Pontifícia Universidade Católica
do Rio de Janeiro

Fernando Graciano Bignotto

Central Banker Talk

Dissertação de Mestrado

Dissertação apresentada como requisito parcial para obtenção do grau de Mestre pelo Programa de Pós–graduação em Economia do Departamento de Economia da PUC–Rio

Orientador: Prof. Vinicius Carrasco

Rio de Janeiro
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DO RIO DE JANEIRO

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Dissertação apresentada como requisito parcial para obtenção do título de Mestre pelo Programa de Pós-Graduação em Economia da PUC-Rio. Aprovada pela Comissão Examinadora abaixo assinada.

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Resumo

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Existem várias formas pelas quais um Banco Central pode se comunicar com o público em geral – essas vão desde atas das reuniões do comitê de política a pronunciamentos feitos por um de seus membros, da publicação de projeções sobre a conjuntura econômica a comentários feitos pelo seu presidente. Esta dissertação considera o papel da comunicação como um instrumento de *política* usado pelo Banco Central.Desenvolvemos um modelo no qual, um Banco Central que possui mais informação que os formadores de preço sobre o estado da economia pode, através de uma comunicação sem custos (*cheap talk*), influenciar suas decisões de precificação. Nós relacionamos o grau de comunicação a fundamentos da economia, como as preferências do Banco Central, a quantidade de informação que os agentes possuem e o grau de complementariedade de suas decisões de precificação.

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Palavras–chave

Comunicação. Banco Central. Cheap-Talk. Jogos Globais.

Abstract

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This dissertation considers the role played by communication as a *policy* instrument by the Central Bank. In the model, a Central Banker who is better informed than the price setters about the state of the Economy can, through (cheap talk) communication, influence their pricing behavior. We relate the degree of communication to fundamentals of the economy such as the Central Banker's preferences, the amount of information possessed by market agents and the degree of complementarity in their price-setting decisions.

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Keywords

Communication. Central Bank. Cheap-Talk. Global Games.

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1
Introduction

There are many ways – ranging from monetary policy minutes to announcements made by monetary policy committee members, from the disclosure of economic outlook forecasts to statements made by its chairmen – in which Central Banks communicate with the general public. This paper considers the role played by communication as a *policy* instrument by the Central Bank.

Over the past few years, there has been an increasing trend toward more communication by the Central Banks' part. As an example, starting in 1994, the Federal Reserve Board (FED) began disclosing changes in its operating stances. In 1999, they began to announce a "bias" for future policy actions, and in 2000 they started to publish a minute of the Federal Open Market Committee meetings.[1]

The amount of communication between the Central Bank and the public we now observe has not always prevailed. In fact, as put by the current FED's chairman, Ben Bernanke:

> "Central bankers long believed that a certain "mystique" attached to their activities; that making monetary policy was an arcane and esoteric art that should be left solely to the initiates; and that letting the public into the discussion would only usurp the prerogatives of insiders and degrade the effectiveness of policy.[2]"

There are at least two reasons why a Central Bank should communicate. First, due to its independence, it is important to make the Central Bank accountable for its actions: the requirement of some information disclosure is one of the ways in which this can be done. Second, communication can

[1]See (6) for further details on the evolution and scope of Central Bank´s communication.
[2] *"Fedspeak", FBR Speech, January 3, 2004.*

influence agents'expectations about important aspects of monetary policy.

This paper addresses explicitly the policy motive for communication in a simple model in which a Central Banker, who is better informed than the price setters about the state of the Economy, can, through communication, condition their behavior. The assumption that the Central Banker is better informed than price setters is founded on both anecdotal and formal empirical evidence (see (18)). The information asymmetry is key in our model, as it is the reason why a Central Banker may want to communicate. In the model, the Central Banker is concerned with the Economy's average price level, and with the overall price dispersion/variability. The source of misalignment of incentives between the Central Banker and the price setters is a bias toward (average) prices that are lower than a state that the Central Banker has.

Communication takes the form of cheap talk, in the sense that communication is direct and it is costless for the Central Banker (see (11)). In fact, our approach follows closely the partisan advice model in (5). There are two substantial differences. The first one is that there are many "receivers" (the price setters), who, after observing the message sent by the "sender" (the Central Banker), decide independently on prices. They care both about the overall state of the Economy and *relative* prices, which leads to a coordination motive among the price-setters. Individual prices are aggregated into an average price level which is, along with the price dispersion, the relevant variable for the Central Banker. Second, and most important, the price setters receive private signals regarding the state of the Economy. This is meant to capture the dispersion and heterogeneity of information across the firms in the Economy. Also, it allows us to analyze how the Central Bank's communication policy is affected by the information the *agents* in the economy have.

The main results we obtain are as follows. First, in general, communication between the Central Bank and firms involves noise: given the misalignment of incentives, the Central Bank cannot reveal all the information he possesses. The second main result is that the more the Central Bank cares about price dispersion, the more information he can convey to firms. In the limit case in which he just cares about price dispersion, full revelation of the state can be approximated. Third, if the Central Bank does not care about price dispersion, and the precision of the price setters' is sufficiently high, no meaningful communication can prevail between them: in any equilibrium, irrespective of the economy's state, the Central Bank will always make the

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same statement; so no information can be learned by the price setters. Finally, if the price setters' decision depends more on relative prices than on the overall economy's state, then the Central Bank can always transmit some information.

In addition to those general results, upon imposing some additional restrictions on the model's informational structure, we are able to fully characterize the set of all possible communication equilibria of the game between the Central Banker and the price setters. For such case, a single parameter, which we interpret as being that *de facto* bias degree of misalignment of incentives between the Central Bank and the price setters, completely pins down the Central Bank's communication possibilities. Such parameter depends on the degree of complementarity in the price setters' decisions (as measured by the weight the relative prices have in their optimal price), the precision of their signals, the Central Bank's bias, and the parameter that measures its with price dispersion. Hence, by analyzing the behavior of the *de facto* bias, we are able to perform many exercises relating the maximum amount of information conveyed by the Central Bank to changes in fundamentals, as captured by preferences and technology parameters.

