FUNDAÇÃO GETULIO VARGAS
ESCOLA DE ECONOMIA DE SÃO PAULO

TATIANA ALEIXO NOGUEIRA

A STUDY OF OPTIMAL MONETARY POLICY UNDER ADMINISTERED PRICES

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Dissertação apresentada à Escola de Economia de São Paulo como pré-requisito à obtenção de título de mestre em Economia de Empresas.

Orientador: Pierluca Pannella.

Coorientador: Vladimir Kuhl Teles.

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Resumo

Este artigo investiga os efeitos de resposta de política monetária a choques de produtividade com a inclusão de um setor de bens administrados na economia, cujos preços são reajustados conforme regra pré estabelecida pelo governo. O artigo apresenta um modelo de equilíbrio estrutural com um setor de preços rígidos e um setor de preços administrados, usando o modelo DSGE padrão. O principal resultado deste trabalho é mostrar que, com a endogeneização de uma regra diferente para o estabelecimento dos preços de alguns bens da economia, a melhor resposta da autoridade monetária é não reagir de forma mais rígida quando o produto desviar do seu potencial ou a inflação da sua meta. Além disso, para o desenho prático da política monetária, identificamos que a autoridade monetária deve adequar os coeficientes dos parâmetros da regra de Taylor, como também o peso dado à variação da inflação dentro da regra de reajuste de preços administrados, dado o tamanho do setor de administrados na cesta de consumo.

Palavras-chave: política monetária ótima, modelo DSGE, preços administrados.

Abstract

This paper investigates the monetary policy's response to productivity shocks and its effects in the welfare, with the inclusion of a administered goods sector in the economy, which prices are readjusted according to a pre-established rule by the government. The paper presents a structural equilibrium model with a sticky-price sector and a administered price sector, using the standard DSGE model. The main result of this paper is to show that, with the endogenization of a different rule for the readjust of some goods' prices in the economy, the best response of the monetary authority is not to react in the most rigid way to any deviation of the output from its potential or the inflation from its target. In addition, for the practical design of monetary policy, we have identified that the monetary authority should adjust the coefficients of the parameters of the Taylor rule, as well as the weight given to the inflation within the rule of readjust of administered prices, given the size of the administered goods in the consumer bundle.

Keywords: Optimal monetary policy, DSGE model, administered prices.

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0.1 Introduction

The debate over an optimal monetary policy has dominated the macroeconomic theoretical landscape for many decades now. Authors like Fischer, Keynes and Friedman offered their contribution on how to tackle the trade-off between output variation and price variation while maximizing welfare given frictions in the economic environment, however the debate about optimal monetary policy persists and is far from an absolute answer. One of these issues involving monetary policy is about the inflation index used to pursue a target and, indeed, the impact of the composition of that index on the outcome of monetary policy on welfare.

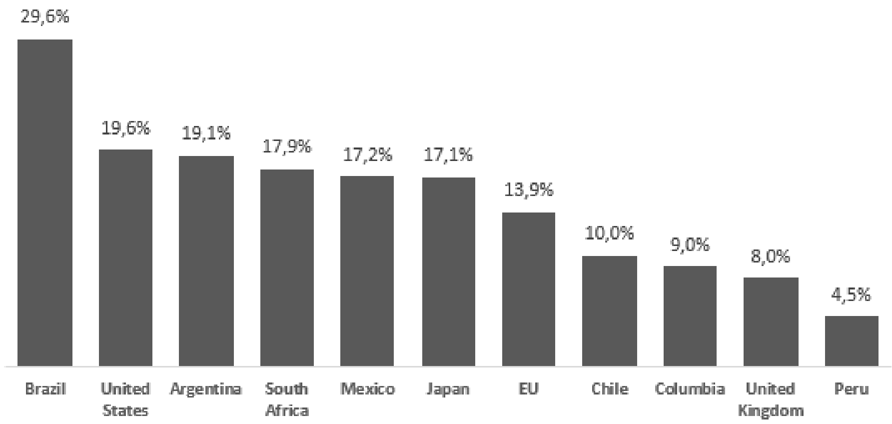
Inflation plays a prominent role in the conduct of monetary policy. Mankiw and Reis (2002) raise the question of which inflation measure is most appropriate for this purpose and they also propose a "stability price index" that weight the sector in the index depending on the sector's characteristics, including size, cyclical sensitivity, sluggishness of price adjustment, and magnitude of sectoral shocks. Although they show this index is the best to maximize economic stability, in real world, most of the Central Banks adopt Consumer Price Index (CPI) or variants, as inflation measure, so should we.

According to Schmidt-Hebbel and Tapia (2002) there are at least two important arguments to support the adoption of a headline inflation index. The first one is related to the issue of the perceived credibility and transparency of the monetary policy. The second reason is based on the relative weight of the excluded items from the index in the representative consumption bundle. Hence, real wages could vary even though the core inflation is stable, causing negative social effects on the population. Finally, the higher sensitivity of the headline inflation rate to changes in relative prices constitutes another important factor in favor of its use as the targeted inflation measure. Moreover, according to those authors and to Ferreira and Petrasi (2002), about 75% of all the central banks adopting the inflation targeting regime set the headline inflation rate as target.

In recent years, many central banks have adopted an inflation targeting to control the general rise in the price level. In this framework, a central bank estimates and makes public a target inflation rate and then attempts to steer actual inflation toward that target, using such tools as interest rate changes. Central banks from advanced, emerging, and developing economies have adopted inflation targeting, such as United Kingdom, New Zealand, Australia, Canada, Mexico, Chile, Colombia, Brazil, Turkey, South Africa, Peru and so on. Even for those Central Banks which have not adopt a well-defined inflation target, including the European Central Bank (ECB), the Swiss National Bank and the Federal Reserve in the United States, have moved toward regimes that have many of the attributes of inflation target.

We can desegregate the CPI in free and administered prices. The administered prices are prices set by firms that do not vary in response to short-run fluctuations in demand and supply conditions. Administered and regulated prices are heavily influenced by government policies (by price or quantity controls, subsidies) rather than being set freely in the market. The share of administered prices in many countries is significant, ranging from about 8% in United Kingdom to about 30% in Brazil. The sectors covered include energy related items and other utilities (eg fuels and electricity, water and sewage), public transportation, rents, and public services (eg education, postal services).

Figure 1 – Administered and regulated prices



Source: BIS 2009, Monetary policy and the measurement of inflation: prices, wages and expectations; Ministry of Internal Affairs and Communications of Japan; BLS; Eurostat.

The main objectives of administered (and monitored) pricing are: (i) to protect the interests of weaker sectors of society against high prices; (ii) to curb or to encourage the consumption of certain commodities; (iii) to contain inflation and ensure price stability; (iv) to counter stagflation and the consequent recession; (v) to mobilize revenue for the government; (vi) to ensure efficient allocation of resources among different users, among others. Although it aims to improve the society's welfare, the introduction of an administered price could potentially lead to a limitation on the effectiveness of monetary policy and likely becomes major challenge on central bank inflation controllability (BIS, 2009).

Based on the specificity of these goods, the present study analyzes the (optimal) monetary policy, where the monetary authority can choose the parameters of a Taylor rule, but also influences the prices of administered goods in order to minimize the welfare losses. We introduce into the model economy a sector of administered good and propose a rule of price adjustment to the sector. We will show how changes in the interest rates, responding to deviations of inflation and output from their steady states, affect the welfare losses when we introduce the administered prices as a new channel of monetary policy.

Results show that, in the one hand, when the participation of the administered goods in the total bundle is very small (5%), then the the monetary authority should not be tolerable with the deviation of inflation from its target. On the other hand, when the share of administered good in the total bundle increases (to 15% or 30%), the best strategy is to stop being completely intolerant with inflation deviations from its steady state value if it is concerned about welfare. We have found similar results to output deviations from its potential.

The paper is organized as follows. Still in this Section, we discuss related literature. In Section II, we describe the model. In Section III, the welfare evaluation is described. We discuss the parameter calibration in Section IV. In Section V, we show the simulation and its results, and we offer conclusions.

0.1.1 Literature Review

Dynamic Stochastic General Equilibrium (DSGE) models have become an increasingly important tool for Central Banks around the world (Tovar, 2009) in the last twenty years. The list of Central Banks that are using and have published their work with DSGE models is increasing, as is the literature about the topic.

As for the development of DSGE models, the New Keynesian Standard Model has become the "workhorse for the analysis of monetary policy, fluctuations, and welfare" (Galí, 2008). This model incorporates imperfect competition in the goods market (Blanchard, et al., 1987) and price rigidity, through a staggered price setting structure (Calvo, 1983), which sets it apart from the Classical Monetary Model.

