a + (y^*+1)(1+\lambda a^2)]}{\pi_1 a} \\ &\quad - \frac{\psi[\pi_2(1+\lambda a^2) - \lambda a^2](1+\lambda a^2)}{\beta[\pi_2(1+\lambda a^2) - \lambda a^2] + \pi_1 \phi \lambda a^2}. \end{aligned} \tag{2.8}$$

It is possible to observe in (2.8) that the basic interest rate does not decrease in response to increases in the amount of bonds kept by the financial institution. Further, that result is independent from the assumption 2.2, in contrast to the proposition 2.3. This fact may

[10] Values are $\pi^* = 2$, $y^* = 1$, $a = \frac{1}{2}$, $\lambda = 1$, $\pi_1 = \frac{1}{2}$, $\psi = 1$ and $\phi = \frac{1}{2}$. Therefore, we have $M = \frac{1}{5}$, such that chosen values for π_2 are $\frac{1}{2}$, $\frac{1}{8}$ and $\frac{1}{5}$. The graphic's intercept, that is, the expectation when $\beta = 0$, is $\theta = -3$.

also be seen in

$$\frac{\partial i^I}{\partial \beta} = \frac{\psi[\pi_2(1+\lambda a^2) - \lambda a^2]^2(1+\lambda a^2)}{\{\beta[\pi_2(1+\lambda a^2) - \lambda a^2] + \pi_1\phi\lambda a^2\}^2} \geq 0.$$

Then, changes in β have no effect on i^I only if $\pi_2 = M$. In all other cases, increases in the financial institution's creditor position are replied by higher equilibrium interest rate.

Using (2.7) and (2.8) in (2.1) we obtain the equilibrium current inflation:

$$\pi^I = \pi^* + \lambda a(y^* + 1) - \frac{\pi_1\psi\lambda a^2}{\beta[\pi_2(1+\lambda a^2) - \lambda a^2] + \pi_1\phi\lambda a^2}. \tag{2.9}$$

Expression (2.9) may be used for comparative statics. For example, it is possible to investigate how changes in the monetary policy's efficiency (increase in π_1) affect π. One may think that more efficient monetary policy implies lower current inflation rate. However, that is not always the case. A situation which such effect does occur is when the financial institution has power to affect inflation positively and it is creditor position in indexed bonds ($\pi_2 > M$ and $\beta > 0$, respectively). As we are more interested in the cases in which the assumption 2.2 is satisfied, below proposition provides an important and intuitive result: an institutional improvement which makes the monetary policy more efficient may reduce the current inflation[11].

Proposition 2.4 *Consider the equilibrium current inflation π^I and suppose that $\beta > 0$. Then:*

(i) if assumption 2.2 is satisfied, increases in the monetary policy efficiency make the equilibrium current inflation decrease, that is, $\frac{\partial \pi^I}{\partial \pi_1} < 0$;

(ii) if assumption 2.2 is not satisfied, increases in the monetary policy efficiency make the equilibrium current inflation not decrease, that is, $\frac{\partial \pi^I}{\partial \pi_1} \geq 0$.

We may also analyze the effect of increases in β on π^I. As we may see below, that result is similar to those of proposition 2.3.

Proposition 2.5 *Consider the equilibrium current inflation π^I. Then:*

(i) if assumption 2.2 is satisfied, increases in the financial institution's creditor position make the current inflation increase, that is, $\frac{\partial \pi^I}{\partial \beta} > 0$;

(ii) if assumption 2.2 is not satisfied, increases in the financial institution's creditor position make the current inflation not increase, that is, $\frac{\partial \pi^I}{\partial \beta} \leq 0$.

As we have already mentioned, the above result is important for our model because it shows that when the financial institution has no power to affect positively inflation, it chooses to report a lower expectation in order to raise its profit through the demand channel - via y. That makes the current inflation reply negatively to positive changes in β. On the other hand, when the assumption 2.2 is satisfied, the institution has such a power, such that its profit raises through two other channels π e i. Indeed, observe that propositions 2.1, 2.3 and 2.5 jointly say that when $\pi_2 > M$ there exist incentives to raise θ, which, in its turn, affects positively both i^I and π^I.

