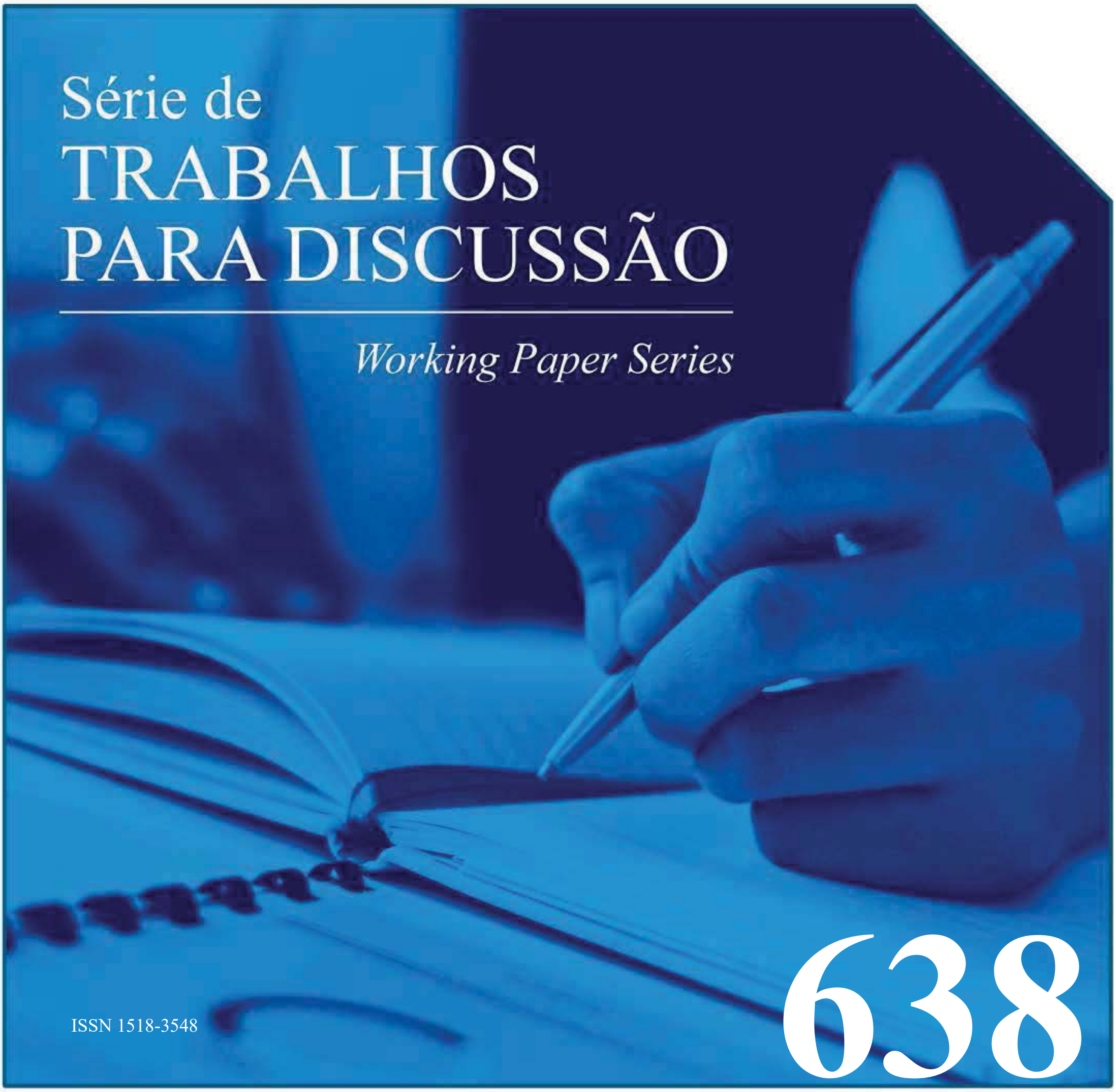

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An Organizational Structure Approach to Price Setting and Monetary Policy

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Non-technical Summary

This paper develops a new mechanism to study sticky prices and its stylized facts, grounded in a theoretical framework based on incomplete information given by the misalignment of incentives within the organizational environment of the firms. The foundation of the model lies in the informational environment generated by the strategic interaction between a boss, who lacks full knowledge of economic shocks, and local managers, who hold private information about the state of the economy. Their interplay takes the form of a cheap-talk game in which the local managers (the senders) may choose not to reveal information fully, given the misalignment of incentives of the firm.

Applying the seminal results of cheap-talk game literature to this setting, the optimization problem of the firm yields a partitioned price equilibrium in which the local managers communicate to the boss the partition that optimal price belongs to instead of the price *per se*. Therefore, prices are discrete, with the number and size of the resulting intervals being functions of the degree of incentive misalignment within the firm.

In contrast to seminal models of price rigidity, such as menu-cost models or informational frictions like rational inattention, the mechanism developed in this paper shows that price rigidity can emerge endogenously purely from the organizational structure of firms. Through the lens of optimal pricing, our model explains a variety of micro price stylized facts, such as the existence of discrete prices, infrequent price adjustments, and heterogeneous price-change dynamics across sectors and product categories.

After the characterization of the firm-level environment, we embed our model into a New Keynesian general equilibrium model, in which the Phillips curve becomes a function of the organizational environment of firms. We show that both the slope of the Phillips curve and the effectiveness of monetary policy depend on the degree of misalignment within firms in the economy as well as the number of organizational divisions. Intuitively, firms with deeper organizational hierarchies transmit more information internally, reducing asymmetry between decision-makers and informed managers, thereby reducing price rigidity and weakening monetary policy effects in the short-run.

Empirically, we use a daily dataset of retail firms in Brazil, which incorporates information from the six largest supermarket chains in the country, across all geographic regions between 2018 and 2021. The dataset covers between 6,000 and 28,000 products per day for each retailer, which means more than 75 million observations. To bring our theoretical model to the data, we develop a fuzzy matching-based text-classification algorithm that allows products to be grouped into categories and sectors consistent with the structure of the Brazilian Consumer Price Index.

We then estimate the degree of misalignment at different hierarchical levels (product, category, sector, and retailer). Using these estimates, the model successfully replicates the main stylized facts of the price-rigidity literature: (i) the duration of price spells, (i) the existence of reference and sales prices, (iii) small price, (iv) heterogeneous pricing dynamics, and (v) the absence of price selection.

From a macroeconomic perspective, our findings show that organizational failures have relevant macroeconomic effects, increasing inflation persistence, and impacting the optimal conduct of monetary policy. When misalignment within firms rises, prices become less responsive to shocks, the Phillips curve becomes flatter, and the costs of disinflation increase. Conversely, economies with more decentralized firms and greater internal information flows exhibit lower rigidity and lower inflation persistence.

Sumário Não Técnico

Este artigo propõe um arcabouço teórico para estudar o fenômeno da rigidez de preços e seus fatos estilizados a partir da interação organizacional dentro do ambiente das firmas entre um chefe, responsável por tomar a decisão de preços, e os gestores locais, responsáveis por munir o chefe com informação privada sobre os choques da economia. O pilar da construção teórica consiste na incorporação da existência de um desalinhamento de incentivos entre o tomador de decisão de preços e seus gestores locais para modelar o ambiente de optimização de preços da firma, fazendo com que os agentes informados não revelem plenamente o seu conjunto informacional para o chefe.

Aplicando os resultados seminais da literatura de *cheap talk games* encontramos que o preço ótimo é caracterizado como um equilíbrio particionado. Portanto, diferentes preços estão associados a um mesmo intervalo da distribuição dos choques, fazendo com que o gestor local reporte para o chefe somente a participação na qual o preço faz parte e não o preço em si. Com isso, preços tornam-se rígidos e discretos mesmo com uma distribuição contínua de choques acontecendo ao longo do tempo, onde tanto o tamanho dos intervalos nos quais os preços pertencem quanto seus valores tornam-se funções do desalinhamento entre os agentes dentro da firma.

Em contraste aos modelos tradicionais da literatura de rigidez de preços, como custos de menu ou fricções informacionais, como o caso de *rational inattention*, o mecanismo desenvolvido neste artigo ilustra que o fenômeno da rigidez de preços pode emergir endogenamente apenas da estrutura organizacional das firmas. Possibilitando inclusive explicar diferentes fatos estilizados sobre a dinâmica de preços na economia, como a existência de preços discretos, mudanças infrequentes de preços e heterogeneidade na dinâmica de preços de acordo com setores da economia e categorias dos produtos.

Após a caracterização do ambiente das firmas, o artigo insere esta configuração em um modelo Novo Keynesiano de equilíbrio geral, no qual a curva de Phillips torna-se uma função do ambiente organizacional das firmas. Metodologicamente, mostra-se que a inclinação da curva de Phillips e a potência da política monetária dependem do grau de desalinhamento informacional das firmas assim como o número de divisões existente nelas. Intuitivamente, firmas com uma cadeia hierárquica e organizacional mais estruturadas transmitem mais informação internamente, reduzindo o grau de informação entre o tomador de decisão e os gestores locais, consequentemente reduzindo a rigidez de preços e atenuando os efeitos da política monetária no curto prazo.

Empiricamente, o artigo utiliza uma base de dados diária de empresas do varejo no Brasil, incorporando informação sobre os 6 maiores supermercados do país, de todas as regiões geográficas brasileiras, entre 2018 e 2021. A base contém entre 6.000 e 28.000 produtos por dia em cada varejista, representando um total de mais de 75 milhões de observações. Para levar o modelo teórico aos dados, o artigo desenvolve um algoritmo de classificação textual baseado em *fuzzy matching*, o que permite agrupar produtos em categorias e setores compatíveis com a estrutura do Índice de Preços ao Consumidor brasileiro.

Com isso, este artigo, primeiro, estima o grau de desalinhamento em diferentes níveis hierárquicos (produto, categoria, setor e varejista). A partir disso, replica-se os principais fatos estilizados da literatura de rigidez preços: duração dos preços, presença de preços de referência e preços promocionais, existência de pequenos ajustes nos preços, heterogeneidade na dinâmica de preços e ausência de viés de seleção nos preços.

Sob a ótica macroeconômica, este artigo contribui para a literatura revelando que falhas organizacionais têm efeitos macroeconômicos relevantes, ampliando a persistência inflacionária e alterando a condução ótima da política monetária. Quando o desalinhamento do ambiente das firmas aumenta, os preços respondem menos aos choques da economia, a curva de Phillips torna-se menos inclinada e os custos de desinflação aumentam. Por outro lado, economias com firmas mais descentralizadas e com maior fluxo de informação interna apresentam menor rigidez e menor persistência inflacionária.