Some authors, when modeling the Brazilian economy in a DSGE model, do not clearly define an administered sector, but consider the nature of the administered prices as part of the price rigidity created by Calvo pricing, since their focus is not on this dynamic between sectors. The Central Bank of Brazil SAMBA (Stochastic Analytical Model with a Bayesian Approach) model (Castro, et al., 2011), although far more complex model than a New Keynesian Basic Model, incorporates an administered price as one type of intermediate producers in the consumption goods sector. This producer will face almost the same challenges (cost minimization problem and downward-sloping demand curve) as the other producers in the consumption goods sector, except for the fact that the adjustment rule for the administered prices is not optimal.

In Vereda, et al.(2010), the model consider three subsector in the producers sector group - tradable, non-tradable and administered - with each subsector being composed by a continuum $[0, 1]$ of firms, facing imperfect competition and Calvo type pricing mechanism. The model presents the main characteristics of the New-Keynesian paradigm, such as individual with rational expectations, firms with market power, price and wage rigidity, and real frictions. And besides these characteristics, the model for Brazil adds typical characteristics of emerging economies - one of them is that of the goods and services are excluded on items with prices that are "non-administered" (free) or "administered" (negotiated to be set at some level of monitoring or intervention of the government).

Another paper, written by Freitas, et al. (2006), builds its model on a much simpler environment, with firms from two sector, administered and non-administered (free). Free prices sector is composed by a continuum $[0, 1]$ of firms, while the administered prices sector is composed by only one firm. Furthermore, firms in the free sector faces imperfect competition, with Calvo type prices, while the administered sector firm has only one price correction rule.

The firm acting in the administered sector obeys a pricing rule which adjusts the price by a linear combination of the previous period headline inflation, nominal exchange rate variation and price prevailed in the previous period. Their simulation results show that the backward pricing rule governing the administered price adjustment is particularly important for explaining the optimal response of the free sector inflation rate to exogenous shocks.

Loyo and Vereda (2004), in their paper "Can monetary policy be helped by domestic oil price stabilization?" answered this question in the presence of market imperfections. Although with a different approach, and not directly interested in administered prices, the authors seek to evaluate the efficiency of the intervention in the definition of a specific set of goods (oil). The authors show the arguments usually lined in favor of intervention in domestic prices are not enough to justify such intervention. The authors use welfare losses criterion.

Ben Aïssa, et al. (2012) show that strict headline inflation targeting could be easily dominated by sectoral inflation targeting, output gap stabilization, or a combination of these, when a sector receiving subsidies is introduced into the model. They show that the appropriate monetary policy to adopt in the presence of subsidized prices and costly adjusting of prices is sensitive to the relative importance of the two distortions. Furthermore, they find cases where price subsidies are relatively more distorting than nominal price inertia in the non-subsidized sector. They numerically identify country specific thresholds for the degree of government intervention in price setting under which core inflation targeting turns out to be the optimal choice in the context of implementable Taylor rules.

All these studies use DSGE models for their simulations. Despite a similar framework, they make important modifications and expansions to suit their objects of interest.

What they bring together is to introduce government intervention in the definition of some prices of goods, used in the productive sector or for consumption, to better fit the results with what is observed in the real economy.

0.2 Model

The model is a standard New Keynesian Basic Model, as described by (Woodford, 2003) and (Galí, 2008), and it incorporates imperfect competition in the goods market (Blanchard, et al., 1987) and price rigidity, through a staggered price setting structure (Calvo, 1983). The model contains two sectors, free and administered price firms, in the same way as in (Freitas, et al., 2006).

0.2.1 Household

Assume a representative infinitely-lived household, seeking to maximize its intertemporal discounted utility function by solving the following problem:

$$\max_{C_t, N_t} E_0 \sum_{t=0}^{\infty} \beta U(C_t, N_t) \quad s.t. \quad P_t C_t + Q_t B_t \leq B_{t-1} + W_t N_t + T_t \tag{1}$$

Where β is the subject discount factor, P_t is prices of good and C_t is are the quantities goods consumed. Q_t is the price of a bond in t, with maturity in t+1, that solves Q_t=$(1 + i_t)^{-1}$. i_t is the nominal interest rate in t. B_t is the quantity of bonds in period t. W_t is the nominal wage, and N_t is the hours of work in the period. Finally, T_t is the lump-sum tax and dividends.

The utility function is a constant relative risk aversion (CRRA), given by:

$$U(C_t, n_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \tag{2}$$

Where σ^{-1} is the intertemporal elasticity of substitution and φ^{-1} is the Frisch elasticity of labor supply. Since total labor supplied is given by:

$$N_t = N_{F,t} + N_{A,t} \tag{3}$$

The utility function must have certain characteristics: $U_C > 0$ and $U_L < 0$, this means that consumption and labor have positive and negative effects, respectively, on the utility of households. On the other hand, $U_{CC} < 0$ and $U_{LL} < 0$ indicate that the utility function is concave. This represents the fact that, as consumption increases, so does utility, albeit at increasingly lower rates.

Maximizing the household intertemporal discounted utility function will result in the following optimal labor supply and Euler equation

$$\frac{W_t}{P_t} = \frac{W_{F,t}}{P_t} = \frac{W_{A,t}}{P_t} = -\frac{U_{N,t}}{U_{C,t}} = N_t^{\varphi} C_t^{\sigma} \tag{4}$$

$$\frac{1}{C_t^{\sigma}} = \beta E_t \left(\frac{P_t}{P_{t+1}} (1 + i_t) \frac{1}{C_{t+1}^{\sigma}} \right) \tag{5}$$

The consumption bundle aggregator for the goods from the free and administered sectors is given by:

$$C_t = [\delta^{\frac{1}{\psi}} C_{F,t}^{\frac{\psi-1}{\psi}} + (1-\delta)^{\frac{1}{\psi}} C_{A,t}^{\frac{\psi-1}{\psi}}]^{\frac{\psi}{\psi-1}} \tag{6}$$

Where $C_{F,t}$ and $C_{A,t}$ are the consumption bundles from free and administered sectors and $P_{F,t}$ $P_{A,t}$ are their prices, respectively. The ψ is the elasticity of substitution between free and administered goods and δ defines the share of free good in the total bundle.

We also have:

$$P_{F,t} C_{F,t} + P_{A,t} C_{A,t} \leq C_t P_t \tag{7}$$

When $P_{F,t} C_{F,t} + P_{A,t} C_{A,t} = C_t P_t$, we find the demand for the goods of each sector as:

$$C_{F,t} = \left(\frac{P_{F,t}}{P_t} \right)^{-\psi} C_t \delta \tag{8}$$

$$C_{A,t} = \left(\frac{P_{A,t}}{P_t} \right)^{-\psi} C_t (1-\delta) \tag{9}$$

When substituting (8) and (9) in (6), we find the price index for period t

$$P_t = [\delta (P_{F,t})^{1-\psi} + (1-\delta)(P_{A,t})^{1-\psi}]^{\frac{1}{1-\psi}} \tag{10}$$

0.2.2 Firms

There are two types of firms. The first one produces the free goods and the second type produces the administered goods, it is assumed there is a unitary mass continuum of firms in both types.

Each sector is thus divided into two parts: an intermediate goods sector (wholesale firms) and a final goods sector (retail firms). The intermediate goods sector consists of a large number of companies, each one producing differentiable goods. In the final goods sector, there is a single firm that aggregates intermediate goods into one single good that will be consumed by economic agents.

Firms will use labor and technology to produce differentiated goods accordingly to the functions

$$Y_{z,F,t} = A_{F,t} N_{z,F,t}^{1-\alpha_F} \tag{11}$$

$$Y_{F,t} = A_{F,t} N_{F,t}^{1-\alpha_F} \tag{12}$$

$$Y_{z,A,t} = A_{A,t} N_{z,A,t}^{1-\alpha_A} \tag{13}$$

$$Y_{A,t} = A_{A,t} N_{A,t}^{1-\alpha_A} \tag{14}$$

Where $A_{F,t}$ and $A_{A,t}$ are exogenous process for technology levels in each sector, that we will assume to be stationary, and $0 < (\alpha_F, \alpha_A) < 1$.