Our next result establishes a lower bound for β, from which the equilibrium current inflation π^I is higher than its target π^*.

[11] Analysis of the case in which $\beta < 0$ is not too direct. When the financial institution is debtor, more efficient monetary policy impacts negatively its profit. In that case, it may want to increase its inflation expectation in order to raise the profit through π.

Proposition 2.6 *Consider the equilibrium current inflation π^I. Then:*

(i) if $\beta > K$, so $\pi^I > \pi^*$;

(ii) if $\beta < K$, so $\pi^I < \pi^*$;

(iii) if $\beta = K$, so $\pi^I = \pi^*$;

Where $K = \frac{\pi_1 a}{(y^*+1)} \frac{[\psi - \phi\lambda a(y^*+1)]}{[\pi_2(1+\lambda a^2) - \lambda a^2]}$.

What is above stated is that there exists a minimum amount of bonds indexed to the interest rate, such that any amount above this minimum makes the equilibrium current inflation be higher than its target. We must investigate the sign of K as well as its determinants. The first aspect to note is that the sign is determined by $[\psi - \phi\lambda a(y^* + 1)]$ and $[\pi_2(1 + \lambda a^2) - \lambda a^2]$. This second term is positive if and only if $\pi_2 > M$. We start analysing that case.

Case 1: $\pi_2 > M$. In this case, $K > 0$ if and only if $\psi - \phi\lambda a(y^* + 1) > 0$. By rewriting this last expression we obtain $\frac{\psi}{\phi} > \lambda a(y^* + 1)$. Thus, we have that $K > 0$ if and only if the output's contribution to profit relative to the inflation's contribution, $\frac{\psi}{\phi}$, is larger than a bound. In other words, when the output's contribution to profit is sufficiently larger than the inflation's contribution, then the financial institution must have a positive minimum amount of bonds (be a creditor) in order to the equilibrium current inflation is above its target. On the other hand, when the output's contribution to profit is sufficiently lower than the inflation's contribution, then the institution must have a negative minimum amount of bonds (be a debtor) in order to exist inflationary bias.

Case 2: $\pi_2 < M$. Now, necessary and sufficient condition for $K > 0$ is the opposite of case 1: $\frac{\psi}{\phi} < \lambda a(y^* + 1)$. Thus, for $K > 0$, the weight given to output relative to inflation in the institution's profit must be lower than that bound. Analysis of $K < 0$ is analogous to the previous case.

Case 3: $\pi_2 = M$. Observe that K is not defined under this condition. Nevertheless, we may verify that $\lim_{\pi_2 \to M} K = +\infty$ if $\frac{\psi}{\phi} > \lambda a(y^* + 1)$, such that β is never greater than K, indicating that we have always $\pi^I < \pi^*$; and that $\lim_{\pi_2 \to M} K = -\infty$ if $\frac{\psi}{\phi} < \lambda a(y^* + 1)$, such that $\beta > K$, implying that $\pi^I > \pi^*$.

Given that our interest is in situations which satisfy the assumption 2.2, we restrict our analysis to the case 1. Based on empirical observation reported by literature in the introduction we may conjecture that the inflation's contribution to profit is greater relative to the output's contribution. Therefore, it is not unrealistic to consider the case in which $\frac{\psi}{\phi} < \lambda a(y^* + 1)$ as the most usual found in the economy. Proposition 2.6 then states that if $\beta > K$, with $K < 0$, we have $\pi^I > \pi^*$. A corollary of that result is that even if the institution has debts indexed to the basic interest rate, then equilibium current inflation is above its target.

