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ABSTRACT

In order to model the inflation dynamics, we investigated various combinations of nominal rigidities. For this purpose, we analyze two adjustment-of-prices hypotheses as in the new Keynesian literature, namely the price stickiness and the sticky information, within a Dynamic Stochastic General Equilibrium (DSGE) model. For each model, we compare the responses of inflation and output to shocks. We found that sticky information modeling correctly reproduces some important stylized facts after monetary shocks, but with hump-shaped responses. The sticky price model, considering that some fixed prices lead to that Phillips curve, does not correctly reproduce the dynamic inflation response to monetary shocks. We show that single indexation does not add persistence to the two specifications, and the choice of rigidity structure appears to be more important than the presence or absence of lagged values of inflation in the dynamics.

Keywords. DSGE model; Phillips curve; Sticky information; Sticky prices; Inflation

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Journal of Economic Literature (JEL) Classification. *C11, E31, E32, E40.*

1. **INTRODUCTION**

Many researches addressing the impact of monetary policy apply a reduced set of equations of an optimizing behavior by private agents. The non-neutrality of money is explained by the existence of nominal rigidities, which prevents companies from continuously adjusting their prices according to economic conditions. Fischer (1977) assumes that the nominal rigidity comes from a presetting price. The prices are predetermined for the period t to $t + i$, when their trajectory during this period is fixed at time *t* (Blanchard and Fischer 1989); this assumption appears to be unsatisfactory. Taylor (1980) and Calvo (1983) use another form of the price rigidity by supposing that prices are predetermined and constant. Roberts (1995) shows that the fixed price approaches of Taylor (1980) and Calvo (1983) generate the same relationship between inflation and the product. This relationship is known as the New Keynesian Phillips curve (hereafter NKPC) (Clarida et al. 1999). The main characteristic of the NKPC is to represent a future-oriented phenomenon (forward-looking) on prices resulting from the dynamic optimizing behavior of firms. Ball (1994), Mankiw and Reis (2006, 2002) found that the forward-looking aspect excludes any persistent inflation and predicts that a credible disinflation policy has no cost towards the output. However, there are some contradictions; the first one is that a policy of disinflation leads to a recession (Romer and Romer 1989). The second one is that the response of inflation to a monetary shock is delayed and gradual (Mankiw 2001). Even though, the forward-looking of NKPC is widely used and some authors have tried to modify it by introducing delayed inflation to increase its persistence (Gali and Gertler 2007, Fuhrer and Moore 1995). For the same purpose, Kiley (2007), Mankiw and Reis (2006, 2002) replaced the assumption of price rigidity by the stiffness of the information phenomenon (backward-looking) using the Fischer (1977) hypothesis of predetermining prices.

The current literature on the impact of monetary policy uses various models of inflation dynamics by choosing the form of underlying price rigidity. Many papers have adopted a simple model with reduced equations to tackle a similar question and compare the sticky price with sticky information models for many developing countries. By compared the empirical performance of the sticky information of Phillips against the sticky-price NKPC, Gillitzer (2016) found that the sticky information Phillips curve generates excessive inertial inflation dynamics, and then can be rejected in favor of the NKPC. Using Structural VAR, Carrillo (2012) found that a model with sticky information is less successful than a standard model featuring nominal rigidities. Also, Carrillo (2012) stated that the sticky information model fails to replicate the observed inertial response in the real wage. Arslan (2008) compared the two models under cost-push shock and found that the sticky information model reproduces the underlying dynamics more reasonably. Keen (2007) explains the impact of monetary policy by using a variety of inflation dynamics models under many shapes of underlying price rigidity.