An Organizational Structure Approach to Price Setting and Monetary Policy

Diogo Abry Guillen* and Victor Monteiro†‡

9 de dezembro de 2025

Abstract

We build a general equilibrium setup that embeds the organizational structure and its misalignment of incentives in the firm's pricing decision. On the firm level, such a mechanism endogenously generates discrete prices and explains price stickiness. On the macro level, we derive a Phillips curve where the incentive-provision and the number of divisions of the firms drive its slope. Empirically, we take the model into a novel Brazilian retail daily database to estimate the parameters of the theoretical mechanism. Our model matches price-setting facts, such as the length of price spell, heterogeneity of price distribution, existence of small changes, and sales behavior.

JEL Classification: E31, E30, D83

Keywords: Price Rigidity, Phillips Curve, Real Effects of Nominal Shocks, Information Transmission

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1 Introduction

"A pricing analyst described how at one of the early pricing strategy meetings, a representative from the marketing group and one of the members of the sales force "...were shouting back and forth, ..." and the argument became so heated that I thought they were going to throw punches." Zbaracki et al. (2004)

The literature on price stickiness and its macroeconomic repercussions has flourished in recent years through the revolution of microdata at the firm-level that have helped discipline price-setting models in order to match aggregate pricing patterns and explain individual price dynamics.[1] We argue that incorporating the firms' organizational structure and their within communication is key to matching microdata at the firm level, elucidating pricing decision making, and explaining macro stylized facts.

In this vein, the evidence on organizational economics, as in Garicano and Rayo (2016), highlights the relationship between the organizational structure and the pricing decision, in which organizations fail due to "agents who do not want to act in the organization's interests"or "agents who do not have the necessary information to do so". Then, unlike the models that rely on frictions such as acquiring information or menu costs on adjusting prices,[2] we incorporate both organizational aspects in a simple way in our setup. First, intra-firm communication, through the strategic interaction between the decision-maker and the employees, is an important ingredient in how price decisions happen.[3] Second, the vertical organizational structure, that is, the manager and employee relationship, affects both individual performance as well as firm performance.[4] The interaction of these two aspects leads to price stickiness and lower profits.

Inspired by the empirical studies on firm structure and within firm communication that give rise to an endogenous managerial cost as in Zbaracki et al. (2004), we embed the organizational structure of the firm into a general equilibrium macroeconomic model, in which the within-firm communication and incentive provision characterize the friction of this setup. Even though we do not rely on imposing exogenous menu costs or constraints on absorbing or acquiring information, this approach allows us to match micro facts on price setting as well as macroeconomic stylized facts, such as the non-neutrality of monetary policy.

We start with a simple model of a multi-divisional large firm as Alonso et al. (2008) in which the incentives of the manager and the employees are not perfectly aligned.[5] Assuming that employees have private

[1] Nakamura and Steinsson (2013).
[2] Reis (2006), Sims (2003), Golosov et al. (2003) among many others.
[3] Bandiera et al. (2020).
[4] Impink et al. (2021).
[5] One can think of a non-optimal contract design, an inefficient bonus structure, or any other reason for that.

information, but the manager is the one who sets the price, the communication between them is an important feature in this context, setting the channel on how the asymmetry of information can be mitigated by the information revealed from the employee to the manager. This private information can be loosely considered as a marginal cost or a demand shock. However, as they have different payment structures,[6] not conditional on the disclosure of information, the employee may decide not to reveal everything he knows.

We find that this setup endogenously generates price stickiness through the notion of partitioned equilibria borrowed from early works, such as Crawford and Sobel (1982), and easily reproduces price-setting patterns even if shocks are continuous. When numerically evaluated, the pure existence of our mechanism of intra-firm communication flow already generates discrete prices, sales/references prices and small changes in prices.

We embed this firm structure in an otherwise standard flexible price general equilibrium macroeconomic model, and we show that a new Phillips curve naturally arises, where its slope depends on the misalignment of incentives within a firm as well as the number of divisions of a representative firm of this economy.

We enrich our supply side model with a Taylor-type rule and a stylized consumer structure to proceed to the macro simulations. We find a larger non-neutrality of money in the short run when compared with a Calvo-standard model, a decrease of the monetary policy power as the number of divisions in the firms increases,[7] and a negative relationship between the degree of misalignment within the firm and social welfare. Moreover, we argue that intra-firm information flow is relevant to understanding microdata pricing behavior (through the incentives within firms), inflation dynamics (through the Phillips curve) and welfare dynamics, since we show how optimal monetary policy depends on the firm structure.

Empirically, we take the model into a novel online price daily dataset, especially suited to evaluate the mechanism described above, which covers six of the major supermarket chains from Brazil. Our data cover a wide range of products, with a range of 6,000 to 28,000 products per day in each retailer, between January 2018 and October 2021. Furthermore, to match the firm structure derived theoretically, we develop a dictionary algorithm structured as a fuzzy string matching algorithm based on a supervised learning method to classify each product on a given CPI category using textual analysis, which allows us to compare goods within sectors and categories across retailers.

Our first set of empirical results tests the relationship between price-setting, partition-structure and level of misalignment stated in our theoretical mechanism. Intuitively, firms with more misalignment have less informative communication structures, which unleash in local managers that report fewer partitions to

[6] A particular case of this setup is when their wage/bonus schedule is not the same.

[7] Even though we use a different approach, this result resembles the one found by Pasten and Schoenle (2016) through a rational inattention model, where, for them, a large number of products likewise lead to less monetary non-neutrality.

their bosses and lower frequency of price changes. Empirically, we find a negative relationship between the partition-structure and the misalignment level, which corroborates this intuition.

Our second set of empirical results provide simulations of the optimal theoretical prices for a set of goods that illustrate that our mechanism manages to match the observed prices, the length of price spell, its moments and a list of stylized facts. From those simulations, we match stylized facts such as (i) sales behavior, (ii) small changes in prices, (iii) prices with frequent changes, (iv) constant, increasing or decreasing reference prices, and (v) prices with high stickiness.

Our analysis is related to two strands of the literature. First, our analysis builds on empirical and theoretical work on intra-firm communication and firm structure. On the theoretical side, on communication, we assume that the incentives of the manager and the employees are not perfectly aligned, following the seminal work on cheap talk by Crawford and Sobel (1982), applied by Alonso et al. (2008). Still in theory, but in firm structure, our work is related to Alonso et al. (2008) and Dessein et al. (2019), who develop agency problem models based on the trade-off of lower-level managers who have better information with the need for coordination for firm decision making. On the empirical side, we follow the "insider econometrics"literature that stresses the importance of how management matters.[8] Our mechanism matches the results of intra-firm studies on (i) information flow, where we find that more information leads to higher returns (Impink et al. (2021); and (ii) incentive provision, where we find that individual incentive pay reduces cooperation and overall productivity (Chan et al. (2014)).

The second strand of the literature refers to theories of price stickiness. We relate to informational theories such as rational inattention, where agents have a cost to acquire the information,[9] and sticky information,[10] where the agents have an infrequent update of information. We also focus on an endogenous information flow, but we do not assume any constraint on information acquisition or processing. Our contribution is to propose a novel, micro-founded price setting mechanism that builds on the organizational structure and the incentive provision within firms in great detail and realism to generate price stickiness, address the stylized facts from microdata evidence[11] and match the macroeconomic data.

The paper is structured as follows: Section 2 discusses the microeconomic mechanism and its numerical simulation. Section 3 provides the dynamic general equilibrium model. Section 4 presents the empirical estimation and analyzes the microdata stylized facts, while Section 5 provides the numerical estimation of

[8] A name suggested by Ichniowski and Shaw (2009).

[9] Sims (2003), Mackowiak and Wiederholt (2009), Matějka (2016), Pasten and Schoenle (2016), among others.

[10] Mankiw and Reis (2002), Mankiw and Reis (2003) and Reis (2006), among others.

[11] Such as Klenow and Malin (2010), Alvarez and Lippi (2014), Bhattarai and Schoenle (2014), Nakamura et al. (2018), Bonomo et al. (2021), Carvalho et al. (2021), Nakamura and Steinsson (2013), Cavallo (2018b) and Karadi et al. (2021).

the theoretical model. In Section 6, we conclude the paper.

2 Simple model of a firm

The purpose of this section is to provide a clear and concise presentation of the model, its key mechanisms, and the channels involved. In the following subsections, we present a partial equilibrium version of the model, where we set the internal environment of a representative firm that produces a unique good subject to independent and identically distributed shocks. The within-firm environment is depicted by the existence of short-lived agents that interact during a unique period through a sender-receiver game. Even though this simple version of the model provides the tools to explain price-setting and price stickiness patterns, in the fully-fledged model, we generalize our setup to a general equilibrium model considering multi-department firms with n departments.

2.1 Environment

In this subsection, we present an intuitive description of the firm's structure, information configuration, the agents involved in the environment, and how they engage in a strategic interaction within the firm.

Firm structure - We consider a company with a boss who decides the price of the unique good produced and two local managers who work directly in the production of the good. Drawing from the organizational economics literature,[12] we assume that the boss extracts the total profit of the firm, while local managers are rewarded based on the performance of their departments. This setup creates a typical principal-agent conflict of interest in the environment, as described by Zbaracki et al. (2004). Agents interact through a meeting to exchange information about the price of the good.

Information - We assume that local managers work directly in the production of the good they have private information about the shocks, while the boss only knows the distribution of them. Then, at every period, there is a meeting between the boss and the local managers to exchange information, in which local managers send their signal of the price, based on their private information and common knowledge information, while the boss uses this information to partially retrieve the state of the economy and decide on the optimal price to set. All remaining information about the economy is assumed to be common knowledge. We assume there is no cost to provide or receive information as the meeting is a regular interaction in the

[12] For a survey, refer to Garicano and Rayo (2016).

schedule of the office as well as the exchange of information does not affect payoffs since the repayment of local managers is based only on the performance of their departments.

Cheap-talk game - As preferences of the agents are not fully aligned, information provision is costless, and there is no contingent contract on the information, we interpret the strategic interaction as a cheap-talk game, as in Alonso et al. (2008). In this incomplete information game, each player is a short-lived player who lives a unique period. As usual in cheap talk games,[13] due to conflict of interest the communication equilibrium is partitioned, meaning that each sender reveals only the interval in which the price belongs based on his private information.

2.2 Setting up a Simple Firm

Figure 1 provides an organizational chart of within-firm environment in the stage-game, highlighting the nature of the shocks z_{1t} and z_{2t}, the private information held by the local managers μ_1 and μ_2, the information exchanged between the agents, M_1 and M_2, and the misalignment of incentives. By analyzing the contract between the boss and the local managers, where they maximize different goals, we note the typical conflict of interests in principal-agent economies that characterizes the strategic interactions among them.