As per the market clearing condition, where $Y_t = C_t$, the demand for each firm of the free sector and administered sector, the firms demand of each sector and the aggregate production are set at

$$Y_{z,F,t} = \left(\frac{P_{z,F,t}}{P_{F,t}}\right)^{-\epsilon_F} Y_{F,t} \tag{15}$$

$$Y_{F,t} = \left[\int_0^1 Y_{z,F,t}{}^{\frac{\epsilon_F - 1}{\epsilon_F}} dz\right]^{\frac{\epsilon_F}{\epsilon_F - 1}} \tag{16}$$

$$Y_{F,t} = \left(\frac{P_{F,t}}{P_t}\right)^{-\psi} Y_t \delta \tag{17}$$

$$Y_{z,A,t} = \left(\frac{P_{z,A,t}}{P_{A,t}}\right)^{-\epsilon_A} Y_{A,t} \tag{18}$$

$$Y_{A,t} = \left[\int_0^1 Y_{z,A,t}{}^{\frac{\epsilon_A - 1}{\epsilon_A}} dz\right]^{\frac{\epsilon_A}{\epsilon_A - 1}} \tag{19}$$

$$Y_{A,t} = \left(\frac{P_{A,t}}{P_t}\right)^{-\psi} Y_t(1-\delta) \tag{20}$$

$$Y_t = [\delta^{\frac{1}{\psi}} Y_{F,t}^{\frac{\psi-1}{\psi}} + (1-\delta)^{\frac{1}{\psi}} Y_{A,t}^{\frac{\psi-1}{\psi}}]^{\frac{\psi}{\psi-1}} \tag{21}$$

The Free Sector Firms

The retail firm solves its problem in two stages. First, the firm takes the prices of the factors of production (wages) and determines the amount of labor that it will use to minimize its total production cost:

$$\min_{L_{j,F,t}} W_t L_{j,F,t} \quad s.t. \quad Y_{j,F,t} = A_{j,F,t} N_{j,F,t}^{1-\alpha_F} \tag{22}$$

Taking first-order condition for the previous problem we get demand of a wholesale firm j for labor.

$$N_{j,F,t} = (1-\alpha_F) MC_{j,F,t} \frac{Y_{F,t}}{W_t} \tag{23}$$

Where $MC_{j,F,t}$ is the marginal cost of firm j. Since firms of free sector have same production function and costs $MC_{j,f,t} = MC_{F,t}$.

$$MC_{F,t} = \frac{1}{A_{F,t}} \left(\frac{W_t}{(1-\alpha_F)}\right)^{(1-\alpha_F)} \tag{24}$$

In the free sector firms will follow a Calvo pricing mechanism, in which firms will optimally readjust their price with a probability $(1-\theta_F)$ to $P_{z,F,t} = P^*_{z,F,t}$, while with a probability θ_F, firms will readjust their price accordingly to the rule

$$P_{j,F,t} = P_{j,F,t-1} \tag{25}$$

Where $\pi_t = \frac{P_t}{P_(t-1)}$. For the optimizing firms, when adjusting its price, firms will seek to maximize the expected profit, since they do not know when they will adjust their prices again, so this problem becomes:

$$\max_{P^*_{j,F,t}} \quad E_t \sum_{i=0}^{\infty} (\beta\theta_F)^i (P^*_{j,F,t} Y_{j,F,t} - Y_{j,F,t} CM_{j,F,t}) \tag{26}$$

Substituting equation (14) in equation (25),

$$\max_{P^*_{j,F,t}} \quad E_t \sum_{i=0}^{\infty} (\beta\theta_F)^i \left(P^*_{j,F,t} \left(\frac{P_{j,F,t}}{P_{j,t}} \right)^{-\epsilon_F} Y_{F,t} - \left(\frac{P_{j,F,t}}{P_{F,t}} \right)^{-\epsilon_F} Y_{F,t} CM_{j,F,t} \right) \tag{27}$$

By the first order condition,

$$P^*_{j,F,t} = \left(\frac{\epsilon_F}{\epsilon_F - 1} \right) E_t \sum_{i=0}^{\infty} (\beta\theta_F)^i CM_{j,F,t} \tag{28}$$

Free sector prices will evolve according to

$$P_{F,t} = [\theta_F (P_{F,t-1})^{1-\epsilon_F} + (1-\theta_F)(P^*_{z,F,t})^{1-\epsilon_F}]^{\frac{1}{1-\epsilon_F}} \tag{29}$$

The Administered Price Sector Firm

For the firms in the administered sector, in each period t, a fraction $(1-\theta_A)$ of firms are allowed to set their prices to $\Upsilon_{A,t} P_{A,t-1}$ according to a pre-specified rule. The remaining fraction θ_A of firms that were not drawn by the rule simply maintain their prices equal the last period.

Taking this into account, $\Upsilon_{A,t}$ is defined:

$$\Upsilon_{A,t} = \left(\frac{MC_{A,t}}{MC_{A,t-1}} \right)^{(1-\chi_A)} \left[\left(\frac{P_t}{P_{t-1}} \right)^{-v_A} \right]^{(\chi_A)} Z_{A,t} \tag{30}$$

Where $MC_{A,t}$ is the marginal cost of the administered goods sector, v^1_A is a positive weight, and P_t/P_{t-1} is the relative total price, raised to the exponent (χ_A), which ensures that freely-set and administered prices do not diverge permanently. The term $Z_{A,t}$ is an AR(1) process that captures shifts in the administered prices that are not modeled explicitly.

Since all administered price firms always update their prices randomly and the rule above depends only upon aggregate variables, we can define the overall administered price index as follows:

$$P_{A,t} = [\theta_A (P_{A,t-1})^{1-\epsilon_A} + (1-\theta_A)(\Upsilon_{A,t} P_{A,t-1})^{1-\epsilon_A}]^{\frac{1}{1-\epsilon_A}} \tag{31}$$

0.2.3 Aggregate Inflation

We take the equation $P_t = [\delta(P_{F,t})^{1-\psi} + (1-\delta)(P_{A,t})^{1-\psi}]^{\frac{1}{1-\psi}}$, divided by P_{t-1}, and after some algebra, we have the aggregate inflation equation:

$$\pi_t = [\delta(\pi_{F,t}\frac{P_{F,t-1}}{P_{t-1}})^{1-\psi} + (1-\delta)(\pi_{A,t}\frac{P_{A,t-1}}{P_{t-1}})^{1-\psi}]^{\frac{1}{1-\psi}} \tag{32}$$

0.2.4 Technological shock

The processes of motion of productivities are assumed to follow a first-order autoregressive process, such that:

$$A_{F,t} = \rho_F A_{F,t-1} + \omega_{F,t} \tag{33}$$

$$A_{A,t} = \rho_A A_{A,t-1} + \omega_{A,t} \tag{34}$$

where ρ_F and ρ_F are the autoregressive parameters of productivity, whose absolute value s must be less than one ($\rho_F \leq 1$ and $\rho_F \leq 1$) to ensure the stationary nature of the process, $\omega_{F,t} \sim N(0, \sigma_F)$ and $\omega_{A,t} \sim N(0, \sigma_A)$.

0.2.5 Monetary Policy

The monetary authority sets a Taylor rule to reflect inflation targeting policy and the desire not to deviate from the potential output:

$$\left(\frac{1+i_t}{1+i_{ss}}\right) = \left(\frac{1+i_{t-1}}{1+i_{ss}}\right)^{\phi_i} \left(\frac{\pi_t}{\pi_{ss}}\right)^{\phi_\pi} \left(\frac{Y_t}{Y_n}\right)^{\phi_Y} \exp v_t \tag{35}$$

Where i_t is the nominal interest rate, i_{ss} is the interest rate in staedy state (neutral interest rate),ϕ_i, ϕ_π and ϕ_y are non-negative Taylor's rule coefficients, chosen by the monetary authority, regarding the deviations from the neutral interest rate, inflation target and potential output, respectively.

The policy description assumes that the monetary authority moves the level of interest rate partially toward its target. That is, the predicted interest rate is the intermediate target given by the Taylor rule, adjusted by a portion of the last period's interest rate. In other words, this estimate suggests that after each period, the level of adjustment contains an inertial component, which reflects that the monetary authority prefers to soften the effect of monetary policy on the interest rate.

0.3 Welfare evaluation

Following Rotemberg and Woodford (1999), we adopted a welfare-based criterion, relying on a second-order approximation to the utility losses experienced by the representative consumer as a consequence of deviations from the efficient allocation, in order to assess the performance different policy rules under administered prices.

We take the equation (2) and substitute current consumption and labor for their deviations from their steady state values, thus we get:

$$U(\tilde{C}_t, \tilde{N}_t) = \frac{\tilde{C_t}^{1-\sigma}}{1-\sigma} - \frac{\tilde{N_t}^{1+\varphi}}{1+\varphi} \tag{36}$$

Where $\tilde{C}_t = logC - logC_{ss}$ and $\tilde{N}_t = logN - logN_{ss}$[1].