As Pereau (1998) have proposed that a systematic effort must be made to check whether the different assumptions of rigidity have the same implications in terms of reactions of inflation and product to monetary policies changes. To achieve this goal, we develop a Dynamic Stochastic General Equilibrium (DSGE) model in a closed economy with a common microeconomic framework, but with two dynamic equations of inflation and using two adjustment-of-prices assumptions. Otherwise, in the standard Calvo (1983) model, some prices are fixed for certain periods of time and its associated Phillips curve performs badly at reproducing the gradual and delayed effects of monetary shocks on inflation. Mankiw and Reis (2002) propose a sticky information model where the firms face some frictions when updating their information sets to determine the optimal flexible price. However, in the two cases, the frequency of price revision is supposed constant and without cost. We follow the papers of Gillitzer (2016), Kolasa (2009), Adjemian et al. (2007), Smets and Wouters (2007), Liu (2006), and Lubik and Schorfheide (2006) to make methodological contribution consisting of integrating both the real and nominal rigidities in the NKPC. By using two versions (Calvo and sticky information models) of a new Keynesian framework, we compare the inflation dynamics responses. Our empirical work consists of determining the responses of the output and inflation to specific shocks using quarterly data of the Tunisian economy and based on a Bayesian estimation.

Our model specification, focused on nominal and real rigidities, uses micro-economic foundations, habit formation, and allows to the central bank the policy-objectives of price stability and economic growth. Two classes of non-nested specifications can be used to achieve a plausible representation of the inflation dynamics. The reactions from the two models are compared with the stylized facts. The empirical work would be instructive, because a short-term macroeconomic model provides normative implications when the generated dynamics are consistent with certain real facts.

The findings show that different price rigidities generate inflation and output responses that are different from each other. As shown by Mankiw and Reis (2002), the Calvo model does not reproduce either of the two stylized facts about inflation and output dynamics, but the persistence of inflation is quite low. The apparent similarity of the two Phillips curves holds only for specific values of the duration of the price contracts. The model of Mankiw and Reis (2002) correctly reproduces the stylized facts. Also, we show that the sticky price models consistently and smoothly generate the dynamics of output and inflation to various shocks, except for the output responses to price markup and monetary policy shocks. However, the sticky information models integrate a delay factor, which might better reflect the inflation dynamic and persistence. Such models fairly reproduce the stylized facts of the impacts of monetary shocks. In addition, this approach results in a hump-shaped shift in the behaviors of the output and inflation to various shocks, except for the output reactions to price markup shock.

The outcomes are in line with the recent literature (Söderberg 2015, Caraiani 2013, Dupor et al. 2010, Paustian and Pytlarczyk 2006) indicating the importance of the sticky information modeling. However, the sticky price modeling still requires complex specifications. Otherwise, the specification based on the information rigidities hypothesis, with predetermined prices, correctly reproduces some important stylized facts after specific monetary shock. The selected rigidity of the structure, depending on the duration of price contracts, apprehends some inflationist aspects of the market and exhibits different reactions of the product. The two models are statistically equivalent after a monetary policy shock. However, these models are unable to reproduce a sufficient persistence of inflation. This shows that, indexation does not add persistence to the two specifications, and the choice of rigidity structure appears to be more important than the presence or absence of lagged values of inflation in the dynamics. The rest of the paper is structured as follows. Section 2 lays out firstly the common theoretical framework. Section 3 characterizes two prices setting as different nominal rigidities. In section 4, we show the empirical setup and discuss the empirical results. We conclude in section 5.

2. THEORETICAL FRAMEWORK

We consider that the economy is characterized by six categories of agents:

(i) a representative intermediary in the labor market;

(ii) a continuum of households indexed by i belonging to [0; 1];

(iii) a continuum of financial intermediaries indexed by s belonging to [0; 1];

(iv) a representative enterprise of final good;

(v) a continuum of intermediary enterprises indexed by j belonging to [0; 1], and

(vi) a political authority, including a central bank.

In addition, in order to improve the model's ability to reproduce empirical facts, we integrate into the model, real rigidities via consumption habits (Fuhrer, 2000) and capital adjustment costs. The nominal rigidities are integrated in the model with a Calvo mechanism (1983). Prices and wages are also indexed to past inflation. Using the seminal modeling develop by Christiano et al. (2005) and Smets and Wouters (2003), we introduced frictions about nominal rigidities by comparing Phillips curves of price stickiness, sticky information and explaining the responses to shocks of monetary policy, price markup and wage markup, in a dynamic and stochastic general equilibrium model for a small emerging country.