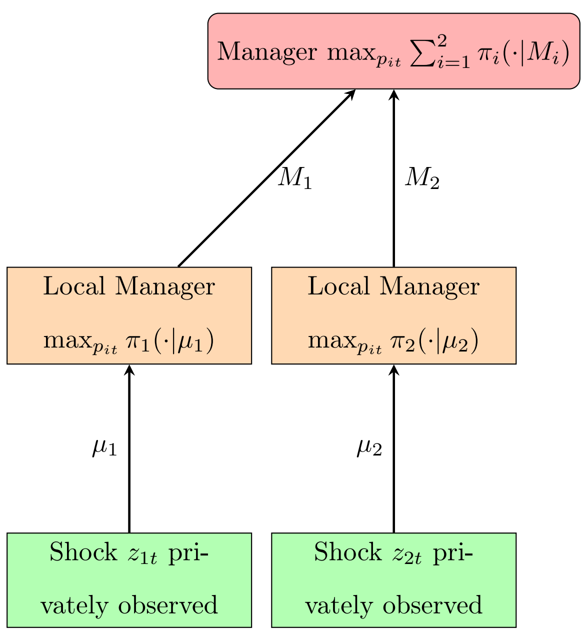


Figura 1: Organizational Chart

[13]Crawford and Sobel (1982), Alonso et al. (2008) and Dessein et al. (2019).

Intuitively, a multi-divisional firm helps us deal with the trade-off in gathering information-misalignment and its relationship to price-setting. In this regard, the number of agents involved in the firm has a tight relationship to the amount of knowledge that the agents have about the economy. On the one hand, the higher the number of agents tuned with the shocks, more information is exchanged, which means that the equilibrium price has more partitions and consequently lower price stickiness, such as the case of flight companies. However, more agents interacting within the firm may lead to more conflicts of interest and consequently higher price stickiness, such as the case of large retail companies.

2.2.1 Contract

As in Grossman and Hart (1986) and Hart and Moore (1990), we assume there is commitment only for *ex ante* allocations, such that information exchanged cannot be explicitly written in a contract, the provision of information is costless, and the signal does not appear in the payoff of the agents.[14] Therefore, there is no contract contingent in our within firm environment, in which the boss of the firm is not able to make a payment proportional to the information provided during the meeting, and he cannot construct a mechanism design to enforce the local managers to truthfully reveal their information about the shocks.

2.2.2 Shocks

We consider that each local manager privately observes a shock z_{it}, $\forall i \in \{1,2\}$ with $z_{1t} \perp z_{2t}$, such that each shock is independent and identically uniformly distributed in the interval $[0,1]$ for each period t and orthogonal between each other. We also assume that the information set, μ_{it}, $\forall i \in \{1,2\}$, contains the information privately observed about the shocks, while their distributions are common knowledge. Thus, the boss knows the intervals of the shocks as well as their distributions, but not their size in each period. Therefore, the magnitude of the shocks and how it is transmitted by the local managers influence a firm's decision-making about the price.

2.2.3 Communication

We assume that at each period, the boss has a meeting with both local managers, where he communicates simultaneously with them, as in Alonso et al. (2008), to receive their messages M_{it}, $\forall i \in \{1,2\}$, in a tuple $M_t = (M_{1t}, M_{2t})$, about the price p_{it}. The shocks are orthogonal, and the boss interacts with each department independently as independent sub-games. There is no horizontal exchange of information, which means that

[14] Such as Crawford and Sobel (1982) and Alonso et al. (2008).

departments do not communicate with each other, and the boss only captures information through the meeting. This assumption maintains our sender-receiver game analogous to Crawford and Sobel (1982), as each sub-game is an independent game that involves the interplay between one sender (local manager) and one receiver (boss), unlike in the multi-dimensional cheap-talk setup of Battaglini (2002).

2.2.4 Profit Function

We consider that departments, who are short-lived players, maximize their profit functions, while the boss maximizes the total profit of the firm, in which they interact exchanging information only during a single period.[15] Therefore, we assume that the stage-game is repeated infinitely and in order to set closed form solution, we consider that the profit function is twice continuously differentiable, homogeneous of degree zero in its first two arguments, and single-peaked for all variables.[16]

Profit Function of the Local Managers - To define the messages M_{it} provided in the meeting with the boss, the local managers maximize their profit function with respect to the price P_{it}, such that $P_{it} \in M_{it}$, given their information sets μ_{it}, which incorporate private information about the shocks Z_{it}, $\forall t$ and for $i \in \{1, 2\}$.

$$M_{it} \in ArgMax_{P_{it}} \;\; E_t \sum_{t=0}^{\infty} \beta^t \pi_{it}(P_{it}, P_t, Y_{it}, Z_{it} | \mu_{it}) \tag{1}$$

Where $\pi_{it}(P_{it}, P_t, Y_{it}, Z_{it}|\mu_{it})$ is the real profit in period t for each agent i, such that $i \in$ {Local Manager 1, Local Manager 2}. It depends on four variables $(P_{it}, P_t, Y_{it}, Z_{it})$: price at the firm level (which will be set), aggregate price of the economy, local-level production, and department-level shocks respectively. Moreover, the information set is given by μ_{it}, which incorporates each local manager's private information about the shocks Z_{it} and the common knowledge information about the economy.

Profit Function of the Boss - The pricing decision of the firm is given by a constrained maximization, where the boss maximizes his profit function taking into account the information about the price received from the local managers in the meeting, which depends on their private information about the shocks, their preferences and within-firm incentives, as stated in the following definition.

Definition 1. *The pricing decision of the firm is given by a constrained maximization of a profit function,*

[15] Such setup is usual in the cheap talk literature, such as Alonso et al. (2008).

[16] Different functional forms, such as the one assumed in Galí (2015), could also be explored in our setup.

where the boss maximizes his profit function conditional on the message M_{it} received from the local managers to close the price of the good, as the following:

$$\begin{aligned} &\max_{\{P_{it}\}} E_t \sum_{i}^{2} \sum_{t=0}^{\infty} \beta^t \pi_{it}(P_{it}, P_t, Y_{it}, Z_{it}|M_{it}) \\ &s.t.\ M_{it} \in ArgMax_{\{P_{it}\}}\ E_t[\sum_{t=0}^{\infty} \beta^t \pi_{it}(P_{it}, P_t, Y_{it}, Z_{it}|\mu_{it})] \end{aligned} \tag{2}$$

For $i \in \{$Local Manager 1, Local Manager 2$\}$.

Since agents maximize different goals, their preferences are not fully aligned, so the messages of the local managers could misrepresent the price whenever the private information contained in μ_{it} is not perfectly revealed in message M_{it}. Therefore, this misalignment in the communication between the local managers and the boss underpins the foundations of our mechanism and provides the main implications for price behavior.

To derive the pricing decision and tie the relationship between misalignment in communication and price-setting, we calculate Taylor second order log-approximation for the profit function for each agent around the nonstochastic (complete information) steady state.[17] This approximation describes how much profit under organizational failure is deviating from the optimal profit under complete information due to misalignment in the communication.

$$\begin{cases} \pi^i(p_{it,}p_t, y_{it}, z_{it}|\mu_i) = \pi_1 p_{it} + \frac{\pi_{11}}{2} p_{it}^2 + \pi_{12} p_{it} p_t + \pi_{13} p_{it} y_{it} + \pi_{14}^i p_{it} z_{it} \\ \pi^{boss}(p_{it,}p_t, y_{it}, z_{it}|M_{it}) = \pi_1 p_{it} + \frac{\pi_{11}}{2} p_{it}^2 + \pi_{12} p_{it} p_t + \pi_{13} p_{it} y_{it} + \pi_{14}^{boss} p_{it} z_{1t} + \pi_{15}^{boss} p_{it} z_{2t} \end{cases} \tag{3}$$

Where the superscript $i \in \{$Local Manager 1, Local Manager 2$\}$.

These equations provide a flavor on how we approach the misalignment of incentives in the firm environment. The parameters π_{14}^{boss} and π_{15}^{boss} depict how the marginal effects of the shocks z_{it}, for $i \in \{1, 2\}$, in the profit function of the boss deviate from the complete information case. Therefore, whenever there exists a misalignment the weights attributed to the shocks by the boss and the local managers in their profit function become different, we have that $\pi_{14}^{LM1} \neq \pi_{14}^{boss}$ or $\pi_{14}^{LM2} \neq \pi_{15}^{boss}$.

[17] In the interest of clarity, we use a superscript to represent the player and drop the subscripts of the profit function, which represents the Taylor second-order approximation for all periods of the game. This configuration of log-quadratic approximation of a general profit function is analogous to Mackowiak and Wiederholt (2009).

As the boss maximizes the total profit of the firm, deriving the first-order condition, the optimal price equation stresses that price decision depends on both public and private information. First, it is affected by the aggregate price of the economy p_t, second, the production of the firm y_{it}, third the department-level shocks $z_{it}\, \forall i \in \{1, 2\}$, and fourth the degree of misalignment, given by the expressions $\frac{\pi_{14}^{boss}}{|\pi_{11}|}$ and $\frac{\pi_{15}^{boss}}{|\pi_{11}|}$, as the following equation elicits.

$$p_{it}^{boss} = p_t + \frac{\pi_{13}}{|\pi_{11}|} y_{it} + \frac{\pi_{14}^{boss}}{|\pi_{11}|} z_{1t} + \frac{\pi_{15}^{boss}}{|\pi_{11}|} z_{2t} \tag{4}$$

It becomes clear that since the boss cannot observe the size of the shocks z_{it}, only their distributions, communication provides a major role for setting prices. Therefore, when the transmission of information is coarsened, which happens when $\frac{\pi_{14}^{boss}}{|\pi_{11}|} \neq \frac{\pi_{14}^{LM1}}{|\pi_{11}|}$,[18] misalignment in communication is positive, which encourages the local departments to misrepresent the optimal price.

2.2.5 Environment of the Game

To complement our discussion on pricing behavior and its relationship with the within-firm communication strategy, we provide details on the environment of our strategic interaction game. We assume that each period is divided into three stages. First, the local managers observe the shocks z_{it}. Second, they send a message M_{it} about the price p_{it} to the boss. Finally, in the third stage, the boss decides the price at the firm-level.