It is important to observe that in our model even if $\beta = 0$, that is, the financial institution is neither a creditor nor a debitor in bonds indexed to the interest rate, we may have inflationary bias if the weight given to output in profit is sufficiently greater than the weight given to inflation. In addition, note that there exists a level of β such that the current inflation is exactly equal to that defined as target. If the monetary authority could induce the financial institution to buy (or to sell) bonds in the amount $\beta = K$, then there would not be inflationary bias. Those conclusions may be visualized in the figure 2, which provides a graph of inflationary bias as function of β with all other parameters fixed[12].

[12]Parameters assume the same values used in the figure 1.

We allow the monetary authority induce the institution's choice in the next section. Before that, however, lets note that a result analogous to the proposition 2.6 is valid for the equilibrium current output.

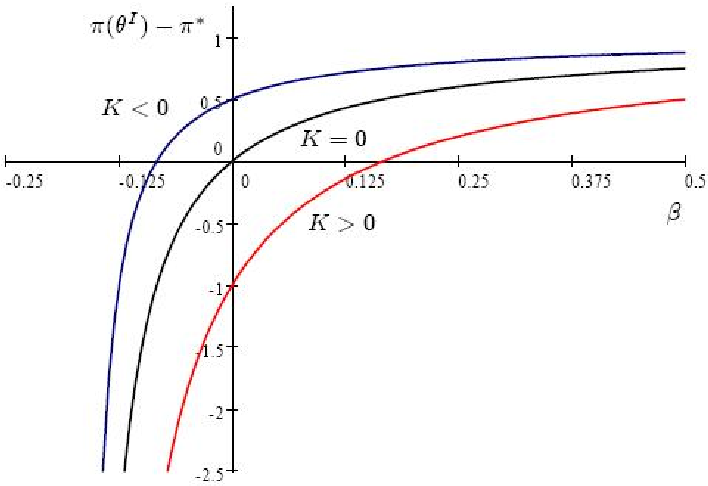

Figure 2: Inflationary bias and financial institution's level of bonds

Proposition 2.7 *Consider the equilibrium current output* y^I*. Then:*
(i) if $\beta > K$*, so* $y^I < y^*$*;*
(ii) if $\beta < K$*, so* $y^I > y^*$*;*
(iii) if $\beta = K$*, so* $y^I = y^*$*;*
Where $K = \frac{\pi_1 a}{(y^*+1)} \frac{[\psi - \phi\lambda a(y^*+1)]}{[\pi_2(1+\lambda a^2) - \lambda a^2]}$.

All reasoning used in the above analysis of the inflationary bias may be applied to understand the proposition 2.7. In fact, in the most usual case, we have the current output below to its potential level. Futhermore, as before, there exists a level of β that makes the current output equal to potential one, namely $\beta = K$.

2.3 Overcoming the inflationary bias: a three period game with money supply choice

In this section we modify the basic model by introducing an additional period. Now, the central bank is the first to play by choosing the economy's money supply, Δm. Next, the financial institution observes that first move and so chooses the inflation expectation θ to report to the monetary authority. Finally, the central bank observes the institution's choice and so defines the economy's basic interest rate i. In order to solve this game, we include an additional assumption: changes in the money supply are due exclusively to buying and selling bonds indexed to the interest rate i (open market operations). Hence, given that a positive (negative) change in the money supply means buying (selling) of bonds, we have the following definition:

Definition 2.8 *We say that bond market is in equilibirium if supply and demand are equal, that is,* $\beta = -\Delta m$*.*

With the possibility to affect β through the money supply Δm, the central bank may control the inflation expectation reported by the financial institution and so affect inflation. Therefore, we assume as satisfied:

Assumption 2.9 *Bond market is in equilibrium, that is, $\beta = -\Delta m$.*

We now search for a SPE in the following form $\{(\Delta m, i(\theta, \Delta m)), \theta(\Delta m)\}$. Since the period just added is the first, we have already obtained the best response for the two last periods, which are given by (2.5) and (2.7). Thus, for our purposes, we must use the bond market's equilibrium condition in order to obtain the institution's best response:

$$\theta(\Delta m) = \pi^* + \frac{(y^*+1)(1+\lambda a^2)}{a} - \frac{\pi_1\psi(1+\lambda a^2)}{\pi_1\phi\lambda a^2 - \Delta m[\pi_2(1+\lambda a^2)-\lambda a^2]}. \tag{2.10}$$

By substituting (2.5) and (2.10) into the central bank's loss function (2.3), we have

$$\begin{aligned} U_{CB} &= \frac{\lambda a^2}{2}\left\{\frac{\pi_1\psi}{\pi_1\phi\lambda a^2 - \Delta m[\pi_2(1+\lambda a^2)-\lambda a^2]} - \frac{(y^*+1)}{a}\right\}^2 \\ &\quad + \frac{(\lambda a^2)^2}{2}\left\{\frac{(y^*+1)}{a} - \frac{\pi_1\psi}{\pi_1\phi\lambda a^2 - \Delta m[\pi_2(1+\lambda a^2)-\lambda a^2]}\right\}^2, \end{aligned}$$

which yields the following first order condition[13]

$$\begin{aligned} 0 &= \lambda a^2(1+\lambda a^2)\frac{\pi_1\psi[\pi_2(1+\lambda a^2)-\lambda a^2]}{\{\pi_1\phi\lambda a^2 - \Delta m[\pi_2(1+\lambda a^2)-\lambda a^2]\}^2} \\ &\quad \cdot\left\{\frac{\pi_1\psi}{\pi_1\phi\lambda a^2 - \Delta m[\pi_2(1+\lambda a^2)-\lambda a^2]} - \frac{(y^*+1)}{a}\right\}. \end{aligned}$$

Therefore, the money supply which minimize the central bank's loss is given by

$$\Delta m^{II} = \frac{\pi_1 a}{(y^*+1)}\frac{[\phi\lambda a(y^*+1)-\psi]}{[\pi_2(1+\lambda a^2)-\lambda a^2]} = -K, \tag{2.11}$$

where the index II indicates the solution of our second model. Applying the assumption 2.9 we have $\beta = K$, what, by the proposition 2.6, implies $\pi^{II} = \pi^*$. In addition, using the proposition 2.7, we have $y^{II} = y^*$. That conclusion is summarized in below proposition.

Proposition 2.10 *Consider the three period game described in this section and assume that the assumption 2.9 is satisfied. Then, the SPE implies in complete stabilization of the economy, with $\pi^{II} = \pi^*$ and $y^{II} = y^*$. In other words, there is no inflationary bias.*

By allowing that the central bank plays before the financial institution and so bounds the choice of inflation expectation, we obtain a complete stabilization of the economy. In fact, the key of the bias elimination is in the combination of two new model's features: the antecipated choice of the money supply and the equilibrium in bond market. After the definition of Δm^{II}, the instituition's bond portfolio is already defined by the equilibrium condition, such that the inflation expectation's choice are bound by that. Hence, the best response of financial institution is $\theta^{II} = \pi^*$.

Another interesting analysis that we may perform in (2.11) concerns to relationship between the monetary policy's instruments Δm and i. Recall that the money supply is chosen before the interest rate in this section. We may wonder whether that lag in the

[13] The problem is convex under the assumption 2.2, such that the first order condition ensures the minimum for the central bank. Note that $\frac{\partial^2 U_{CB}}{\partial \Delta m^2}(\Delta m^{II}) = \frac{\lambda(1+\lambda a^2)(y^*+1)[\pi_2(1+\lambda a^2)-\lambda a^2]}{(a\psi\pi_1)^2} > 0$.

decision process makes instruments substitute or complementary. In this regard, observe that sensitiveness of Δm^{II} to changes in efficiency of i is given by:

$$\frac{\partial \Delta m^{II}}{\partial \pi_1} = \frac{a}{(y^*+1)} \frac{[\phi\lambda a(y^*+1) - \psi]}{[\pi_2(1+\lambda a^2) - \lambda a^2]} = -\frac{K}{\pi_1}.$$