We will use the second order approximation of relative deviation in consumption from its steady state counterpart and the same kind of second order approximation is performed on labor N_t, so that:

$$U(\tilde{C}_t, \tilde{N}_t) = \frac{C_{ss}^{1-\sigma}}{1-\sigma} - \frac{N_{ss}^{1+\varphi}}{1+\varphi} + C_{ss}^{1-\sigma}\tilde{C}_t - N_{ss}^{1+\varphi}\tilde{N}_t + \frac{1-\sigma}{2}C_{ss}^{1-\sigma}\tilde{C}_t^2 - \frac{1+\varphi}{2}N_{ss}^{1+\varphi}\tilde{N}_t^2 \tag{37}$$

We maximize the unconditional expectation of lifetime utility of households over the parameters of the Taylor rule.

$$\begin{aligned} E[U(\tilde{C}_t, \tilde{N}_t)] = \frac{C_{ss}^{1-\sigma}}{1-\sigma} - \frac{N_{ss}^{1+\varphi}}{1+\varphi} + C_{ss}^{1-\sigma}E[\tilde{C}_t] - N_{ss}^{1+\varphi}E[\tilde{N}_t] + \frac{1-\sigma}{2}C_{ss}^{1-\sigma}E[\tilde{C}_t^2] \\ -\frac{1+\varphi}{2}N_{ss}^{1+\varphi}E[\tilde{N}_t^2] \end{aligned} \tag{38}$$

The equation above will be useful to evaluate the better monetary authority response to shocks in the economy.

[1] More detailed explanation of log linearization in the appendix

0.4 Calibrated Parameters

We calibrate the structural parameters of the model to values similar to those found in the literature. The baseline model is calibrated at a quarterly frequency. The subjective discount factor, β, is set to 0.985, which implies that the annual nominal interest rate is equal to 8 percent in the deterministic steady state. The intertemporal elasticity of substitution, σ^2, and the Frisch elasticity of labor supply, φ, are set to 0.5 and 1.5, respectively. The elasticity of substitution between free and administered goods, ϵ, is set to 0.5 These values have become quite standard in the literature.

Capital shares in production of the free sector, α_F, is set to 0.15, while the administered sector, α_A, is chosen to be 0.3, according to National Account Statistics (IBGE).The parameter θ_F, the probability that firms in free sector will not readjust their price, is set to 0,64, as suggested in SAMBA, while θ_A, the probability of maintain administered prices equal the last period, is set to 0,75, since, in practice, administered prices are usually allowed to change once a year.

The relation of all parameters and their calibrated values are shown in the table below:

Table 1 – Calibrated parameters

Parameter	Calibrated	Source
β	0.985	Historic data on real interest rate
σ	2	Araujo and Issler(2004)
φ	1.5	Fernandes et al(2004)
δ	changing	
ψ	0.5	
α_A	0.3	National Account Statistics, IBGE
α_F	0.15	National Account Statistics, IBGE
ϵ_A	4	
ϵ_F	11	Parrado (2004) and Gironni e Rebucci (2001)
θ_A	0.75	Adjusted once a year
θ_F	0.64	SAMBA
υ_A	0.2	SAMBA
χ_A	0.8	SAMBA
ρ_A	0.8	Freitas and Bugarin
ρ_F	0.7	Freitas and Bugarin
ρ_Z	0.8	Freitas and Bugarin
$\phi_p i$	changing	
ϕ_y	changing	

0.5 Simulation and Results

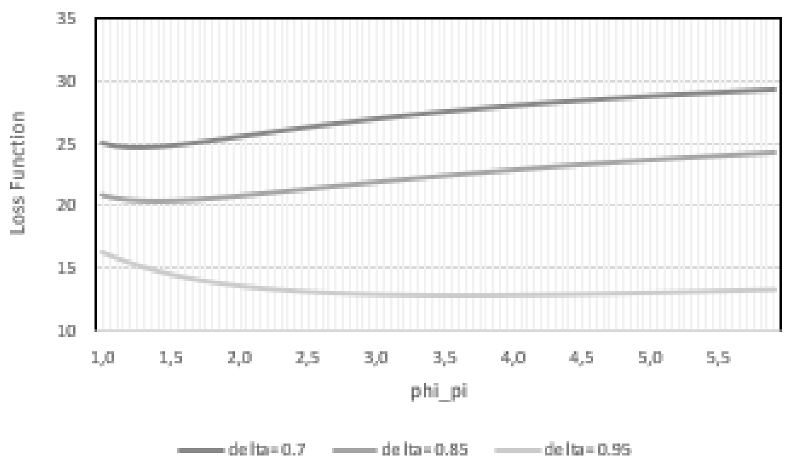
This section presents the main results obtained from our simulation. First, we analyze the impulse responses of selected variables to productivity shocks in both free and administered sectors, also in terms of their percentage deviation from the respective steady state values. Secondly, we compare results, by welfare losses criterion, of different levels of administered prices in the consumption bundle after the shock.

The results of a positive productivity shock in both sectors on the model cause the value of the marginal products of labor to rise. Consequently, firms increased their demand for input (labor). The prices of this input thus responded positively to this greater level of demand. Bearing in mind that higher wages increase the income of households, if, on the one hand, this higher level of income increases the acquisition of goods (C), on the other, it increases the demand for another "good", leisure (income effect), as explained in Gali (2008). In short, higher productivity increased the spending variables (consumption) and input prices (wage).

With the productivity shock, the marginal cost of the two sectors falls. The price of free goods decays and leads the inflation of the sector to the negative field, while, in order to counterbalance this decline, the adjustment in the price of administered goods rises, avoiding much variability in the general index, raising the inflation of this sector. In this case, we can infer the monetary policy effect of decreasing the nominal interest rate in order to partially off-set the deflationary pressure.

The main result lies in the welfare evaluation when three different levels of administered goods are analysed within the consumption bundle. In the chart below, we see the welfare variation of each of the three levels in the size of the administered sector, 30%, 15% and 5%, regarding the variation of the coefficient of inflation deviation in Taylor's rule.

Figure 2 – Taylor rule reaction to inflation deviation under technological shock



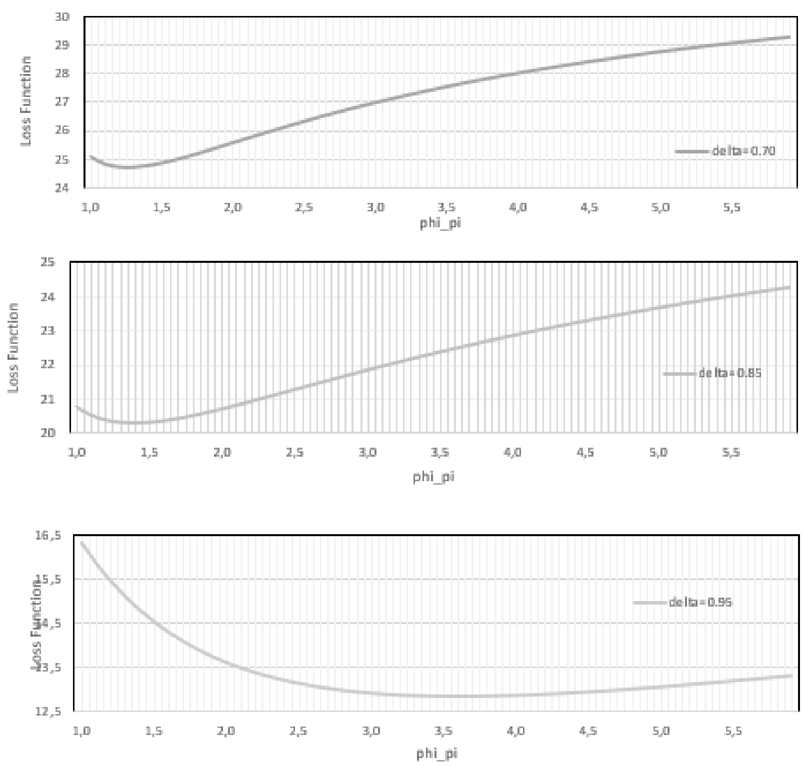
After joint analysis, we separate each line in a graph to observe the behavior of each of them along the change of values of the coefficient of inflation.

When the participation of the administered goods in the total bundle is very small, 5%, there is a more abrupt response of interest rate to the inflation deviation, and there is a smaller welfare loss. In other words, the monetary authority should not be tolerable with the deviation of inflation from its target.

However, when the share of administered goods in the total bundle raises to 15% or 30%, and considering the monetary authority is concerned about the consumer welfare, the best strategy is to stop being completely intolerant with inflation deviations from its steady state value.