Following Crawford and Sobel (1982), we assume that the payoffs of the agents are quadratic, where the signal does not show up their, which means that communication does not affect the payoff of the departments, and the information provided is costless. Thus, we define the payoffs as the quadratic deviation of the optimal profit due to misalignment in the communication.[19]

$$L^{Boss} = -[\pi^{Boss}(p_{it}^*, p_t, y_{it}, z_{it}|\cdot) - \pi^{Boss}(\hat{p}_{it}, p_t, y_{it}, z_{it}|\cdot)]^2 \tag{5}$$

$$L^{LM1} = [\pi^{LM1}(p_{it}^*, p_t, y_{it}, z_{it}|\cdot) - \pi^{LM1}(\hat{p}_{it}, p_t, y_{it}, z_{it}|\cdot)]^2 \tag{6}$$

$$L^{LM2} = [\pi^{LM2}(p_{it}^*, p_t, y_{it}, z_{it}|\cdot) - \pi^{LM2}(\hat{p}_{it}, p_t, y_{it}, z_{it}|\cdot)]^2 \tag{7}$$

Where the conditional term is given by the information set of each player. Moreover, p_{it}^* is the price under

[18] In order to avoid excessive notation here, we skipped the case for the second local managers, although it is analogous.

[19] See the appendix for details about the construction of the payoffs.

complete information, $\hat{p}_{it}$ is the price under incomplete information due to misalignment within the firm, and the superscripts $LM1$, $LM2$ and $Boss$ indicate local manager 1, local manager 2 and the boss, respectively.

We observe from the payoffs that the local managers have an incentive to misrepresent their prices because their payoffs increase when they deviate from the optimal price under complete information. In contrast, the boss's payoff decreases when there is misalignment, then he seeks to reduce it. This configuration also remits to a negative relationship between welfare and level of misalignment that is explored in the fully-fledged model.

2.2.6 Partitioned Equilibrium

To establish the equilibrium of this sender-receiver game, we adopt the concept of perfect Bayesian Nash equilibrium as proposed by Crawford and Sobel (1982), which characterizes the messages received by the boss for all the meetings in this cheap-talk game. This equilibrium concept requires that (i) communication rule comes from profit maximization problem for the local managers, (ii) the decision rule of the boss comes from his profit maximization problem given his information received during the meetings, and (iii) information rule of the boss comes from the communication rule through an application of Bayes' rule, as an attempt to infer the size of the shocks.[20] Then, we formally define an equilibrium as follows:

Definition 2. *An equilibrium is defined as a family of communication rules $\mu_t(M_{it}|z_{it})$ for the set of prices that involves the messages M_{it} provided by the local managers during the meeting to communicate to the boss, and the decision-making of the boss to set the price p_{it} of the good given his information rule $g_i(z_{it}|M_{it})$, such that:*

1. *For each message provided $M_{it} \in [0,1]$, for each local manager, the probability of the distribution of communication strategies is given by $\int_M \mu_{it}(M_{it}|z_{it})dM_i = 1$, where the Borel set M is the set of all possible communication strategies, M^*_{it} is in the support of $\mu_{it}(M_{it}|z_{it})$, then we have that $M_{it} \in ArgMax_{\{P_{it}\}}\, E_t[\sum_{t=0}^{\infty}\beta^t \pi_{it}(P_{it}, P_t, Y_{it}, Z_{it}|\mu_{it})]$.*

2. *For each partition a_i received in communication M_{it} during the meeting, the price p_{it} solves the maximization problem of the firm, in which the boss maximizes the posterior of the profit function, $p_{it} \in ArgMax_{\{p_{it}\}} \int_0^1 E_t[\sum_{t=0}^{\infty}\beta^t \pi_{it}(P_{it}, P_t, Y_{it}, Z_{it}|M_i)]g_i(z_{it}|M_{it})$.*

[20] These conditions hold for each sub-game and since the sub-games are independent, it is enough to stress the complete game analysis here.

In the spirit of Crawford and Sobel (1982), the communication equilibrium is partitioned into intervals, where the local managers only reveal the partition to which price belongs. This means that each local manager does not reveal the actual shock to the boss, instead they reveal a partition that encompasses the correspondent price to the shock observed. This mechanism allows the boss to partially retrieve the shocks, extracting this private information in the meeting, to set the price.

This communication mechanism, based on the existence of partitions, is a fundamental piece to connect our equilibrium discussion with the price-setting literature, because we find that due to organizational failures in the communication the price set by the firm is not fully responsive to the shocks anymore. In a repeated stage-game, different shocks within the same interval could not entail different prices.

In this line, Lemma 1 delves into the impact of within-firm communication on pricing decisions and dynamics. We show that whenever the misalignment of incentives is positive the number of reported partitions is finite. This ensure, despite shocks being continuously distributed, that price set by the boss must be discrete and finite. Consequently, both discreteness and stickiness of price-setting emerge endogenously from the within firm environment as well as its incentives.

Lemma 1. *If the optimal prices chosen from the local managers and the boss are different, for every realization of the shocks z_{it}, then $\exists \varepsilon$: $\forall u, v$, $|u - v| \geq \varepsilon$, where u and v are prices induced in equilibrium. Then, the set of prices induced in equilibrium is finite.*

From the existence of discrete prices due to our within-firm environment, in Proposition 1 we describe the three possible cases that depict the dynamics of the prices according to the conflicts of interest within the firm. This proposition elucidates that the degree of misalignment determines whether prices behave more like a flexible price model or a constant price model.

Proposition 1. *In this simple economy, price-setting is endogenous to within-firm incentives, such that for non-zero idiosyncratic shocks:*[21]

$$\begin{cases} \textit{If } \{\frac{\pi_{14}^{boss}}{|\pi_{11}|} - \frac{\pi_{14}^{LM}}{|\pi_{11}|}\} \to 0 \Rightarrow \textit{Price converges to flexible price} \\ \textit{If } \{\frac{\pi_{14}^{boss}}{|\pi_{11}|} - \frac{\pi_{14}^{LM}}{|\pi_{11}|}\} \to \infty \Rightarrow \textit{Price converges to fixed price} \\ \textit{If } \{\frac{\pi_{14}^{boss}}{|\pi_{11}|} - \frac{\pi_{14}^{LM}}{|\pi_{11}|}\} \in (0, \infty) \Rightarrow \textit{Price is sticky} \end{cases} \tag{8}$$

[21]It is important to stress that the conditions below should hold for the interaction between the boss with each local manager to pricing behavior happens.

Proposition 1 has two key implications. First, it establishes a link between intra-firm decision-making and the New Keynesian literature, where information transmission serves as a nominal friction. Second, from a macroeconomic perspective, the model generates non-neutrality of monetary policy since prices are unresponsive to the shocks.

Since we have already established the existence of a relationship between firm's incentive and pricing behavior, the next step is explain how we determine the number of partitions of a given good. In order to do that, Proposition 2 outlines the procedure to find the price-partitions disclosed in the messages M_{it} as a function of the firm's incentives, where partitions are formed by the edge in which the local manager is indifferent by reporting one interval or another.

Proposition 2. *Following the equilibrium definition, we consider that partitions are set by the point at which the private marginal benefit of revealing the private information is equivalent for partitions a_i and a_{i+1}, for each local manager.*

$$\{(p_{it}^{LM} - p_t - \frac{\pi_{13}}{|\pi_{11}|}y_{it} - \frac{\pi_{14}^{LM}}{|\pi_{11}|}z_{it}(a_i))^2 - (p_{it}^{LM} - p_t - \frac{\pi_{13}}{|\pi_{11}|}y_{it} - \frac{\pi_{14}^{LM}}{|\pi_{11}|}z_{it}(a_{i+1}))^2\} = 0 \tag{9}$$

Where the superscript LM $\in$\{Local Manager 1, Local Manager 2\}.

From the procedure established in Proposition 2, each local manager reports to the boss the partition that represent the price. Since the boss cannot observe the shocks, he uses these partitions to infer about them, which allows us to rewrite the optimal price equation. This new draw sheds light on the importance of communication channel and, indirectly, firm's incentives to the price-setting and price stickiness.[22]

$$p_{it}^{Boss} = p_t + \frac{\pi_{13}}{|\pi_{11}|}y_{it} + \frac{\pi_{14}^{Boss}}{|\pi_{11}|}\frac{a_i + a_{i+1}}{2} + \frac{\pi_{15}^{Boss}}{|\pi_{11}|}\frac{a_j + a_{j+1}}{2} \tag{10}$$

Where a_i refers to the partitions of the local manager 1, while a_j is the analogous to the other local manager.

Therefore, indirectly, each partition encompasses a broader interval of potential shocks, resulting in less frequent transmission of their effects to prices. This occurs because, even with different shocks within the same interval, the department consistently reports the same partition to the boss. Then, the boss "wrongly"infers no different shocks, leading to price stickiness, as supported by Proposition 1.

As a consequence, the degree of misalignment directly affects the size of the partitions as well as the

[22] In the appendix, we provide the derivation of this equation.

number of partitions of a given good, influencing pricing behavior. Notably, partition sizes are uniform for a given margin but vary across margins according to communication between boss and each local manager.

Finally, one important point to be discussed concerns the existence of multiple equilibria in our sender-receiver game, as is common in this literature. To address this, we employ a refinement based on Harsanyi (1986), dropping Pareto-inferior strategies to achieve equilibrium uniqueness. The details of this refinement and its application are further discussed in the the general equilibrium model.

2.3 Numerical Simulations for the Simple Model

In this section, we illustrate a quantitative application of the microeconomic counterpart to gauge the significance of our new mechanism. As there are many possible aspects, we focus here on how our multi-divisional within-firm communication framework matches some stylized facts as reference/sales price behavior, discrete prices and small changes. The fully-fledged macro model will address additional aspects.

We simulate price equation 10 using a simple calibration. We assume the levels of misalignment $\frac{\pi_{14}}{|\pi_{11}|}$ and $\frac{\pi_{15}}{|\pi_{11}|}$ are equal to 1, and normalize the aggregate price p_t to zero as well as the production and its elasticity.[23] Additionally, we arbitrarily impose a three partitioned equilibrium[24] for 100 periods.[25] Shocks in both department-levels are also iid and (0,1) uniformly distributed for simplicity. It is important to mention that even though our explanations of the stylized facts are robust to changes in the calibration, we will further in the paper use microdata to obtain those parameters. Under these assumptions, the simulation results in a price distribution with three distinct prices that allow us to explain a set of stylized facts.

The first aspect that arises is the stickiness of price. As shown in Figure 2, prices are not fully flexible in our setup due to the communication between the boss and the local managers. This fact also impacts the duration of stickiness, such that larger misalignment leads to longer duration of price stickiness.