2.1 Households

The households supply specific types of labor for a wage and determine their consumption. They have access to financial markets and could participate to finance companies. At time *t,* any given household i maximizes the expected stochastic dynamic and conditional utility function:

$$\mathrm{U}_t(i) = \mathrm{E}_t \sum_{s=0}^{\infty} \beta^s \left[\frac{1}{1-\sigma_c} \left(C_{t+s}(i) - \gamma C_{t+s-1}(i) \right)^{1-\sigma_c} - \frac{\tilde{L}\left(L_{t+s}(i)\right)^{1+\sigma_L}}{1+\sigma_L} E_{t+s}^L \right] E_{t+s}^B \quad (1)$$

subject to the budget constraint:

$$\frac{B_{t-1}(i)}{P_t} + \frac{\left(1-\tau_{w,t}\right) W_t(i) L_t(i) + A_t(i) + T_t(i)}{P_t} + \Psi\left(K_{t-1}(i)\right) = \frac{B_t(i)}{P_t R_t} + C_t(i) + I_t(i) \quad (2)$$

where, $\Psi\left(K_t(i)\right) = r_t^k u_t(i) K_t(i) - \Phi\left(u_t(i)\right) K_t(i)$. Each household maximizes its utility under the budgetary constraint (2). The Utility (1) incorporates a consumption preference shock E_t^B and a labor supply shock E_t^L (Rotemberg and Woodford in 1999). The parameter beta (0 < β < 1) is a discount factor and $\gamma \in [0,1)$ is a parameter relative to an internal habit depending on past consumption serving to introduce a type of real rigidity. The parameter $\tilde{L}$ is a positive constant for adjusting the number of hours worked in the steady state level. The parameter σ_c refers to the intertemporal elasticity of substitution. The coefficient σ_L is the inverse elasticity of labor supply with respect to real wages. The variables $B_t(i)$ and $W_t(i)$ are nominal bond and wage, respectively. The value $W_t(i)L_t(i)$ is labor income, $A_t(i)$ is a stream of income coming from contingent securities, $T_t(i)$ are net transfers from the government, and $\tau_{W,t}$ time-varying labor tax respectively, the variable R_t is the interest rate. The component $\left[r_t^k u_t(i) K_t(i) - \Phi\left(u_t(i)\right) K_t(i)\right]$ represents the net return on the real capital stock of cost associated with variations in the degree of capital utilization.[1] It differs from Christiano *et* al. (2005) hypothesis, which considers only the first term of the component.

The separability of preference functions and the complete financial markets ensure that households have identical consumption plans. The first order condition (FOC) of the utility function is:

$$\lambda_t = E_t^B \left(C_t - \gamma C_{t-1}\right)^{-\sigma_c} - \beta\gamma \mathrm{E}_t \left[E_{t+1}^B \left(C_{t+1} - \gamma C_t\right)^{-\sigma_c}\right] \tag{3}$$

where λ_t is the Lagrange multiplier associated with the budget constraint. The FOC corresponding to the quantities of contingent bonds are determined by the following Fisher equation:

$$\lambda_t = R_t \beta \mathrm{E}_t \left[\lambda_{t+1} \frac{P_t}{P_{t+1}}\right] \tag{4}$$

The equation (4) links the real interest rate to the intertemporal marginal rate of substitution.