There are other theoretical papers that study communication by Central Banks. In a model in which the Central Bank cares about both interest rates and the real exchange rate, (19) shows that, if the public does not know what goal the Central Bank is pursuing, an inflationary bias would emerge. To mitigate this problem, the Central Banker can use "cheap-talk" messages to influence the pricing decisions. In contrast to his work, we take the inflationary bias as given, and show how communication policy changes as the fundamentals of the economy change.

Our approach to model the price setters' interaction is similar to the one used in the "Global Games" literature (see, for example, (14), and (16)). The imperfect common knowledge implicit in those models allows us to study, in a tractable way, how information affects decisions and coordination in a imperfect information environment. It also allows us to analyze how a greater transparency from the Central Bank's part might influence pricing decisions, output and welfare.
(15), (21), (1), (2), (9) and (13) have used Global Games to study how Central Bank's transparency affect welfare. With the exception of the first, all of these articles show that social welfare increases with Central Bank's transparency.

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As (20) argues, the cases in which more information can be detrimental to welfare in (15) can be seen as special cases.

In those papers, greater transparency is viewed as an exogenous increase in the precision of the public information. That is, a more transparent Central Bank is translated into a more precise information that is common to all price-setters. This paper, in contrast, takes a step back and treats transparency as a strategic *choice* by the Central Banker. Indeed, the Central Bank's communication policy (and, therefore, its transparency) is derived endogenously in our model.

This paper is organized as follows. In section 2 we describe the model. In section 3 we characterize the equilibrium set and some proprieties of the equilibria, in section 4 we further restrict the model to be able to have stronger proprieties of the equilibrium set. In section 5 we briefly discuss the possibility of costly communication instruments and finally present our conclusions in section 6

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2
The Model

We consider a setting where there is a continuum of price setting firms of measure 1, and a Central Banker. Each firm $i \in [0,1]$ chooses price p_i to maximize profits

$$\pi_i\left(p_i, p_{-i}; \theta\right) = K - (1-r)\left(p_i - \theta\right)^2 - r\left(p_i - \overline{p}\right)^2,$$

where K is a large positive number – the maximum profit level firm i can earn,

$$\overline{p} = \int_{i\in[0,1]} p_i d_i$$

is the average price level, and θ measures the aggregate economic activity.

This utility implies that, when picking its pricing policy, the firm cares about relative prices, through the term $\left(p_i - \overline{p}\right)^2$, and the overall activity level, $\left(p_i - \theta\right)^2$. Such preferences are standard, and can be derived from a monopolistic competition model à la (4)

The Central Banker's preferences are represented by

$$U^{CB}\left(\overline{p}, \sigma_p^2; \theta\right) = -\left(\overline{p} - (\theta - c)\right)^2 - \beta\sigma_p^2,$$

where $\sigma_p^2 = E\left[p_j - \overline{p}\right]^2$ is a measure of price volatility, and $\beta \geq 0$ captures the relative weight that the banker puts on the variability of prices *vis-a-vis* their average price target, $\theta + c$. We assume that such target differs by an amount c from the real state θ. This is meant to capture the misalignment of incentives between the firms and the banker. In fact, there is a myriad of reasons – ranging from time inconsistency problems ((12)) to the possibility of the banker being subject to political pressure by interested parties ((17)) – to believe that a (benevolent) central banker has incentives to produce unexpected inflation. The assumption that the banker would like to convey a higher state than the true one is a reduced form way to model these incentives.

There are at least two reasons to justify why the Central Banker may care about price volatility. The first is straightforward: if the monetary authority cares about the firms, it would dislike volatility. This can be easily seen for the special case in which there is no misalignment of incentives between the firms and the banker, and the latter maximizes the sum of the firms' profits. The second is founded on the anecdotal evidence provided by Central Banks' statements: in most of them, there are explicit references to the authorities' pursuit of price volatility reduction.[1]

The Central Bank is better informed than the agents about θ. The agents view θ as being uniformly distributed over $[0,1]$, whereas the authority knows the exact value of θ. Before setting their prices, however, agent i learns a private signal about the state, x_i, which bounds the degree of asymmetry between the authority and the firms.

We assume the following simple technology for the signal. Letting $I_i = 1$ with probability q, and $I_i = 0$ with probability $1-q$,

$$x_i|\theta, I_i = \begin{cases} \theta \text{ if } I_i = 1 \\ x_i \sim U[0,1], x_i \perp \theta \text{ if } I_i = 0 \end{cases}.$$

In words, the signal fully reveals the state with probability q, but is completely uninformative with complementary probability.

Before the agents receive their private signal about the state, the Central Bank can make a statement about the Economy. We make the natural assumption that the firms cannot commit to any particular pricing policy so that the communication between the Central Bank and firms takes the form of c*heap talk*.

The game unfolds as follows. In period zero, the monetary authority learns θ, and makes a statement s in a set S about the state. In period 1, each firm i observes both the Central Bank's statement and the private signal x_i. Finally firms set prices simultaneously in period 2.

[1]See *FBR Speech* on November 18th, 2005 by Vice-Chairman Ferguson on housing prices or the speech by Otmar Issing, member of the European Central Bank, on the 13th and 14th of December, 2004.

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3
Equilibrium

We proceed by solving the game backwards. To do so, we first derive the communication protocol that a Central Banker must adopt in any equilibrium. Then, taken as given an arbitrary statement made by the Central Banker, we solve for the equilibrium of the pricing game between the price setters. Finally, we solve for the optimal communication policy for the Central Banker.

3.1
The Communication Protocol

The misalignment of incentives bound from above the amount of information that a Central Bank can credibly convey to the price setters through its statements. In fact, it is easy to see that there is no equilibrium in which the Bank completely and truthfully reveals the state of the economy: if there were such an equilibrium, the price setters could ignore their private signals, and set

$$p_i = \theta \text{ for all } i.$$

so that

$$\overline{p}|s_n = \theta, \text{ and } Var(p_n|s_n, \theta) = 0.$$

In such a case, however, the Central Banker would have an incentive to report $\theta + c$ rather than θ, misleading the price setters towards his objectives. The above discussion shows that, if there is a misalignment of interest between the Central Banker and the price-setters, communication must involve *noise*, that is, the state *cannot* be perfectly inverted from the message sent.