The second aspect that arises is the existence of sales and reference prices. In the partitioned equilibrium, the reference price is the highest, and the sales price is the lowest. Sales occur whenever there exists a large shock and the communication is informative enough to change the current partition. This pattern illustrates that our mechanism matches the empirical evidence from Karadi et al. (2021), where there is no price selection in firms decisions.

[23]These assumptions, affecting only the magnitude of prices, do not alter the patterns in the simulation.

[24]In the appendix, we provide simulations with different number of partitions to understand how the shape of the price distribution changes, reproducing more or less stickiness and describing different stylized facts.

[25]To handle with equilibrium multiplicity, we set the lower bound for the value of information to zero and the upper bound to one. This enables us to discard payoff-inferior strategies and the babbling equilibrium, focusing on a unique, almost fully-revealing equilibrium.

The third aspect is small changes in price, as suggested in Cavallo (2018a) and Cavallo (2018b). Informative communication results in small changes, redistributing the equilibrium price into intervals with small sizes. Even small shocks are sufficient to change the partition-setting and make the decision-maker reset the price.

The fourth aspect is the discreteness of the prices. Figure 2 depicts our setup's ability to generate endogenously discrete prices, alternating between stickiness and fluctuation within a rigid interval. This behavior is consistent with Matějka (2016), who also reproduces discrete prices that move back and forth between rigid intervals.

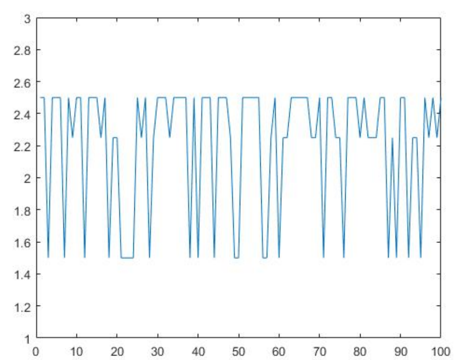


Figura 2: Price Simulation

3 Dynamic Macroeconomic model

In the previous section, we presented a simple model that was able to explain some stylized facts and the underlying mechanism of our proposal. In this section, we make the main changes from our simple model.

First, we develop a model with multi-departments firms, where the misalignment of incentives and communication remains as the nominal friction of the setup. We consider that each firm produces a unique good and there exists a finite number of shocks that hit this good. Then, inside of each firm there exists a boss that interacts repeatedly, playing always the stage-game, with the local managers, which are the leaders of the firm's departments, to extract their private information about the shocks, as in the simple model.

Second, we develop a general equilibrium macroeconomic dynamic model with the within-firm mechanism proposed embedded in it. This means that we have the usual intertemporal and intratemporal margins on the consumer side. In this setup, we also discuss the role of a standard monetary policy rule as well as the role of within-firm misalignment in the conduction of monetary policy and inflation dynamics.

Overall, these changes allow us to address the shortcomings of our simple model and provide a more realistic and comprehensive framework to analyze the proposed mechanism and the empirical evidence.

3.1 Firms

The environment of the firms consists of a set Ω with n multi-department companies, where each one produces a unique good, resulting in n goods produced in the economy.

We assume that the number of departments in a firm is given, where a firm has as many departments as shocks.[26] This assumption implies that firms have access to all possible information required to make pricing decisions, whenever information exchange between the boss and departments is fully informative, however prices could stay sticky depending on the conflict of interests within the firm.

In this subsection, we begin by describing the production function, exchange of information, and profit functions of each agent. We then derive the solution to the firms' problem as a partitioned price-agreement. Additionally, we present our Phillips curve, which highlights the relationship between inflation, within-firm incentives and misalignment in communication, and the welfare function.

Production Function We now describe the production function and labor allocation. In each period, the boss hires as many employees as the number of local managers within the firm. Consequently, local managers have two primary roles in this economy: producing goods and communicating pricing decisions. Additionally, we also assume that labor is supplied inelastically in this environment, and the wage is exogenously determined, independent of the message transmitted to the boss.[27]

We assume that production Y_{it} at the firm-level of the good i is a function of labor allocation at the firm-level N_{it} and the aggregate level of productivity of the economy A_t,[28] as described in the following assumption.

Assumption 1. *The production function for a given firm i is given as follows:*

$$Y_{it} = A_t N_{it}^{1-\alpha} \tag{11}$$

[26] To simplify the derivation, we consider the same number of departments for each firm, however the results still holds when we consider firms with different sizes.

[27] We do not enter into further details to enrich this environment since the focus of this model is on providing a new explanation for price-setting and price stickiness based on the pricing decisions, the exchange of information within the firm, and their conflicts of interest.

[28] Following the same idea used to model the labor counterpart of this economy, we consider an aggregate component for productivity only. However, if we assume heterogeneous productivity the results remain the same.

Where Y_{it} describes the output produced by firm i at period t, such that $i \in \Omega$, A_t is the aggregate productivity of this economy at period t, N_{it} is the level of labor allocated by firm i at period t and α is a parameter, such that $\alpha \in (0,1)$. Moreover, we also consider that aggregate output of the economy is the summation of all firm-level outputs for the n firms of this economy, such that $Y_t = \sum_i^n Y_{it}$.

Information flow We assume that at each period, the boss of each firm holds a meeting with all N local managers. During this meeting, the boss receives simultaneous messages about prices in a tuple $M_{it} = (M_{1t}, ..., M_{Nt})$. As the shocks are orthogonal and departments cannot communicate with each other, the boss interacts with each department independently, treated as independent sub-games, which ensures that the within-firm incentives explored in the simple model remain valid.

Profit function Similar to the simple model, we assume that in this multi-product firm, each local manager maximizes his profit function, while the boss maximizes the total profit of the firm in a forward-looking manner. Therefore, as in the case of Definition 1, the decision-making of the firm is based on the optimization of the profit function of the boss constrained to the messages received from the local managers during the meeting, which come from their optimization pricing problem. We define the forward-looking pricing decision problem of this dynamic version for a given firm as follows:

Definition 3. *To define the price of the goods, the boss maximizes the profit function of the firm conditional on the tuple of message M_{it}, for $M_{it} = (M_{1t}, \ldots, M_{Nt})$, received from the local managers during the meeting as given by the following constrained maximization:*

$$\begin{aligned} &\max_{\{P_{it}\}} E_t \sum_{t=1}^{\infty} \sum_{i=1}^{N} \beta^t \pi_{it}(P_{it}, P_t, Y_{it}, Z_{it} | M_{it}) \\ &s.t. \; M_{it} \in ArgMax_{\{P_{it}\}} \, E_t \sum_{t=1}^{\infty} \beta^t \pi_{it}(P_{it}, P_t, Y_{it}, Z_{it} | \mu_{it}) \\ &for \; i \in \{1, ..., N\} \end{aligned} \tag{12}$$

Partitioned Equilibrium In order to derive the partitioned equilibrium of this economy, we maintain the use of the concept of perfect Bayesian Nash equilibrium for each independent sub-game of our within-firm environment. It requires that (i) local managers maximize their profit function to set their optimal communication strategies, (ii) the price decision of the boss is optimal given his information set, and (iii) the information of the boss comes from common knowledge information combined with the message received from each department. Therefore, this setup endogenously generates a finite number of discrete prices,[29] in which the local managers reveal only the partitions that prices belong to the boss.

At equilibrium, due to conflicts of interest within the firm, prices may no longer be fully-flexible, such that the lower the informativeness of the communication is, the higher the deviation to the flexible price will be. Thus, the price equation is a function of the aggregate price p_t of the economy, the misalignment with respect to each margin, the partitions a^i_j, and the production of the goods at firm-level y_{it}.

$$p_{it} = p_t + \frac{\pi_{13}}{|\pi_{11}|} y_{it} + \sum_{i=1}^{N} \frac{\pi_{13+i}}{|\pi_{11}|} \left(\frac{a^i_j + a^i_{j+1}}{2} \right) \tag{13}$$

This equation emphasizes the trade-off between price stickiness and misalignment of incentives, where even though more departments entail more information about the economy, it also brings more conflicts of interest to address. Therefore, the net effect on pricing behavior depends on how it affects the level of misalignment in communication.

Furthermore, this equation stresses some important points to be highlighted about pricing dynamics. First, the equation enables us to describe the impact of each margin of misalignment on the price of each good as well as the share of their participation in the variation of the price through the elasticity price with respect to misalignment, as a consequence of the independent interaction of the boss with the local managers. Second, this equation describes the role of hierarchy within-firm in pricing dynamics, disentangling which margins are more relevant to explain price-setting as well as its facts.

Phillips Curve From the first-order conditions with respect to the pricing decision at firm-level,[30] we construct a prototype Phillips curve that translates the dynamics of inflation at firm-level for a given firm i. This equation allows us to set the inflation for a given firm and describe how within-firm organizational failure impacts them.

$$\pi_{it} = \kappa_0 + \beta E_t \pi_{it+1} + \frac{\pi_{12}}{|\pi_{11}|} \pi_t + \frac{\pi_{13}}{|\pi_{11}|} y_{it} + \sum_{i=1}^{N} \frac{\pi_{13+i}}{|\pi_{11}|} z_{it} \tag{14}$$

Where π_{it} gives the inflation at firm-level at period t. Moreover, π_t is the aggregate inflation, κ_0 is a

[29] In the appendix, we expose the proposition that characterizes the existence of equilibrium for the dynamic model, which reminds the case of the simple firm.

[30] In the appendix, we provide details about the derivation of the Phillips curve.

constant term and $E_t\pi_{it+1}$ is the expected inflation at firm-level.

This equation describes that the firm-level decision about inflation is a function of a constant term κ_0, the expected inflation at firm-level, aggregate inflation of the economy, total production of the firm and the within-firm communication misalignment.

Now, to derive the Phillips curve, we aggregate all the goods for all the firms in this economy in a weighted mean. Following the logic of the Consumer Price Index, the weight ψ_i represents the proportion of each good in price index that represents the inflation of the economy with n firms. As such, the aggregation of the prototype Phillips curve for all the goods produced in the economy is given by:[31]

$$\pi_t = \sum_{i=1}^{n} \psi_i \pi_{it} \tag{15}$$

Therefore, applying our aggregation to the prototype Phillips curve, we obtain our new Phillips curve that sheds light on the role of within-firm misalignment in inflation dynamics.

$$\pi_t = \zeta + \beta E_t\pi_{t+1} + \zeta_z z_t + \zeta_y \hat{y}_t \tag{16}$$

This Phillips curve emphasizes that inflation is determined by the output gap $\hat{y}_t$ and its elasticity ζ_y, expected inflation $E_t\pi_{t+1}$, misalignment level ζ_z and shocks z_t, representing aggregate supply shocks. It is important to mention that ζ_z captures the degree of price rigidity resulted arising from organizational failure in communication within firms. This Phillips curve also includes an intercept ζ, reflecting the minimum inflation rate based on the number of operating firms.