2.2 Labor Supply and Staggered Wage Setting

Each household is a monopoly supplier of a differentiated labor service. For simplicity, we assume that the household sells his work services to firms at the perfectly competitive market of labor. The firms use the aggregate labor input through the following technology:

$$L_t = \left[\int_0^1 L_t(i)^{1/\mu_w} \mathrm{d}i\right]^{\mu_w} \tag{5}$$

where μ_w is an elasticity of labor supply to wage. The demand curve of aggregate labor of all firms is defined using the constant elasticity of substitution equation:

$$L_t(i) = \left(\frac{W_t(i)}{W_t}\right)^{-\frac{\mu_w}{\mu_w - 1}} L_t \tag{6}$$

with the aggregate wage rate (W_t) is,

$$W_t = \left(\int_0^1 W_t(i)^{\frac{1}{1-\mu_w}} \mathrm{d}i\right)^{1-\mu_w} \tag{7}$$

The households set their wage on a staggered basis. The level of wage is modeled following Calvo (1983) contract. This means that at each period, any household has a probability $\left(1-\alpha_w\right)$ of changing its wage according to the inflation changes. The average length of wage contracts is $1/\left(1-\alpha_w\right)$. Thus, the wage is set to W_t^* for all suppliers of labor. With the probability α_W, the wages are adjusted via the following indexation rule:

[1] The cost of capacity utilization is zero when capacities are fully used: $\Phi(1) = 0$.

$$W_t(i) = \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\xi_w} \left(\frac{\overline{P}_t}{\overline{P}_{t-1}}\right)^{1-\xi_w} W_{t-1}^i \tag{8}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ serves as the GDP deflator rate, $\overline{\pi}_t = \overline{P}_t / \overline{P}_{t-1}$ stands for the inflation objective of the Central Bank. (ξ_w) is the wage indexation parameter to past prices. The aggregate wage dynamic index, given the wage contract with Calvo partial indexation is governed following the relation:

$$w_t^{\frac{1}{1-\mu_w}} = (1-\alpha_w)\left(\mu_w \frac{Z_{W1,t}}{Z_{W2,t}}\right)^{\frac{-1}{\mu_w(1+\sigma_L)-1}} + \alpha_w w_{t-1}^{\frac{1}{1-\mu_w}} \left(\frac{\pi_t}{\pi_{t-1}^{\xi_w} \overline{\pi}^{1-\xi_w}}\right)^{\frac{-1}{1-\mu_w}} \tag{9}$$

Where $w_t = W_t^* / P_t$ is the real wage and $Z_{W1,t}$, $Z_{W2,t}$ are defined as follows:

$$Z_{W1,t} = E_t^B E_t^L \tilde{L} L_t^{1+\sigma_L} w_t + \alpha_w \beta \mathrm{E}_t \left[\left(\frac{\pi_{t+1}}{\pi_t^{\xi_w} \overline{\pi}_{t+1}^{1-\xi_w}}\right)^{\frac{(1+\sigma_L)\mu_w}{\mu_w - 1}} Z_{W1,t+1}\right] \tag{10}$$

and

$$Z_{W2,t} = (1-\tau_{w,t}) \lambda_t L_t w_t^{\frac{\mu_w}{\mu_w - 1}} + \alpha_w \beta \mathrm{E}_t \left[\left(\frac{\pi_{t+1}}{\pi_t^{\xi_w} \overline{\pi}^{1-\xi_w}}\right)^{\frac{1}{\mu_w - 1}} Z_{W2,t+1}\right] \tag{11}$$

2.3 Investment Decisions

The households as investors choose the capital stock, investment and the capacity utilization rate to maximize the inter-temporal utility function subjected to the budget constraint and capital accumulation. The capital of the households is invested in all sectors of the economy at a return rate R_t^k. The capital accumulation equation is:

$$K_{t+1} = (1-\delta) K_t + E_t^I \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{12}$$

where δ is the depreciation rate of capital. Following Smets and Wouters (2003), Christiano *et* al. (2005), we introduced the investment adjustment cost, with $S(\bullet) \in (0,1)$ is a cost adjustment function such that $S(1) = 0$ and $S''(\bullet) = \varphi$. (the adjustment costs will only depend on the second-order derivative). If S(.) =1 (i.e. there is no adjustment cost), the economy works at a steady state level of the net current capital. The FOC result in the real value of capital, investment and the rate of capital are given by the respective equations:

$$Q_t = \mathrm{E}_t \left[\beta \frac{\lambda_{t+1}}{\lambda_t} \left(Q_{t+1}(1-\delta) + R_{t+1}^k CU_{t+1} - \Phi(CU_{t+1})\right)\right] E_t^Q \tag{13}$$

$$1 = Q_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - \frac{I_t}{I_{t-1}} S'\left(\frac{I_t}{I_{t-1}}\right)\right] E_t^I + \beta \mathrm{E}_t \left[Q_{t+1} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{I_{t+1}}{I_t}\right)^2 S'\left(\frac{I_{t+1}}{I_t}\right) E_{t+1}^I\right] \tag{14}$$

$$R_t^k = \Phi'\left(CU_t\right) \tag{15}$$

Where, Q_t is the Lagrangian associated with the equation (12). The equation (15) equalizes R_t^k the return rate to $\Phi'\left(CU_t\right)$ the nominal marginal cost. The shock E_t^I is the investment shock on the prices, and the shock E_t^Q is the output shock on the external financial risk premium, we noted that this shock not related directly to the structure of the economy.

2.4 Firms

We have two types of firms in the economy producing final and intermediate goods. The representative final-goods firm purchases $\mathrm{Y_t(j)}$ units of each intermediate-good j, at the given nominal price $\mathrm{P_t(j)}$, to produce $\mathrm{Y_t}$ units; according to Dixit and Stiglitz (1977) the production technology is described by:

$$Y_t = \left[\int_0^1 Y_t(j)^{\frac{1}{\mu}}\mathrm{d}j\right]^{\mu} \tag{16}$$

where $\mu = \theta_p / \left(\theta_p - 1\right)$ represents the elasticity of substitution between differentiated goods, and θ_p is the relative price $\left(\mathrm{P_t(j)}/P_t\right)$ *with* $\theta_p > 1$.

The intermediate goods firm combines $\mathrm{L_t(j)}$ units of labor from the representative household and owned $\mathrm{K_{t-1}(j)}$ units of capital to produce $\mathrm{Y_t(j)}$ units. The intermediate goods are produced using a Cobb-Douglas production function:

$$\forall\ \mathrm{j} \in [0,1], \quad \mathrm{Y_t(j)} = \mathrm{E_t^A}\left(\mathrm{CU_t(j)K_{t-1}(j)}\right)^{\theta}\left(\mathrm{L_t(j)}\right)^{1-\theta} - \Omega \tag{17}$$

where $\mathrm{CU_t(j)}$ denotes the capital utilization rate and $\theta \in \left(0,1\right)$ is the elasticity related the capital. E_t^A is the technological shock and Ω is an exogenously fixed cost.

The representative final good producer maximizes the profits $P_t Y_t - \int_0^1 P_t(j) Y_t(j)\mathrm{d}j$ subjected to a level of the production function. The FOC is:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\frac{\mu}{\mu-1}} Y_t \quad \forall j \in [0,1] \tag{18}$$

2.5 Central Bank and Government

We consider the government to be the main actor of macroeconomic policy, mainly fiscal and monetary policy. The government spending $\bar{\bar{G}}$ is assumed exogenous and subjected to shocks labelled by E_t^G. The public expenditures are financed by the wage labor tax, products tax, and lump-sum transfers. The government is constrained by:

$$P_t \bar{\bar{G}} E_t^G = \tau_{W,t} W_t\, L_t + \tau_t P_t\, Y_t\, + P_t T_t \tag{19}$$