Now, fix a given noisy statement about the state made by the Central Banker. In any equilibrium of the price setting game induced by such statement, there will be a single average price, $\bar{p} \equiv \int_i p_i di$, and a single price dispersion, σ_p^2. Note that $\bar{p}$ and σ_p^2 depend on θ only through the noisy statement made by the Central Banker. **Since we fixed that statement, we have:**

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$$\frac{\partial \overline{p}}{\partial \theta} = \frac{\partial \sigma_p^2}{\partial \theta} = 0$$

Hence, as the Central Banker's preferences are strictly concave and such that:

$$\frac{\partial^2 U^{CB}\left(\overline{p}, \sigma_p^2; \theta\right)}{\partial \overline{p} \partial \theta} > 0,$$

there can be at most one state θ for which the Central Banker is indifferent between any two **statements, which implies two combinations of average price and price dispersion**. Moreover, the set of states $\{\theta\}$ for which a given average price and dispersion are best must be an interval. Since the Central Banker's payoffs are continuous in the states, those intervals will form a partition of the possible states.

It follows from the above discussion that the communication between the Central Banker and the firms takes the form of intervals (partitions). Formally,

Proposition 1: If there is a misalignment of incentives between the Central Banker and the price-setter ($c > 0$), then communication must involve noisy signaling. The set of possible states is partitioned into intervals, and a message is sent only if the actual state lies in the interval associated with it.

In any equilibrium, the Central Banker states in which interval the actual state lies in, and the price setters update their beliefs about the state in setting their prices. Such communication protocol allows the Central Banker to disclose some information (and consequently influence the actions of the price setters), and, at the same time, withhold enough information so to make such communication policy credible to firms.

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3.2 The Pricing Game

A statement s made by the Central Bank in period zero, and private signals $\{x_i\}_i$ received in period 1 define a game of incomplete information among the price setters in period 2. We now derive the equilibrium set of such pricing game.

After observing the message s and the signal x_i, firm i chooses prices p_i to solve

$$\max_{p_i} -E\left[(1-r)\left(p_i-\theta\right)^2 + r\left(p_i-\overline{p}\right)^2 |s, x_i\right] \tag{3-1}$$

where the overall price level is taken as given.

The solution to 3-1 is

$$p_i = (1-r)\,E\left[\theta|s,x_i\right] + rE\left[\overline{p}|s,x_i\right] \tag{3-2}$$

Given the definition of $\overline{p}$, we can iterate (3-2) to get:

$$p_i = (1-r)\sum_{k=0}^{\infty} E[\overline{E}^k(\theta)|s,x_i] \tag{3-3}$$

where $\overline{E}(x_i) = \int_j E[\theta|s,x_j]dj$ and $\overline{E}^k$ is defined recursively as:

$$\overline{E}^k(\theta) = \int_j E[\overline{E}^{k-1}(\theta)|s,x_j]dj \tag{3-4}$$

As shown in the previous section, in any equilibrium, the communication protocol is such that the set of states $[0,1]$ is partitioned into intervals $\{[\theta_{n-1},\theta_n]\}_n$, and, whenever $\theta \in [\theta_{n-1},\theta_n]$, a message s_n is sent. Hence, after observing a message s_n, the firms can infer that the state lies in $[\theta_n,\theta_{n+1}]$ so that, if $x_i \notin s_n$ firm i can infer $I_i = 0$, so $E[\theta|s_n,x_i] = E[\theta|\theta \in s_n]$. On the other hand, if $x_i \in s_n$ we have:

$$E\left[\theta|s_n,x_i\right] = Pr(I_i=1)E(\theta|\theta\in s_n,x_i,I_i=1)+Pr(I_i=0)E(\theta|\theta\in s_n,x_i,I_i=0). \tag{3-5}$$

Hence

$$E\left[\theta|s_n,x_i\right] = \begin{cases} y_n & \text{if } x_i \notin s_n \\ qx_i + (1-q)y_n & \text{if } x_i \in s_n \end{cases} \tag{3-6}$$

where $y_n \equiv E(\theta|s_n) = \frac{\theta_n+\theta_{n-1}}{2}$.

Given (3-6), we have : $\overline{E}[\theta] = g_n q^2\theta + (1-g_n q^2)y_n$, where $g_n \equiv Pr(x_i \in s_n)$. The following lemma is useful to characterize the equilibria of the pricing game

Lemma 1: Let $\mu^k \equiv g_n^k q^{2k}$. We then have:

1. $\overline{E}^k[\theta] = \mu^k\theta + (1-\mu^k)y_n$

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2. $E[\overline{E}^k[\theta]|s_n, x_i] = \begin{cases} y_n & \text{if } x_i \notin s_n \\ q\mu^k x_i + (1 - q\mu^k) y_n & \text{if } x_i \in s_n \end{cases}$

Proof: As seen above, the Lemma is valid for k=1. Suppose that:

$$\overline{E}^{k-1}[\theta] = \mu^{k-1}\theta + (1 - \mu^{k-1}) y_n$$

so $E[\overline{E}^{k-1}[\theta]|s_n, x_i] = \mu^{k-1} E[\theta|s_n, x_i] + (1 - \mu^{k-1}) y_n$. If $x_i \notin s_n$ then $E[\theta|s_n, x_i] = E[\theta|s_n] = y_n$. On the other hand, if $x_i \in s_n$ then $E[\theta|s_n, x_i] = qx_i + (1 - q)y_n$. Therefore:

$$E[\overline{E}^{k-1}[\theta]|s_n, x_i] = \begin{cases} y_n & \text{if } x_i \notin s_n \\ q\mu_{k-1} x_i + (1 - q\mu_{k-1}) y_n & \text{if } x_i \in s_n \end{cases}$$