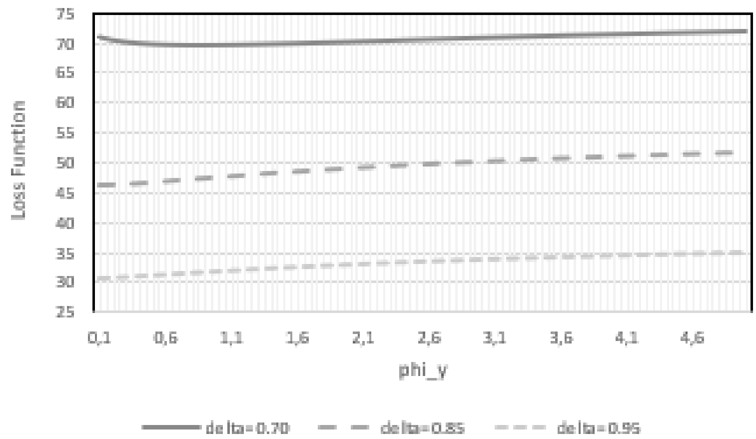
The intuition for such an outcome may lie in the fact that the government reacts through the rule of administered prices, in which a component of the rule seeks to soften large fluctuations of total prices through the term $\left[\left(\frac{P_t}{P_{t-1}}\right)^{-\upsilon_A}\right]^{\chi_A}$. Thus, the larger the managed goods sector is, the greater the softening of any abrupt movement will be in response to the deviation of inflation from its target, contradicting the strong monetary policy response through high interest rates.

Figure 3 – Taylor rule reaction to inflation deviation under technological shock (2)



Repeating the exercise, but now changing the values of the coefficient of output gap in the taylor's rule, we find a similar result, although, in this case, in none of the three scenarios is the monetary authority's best strategy to be completely intolerant with deviation of the output from its potential.

Figure 4 – Taylor rule reaction to inflation deviation under technological shock

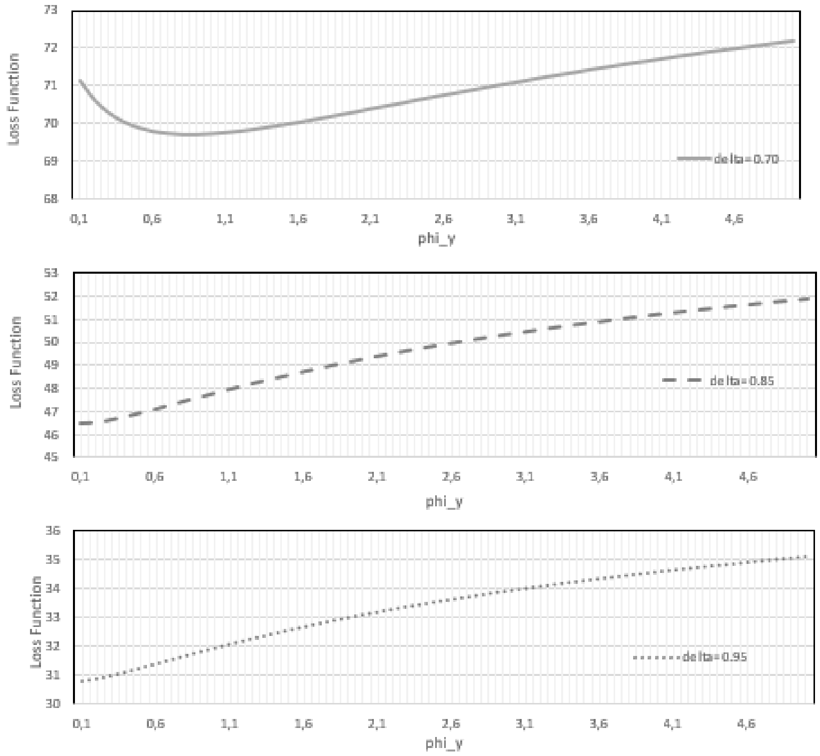


Analyzing separately, we can observe that, when levels of administered goods are low in the composition of the bundle of consumption (larger delta), the central bank should react less to the deviation of the product of its potential, whilst when the share of administered goods increases (delta lower), the optimal output's coefficient increases its value.

It is interesting to note this behavior, as it is commonly found in literature considering only one sector of goods produced in the economy, the monetary authority should, by optimality, respond more radically to the deviations of production and inflation. In these two cases discussed above, there is an optimal intermediate response to these deviations when the participation of the administered goods sector is larger.

Again, the economic intuition behind this behavior lies in the fact that the productivity shock increases the potential output and, as a consequence, increases the real output deviation from its potential. The reaction of monetary policy is to cut the interest rate and lead to a higher production, but, to suppress the movement of the price fall that occurs, the government increases the price of the administered goods and, as a consequence, reduces its demand.

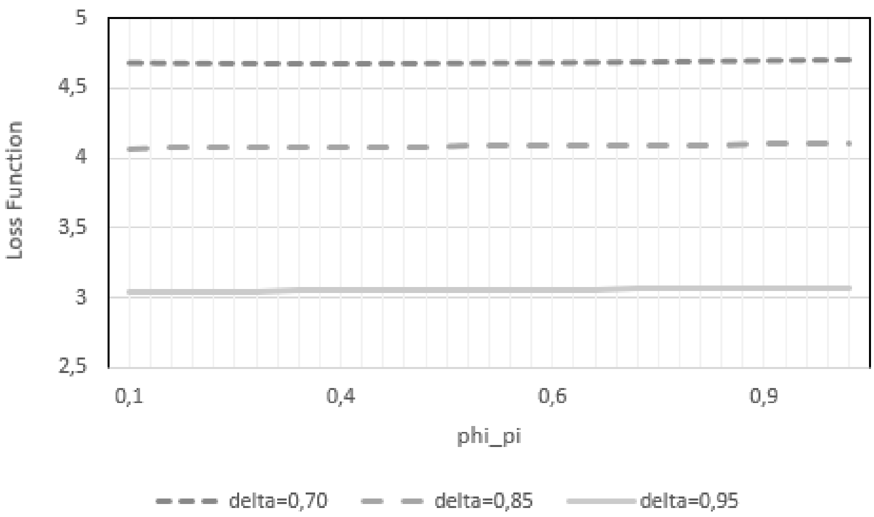
Figure 5 – Taylor rule reaction to inflation deviation under technological shock (2)



As we have seen above, the results are sensitive to the size of the productive sectors (proportion of administered goods in the consumption bundle), and also to the definition of the rule of adjustment of administered prices. In this paper, we focused in a subjective rule described in equation (30). Maintaining the same rule, we can adjust the coefficient χ_A in order to minimize the welfare losses of the economy after a technological shock.

We can interpret the parameter χ_A as the government's degree of commitment to readjust administered prices to minimize inflation, while $(1 - \chi_A)$ means the government's readjustment of the price of goods in response to changes in the sector's marginal production costs. In the case ofχ_A equals to zero, then the sector would readjust competitively, taking into account only the variation in the costs of production.

Figure 6 – Administered rule's parameter impact in welfare loss



Fixing the size of administered goods sector, we find the optimal value of the coefficient χ_A.

As discussed in the introduction of this paper, in consumption bundle's composition there are some goods that have their prices administered or regulated by the government for some reasons we also saw in the introduction. Besides that, the withdrawal of these goods from the inflation index to estimate the optimal monetary policy would cause problems (such as perception of credibility and transparency of monetary authority and also related to the relative weight of the excluded items from the index within the representative consumption bundle).

Once these goods (from which prices are readjusted differently in relation to the other prices of the economy) are kept in the inflation index, then the choice of χ_A becomes relevant.

To the level of only 5% administered goods in the consumer's bundle, then the best thing for the government is to adopt a small value of χ_A, that is, let the price of the goods adjust according to the variation of marginal costs of production. Whereas, when the quantity of administered goods increases to 30%, then the government should choose a larger χ_A.