It is possible to notice that sign of $\frac{\partial \Delta m^{II}}{\partial \pi_1}$ depends on the value of K, that is, depends on which of the three cases cited in section 2.2 the economy is[14]. By assuming again the case 1 ($\pi_2 > M$) as the most usual, we may note that instruments have complementary functions if $\frac{\psi}{\phi} < a\lambda(y^*+1)$. In other words, if the output's contribution to profit is sufficiently lower than the inflation's contribution, then the central bank uses both instruments jointly: the more efficient the interest rate is the higher is the money supply. On the other hand, if more weight is given to output, then increases in the efficiency of i make Δm^{II} decrease.

3 Concluding remarks

Many central banks use the inflation expectation reported by a group of agents as one of their Taylor rule's inputs. That gives power to those agents affect important macroeconomic variables, specially the economy's basic interest rate. In this paper we show that such power may be used for benefiting themselves, such that it results in higher reported values to the monetary authority. Further, since such agents usually are financial institutions (e. g., commercial banks), we found that there exists a potential inflationary bias in economies with inflation target regimes. Therefore, the central bank have to use avaiable instruments in order to overcome that bias. In particular, we show that a combination between suitable money supply and equilibrium in bond market may be an effective alternative.

All our results have in common the relevance of banks' financial budget (amount of bonds indexed to the basic interest rate) in the monetary authority's decision. Thus, in a normative sense, in inflation targeting regimes central banks must pay attention to portfolio of those agents. Furthermore, central banks that adopt such regime must monitor institutions' structure of revenues - whether depends on interest rate, inflation or output - as well as how large is their power of affecting the economy.

Our model is a first step toward studying inflationary bias as result of false reported expectations in inflation targeting regimes. Therefore, we suffer from some limitations that we expect future researches may overcome. The first of those limitations is that we do not allow the financial institution to choose its portfolio (amount of bonds), rather we define it exogenously. In our framework, inclusion of this possibility make the financial institution's problem not concave[15]. An alternative for overcoming such difficulty is to modify the functional form of the institutions's profits or even part of the economy's structure (equations (2.1) and (2.2)). We conjecture that such modification would exacerbate the inflationary bias, because banks now could buying a large amount of bonds in the first period and then to report a higher inflation expectation, for example.

Further in this regard, the proposal of overcoming the inflationary bias presented in the section 2.3 is based on two assumptions which may be object of discussion. One

[14]There is no economic intuition in $\pi_1 < 0$, because it implies monetary policy with effect completely different from that observed and theorized. Then, sign of $\frac{\partial \Delta m^{II}}{\partial \pi_1}$ depends only on K.

[15]That occurs because we are considering only interior solutions.

may wonder, for instance, how our result would be modified if we give up of all money supply is executed through open market. Observe that such change would modify our definition of equilibirum in bond market (definition 2.8 and assumption 2.9), because now we have $-\beta \neq \Delta m$. If the bond market continues in equilibrium - under a new definition -, the central bank's power of choosing the money supply would continue to eliminate the inflationary bias. However, by abdicting of market equilibrium, the bias probably would persist because it is not longer possible to affect directly the institution's portfolio.

Other limitation concerning to the market bond equilibrium assumption is that due to the complexity of financial markets there can be many financial assets (e. g., financial derivatives) others than public bonds which are indexed to the the economy's basic interest rate. Furthermore, the central bank hardly controls two different monetary policy's intruments, as we have assumed. As suggested by Friedman (1990), there can be intermediate targets of policy and some avaiable instruments must be used to achieve these targets. That may reduce the central bank's freedom of choice concerning the ultimate target.