It is assumed that the Central Bank controls the short-term interest rate R_t. The monetary policy follows the generalized Taylor (1993) rule, which incorporates deviations of the lagged inflation and output gap:

$$(1+i_t) = (1+i_{t-1})^{\rho_i}\left[\left(\frac{\bar{P}_t}{\bar{P}_{t-1}}\right)\left(\frac{P_{t-1}}{P_{t-2}}\frac{\bar{P}_{t-1}}{\bar{P}_t}\right)^{\psi_\pi}\left(\frac{Y_t}{Y_t^n}\right)^{\psi_y}\right]^{1-\rho_i} \times\left(\frac{P_t}{P_{t-1}}\frac{P_{t-2}}{P_{t-1}}\right)^{\psi_{\Delta_\pi}}\left(\frac{Y_t}{Y_t^n}\frac{Y_{t-1}^n}{Y_{t-1}}\right)^{\psi_{\Delta_y}} E_t^R \tag{20}$$

where Y_t^n is the equilibrium level of output at flexible prices and wages. The parameters ψ_π and ψ_y give the intensity responses to shocks. The parameter ρ_i represents the smoothing of the interest rate. The interest rate gradually responds to deviations in inflation delayed to the inflation target, i.e. $\left(\frac{\bar{P}_t}{\bar{P}_{t-1}}\right)$ and in output delayed to its natural value Y_t^n.

3. PRICE SETTING MODELS

This section presents the baseline version of the Calvo and the Sticky information model of price setting as two different nominal rigidities modeling strategies.

3.1 Calvo Model (stickiness prices)

We described the competing models based on stickiness price labeled standard Calvo (1983) model. In each period, the firms receive a random signal with the probability $(1-\alpha_p)$ that allows changing the prices, the average duration of a rigidity period is $1/\left(1-\alpha_p\right)$. The intermediate goods firms can re-optimize their prices at time t by choosing p_t^* that maximize the expected profits:

$$\mathrm{E}_t\left[\sum_{s=0}^{\infty}\alpha_p^s\Xi_{t,t+s}\left((1-\tau_{t+s})p_t^*(j)Y_{t+s}(j)\left(\frac{P_{t-1+s}}{P_{t-1}}\right)^{\xi_p}\left(\frac{\bar{P}_{t-1+s}}{\bar{P}_{t-1}}\right)^{1-\xi_p} - MC_{t+s}P_{t+s}\left(Y_{t+s}(j)+\Omega\right)\right)\right] \tag{21}$$

under sequential constraints of demand from the final-good firm given by:

$$Y_{t+s}(j) = \left(\frac{p_t^*(j)}{P_t}\right)^{-\frac{\mu}{\mu-1}}\left(\frac{P_t}{P_{t+s}}\left(\frac{P_{t-1+s}}{P_{t-1}}\right)^{\xi_p}\left(\frac{\bar{P}_{t+s}}{\bar{P}_t}\right)^{1-\xi_p}\right)^{-\frac{\mu}{\mu-1}} Y_{t+s} \tag{22}$$

where $\Xi_{t,t+s} = \beta^s\frac{\lambda_{t+s}P_t}{\lambda_t P_{t+s}}$ is the marginal value of one unit of money to the household. MC_{t+s} is the real marginal cost, and τ_t is a time-varying tax on the revenues of intermediate goods firms. Due to the assumptions on market of labor and capital return rate, the real marginal cost, which is supposed identical for all firms, is determined as:

$$MC_t = \frac{W_t^{(1-\alpha)}\left(R_t^k\right)^\alpha}{E_t^A\alpha^\alpha(1-\alpha)^{(1-\alpha)}} \tag{23}$$

The FOC from the system (21, 22) for the optimal nominal price p_t^* is:

$$\mathrm{E}_t\left[\sum_{s=0}^{\infty}\alpha_p^s\Xi_{t,t+s}Y_{t+s}(j)P_{t+s}\left((1-\tau_{t+s})p_t^*(j)\frac{P_t}{P_{t+s}}\left(\frac{P_{t-1+s}}{P_{t-1}}\right)^{\xi_p}\left(\frac{\bar{P}_{t+s}}{\bar{P}_t}\right)^{1-\xi_p}-\mu MC_{t+s}\right)\right]=0 \tag{24}$$