Now, since

$$\int_i E[\overline{E}^{k-1}[\theta]|s_n, x_i] di = g_n q^2 \mu^{k-1}\theta + (1 - g_n q^2 \mu^{k-1}) y_n$$

we have $\overline{E}^k[\theta] = \mu^k \theta + (1 - \mu^k) y_n$. Finally:

$$E[\overline{E}^k[\theta]|s_n, x_i] = \begin{cases} y_n & \text{if } x_i \notin s_n \\ q\mu_k x_i + (1 - q\mu_k) y_n & \text{if } x_i \in s_n \end{cases}$$

where $\tilde{k} \equiv \frac{(1-r)q}{(1-rq^2 g_n)}$

■

From Lemma 1 , it follows that

$$\begin{aligned} p_i(s_i, x_i) &= (1 - r) \sum_{k=0}^{\infty} E\left[\overline{E}^k(\theta)|s, x_i\right] \\ &= \begin{cases} (1 - r) \sum_{k=0}^{\infty} r^k y_n & \text{if } x_i \notin s_n \\ (1 - r) \sum_{k=0}^{\infty} r^k \left[q\mu^k x_i + \left(1 - q\mu^k\right) y_n\right] & \text{if } x_i \in s_n \end{cases} \\ & \begin{cases} y_n & \text{if } x_i \notin s_n \\ \widetilde{k} x_i + \left(1 - \widetilde{k}\right) y_n & \text{if } x_i \in s_n \end{cases} \end{aligned}$$

where $\widetilde{k} \equiv \frac{(1-r)q}{(1-rq^2 g_n)}$.

We then have

Proposition 2: Given a statement s_n made by the Central Bank when $\theta \in [\theta_{n-1}, \theta_n]$, and private signals $\{x_i\}$, an equilibrium in the pricing game

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takes the form of

$$p_i = \left(\frac{q(1-r)}{1-rq^2g_n}\right)x_i + \left(1 - \frac{q(1-r)}{1-rq^2g_n}\right)y_n \quad \forall\, i \in [0,1],$$

where

$$y_n \equiv E(\theta|s_n) = \frac{\theta_n + \theta_{n-1}}{2}$$

3.3 The Communication Game

Having characterized the firms' equilibrium pricing policy for a *given* statement made by the Central Bank, we now move on to derive the set of equilibrium communication policies.

Given Proposition 3.2, the average price level is

$$\begin{aligned} \overline{p}|(\theta, s_n) &= g_n\tilde{k}q\theta + (1 - g_n\tilde{k}q)y_n \\ &\equiv \overline{k}\theta + (1 - \overline{k}y_n), \end{aligned} \tag{3-7}$$

while the price variability is

$$\begin{aligned} Var(p_i|s_n, \theta) &= g_n\tilde{k}_n^2[(1-q)1/3\left(\tfrac{\theta_n - \theta_{n-1}}{2}\right)^2 + q(1-q)(\theta - y_n)^2] \\ &+ g_n(1-g_n)\tilde{k}_n^2 q^2(\theta - y_n)^2 \end{aligned} \tag{3-8}$$

Using these expressions, one has that the Central Bank's expected payoff, given a state $\theta \in [\theta_{n-1}, \theta_n]$ and the correspondent statement s_n, is

$$(\bar{p}|(\theta, s_n) - \theta + c)^2 + \beta Var(p_n|s_n, \theta).$$

In equilibrium, a Central Banker who faces a "cut-off" state θ_n must be indifferent between making the statements s_n and s_{n+1} (which is the statement made when the state lies in $[\theta_n, \theta_{n+1}]$). Hence, one must have:

$$(\bar{p}|(\theta_n, s_n) - \theta_n + c)^2 + \beta Var(p_n|s_n, \theta_n) = (\bar{p}|(\theta_n, s_{n+1}) - \theta_n + c)^2 + \beta Var(p_n|s_{n+1}, \theta_n).$$

These indifference conditions define the set of partitions $\{[\theta_{n-1}, \theta_n]\}_n$ that can be part of a communication equilibrium. The next result states the amount of informativeness that can prevail in any communication equilibrium.

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Proposition 3: Given (c, q, r, β), there exists an integer $M(c, q, r, \beta)$ such that $\forall 1 \leqslant N \leqslant M(\cdot)$, $N \in \mathbb{N}$, there is at least one equilibrium with N different messages been sent. Further, message s_n is sent if, and only if, $\theta \in [\theta_{n-1}, \theta_n]$.

It follows that the key parameters to determine the informativeness of a Central Banker policy are related to his preferences – though the bias c, and the parameter that measures his aversion to price dispersion, β –, the precision of the price setters signal, q, and the degree of complementarity in their pricing decisions.

We first shows that, if the Central Banker is only concerned with price dispersion, there exists an equilibrium in which he can perfectly communicate the state in which the economy is.

Proposition 4: The more the Central Banker cares about the price dispersion (larger β), the more informative an equilibrium can be. In the limit, if the Central Banker cares only about the price dispersion, $(\beta \to \infty)$, the the communication can be fully informative.

Proof: Let $\{\theta\}_{n=1}^{N}$ be a set of limiting partitions of an equilibrium. Given θ_{n-1}, θ_n and θ_{n+1}, let: $V(\theta_{n-1}, \theta_n, \theta_{n+1}) = 0$ be the indifference condition that defines those partitions. For all $\beta > 0$, $1/\beta V(\cdot) = 0$, as $\beta \to +\infty$, $V(\cdot)$ tends to:

$$\begin{aligned} & g_{n+1}\tilde{k}_{n+1}\left(\frac{\Delta\theta_{n+1}}{2}\right)^2\left[(1-q)(1/3+q)+(1-g_{n+1})q^2\right] \\ & -g_n\tilde{k}_n\left(\frac{\Delta\theta_n}{2}\right)^2\left[(1-q)(1/3+q)+(1-g_n)q^2\right] \end{aligned}$$

which is equal to zero when $\Delta\theta_n = \Delta\theta_{n+1}$. So, any equal partition of $[0, 1]$ can be an equilibrium.

■

The intuition behind this result follows immediately from an analysis of the Central Bank's incentives. On the one hand, it would like the price setters to set $p_i = \theta + c$; such a force is, given the bias c, partly in dissonance with the agents' interests. On the other hand, the Bank would like to reduce the variability of prices; such a force is in consonance with the agents' interests.The larger β, the larger the consonance between the Bank, and the firms. As $\beta \to \infty$, we move toward full alignment of interests.