Unlike Calvo or Menu Cost models, our Phillips curve aligns with empirical evidence from Zbaracki et al. (2004) and Blinder et al. (1998), accounting for the impact of organizational environment within firms on inflation dynamics. Misalignment presents two effects: indirect impact on inflation through the intercept, and direct impact on inflation persistence. Intuitively, higher misalignment leads to less informative communication, resulting in less responsiveness of prices to shocks, widening the gap between sticky and flexible prices, higher price stickiness and increasing inflation inertia. Therefore, organizational failure increases the persistence of inflation as well as its level and induces a flatter slope and higher real effects of monetary policy.

Moreover, our Phillips curve highlights a trade-off between the information exchange and firms' organi-

[31] It is important to mention that implicitly in the derivation of this Phillips curve, we consider that each boss from each firm acts atomistically.

zational incentives. On the one hand, more departments mean more information transmitted about shocks, since the boss receives more partitions in his communication with the local managers, resulting in lower misalignment and, hence, lower persistence of inflation. However, on the other hand, more departments also entail more conflicts of interest to be managed, resulting in higher ζ_z and thus higher misalignment within firms and higher persistence of inflation. Therefore, this trade-off sheds light on the relationship between inflation dynamics, firms size and conflicts of interests.

3.2 Consumer Side

For the consumer side, we consider a continuous and twice differentiable utility function. We assume a representative household that extracts utility from consumption and disutility from labor, as represented by the following utility function.

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi}\right) \tag{17}$$

Similar to Galí (2015), C_t gives the bundle of the aggregate consumption of this economy at period t and N_t describes the aggregate employment of this economy. A representative household consumes all the finite n goods produced in this economy for a given period t. The intertemporal budget constraint is given by:

$$P_t C_t + Q_t B_t \leq B_{t-1} + W_t N_t + D_t \tag{18}$$

Resolving the problem of the household,[32] we obtain the IS curve, which shows that the output gap depends on the expected output gap, nominal interest rate, expected inflation, and natural real interest rate. Both the expected output gap and inflation have a positive effect on current output, while the nominal interest rate has the opposite effect. One point to stress here is the relationship between the household decision choice and the within-firm environment. As described in the Phillips curve, the level of misalignment impacts the expectation of inflation; hence, it also affects the output gap, in which the higher the level of misalignment, the higher the persistence of variables such as the nominal interest rate and output gap.

$$\hat{y}_t = E_t \hat{y}_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1} - r_t^n) \tag{19}$$

Where $\hat{y}_t$ is the current output gap, $E_t \hat{y}_{t+1}$ is the expected output gap and r_t^n is the natural real interest

[32] Details can be found in the appendix.

rate.

3.3 Monetary Policy Rule

To set up the New Keynesian economy, we first analyze the equilibrium under the standard monetary policy rule, given by:

$$i_t = r^n + \phi_\pi \pi_t + \phi_y \hat{y}_t + v_t \tag{20}$$

The Taylor rule shows that the nominal interest rate is a function of the natural real interest rate at equilibrium r^n, the output gap $\hat{y}_t$, inflation π_t, which captures the organizational failure generated by the misalignment of incentives within the firm, and a zero value target for inflation rate. Moreover, ϕ_y and ϕ_π are the sensibilities with respect to output and inflation, respectively, and v_t is the monetary shock.

Although this Taylor rule resembles the usual format of a monetary policy rule, it emphasizes the relevance of within-firm incentives and communication. Intra-firm misalignment is crucial in setting the nominal interest rate for monetary policy, as it affects both inflation and the output gap. Economies with higher misalignment experience greater inflation persistence, as exploited in the Phillips curve. Consequently, disinflation processes require higher duration of tightening in monetary policy, resulting in a higher disinflation cost.

3.4 Welfare Function

We also provide an analysis of the optimal welfare function for this economy, based on the standard dual-mandate approach for inflation and output gap. The within-firms dynamics play an important role in the aggregate environment through intra-firm misalignment, as depicted below:[33]

$$W = -\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t [\frac{\epsilon}{\Theta} [(\frac{1}{12} \sum_{i}^{n} \frac{\pi_{13+i}}{|\pi_{11}|})^2 + \pi_t^2] + (\sigma + \frac{\phi + \sigma}{1-\alpha}) y_t^2] \tag{21}$$

Similar to Galí (2015), our welfare function depends on the quadratic terms of inflation and output gap. However, there are three key distinctions in our case. First, we obtain a negative relationship between misalignment and welfare, where increased misalignment distorts prices, resulting in a decline in welfare. Second, the magnitude of the distortion determines whether the impact of inflation on welfare is amplified or dampened, thereby dictating the dynamics of the welfare response. Third, misalignment enters additively

[33] Refer to the appendix for details.

in the welfare function.

It is important to mention that before delving into simulations of our general equilibrium New Keynesian model, we dive in the empirical aspect of the paper in the following section. It allows us to develop a data-driven approach to calibrate our theoretical model, mainly the levels of misalignment within the firm, which do not have evidence in the literature to be followed. Then, in the final section of the paper, we provide the numerical simulations of our macroeconomic model.

4 Empirical Counterpart

In this section, we bring our model to the data describing our dataset and finding the optimal calibration for the pricing decision through a data-driven approach. Moreover, we conduct various tests to show how misalignment can explain price movements, and complement the existing literature on price stickiness.

However, we need to make a couple of choices regarding the existence of N shocks to ensure tractability in the estimation of the model. We consider the existence of four shocks and four local managers at each firm. One local manager is informed about idiosyncratic (item-level) shock, other local manager has private information about the shock that affects the category of the good produced, a third agent is informed about the sector that this category belongs, and the last local manager is informed about the shocks that impact the retailer-level, which we can the aggregate shock in the rest of the paper. This structure holds for all the firms in our economy.

4.1 Data Description

While we delve into details of our proprietary scrapped dataset in the appendix, Table 1 provides a summary overview of our dataset, including the number of goods, categories, and sectors of the retailers, along with the start and end dates of the observations in our sample. There are notably several features of our data that make it particularly useful of our purpose.

Counting Statistics	Retailer 1	Retailer 2	Retailer 3	Retailer 4	Retailer 5	Retailer 6
Number of Products	285068	48288	21887	54275	25406	33399
Avg Number of Products per day	27459.72	9818.79	6935.51	10806.69	5343.17	6552.91
Observations	30,837,263	10,702,485	7,989,711	11,736,065	6,128,611	7,621,034
Total Days	1276	1238	1367	1245	1367	1367
Initial Date	2018-04-24	2018-05-10	2018-01-01	2018-05-03	2018-01-01	2018-01-01
Final Date	2021-10-21	2021-09-29	2021-09-29	2021-09-09	2021-09-29	2021-09-29
Sector	4	4	4	4	4	4
Category	19	19	19	19	19	19
Missing (%)	29.49	35.08	33.00	36.16	31.02	31.12

Tabela 1: Counting Statistics at the Retailer Level

When we look at the empirical literature on sticky prices, three major sources of datasets are typically used, namely:[34] (i) online data, (ii) scanner data and (iii) CPI data.[35] These sources offer different advantages and pitfalls. For example, online and scanner data may lack goods categorization, while CPI data lack high-frequency information. In our case, we enjoy the advantages of online data, such as daily frequency and lower measurement errors, combined with the categorization advantages at category and sector levels provided by CPI data.

At this point, it is crucial to explain our proposed categorization algorithm and the methodology for defining and differentiating categories and sectors in the economy. To calculate CPI, the Brazilian Institute of Geography and Statistics (IBGE) first aggregate goods into groups representing the consumption basket of the representative household of the Brazilian economy.[36] These aggregated groups constitute the goods category, with 19 official categories available for matching. Subsequently, IBGE defines 9 groups that aggregate these

[34] For a review of this literature, see Cavallo and Rigobon (2016). Other sources are used by some works, such as PPI data, although they usually focus on international price-setting analysis.

[35] Key references for databases used in the study of sticky prices are the following: Bils and Klenow (2004), Nakamura and Steinsson (2008), Cavallo and Rigobon (2016), Cavallo (2018a), Eichenbaum et al. (2011), Klenow and Malin (2010).

[36] In the appendix, we provide more details about this categorization.

19 categories, each representing a sector of the economy, from which we consider 5 to match.

To obtain this categorization, we draw a dictionary-classification algorithm, converting the database into tailor-made hierarchical microdata to investigate the relationship between misalignment and price movements. This approach enables us to disentangle the misalignment at different hierarchy levels. The algorithm involves manually matching each product in our dataset to our Consumer Price Index classification, closely mirroring the hierarchy outlined in official statistics. We were able to obtain prices for the majority of goods within the Brazilian Consumer Price Index, matching 120 out of the 377 goods calculated by national statistics.

On the first level, there could be a misalignment within a supermarket. By analyzing different goods within the supermarkets, we can determine whether there is a difference in price as a consequence of a supermarket misalignment or if there is another source of misalignment.

On the second level, there could be misalignment due to sectors and categories and this deserves attention. By analyzing different supermarkets in Brazil, we can compare the same good, category and sector, across different supermarkets. For instance, if we want to look at food - food at home - pasta - spaghetti, we have to classify each of these levels, which allows us to disentangle their margins of misalignment. To do that, we applied the term frequency-inverse fuzzy string matching algorithm.

Another contribution of our dataset is that we bring a database with several retailers, which allows us to assess if our mechanism works for different retailers as it should be expected and guarantee the absence of some selection bias. Meanwhile, the remaining statistics, such as the number of products, missing, and so on, are aligned with other online datasets, such as Cavallo (2017).

To illustrate the empirical moments of the data, Table 2 provides the main descriptive statistics on prices from the six major retailer chains in Brazil. This database distinguishes from the literature by (i) very frequent price changes and (ii) a sizable share of price changes above 5 percentage points, which happen due to a significant share of food products. On the other hand, this database shares some similarities with the literature, such as the size of price change. When combined, these patterns sheds light to the existence of small changes in prices because even though the prices change very frequently, their sizes have the same magnitude as other datasets, which may occur because in daily data we can note temporary changes.