The aggregate price level incorporates the rule price, which evolves according to:

$$P_t^{\frac{1}{1-\mu}}=\alpha_p\left(\Pi_{t-1}^{\xi_p}\bar{\Pi}_t^{1-\xi_p}P_{t-1}\right)^{\frac{1}{1-\mu}}+\left(1-\alpha_p\right)\left(p_t^*\right)^{\frac{1}{1-\mu}} \tag{25}$$

This price-setting scheme (equation 25) can be written in the following recursive form:

$$p_t^*=\mu\frac{Z_{P1,t}}{Z_{P2,t}} \tag{26}$$

Where, $Z_{P1,t}$ and $Z_{P2,t}$ are defined as follows:

$$Z_{P1,t}=\lambda_t MC_t Y_t+\alpha_p\beta\mathrm{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi_t^{\xi_p}\bar{\Pi}_{t+1}^{1-\xi_p}}\right)^{\frac{\mu}{\mu-1}}Z_{P1,t+1}\right] \tag{27}$$

and

$$Z_{P2,t}=(1-\tau_t)\lambda_t Y_t+\alpha_p\beta\mathrm{E}_t\left[\left(\frac{\Pi_{t+1}}{\Pi_t^{\xi_p}\bar{\Pi}_{t+1}^{1-\xi_p}}\right)^{\frac{1}{\mu-1}}Z_{P2,t+1}\right] \tag{28}$$

The dynamic equation of aggregate prices (26) leads to the relation:

$$1=\alpha_p\left(\frac{\Pi_t}{\Pi_{t-1}^{\xi_p}\bar{\Pi}_t^{1-\xi_p}}\right)^{\frac{1}{\mu-1}}+\left(1-\alpha_p\right)\left(p_t^*\right)^{\frac{1}{1-\mu}} \tag{29}$$

Where Π_t is the gross inflation rate. When the probability of changing prices tends to one, the first term of (29) is null; in other words, all intermediate goods firms set their markups $\mu/(1-\tau_t)$.

3.2 The Sticky Information Model

Mankiw and Reis (2002) assume that the information is diffused slowly throughout price setters. In other words, the firm sets a price even if there is no full information about the economic environment (Drissi 2014). Nevertheless, the prices are flexible, so some firms can change their prices at each period based on a new signal from the markets. These processes do not require the availability of all contemporaneous information about the markets. The remaining firms do not receive the new signals, their prices are setting based on their previous information set. Formally, at time t, a firm *j* that updated its information *s* period ago, sets the price $x_t(j)$ as:

$$x_t(j)=E_{t-s}\left(p_t^*(j)\right)$$

where $p_t^*(j)$ is the optimal price of firm *j* at time *t*. The profit firm is maximized by using the following equation:

$$\underset{p_t(j)}{Max}\ \ E_{t-s}[(1-\tau_t)p_t(j)Y_t(j)-MC_tP_t(Y_t(j)+\Omega)] \tag{30}$$

Where $Y_t(j)$ is the demand of the intermediate goods:

$$Y_t(j) = \left(\frac{p_t^*(j)}{P_t}\right)^{-\frac{\mu}{\mu-1}} Y_t \tag{31}$$

The FOC of (30) gives the relationship between the optimal price $p_t^*(j)$ and the real marginal cost MC_t:

$$p_t^*(j) = \frac{\mu}{1-\tau_t} MC_t P_t \tag{32}$$

To allow more consistency to the information rigidity, we consider the specification with backward looking agents as in Gali and Gertler (1999). The aggregate price level is given by:

$$\left(P_t\right)^{1-\frac{\mu}{\mu-1}} = \alpha_p \left(P_{t-1}\Pi_{t-1}^{\xi_p}\bar{\Pi}^{1-\xi_p}\right)^{1-\frac{\mu}{\mu-1}} + (1-\alpha_p)\alpha\sum_{s=0}^{+\infty}(1-\alpha)^s \left(E_{t-s}p_t^*(j)\right)^{1-\frac{\mu}{\mu-1}} \tag{33}$$