In the previous result, we have shown that *all* relevant information can be transmitted if the Central Banker just cares about price dispersion. The next

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result, in turn, illustrates the importance of the Central Banker's aversion to price dispersion for the possibility of conveyance of *some* information

Proposition 5: If the Central Banker does not care about the price dispersion ($\beta = 0$), and the price-setters care almost only about the actual state ($r \sim 0$), then, as their information becomes almost precise ($q \to 1$,), the unique communication equilibrium leads to a *single* statement s being made irrespective of the state θ.

Proof: Let $V(\theta)$ be the indifference condition of the Central Banker at a 2 partition equilibrium. So θ such that $V(\theta) = 0$ defines the partition. If $r \sim 0$, then $\tilde{k}_n \sim q$ and $\overline{k}_n \sim g_n q^2$. Therefore:

$$V(\theta) \sim (c-(1-g_1q^2)\theta/2+(1-q_2q^2)(1-\theta)/2+c)(-(1-g_1q^2)\theta/2-(1-q_2q^2)(1-\theta)/2)$$

since the second term of the above equation is always negative, $V(\theta) = 0$ only if:

$$(c - (1 - g_1q^2)\theta/2 + (1 - q_2q^2)(1 - \theta)/2 + c) = 0$$

which implies:

$$\theta = \left(\frac{1}{1 - q^2}\right)[4c + (1 - g_2)q^2)]$$

$\Rightarrow \lim_{q\to 1} \theta = \infty$ which proves that there is no equilibrium in two partitions. ■

The non-informative equilibrium characterized in 3.3 is called the "Babbling Equilibrium" in the cheap talk literature. Such an equilibrium always exist in any cheap talk game.[1] The reason why, when $\beta = 0$ and $q \to 1$, this is the *unique* equilibrium in our setting is simple. When the agents learn x_i, it is almost as if they learned the state. This means that all price setters will coordinate their pricing decisions almost perfectly, so there will be no variability in prices. It follows that the Central Bank's only concern will be its price level target. Hence, its incentives to deceive the agents are magnified, making any informative statement about the economy not credible. Note that, apart from taking that some bias is present, this result holds irrespective of any other assumption regarding c. This contrasts with what is found in, for example, (5). In their model, for moderate values of c, a partially infor-

[1]As, for all parameter values, the following is always an equilibrium: the price setters ignore whatever message the Central Banker sends, and the Central Banker sends a single statement for all possible states.

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mative equilibrium always exist. In addition to the lack of aversion to price dispersion by the Central Bank, what is key for the above result is the fact that the price setters, through their private signals, almost learn the true state.

The results in propositions 3.3 and 3.3 cover two extreme cases of informativeness. We can also show that, when the price setters are more concerned with relative prices than with the actual state of the economy ($r \sim 1$), the Central Banker can always convey some information about the state, irrespective of β. More precisely,

Proposition 6: If firms care more about the average price than the actual state of the economy ($r \sim 1$), there always exists an equilibrium with at least two statements being made by the Central Banker, for all $q \in (0, 1)$, $\beta \in [0, +\infty)$; given $c \in (0, \bar{c})$.

Proof: Let $V(\theta)$ be the indifference condition of the Central Banker at a 2 partition equilibrium. So θ such that $V(\theta) = 0$ defines the partition. If $r \sim 1$, then $\tilde{k}_n \sim 0$ and $\overline{k}_n \sim 0$. Therefore:

$$V(\theta) = (-\theta/2 - (1 - \theta)/2)(c - \theta/2 + c + (1 - \theta)/2)$$

The first term of the above equation is always negative, so $V(\theta) = 0$ implies $\theta = 2c + 1/2$, which does not depend on q or β and $\theta \in [0, 1]$ if $c \in (0, 1/4]$. ■

The interpretation for the result is as follows. Irrespective of the statement made by the Central Banker, price setters will coordinate on the same price. Moreover, as $r \sim 1$, they won't care if this price is different than the state. Hence, they will not be concerned with how informative the statement is. The only important thing is that a statement is made and it can serve as a coordination device.

Although we are able to derive some properties of the set of equilibria for the general model, it is quite difficult to fully characterize it. To make some progress, we specialize further the informational structure in the next section.

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4
Uniformly Informative Signals

In this section, we specialize the model to a uniformly informative private signal. More specifically, we assume that the private signals, x_i, carry the same amount of information across every possible message sent by the Central Banker:

$$x_i|\theta, I_i, s_n = \begin{cases} \theta \text{ if } I_i = 1 \\ x_i \sim U[\theta_{n-1}, \theta n], x_i \perp \theta \text{ if } I_i = 0 \end{cases} .$$

The assumption here is that $g_n = 1\ \forall n$, so that the price setters can never infer from x_i whether $I_i = 0$ or $I_i = 1$ *irrespective* of the message sent by the Central Banker. While restrictive, this allows us to fully characterize the set of communication equilibria.

Indeed, in the appendix, we show that the equilibrium of the pricing game is as follows

Proposition 7: Given a statement s_n made by the Central Bank when $\theta \in [\theta_{n-1}, \theta_n]$, and private signals $\{x_i\}$, an equilibrium in the pricing game takes the form of

$$p_i = \left(\frac{q(1-r)}{1-rq^2}\right) x_i + \left(1 - \frac{q(1-r)}{1-rq^2}\right) y_n \quad \forall\, i \in [0,1],$$

where

$$y_n \equiv E(\theta|s_n) = \frac{\theta_n + \theta_{n-1}}{2}.$$

It follows that the average price level is

$$\overline{p}|\theta, s_n = kq\theta + (1-qk)y_n$$

while the price variability is

$$Var(p_n|s_n, \theta) = k^2[q(1-q)(\theta - y_n)^2 + (1-q)\frac{1}{3}(\frac{\theta_n - \theta_{n-1}}{2})^2].$$