Descriptive Statistics	Retailer 1	Retailer 2	Retailer 3	Retailer 4	Retailer 5	Retailer 6
Frequency of Price Change (p.p.)	4.77	2.35	1.49	1.79	1.93	3.13
Size of Price Change	6,01%	7,5%	6,27%	4.70%	7.32%	0.35%
Days to Price Change	1.87	2.14	3.04	2.09	1.95	3.65
Percentage of Price Change	96.63%	89.47%	93.31%	89.76%	89.22%	98.74%
Change of Price above 5p.p.	1.68	1.87	0.96	1.24	1.83	2.38

Tabela 2: Descriptive Statistics at the Retailer Level

4.2 Empirical Methodology and Results

In this section, we present our estimation of the optimal price equation and its ability to explain the stylized facts of the empirical literature. To achieve this, we closely follow our theoretical counterpart model and estimate our dynamic firm-level price equation.

Since our theoretical price agreement is characterized by multiple equilibria, we follow the approach suggested in Crawford and Sobel (1982) and propose an empirical method based on the idea of Harsanyi (1986) to exclude equilibria-strategies that yield Pareto-inferior payoffs. Unlike Crawford and Sobel (1982), our method finds empirically the optimal calibration to the levels of misalignment that enable price-setting to match the empirical prices as well as their moments for some large retailers in the Brazilian economy. Therefore, any other values for the levels of misalignment would result in prices that deviate from the empirical prices and represent Pareto-inferior strategies.

4.2.1 Algorithm Estimation

Our empirical exercise has two main dimensions that we want to understand: the number of partitions and the misalignment for each hierarchical level of each good. Here, we provide a two-stage algorithm that encompasses these dimensions.

In the first stage, we follow the theoretical setup to build the finite difference equations that illustrate our price equilibrium[37] as a function of misalignment and partition structure for each margin. In order to

[37]The derivation of these equations is provided in the appendix.

estimate those equations, we need the shocks and the number of partitions; thus, for the former, we simulate a uniform (0,1). For the latter, since the number of actual observed partitions for our sample can be misleading because we have just a span of the full time-series, we provide an algorithm that runs iterations assuming each combination from 1 to 10 partitions in each of the levels, covering exhaustively all possible combinations of the number of partitions. This means that for goods with low stickiness, we have many partitions, with different sizes according to the margins, while for goods with high stickiness, we have few partitions.

In the second stage, for each iteration that we have, we simulate the pricing deicion running a panel OLS at the CPI-item. For simplicity, take the example of pasta. One possible configuration would be 5 partitions in Retailer-level, 2 partitions in Food, 4 partitions in Pasta, and 3 partitions in Spaghetti. Then, the steps in this second stage can be enumerated as follows:

1. We start at the CPI-level item, where we run a panel OLS on the time-series change of the price for each good over the item-misalignment and the idiosyncratic shocks.

2. At the category-level, we run a similar regression, a panel OLS on the category price over the category-misalignment and category shocks, already incorporating the previous stage.

3. At the sectoral-level, we run a panel OLS on the sector price over the sector-misalignment and the sector shocks, already incorporating the results of the first two stages.

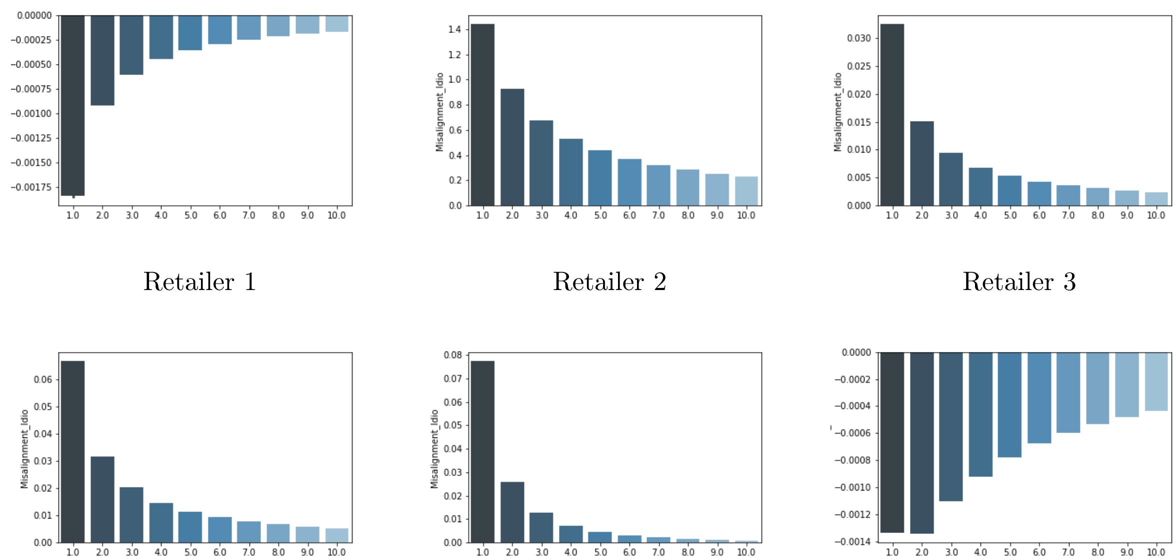
4. At the retailer-level, we run a panel OLS on the aggregate price over aggregate misalignment and aggregate shocks, already incorporating the estimations of the previous stages.

From that, we perform thousands of panel regressions for each supermarket, considering all possible combinations of partitions-setting, where each regression characterizes the simulated price under one possible combination of the partitions. For instance, taking our example of pasta, one regression provides the simulated price when we have 1 partition at the Retailer-level, 1 partition in the Food category, 1 partition in Pasta and 1 partition in Spaghetti. A second regression computes the price when we have 2 partitions at the Retailer-level, 1 in Food, 1 in Pasta and 1 in Spaghetti, and so on up to the case with 10 partitions at the Retailer-level, 10 in Food, 10 in Pasta and 10 in Spaghetti. For each of these regressions, we compute the root mean square error (RMSE), which describes the extent to which the simulated prices deviate from the empirical prices. Then, inspired by Harsanyi (1986), we select the regression with the lowest RMSE to define the optimal calibration, because whenever the calibration deviates from the optimal, the corresponding strategies are Pareto-inferior, thus must be discarded.

4.2.2 The Relationship Between Partition-Configuration and Misalignment

To test our theoretical mechanism, we first examine the empirical relationship between the partition-structure and the misalignment at the item-level. Figure 3 describes a negative relationship between the absolute value of the misalignment and the number of partitions. Intuitively, this means that when the conflicts of interest are less relevant, the intervals of the partitions are smaller, since there is almost no noise in the communication, and even small shocks are reset to the prices, delivering a lower stickiness. Conversely, when the agents have a significant misalignment, the size of the partitions become higher, with a less informative communication and, as a consequence, prices remain the same for more periods, resulting in higher stickiness.

Furthermore, Figure 3 also illustrates another two interesting patterns: (i) misalignment could be negative or positive, and (ii) misalignment could be high or low. The first pattern depicts that retailers could underestimate or overestimate the shocks when reporting the prices, respectively.[38] The second pattern depicts that communication could have different gradations, which demonstrates the relevance of conflicts of interest within the retailers and depicts that the margins of communication have different effects in pricing decisions.



Retailer 1 Retailer 2 Retailer 3

Retailer 4 Retailer 5 Retailer 6

Figura 3: Item-Level Misalignment x Partition

[38]We can think on some examples that represent these effects. If the local manager receives a bonus whether he attains a target of sales, then underestimate the price could be optimal choice, while if the local manager receives a bonus whether he attains a target on revenue then overestimate the shock could be optimal.

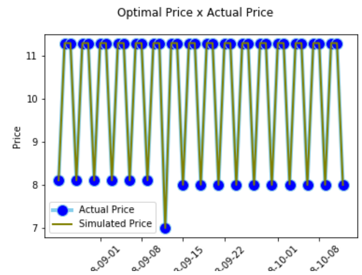
4.2.3 Do Retailers Match our Optimal Prices?

Now, we enter into our second set of empirical results, we simulate the theoretical prices, using the optimal calibration, to fit the empirical prices as well as their moments for a basket of products from the first retailer. Figure 4 depicts the ability of our setup in closely reproduces a wide range of pricing stylized facts such as reference/sales prices, stickiness, small changes in prices, and heterogeneity in price-setting.

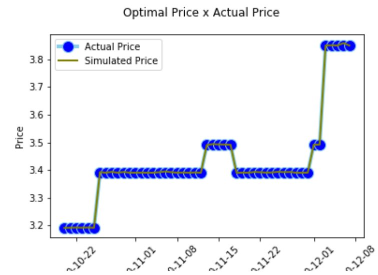
The first chart of Figure 4 describes a suggestive pattern with frequent changes in prices and recurrent sales prices that back and forth to the same reference price. This behavior happens due to a coarsened communication, with an equilibrium marked by only a few partitions, where aggregate margin moves reference price whilst item-level margin affects sales.

The second chart depicts different patterns now, such as temporal stickiness and changes in the reference prices. This happens as a consequence of an uninformative communication structure, where the (reference) price only changes when a large shock hits the economy, while for the smaller shocks, the departments mask them always revealing the same partition

The third chart presents very frequent small changes in prices, which are explained due to a fully informative communication. Empirically, the share of small price changes is large because the item-level margin fluctuates widely across the partitions, then even small shocks are communicated to the boss and reset to the prices. Finally, the chart of soap powder summarizes the other figures in a unique one, describing length of price spell, period of high stickiness and periods of small changes and eventual V-shape sales.



Apple



Tomato Sauce

Rice

Soap Powder

Figura 4: Examples of Optimal Price Simulation

4.2.4 How Partitions Dynamics Change According to the Micro Price Facts?

In our final empirical exercise, Figure 5 describes the frequency of partitions for the optimal prices simulated in Figure 4. This figure sheds light on some patterns that, when combined with the theoretical counterpart, aid in reconciling empirical observations with the within-firm organizational structure.

First, we note a concentration of two primary partitions for apple (blue bars) at the same time that Figure 4 presents two main prices, the reference and the sale price. This pattern suggests that item-level communication plays an important role in driving sales, while communication about the retailer-level matters for reference price.

Second, the frequency of partitions of rice (orange bars) describes an interesting pattern. It describes a dispersal of partitions for both margins, coinciding with the small price changes observed in Figure 4. This behavior square nicely with the theoretical intuition that more informative communication leads to an equilibrium of more partitions, with small sizes. These partitions allow even small shocks to reset prices, justifying the existence of small price changes.

Third, the frequency of tomato sauce (green bars), a goods displaying price stickiness at various price levels, demonstrates a concentration at four partitions for the aggregate margin. This matches the number of prices that remain sticky in Figure 4. This pattern suggests that communication about the aggregate margin dictates the existence of temporal stickiness. Finally, when considering all four goods combined, we note a positive correlation between the pulverization of the frequency of partitions and the number of distinct prices in the goods.