Figure 7 – Administered rule's parameter impact in welfare loss, $\delta = 0.95$

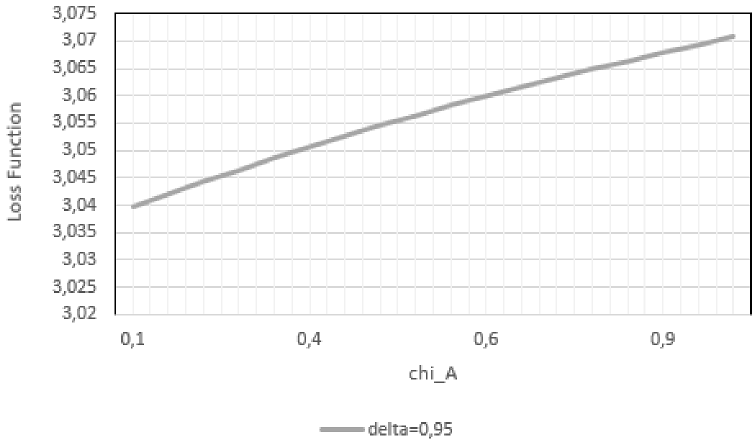
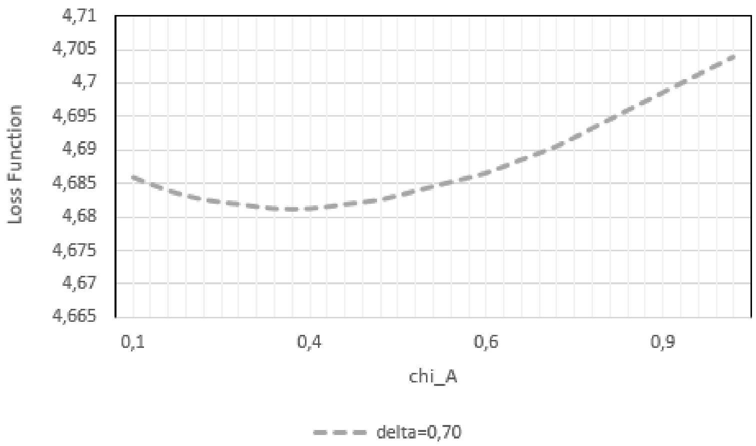


Figure 8 – Administered rule's parameter impact in welfare loss, $\delta = 0.80$



0.5.1 Conclusion

We analyze welfare-improving monetary policy reaction functions in the context of a New Keynesian economy model with administered and a free goods sectors, where both exhibits sticky prices. The model is used to evaluate the welfare gains of alternative specifications of the Taylor's rules coefficients by different levels of administered goods sector.

We find that welfare losses respond more aggressively to the coefficients of Taylor's rule when delta is lower. The right monetary policy is intimately dependent on the relative participation of administered goods in the consumption bundle (sector that has its price adjustment previously ruled by the monetary authority as it has previously been established in this paper).

The main contribution here was to show that, with the endogenization of a different rule for the establishment of the goods' prices of the economy, the best response of the monetary authority is no longer to react in the most rigid way to any deviation of the output from its potential or the inflation of its target. The result is corroborated when productivity shocks in the sectors are given separately, as well as a monetary policy shock.

0.6 References

Ben Aïssa, Mohamed Safouane and Rebei, Nooman. 2012. Price subsidies and the conduct of monetary policy. Journal of Macroeconomics, Elsevier, vol. 34(3), pages 769-787.

BIS (2009). Some issues in measuring and tracking prices in emerging market economies. [online] Bank for International Settlements. Available at:

https://www.bis.org/publ/bppdf/bispap49.pdf [Accessed 14 Apr. 2019].

Blanchard, Olivier Jean and Kiyotaki, Nobuhiro. 1987. Monopolistic Competition and the Effects of Aggregate Demand. The American Economic Review. 1987, Vols. Vol. 77, No. 4.

Calvo, Guillermo A. 1983. Staggered Prices In a Utility-Maximizing Framework. Journal of Monetary Economics. 1983, Elsevier Science Publishers B.V.

Castro, Marcos R. de, et al. 2011. SAMBA: Stochastic Analytical Model with a Bayesian Approach. Brasília : Banco Central do Brasil, 2011.

Ferreira, T. and Petrassi, M. 2002. Regime de metas para a inflação: resenha sobre a experiência internacional. Notas Técnicas do Banco Central do Brasil, 30.

Freitas, Paulo Springer de and Bugarin, Mirta Noemi Sataka. 2006. A Study On Administered Prices And Optimal Monetary Policy: The Brazilian Case. LAMES - Theoretical and Applied Economics. Mexico City : s.n., 2006.

Galí, Jordi. 2008. Monetary policy, inflation, and the business cycle : an introduction to the New Keynesian framework. New Jersey : Princeton University Press, 2008. ISBN 978-0-691-13316-4.

Loyo, Eduardo and Vereda, Luciano. 2005. Can monetary policy be helped by domestic oil price stabilization?. No 502. Textos para discussão, Department of Economics PUC-Rio (Brazil).

Schmidt-Hebel, K. and Tapia, M. 2002. Monetary policy implementation and results in twenty inflation targeting countries. Working Paper Central Bank of Chile, 166.

Tovar, Camilo E. 2009. DSGE Models and Central Banks. Economics: The OpenAccess, Open-Assessment E-Journal. 2009, Vols. Vol. 3, 2009-16, Bank for International Settlements.

Vereda, Luciano and Cavalcanti, Marco A. F. H. 2010. Modelo Dinâmico Estocástico de Equilíbrio GeraL (DSGE) Para a Economia Brasileira: Versão 1. Texto para Discussão No 1479. Brasília : IPEA Instituto de Pesquisa Econômica Aplicada, 2010.

Woodford, Michael. 2003. Interest and Prices: Foundation of a Theory of Monetary Policy. Princeton, New Jersey : Princeton University Press, 2003. ISBN 0-691-01049-8.

0.7 Appendix

0.7.1 Table of Administered and regulated prices

Table 2 – Administered and regulated prices

Central Bank	**Categories**	**Weight in CPI**
Argentina	Fuels for housing (1.57%), electricity (1.60%), water and sewage services (0.55%), public transport (6.31%), vehicle maintenance (5.31%), postal services (0.08%), phone services (3.70%)	19.1%
Brazil	Housing (water, electricity, gas) (6.14%); Transportation (bus, subway, gasoline, ethanol, vehicle gas etc) (11.71%); Healthcare (medicines and health insurance) (6.21%); Communication (post and telephone) (5.15%); Other (0.40%)	29.62%
Chile	Electric power (1.6%); water distribution (1.1%); telecommunications (2.3%); public transport (3.0%); and certain local taxes (2.7%)	10%
Columbia	Natural gas (home use) 0.6%; electric energy 1.46%; water, sewage and garbage collection 1.29%; urban public transportation 3.81%; intermunicipal transportation 0.78%; fuel (gasoline, diesel) 1.08%	9.04%

EU		13.9%
Japan	Electricity and gas(4.13%); Water and sewerage charges (1.62%); Transportation services (1.84%); Medical services (1.96%) Educational services (0.75%)	17.12%
Mexico	Administered prices are energy products (gasoline, electricity, propane and natural gas) set by the federal government (7.77%); Regulated prices by different government levels: goods and services such as public transportation, telephone service, property taxes, road fees, parking fees, passports and licenses (9.39%)	17.17%
Peru	Electricity (2.2%); telephone services (1.3%); water services (1.0%)	4.5%
South Africa	Housing (3.57%); Fuel and power (3.21%); Medical care (0.09%); Communication (2.90%); Education (2,70%); Transport (5,21 %); Recreation and entertainment (0,21%);	17.89%

United Kingdom	Electricity and gas(4%); Water and sewerage charges (1.2%); Transportation services (2.4%); Medical services (0.2%) Educational services (0%)	8%
United States	Electricity and gas(3.59%); Water and sewerage charges (0.87%); Transportation services (1.14%); Medical services (7.34%) Educational services (2.99%)	19.61%

Source: BIS 2009, Monetary policy and the measurement of inflation: prices, wages and expectations; Ministry of Internal Affairs and Communications of Japan; BLS; Eurostat.

0.7.2 The Steady State

After defining the economy's equilibrium, the steady state values be defined. An endogenous variable X_t is at the steady state in each t, if $E_t X_{t+1} = X_t = X_{t-1} = X_{ss}$. The steady state is the point of origin of the simulations that will be performed and the point of reference for log-linearization.