Using these expressions, one has that the Central Bank's expected payoff, given a state θ and a statement s_n, is

$$(\overline{p}|s_n - \theta + c)^2 + \beta Var(p_n|s_n, \theta).$$

Given that, it is easy to compute the indifference condition that characterizes the set of equilibria. The counterpart of proposition 3.3 for the present setting is:

Proposition 8: Given (c, q, r, β), there exists $M(c, q, r, \beta) \in \mathbb{N}$ communication equilibria, such that, $\forall N \leqslant M(\cdot),\ N \in \mathbb{N}$, the partitions $\{[\theta_{n-1}, \theta_n]\}_n$ are defined by cut-off states $\{\theta_n\}$ that satisfy the following difference equation:

$$\theta_{n+1} - 2\theta_n + \theta_{n-1} - 4c\eta = 0$$

where

$$\eta \equiv \frac{(1-qk)}{(1-qk)^2 + \beta k^2(1-q)(q+1/3)}$$

Under the uniform informativeness assumption, the set of all possible equilibria is completely indexed by ηc, so that η indexes the degree of informativeness that an equilibrium may have [1]. The larger η, the lesser informative the communication policy from the Central Bank. Therefore, we can derive the properties of the communication equilibria by simply analyzing the behavior of η. Throughout the analysis, we focus on the most informative equilibrium.

We first establish the counterpart of proposition 3.3.

Proposition 9: If the Central Banker does not care about the price dispersion ($\beta = 0$) , as the agents information gets almost perfectly precise ($q \rightarrow 1$,) the unique communication equilibrium leads to a *single* statement s being made, irrespective of the state θ, and the coordination motive ($r \in (0,1)$).

Proof: First note that $\forall\, r \in (0,1)$, $\frac{\partial k}{\partial q} > 0$. Further more, when $\beta = 0$, $\eta = 1/(1-qk)$. By the definition of k, $\lim_{q\to 1} k = 1$ and $\lim_{q\to 0} k = 0$ for all $r \in (0,1)$. Therefore, we have:

$$\lim_{q\to 0} \eta|_{\beta=0} = 1 \quad and \ \lim_{q\to 1} \eta|_{\beta=0} = +\infty$$

Additionally:

$$\frac{\partial \eta}{\partial q}|_{\beta=0} = \frac{k + q\frac{\partial k}{\partial q}}{(1-qk)^2} > 0$$

[1] In fact, every equilibrium in our setting corresponds to an equilibrium of the communication game given in (5) with a bias that is adjusted by η.

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Therefore, as $q \to 1$, η increases monotonically, converging to $+\infty$. ■

Much as in the previous section, if the Central Banker doesn't care about price dispersion ($\beta = 0$), and the price setters' information becomes precise ($q \to 1$), the only equilibrium is such that no information is conveyed. The difference here is that such results holds irrespective of the degree of complementarity among price setters (r).

The behavior of η is represented in figure 4.1.

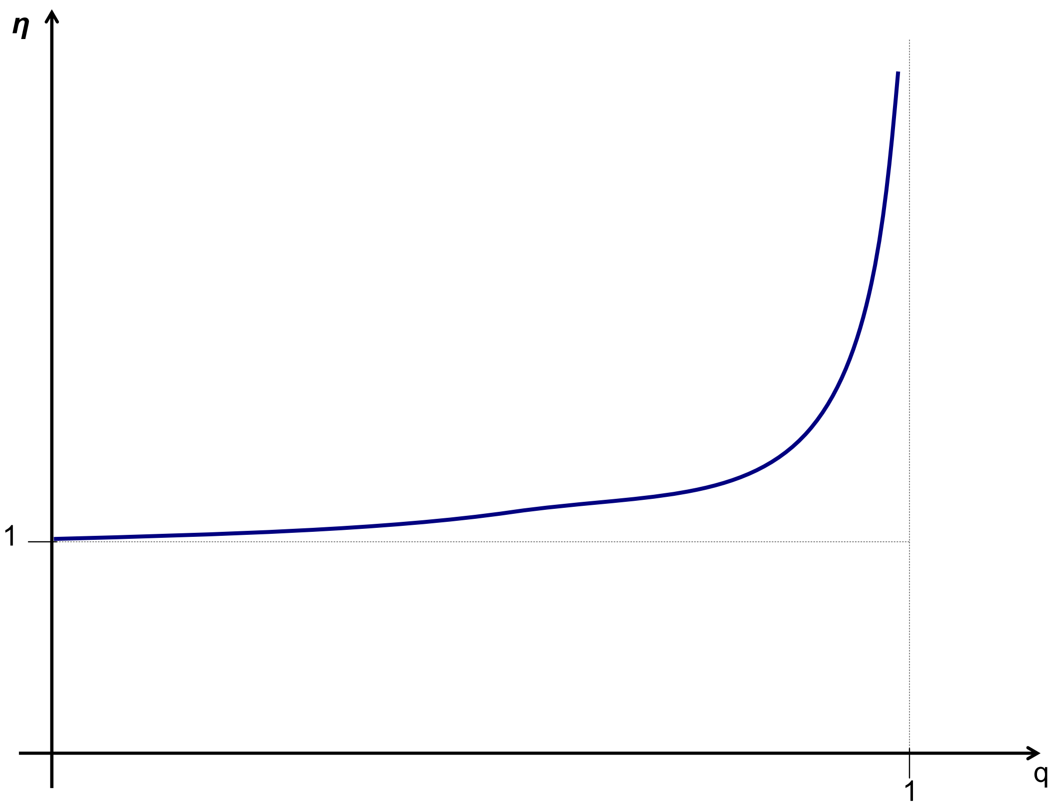

Figura 4.1: Behavior of η when $\beta = 0$

We now address the question of how the communication policy changes as the fundamentals (q, β, r) change. First, note that, no matter how much the Central Banker cares about the price dispersion ($\beta \in [0, +\infty)$), as the agents information gets completely uninformative ($q \to 0$), the game converges to that of (5), and so $\eta \to 1$. On the other hand, as the firm's information gets almost perfectly precise ($q \to 1$):

$$\lim_{q \to 1} \eta \equiv \bar{\eta} = \frac{3(1 + \frac{r}{(1-r)^2})}{2\beta}. \tag{4-1}$$

For a given value of the coordination motive (r), there is a large enough β such that $\bar{\eta} < 1$. In words the misalignment of incentives decreases when the information of the firms is very precise and the Central Banker cares

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significantly about the price dispersion. Much as before, the reasoning is simple: the influence of the Central Banker on the average price is almost none, so he can credibly transmit more information in equilibrium.