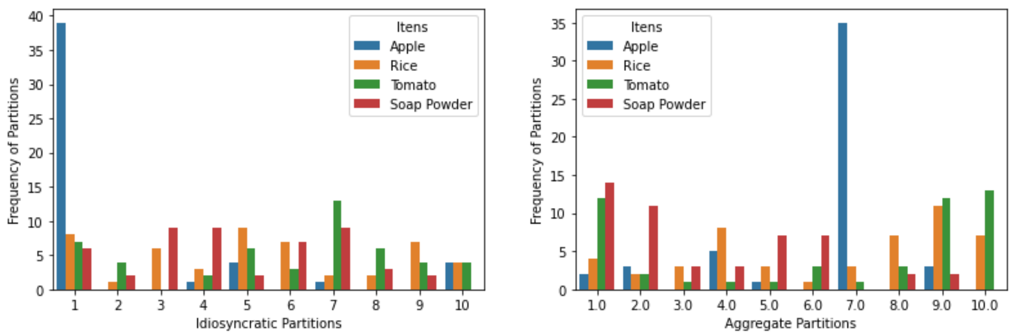


Figura 5: Optimal Partitions Apple

5 Numerical counterpart

In this section, we develop some illustrative quantitative applications of the macroeconomic counterpart to gauge the importance of this new mechanism. To this end, we propose three different venues to explore the numerical macroeconomic counterpart.

The first one shows the impulse response functions and offers a discussion of how it differs from a standard Calvo model. Additionally, we highlight the connection between the within-firm communication mechanism and the persistence of real variables.

The second venue illustrates how the number of departments of the firms impacts the effects of monetary policy and the macro moments of the model.

The third venue describes the optimal policy in this model. We estimate the welfare function described in the theoretical counterpart and depict the role of misalignment.

Regarding calibration, we apply our data-driven approach to discipline the levels of misalignment. Then, the term ζ_z gives the average of sum of all the levels of misalignment within the firms. To the remaining parameters of the within firm counterpart that are unobserved as ζ_y and ζ we consider arbitrary value that do not change the dynamics of the simulation. For the others parameters of the New Keynesian economy, we assume a standard calibration for quarterly frequency, following Galí (2015), except the discount factor that we consider 0.98, aligned to Cavalcanti et al. (2015). Thus, the calibration used for the model, except when stated differently, follows Table 3.

ζ_z	ζ_y	ζ	σ	ϕ	ϵ	ϕ_y	ϕ_π	ϵ_π	β
0.33	0.99	1	1	1	6	0.5/4	1.5	1	0.98

Tabela 3: Calibration

5.1 Impulse Response functions

We start our first numerical exercise by describing the impulse response functions with respect to a monetary shock, in which the endogenous variables are output gap, nominal interest rate, and inflation.[39] Figure 6 stresses some issues within our simulated model that distinguish it from a Calvo model, such as Galí (2015), or a Menu Cost model, such as Golosov et al. (2003).

While the overall direction of the effects is analogous to a Calvo model, as can be observed by comparing the blue lines with the dashed orange lines, the dynamics, magnitude, and persistence of the effects differ significantly. One can note that in response to the same increase in the nominal interest rate, our model exhibits a more substantial and rapid decrease in inflation compared to the Calvo model. This behavior describes the impact stressed in the Taylor rule and the Phillips curve, indicating that communication within the firm impacts the conduction of monetary policy.

Intuitively, a higher degree of within-firm misalignment implies less informative firm-level communication, leading to longer periods of unchanged prices. This, in turn, results in higher levels of inflation and greater inflation persistence. In terms of output, the short-run impact of a tightening monetary policy is nearly identical to a Calvo model. However, the economy recovers more swiftly, ultimately reaching a new equilibrium with higher output levels when compared to the benchmark model.

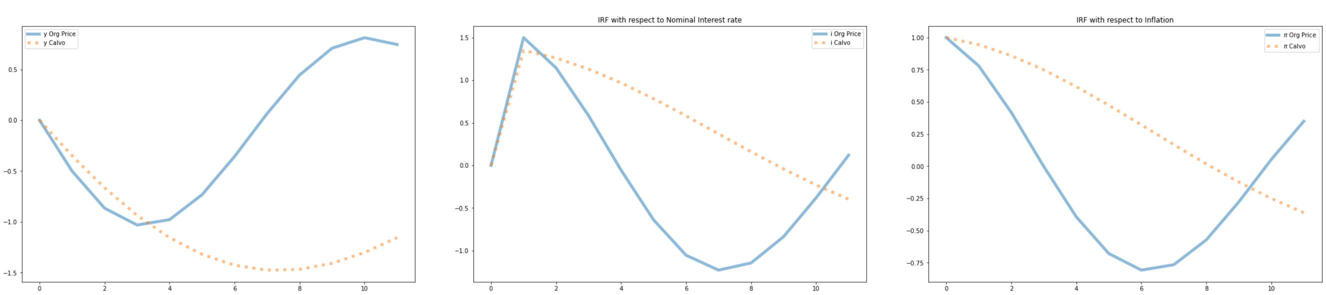


Figura 6: Impulse Response Function to Monetary shock

[39] Naturally, our inflation already considers the within-firm environment; then, this impulse response function implicitly incorporates the relationship between the monetary shock and the conflicts of interest within the firm.

5.2 Monetary Policy and Number of Departments

In our second exercise, we explore the relationship between the number of divisions in the firms and the real effects of monetary policy. Since our model emphasizes the importance of within-firm dynamics in pricing decisions, this exercise allows us to examine how the impact of monetary policy in output gap changes as we vary the number of divisions in the firms. To simplify the simulation, we assume an equal distribution of divisions across firms under the same level of misalignment.

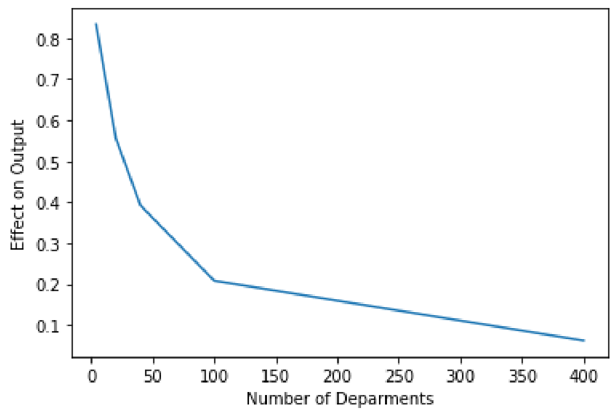


Figura 7: Power of Monetary Shock x Number of Departments

Our simulation demonstrates that the impact of monetary policy is stronger for an economy where the firms have fewer divisions. This means that as the number of divisions increases, the within-firm communication becomes more efficient, reducing pricing rigidities and dampening the impact of monetary policy on the economy as well as its persistence. Specifically, in an environment where there are almost 400 departments, the real effect of monetary policy becomes negligible.

Furthermore, this simulation also highlights the non-linear nature of this relationship, whereby an initial increase in the number of multi-divisional firms, represented here as the number of divisions, entails a rapidly decay in the real effects of monetary policy. However, this trend slows down as the number of departments increases.

This result is in line with the empirical evidence from surveys on price-setting and firms decision-making, such as Druant et al. (2009), which elucidate that firm's size impacts the price rigidity, where larger firms have lower stickiness. From a macroeconomic perspective, this empirical result describes that economies with larger multi-product firms should have smaller real effects of monetary policy, as demonstrated in our Figure 7. In our approach, as previously mentioned, this is a consequence of the fact that the exchange of information proves to be more informative for multi-divisional firms, and its effect outweighs the negative impact of the conflict of interests.

5.3 Welfare Function and Optimal Policy

In Table 4, we simulate welfare function from equation 21 for different levels of total misalignment in the economy in order to understand how changes in within-firm conflicts of interests impact the welfare of the economy. To do that, we follow calibration as in Table 3, and we also consider that, for the Brazilian economy, both inflation and output gap at 4%. Then, this table presents three scenarios to the levels of (total) misalignment,[40] where, following our empirical estimation, the baseline case is given by total misalignment equals to 0.33.

Total Misalignment	Welfare
0.23	-0.530
0.33	-0.558
1	-0.993

Tabela 4: Welfare Simulation

Table 4 highlights the relationship between the within-firm environment and the macroeconomic dynamics. The simulation describes that the way how the macroeconomic fluctuations affect the welfare of the economy depends on how firms address their internal conflicts of interest, which can promote greater information sharing among local managers and lead to lower inflation and higher welfare. This can be noted by the increasing of welfare as the sum of the parameters related to misalignment reduces. In other words, as firms become more effective in managing internal conflicts of interest, the overall welfare of the economy raises, which happens due to reduction in the distortion in the dynamics of the pricing decisions.

6 Conclusion

In this paper, we have provided a parsimonious general equilibrium setup, built-in the informational misalignment within the firms' setting, without any type of cost, to explain macro and micro stylized facts of sticky prices. This framework sheds light on the importance of within-firm communication and incentive provision for understanding sticky prices, thereby opening up new possibilities for research in this area.

[40] To simplify the simulation, we consider a unique firm living in this economy with four departments, as in the theoretical counterpart. However, there is no loose of generality in this calibration since the intuition remains the same whether we allow for multiple firms and departments in this economy.

Therefore, in addition to an informational explanation for price-setting, in which sales are observed, we contribute constructing a new Phillips curve, based on the idea that prices may not be flexible due to existent conflicts of interest within the firm. Moreover, we also provide an optimal monetary policy that endogenizes the relationship between welfare and firms' misalignment, in which the higher the conflicts of interests within the firms the lower is the welfare of the economy.

The endogenous communication mechanism, when empirically evaluated, generates the following patterns of firm dynamics: (i) discrete prices, and (ii) simulated prices that match the empirical prices. Moreover, through the incentives provision of the firms and its relationship to partition-misalignment structure, we address facts related to firm, product and shock characteristics, such as (i) the heterogeneity of price distribution, (ii) the reference/sales price behavior, (iii) the small changes on prices and (iv) the gathering information-misalignment. On the macro side, our Phillips curve helps us explain some macro stylized facts as (i) inflation behavior, (ii) the real effects of monetary policy and (iii) its interplay with both the number of divisions within the firms and the level of misalignment.

Finally, we leave for a future research a deeper analysis of the dynamic interaction within the firm, where would be interesting to add learning and horizontal communication in the within-firm environment, in which for a firm that last several periods, the boss learns how to deal with the misalignment of incentives and to find-out even if lagged the actual value of the shocks. This would allow to model the dynamic transition between the short-run incomplete information partitioned price-equilibrium to a long-run complete information steady state. Such work may link organizational structure, paycheck, price-setting and monetary policy.

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