Household

$$C_{ss}^{\sigma} N_{ss}^{\varphi} = \frac{W_{ss}}{P_{ss}} \tag{39}$$

$$\beta = \frac{1}{1 + i_{ss}} \tag{40}$$

$$N_{ss} = N_{F,ss} + N_{A,ss} \tag{41}$$

Firms

$$N_{F,ss} = (1 - \alpha_F) MC_{F,ss} \frac{Y_{F,ss}}{W_{ss}} \tag{42}$$

$$N_{A,ss} = (1 - \alpha_A) MC_{A,ss} \frac{Y_{A,ss}}{W_{ss}} \tag{43}$$

$$MC_{F,ss} = \frac{1}{A_{F,ss}} \left(\frac{W_{ss}}{1-\alpha_F} \right)^{1-\alpha_F} \tag{44}$$

$$MC_{A,ss} = \frac{1}{A_{A,ss}} \left(\frac{W_{ss}}{1-\alpha_A} \right)^{1-\alpha_A} \tag{45}$$

$$Y_{F,ss} = A_{F,ss} N_{F,ss}^{1-\alpha_F} \tag{46}$$

$$Y_{A,ss} = A_{A,ss} N_{A,ss}^{1-\alpha_A} \tag{47}$$

$$P_{F,ss} = \left(\frac{\epsilon_F}{(\epsilon_F - 1)} \right) \left(\frac{1}{(1-\beta\theta_F)} \right) MC_{F,ss} \tag{48}$$

$$\Upsilon_{A,ss} = Z_{ss} \tag{49}$$

Equilibrium condition

$$Y_{F,ss} = C_{F,ss} \tag{50}$$

$$Y_{A,ss} = C_{A,ss} \tag{51}$$

$$Y_{ss} = C_{ss} \tag{52}$$

$$Y_{ss} = [\delta^{\frac{1}{\psi}} Y_{F,ss}^{\frac{\psi-1}{\psi}} + (1-\delta)^{\frac{1}{\psi}} Y_{A,ss}^{\frac{\psi-1}{\psi}}]^{\frac{\psi}{\psi-1}} \tag{53}$$

$$P_{ss} = [\delta(P_{F,ss}) + (1-\delta)(P_{A,ss})]^{\frac{1}{1-\psi}} \tag{54}$$

0.7.3 Log-linearization (Uhlig's method)

As linear models are often easier to solve, we will log-linearize the model around its steady state.We use Uhlig (1999) method of log-linearization of functions. It does not require differentiation: simply replacing a variable X_t with $X_{ss}e^{\tilde{X}_t}$, where $\tilde{X}_t = logX - logX_{ss}$

represents the log of the variable's deviation in relation to its steady state. Uhlig further proposes the following solution tools:

$$e^{\tilde{X}_t + a\tilde{Y}_t} \approx 1 + \tilde{X}_t + a\tilde{Y}_t \tag{55}$$

$$\tilde{X}_t \tilde{Y}_t \approx 0 \tag{56}$$

$$E_t[a\tilde{X}_{t+1}] \approx a + aE_t[\tilde{X}_{t+1}]\tilde{Y}_t \tag{57}$$

Household

$$\sigma\tilde{C}_t + \varphi\tilde{N}_t = \tilde{W}_t - \tilde{P}_t \tag{58}$$

$$\sigma E(\tilde{C}_{t+1} - \tilde{C}_t) = E((1 + \tilde{i}_{t+1}) + \tilde{P}_t - \tilde{P}_{t+1}) \tag{59}$$

Firms

$$\tilde{W}_t = \tilde{Y}_{F,t} - \tilde{N}_{F,t} \tag{60}$$

$$\tilde{W}_t = \tilde{Y}_{A,t} - \tilde{N}_{A,t} \tag{61}$$

$$\tilde{Y}_{F,t} = \tilde{A}_{F,t} - \tilde{N}_{F,t}(1 - \alpha_F) \tag{62}$$

$$\tilde{Y}_{A,t} = \tilde{A}_{A,t} - \tilde{N}_{A,t}(1 - \alpha_A) \tag{63}$$

$$\tilde{MC}_{F,t} = \tilde{W}_t(1 - \alpha_F) - \tilde{A}_{F,t} \tag{64}$$

$$\tilde{MC}_{A,t} = \tilde{W}_t(1 - \alpha_A) - \tilde{A}_{A,t} \tag{65}$$

$$\tilde{P^*}_{F,t} = (1 - \beta\theta_F)E\sum_{i=0}^{\infty}(\beta\theta)^i \tilde{MC}_{F,t+i} \tag{66}$$

$$\tilde{\Upsilon}_{A,t} = \chi_A(\tilde{MC}_{A,t-1} - \tilde{MC}_{A,t-5}) - (1-\chi_A)(\tilde{P}_{F,t-1} - \tilde{P}_{F,t-1}) + \tilde{Z}_{A,t} \tag{67}$$

Equilibrium condition

$$\tilde{Y_{F,t}} = \tilde{C_{F,t}} \tag{68}$$

$$\tilde{Y_{A,t}} = \tilde{C_{A,t}} \tag{69}$$

$$\tilde{Y_t} = \tilde{C_t} \tag{70}$$

$$\tilde{Y_t} = \delta^{\frac{1}{\psi}} \left(\frac{Y_{F,ss}}{Y_{ss}}\right)^{\frac{\psi-1}{\psi}} \tilde{Y}_{F,ss} + (1-\delta)^{\frac{1}{\psi}} \left(\frac{Y_{A,ss}}{Y_{ss}}\right)^{\frac{\psi-1}{\psi}} \tilde{Y}_{A,ss} \tag{71}$$

$$\tilde{\pi}_{F,t} = \beta E \tilde{\pi}_{F,t+1} + \frac{(1-\theta_F)(1-\beta\theta_F)}{\theta_F}(\tilde{MC}_{F,t} - \tilde{P}_{F,t}) \tag{72}$$

$$\tilde{\pi}_{A,t} = \tilde{\Upsilon}_{A,t} \tag{73}$$

$$\tilde{\pi_t} = \frac{\delta}{(1-\psi)}\tilde{\pi_{F,t}} + \frac{(1-\delta)}{(1-\psi)}\tilde{\pi_{A,t}} \tag{74}$$

0.7.4 Impulse Response Graphs

Figure 9 – Impulse response in the model of an technological shock with 0.3 administered share

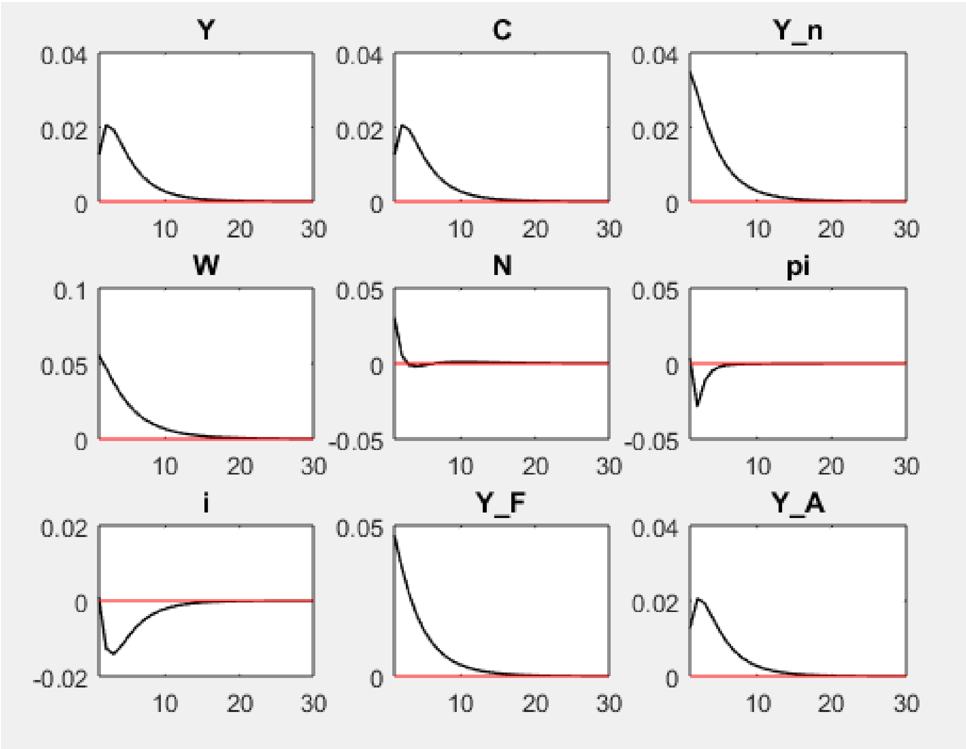


Figure 10 – Impulse response in the model of an technological shock with 0.3 administered share (2)