For intermediate values of information precision ($q \in (0,1)$), η will assume the value of 1 only when:

$$\beta(1-r) = \frac{(1-q^2)}{(1-q)(q+1/3)} \tag{4-2}$$

The left hand side of (4-2) is always between 0 and $+\infty$ as $r \in (0,1)$ and $\beta \in [0,+\infty)$. As for the right hand side of (4-2), it is easy to see that it's partial derivative with respect to q is always negative (therefore it is strictly decreasing function of q) and it can assume values in (3/2,3) as $q \in (0,1)$.

Therefore, if the Central Banker puts a lot of weight on price dispersion, $\eta < 1$ for whatever precision of the firm's information. This means the Banker can always communicate more information. On the other hand, if the price setters have a large enough coordination motive (r), $\eta > 1$ for whatever precision of the firm's information, and less information is transmitted.

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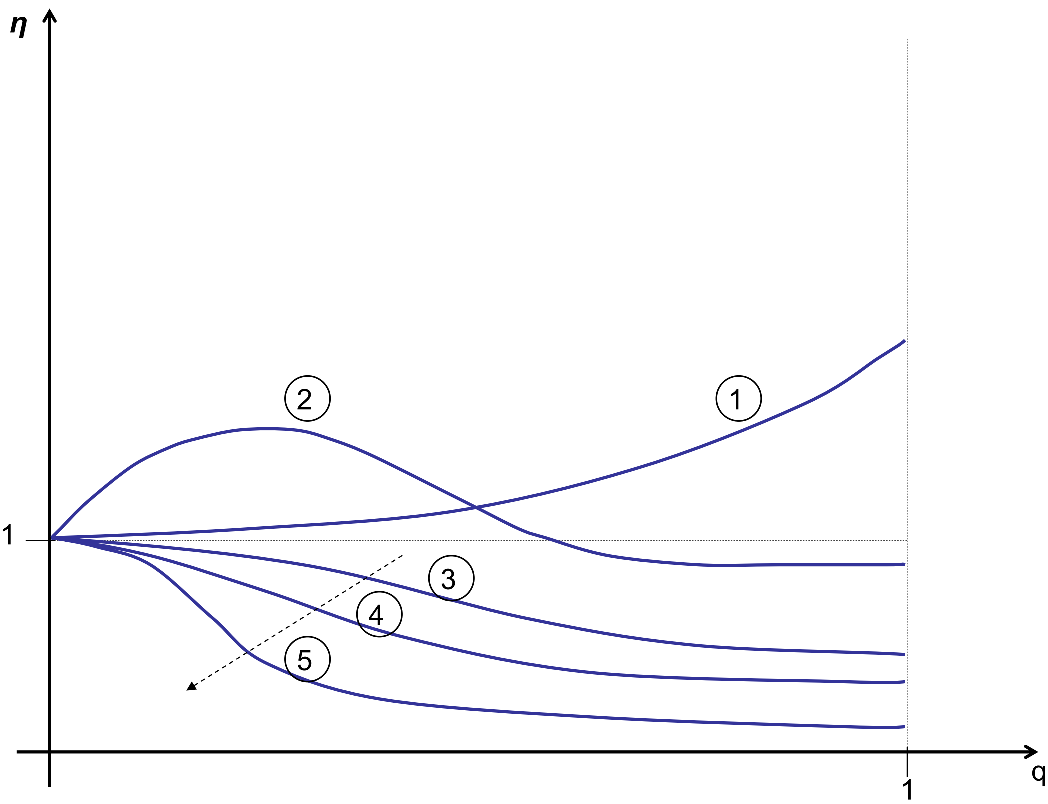

Figura 4.2: Behavior of η as β increases

In Figure 4.2 we show the behavior of η as a function of q. For a given value of r, as β increases the curves follow the sequence depicted above. An increasing aversion to price dispersion on the part of the Central Banker has a monotonic impact upon the amount of information transmitted. The more the Central Banker cares about price dispersion, the more information gets transmitted in equilibrium. In the limit, as β tends to $+\infty$, η converges to:

$$\eta(q) = \begin{cases} 1 & \text{if } q = 0 \\ 0 & \text{if } q \in (0,1] \end{cases}$$

The above result is the same as in Proposition 3.3. So is the intuition.