Other extensios of our model which we believe are promising concerning to make the game repetead by allowing that the monetary authority creates reputation. In addition, repetition may also allow inflation forecasters create reputation: for example, an institution could try to be a good forecaster for a certain period of time and so to acquire a good reputation; if such reputation increases its power of affecting the central bank's decision, it may use that in order to obtain a large benefit in the future by deliberately lying its expectation. Further, other interesting extensions is to add many institutions in the model and to allow that there exists an interbank (second hand) market of bonds.

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A Ommited proofs

Proof. Proposition 2.1. Given that

$$\frac{\partial i}{\partial \theta}(\theta) = \frac{1}{\pi_1} \frac{[\pi_2(1+\lambda a^2) - \lambda a^2]}{1+\lambda a^2},$$

and recalling that all parameters are non-negative, result follows. ■

Proof. Proposition 2.3. Observe that

$$\frac{\partial \theta}{\partial \beta} = \frac{\pi_1 \psi (1+\lambda a^2)[\pi_2(1+\lambda a^2) - \lambda a^2]}{\{\beta[\pi_2(1+\lambda a^2) - \lambda a^2] + \phi \lambda a^2 \pi_1\}^2},$$

such that result again follows from the fact that all parameters are non-negative. ■

Proof. Proposition 2.4. Note that

$$\frac{\partial \pi^I}{\partial \pi_1} = \frac{-\psi \lambda a^2 \{\beta[\pi_2(1+\lambda a^2) - \lambda a^2]\}}{\{\beta[\pi_2(1+\lambda a^2) - \lambda a^2] + \phi \lambda a^2 \pi_1\}^2},$$

such that its sign depend on the term $\beta[\pi_2(1+\lambda a^2) - \lambda a^2]$. Thus, as $\beta > 0$ by assumption, we have the result. ■

Proof. Proposition 2.5. Result directly follows from

$$\frac{\partial \pi^I}{\partial \beta} = \frac{\psi\lambda a^2[\pi_2(1+\lambda a^2)-\lambda a^2]}{\{\beta[\pi_2(1+\lambda a^2)-\lambda a^2]+\phi\lambda a^2\pi_1\}^2},$$

because the term $[\pi_2(1+\lambda a^2)-\lambda a^2]$ again determines the derivative's sign. ■

Proof. Proposition 2.6. Inflationary bias is measured by

$$\pi^I - \pi^* = \lambda a(y^*+1) - \frac{\psi\lambda a^2}{\beta[\pi_2(1+\lambda a^2)-\lambda a^2]+\phi\lambda a^2\pi_1},$$

which is greater than zero if and only if

$$\lambda a(y^*+1) > \frac{\psi\lambda a^2}{\beta[\pi_2(1+\lambda a^2)-\lambda a^2]+\phi\lambda a^2\pi_1}.$$

Solving for β, we have as necessary and suffient condition for $\pi^I > \pi^*$,

$$\beta > \frac{\pi_1 a}{(y^*+1)}\frac{[\psi-\phi\lambda a(y^*+1)]}{[\pi_2(1+\lambda a^2)-\lambda a^2]} = K. \tag{A.1}$$

We can do the same for cases $\pi^I < \pi^*$ and $\pi^I = \pi^*$. ■

Proof. Proposition 2.7. Difference between the current output and the potential output is

$$y^I - y^* = \frac{\pi_1\psi a}{\beta[\pi_2(1+\lambda a^2)-\lambda a^2]+\phi\lambda a^2\pi_1} - 1 - y^*,$$

which is greater than zero if and only if

$$\frac{\pi_1\psi a}{\beta[\pi_2(1+\lambda a^2)-\lambda a^2]+\phi\lambda a^2\pi_1} < (y^*+1).$$

Solving for β again, we obtain (A.1) as necessary and sufficient condition. ■

Proof. Proposition 2.10. Given that, by (2.11), $\Delta m^{II} = -K$, using the assumption 2.9 we have $\beta = K$, what, by the proposition 2.6, ensures $\pi = \pi^*$. ■