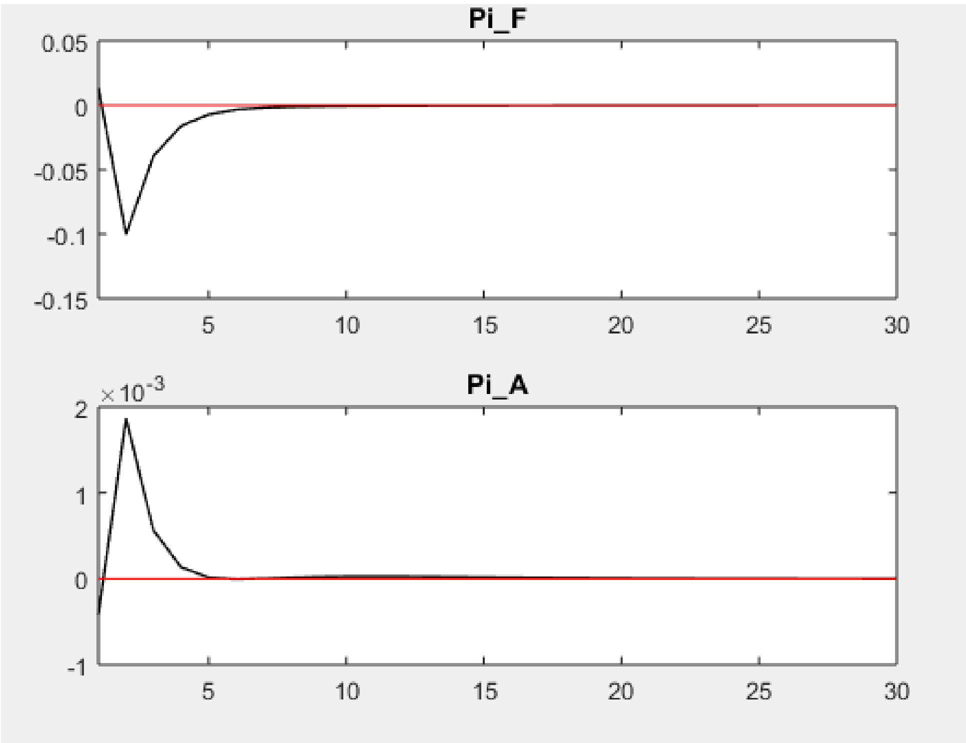


Figure 11 – Impulse response in the model of an monetary shock with 0.3 administered share

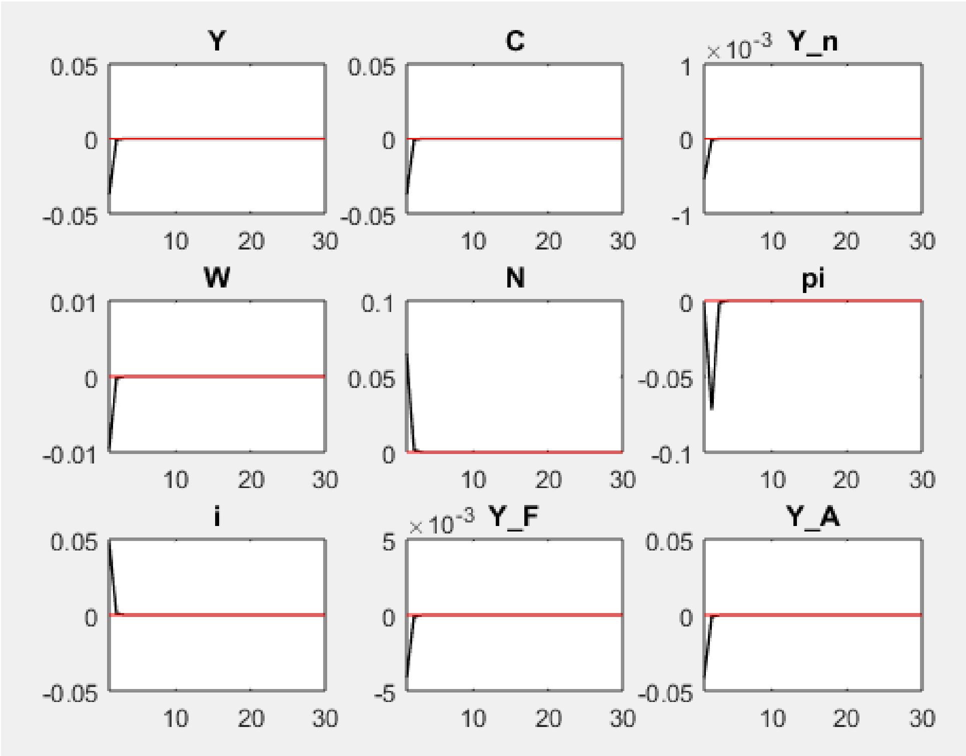


Figure 12 – Impulse response in the model of an monetary shock with 0.3 administered share (2)

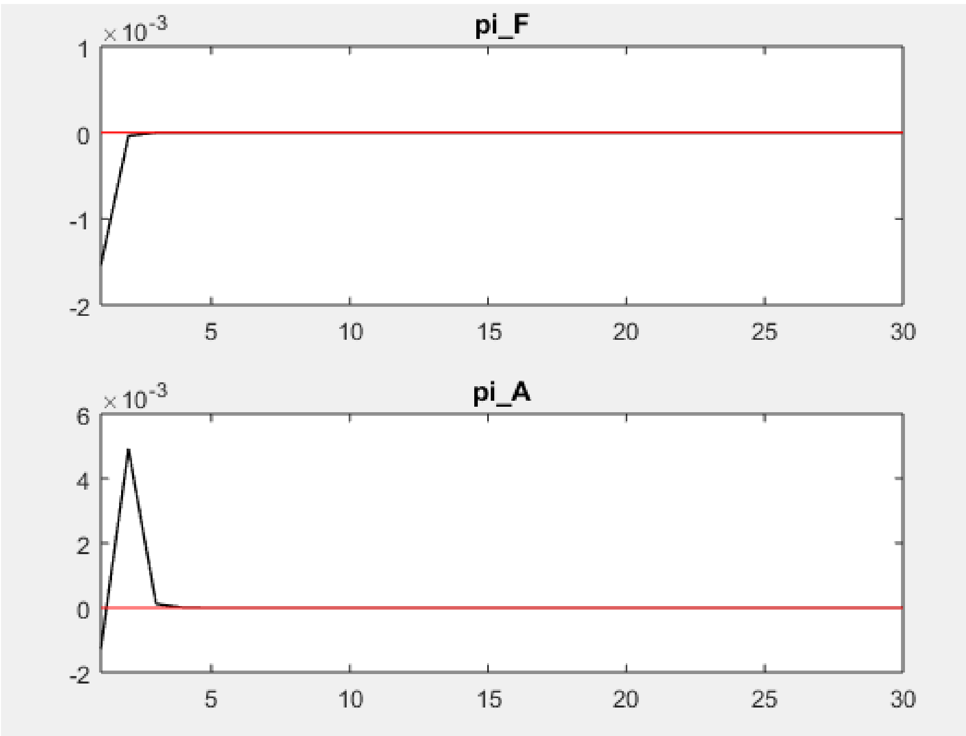


Figure 13 – Impulse response in the model of an administered price shock with 0.3 administered share

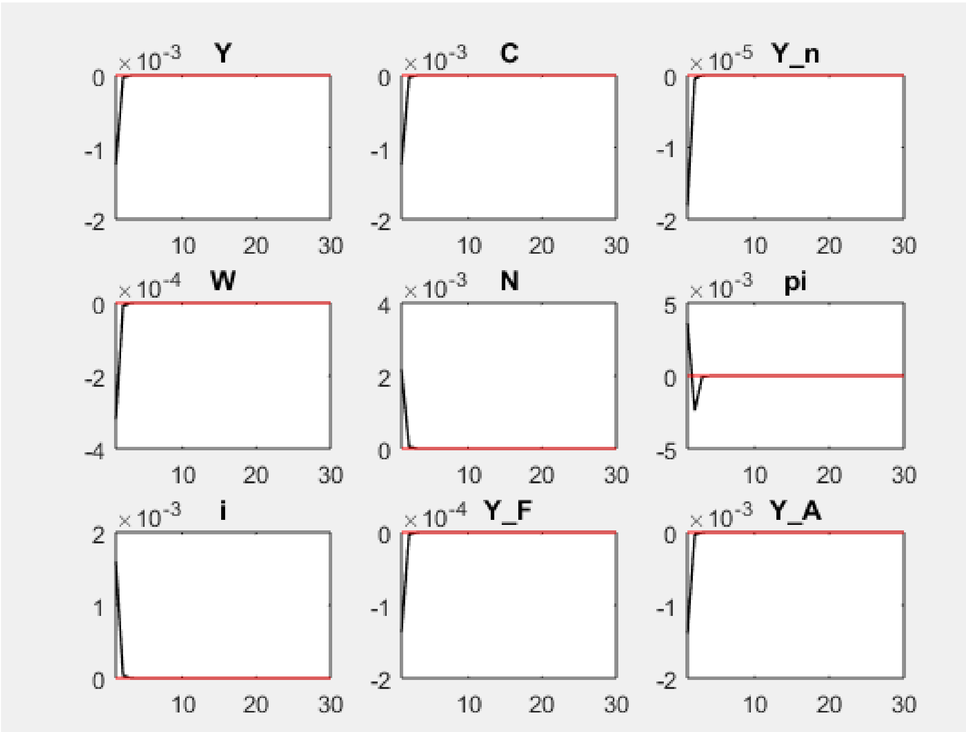


Figure 14 – Impulse response in the model of an administered price shock with 0.3 administered share (2)