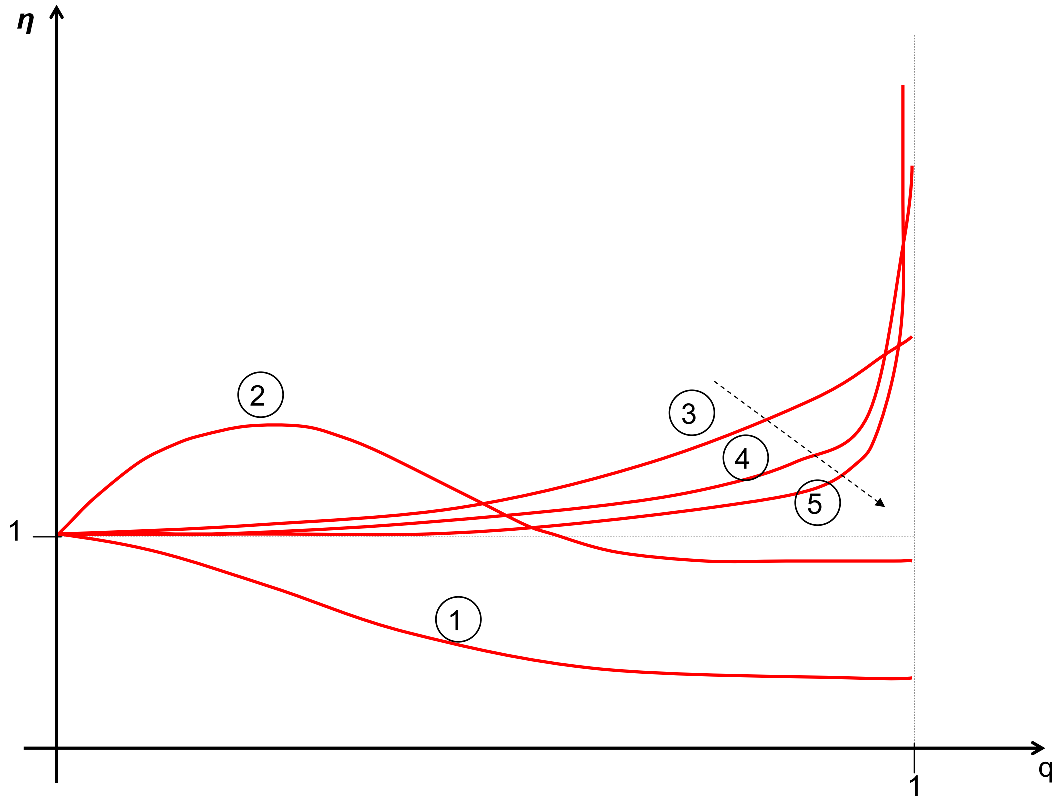

Figura 4.3: Behavior of η as r increases

In Figure 4.3 we show the behavior of η as a function of q. For a given value of β, as r increases the curves follow the sequence depicted. As can be seen, the effect of the coordination motive (r) is non-monotonic. For a given β and information precision q, as r increases, the amount of information transmitted diminishes up to a certain point, when it starts to increase again as η converges back to 1. In the limit, when $r \sim 1$, η as a function of q converges to:

$$\eta(q) = \begin{cases} 1 & \text{if } q \in [0,1) \\ +\infty & \text{if } q = 1 \end{cases}$$

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That is, the coordination motive is so strong that the communication between the Central Banker and the firms is bounded only by the interest misalignment (c), as in (5). The result is similar to that of Proposition 3.3, in which the increasing concern of the firms about the average price allows the Central Banker to credibly transmit *more* information.

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5 Costly Communication

A monetary authority is not limited to use messages that imply no direct payoff costs – *i.e. cheap-talk* messages. In fact, inflation targeting Central Banks use the basic interest rate as their main instrument of monetary policy. One might argue that changes in this rate imposes direct costs to the Central Banker, and may therefore, on top of its direct influence on policy, convey credible information. In this section, we briefly discuss how costly communication instruments might coexist with *cheap-talk* instruments.

Two conditions are needed for cheap talk to coexist with costly signalling. First, there has to be some pooling regarding the costly action chosen. Second, the Central Banker must have incentives to provide more information than that conveyed by the choice of the costly action.
We can think of a couple of settings in which both conditions would hold. Consider, for example, the case in which the economy may be either in recession or booming, but there are different degrees of recessions and booms. Each state, boom or recession, calls for a (different) optimal interest rate (costly action). In such a case, irrespective of the degree of recession, a single interest rate will be set. Hence, while this allows the public to infer that the Economy is in recession, one cannot infer its degree. This would make room for cheap-talk messages that could convey a better idea of the degrees of recession.

Another example is one in which it is very costly to signal a certain set of states through interest rates (costly communication). Suppose, for example, the Central Banker is facing an exogenous inflationary shock (commodities prices are going up due to greater world demand). But, at the same time, financial institutions are facing a lack of liquidity (they need money to attend to their cash balances needs). The inflationary shock would call for the Central Banker to raise interest rates so the inflation might be tamed, but that action could bankrupt some financial market institutions, which would in turn, cause a great welfare loss. The Central Banker, in this situation, could increase liquidity with *lower* interest rates and at the same time use its communication policy to influence market expectations.

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6 Conclusion

From a social welfare point of view, it might be argued that more transparency on the part of the Central Bank is desirable. We have shown, however, that if information is used strategically to accomplish policy goals, and those goals are not perfectly aligned with those of the price-setters', there is a bound to what can be attained in terms of transparency: communication must be noisy.

Within our model, we have also shown that the (maximum) amount of information conveyed by a strategic Central Banker will be larger (i) the lower his bias toward lower (average) prices, (ii) the higher his aversion to price dispersion, (iii) the less informed the agents are, and (iv) the higher the complementarity among the price setters'.

From an institutional design perspective, our model suggests that, by designing its preferences in a way that significant weight is put on aversion to price variability, one can affect substantially the amount of information conveyed by a strategic Central Bank.

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A
Primeiro Apêndice

After observing a message s_n, the firms can infer that the state lies in $[\theta_n, \theta_{n+1}]$ so that

$$\begin{aligned} E\left[\theta|s_n, x_i\right] &= Pr(I=1)E(\theta|s_n, x_i, I=1) + Pr(I=0)E(\theta|s_n, x_i, I=0) \\ &= qx_i + (1-q)y_n \end{aligned}$$

where $y_n \equiv E(\theta|s_n) = \frac{\theta_n + \theta_{n-1}}{2}$.

Now, if receiver $j \neq i$ follows a strategy of the form

$$p_j = kx_j + (1-k)y_n, \tag{A-1}$$

the average price level will be:

$$\begin{aligned} \bar{p}|s_n, \theta &= \int_j p_j dj = \int_x f(x|\theta)P_j(x, s_n) \\ &= qk\theta + (1-qk)y_n \end{aligned}$$

so that

$$E[\bar{p}|s_n, x_j] = qkE[\theta|s_n, x_j] + (1-qk)y_n.$$

Plugging the above in firm $i's$ best response one gets:

$$\begin{aligned} p_i &= (1-r)E(\theta|s_n, x_i) + r[kqE(\theta|s_n, x_i) + (1-kq)y_n] \\ &= q(1-r(1-kq))x_i + (1-q(1-r(1-kq)))y_n. \end{aligned}$$

which takes exactly the same form as A-1 for

$$k = q(1-r(1-qk)) \quad \Rightarrow \ k = \underbrace{\left(\frac{q(1-r)}{1-rq^2}\right)}_{<1} < q.$$

This discussion proves proposition 4

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