In each period, the firms have a constant probability $(1-\alpha_p)$ of receiving a signal allowing the change of prices. The previous equation can be written as:

$$\left(P_t\right)^{\frac{1}{1-\mu}} = \alpha_p \left(P_{t-1}\Pi_{t-1}^{\xi_p}\bar{\Pi}^{1-\xi_p}\right)^{\frac{1}{1-\mu}} + (1-\alpha_p)\alpha\sum_{s=0}^{+\infty}(1-\alpha)^s \left(E_{t-s}p_t^*(j)\right)^{\frac{1}{1-\mu}} \tag{34}$$

Using equations (32) and (34), we obtain a stationary version of the aggregate price equation of the nonlinear Sticky information Phillips curve:

$$\left(\frac{P_t}{P_{t-s}}\right)^{\frac{1}{1-\mu}} = \alpha_p \left(\frac{P_{t-1}}{P_{t-s}}\Pi_{t-1}^{\xi_p}\bar{\Pi}^{1-\xi_p}\right)^{\frac{1}{1-\mu}} + (1-\alpha_p)\alpha\sum_{s=0}^{+\infty}(1-\alpha)^s \left(\mu E_{t-s}\frac{MC_t}{(1-\tau_t)}\frac{P_t}{P_{t-s}}\right)^{\frac{1}{1-\mu}} \tag{35}$$

If $\alpha_p = 0$ i.e. the information set is identical for all firms, the first term of the equation (35) will be dropped; then we get the original specification of standard Sticky information due to Mankiw and Reis (2002).

4. EMPIRICAL ANALYSIS

We outlined briefly the empirical work through data, choice of priors and marginal densities via Bayesian estimation methods. We estimated the parameters using Markov-chain Monte Carlo (MCMC) method with some priors. The likelihood functions of the underlying variables are evaluated by using Kalman filter (Ruge-Murcia 2007), and the posterior distribution of the parameters, with 200000 replications, is obtained using Metropolis-Hastings algorithm. For more details that are technical can be found in Geweke 1999.[2]

4.1 Data

We used quarterly data of the Tunisian economy from 1987Q1 to 2010Q4. The sources of data information are from the National Institute of Statistics (INS), International Financial Statistics, World

[2] All programs and results are available on request.

Economic Outlook database of IMF and the Central Bank of Tunisia. We also considered seven real macroeconomic variables: GDP, consumption, investment, real wages, the number of workers, CPI-inflation, and interest rate.[3] As, in Smets and Wouters (2003) and Forni *et* al. (2009), the worked hours are linked to the number of people employed e_t with the following dynamics:

$$e_t = \beta \mathrm{E}_t e_{t+1} - \frac{(1-\alpha_e)(1-\beta\alpha_e)}{\alpha_e}(l_t - e_t) \quad (38)$$

Where, α_e represent the constant fraction of firms that is able to adjust employment to its desired total labor. All aggregate real variables are expressed per capita using active population and are de-trended. The DSGE model is fitted on seven macro variables, Consumption C; Interest rate i; Real wage w; Inflation π; Capital K; Labor L; Output Y.

As in the recent literature, we will focused on some shocks namely: e_t^P (price mark-up), e_t^W (wage mark-up) and e_t^R (monetary policy). The monetary authority does not have an equation dedicated to the inflation objective. The shock consists on a deviation from the steady state level to a new state level. It allows quantifying the responses of the main variables to such shock. The DSGE framework is a non-linear system; we deduced the log-linearized equations to estimate the model. More details on such procedures, priors are explained in the Appendix A.1.

4.2 Results

4.2.1 Based on Prior Information

We compared Calvo's model to the sticky information model through their prior marginal and posterior marginal densities. Also, we explored the response functions of the two models to detect their respective dynamics related to their underlying hypotheses. These results show the statistical quality of the Calvo and sticky information pricing models. In fact, the Calvo model has the highest marginal densities evaluated at -463.223 and -462.247 with Laplace approximation and Metropolis respectively. However, at s = 12 quarters (i.e., 3 years as likelihood values of marginal densities) the sticky information model returns values of -589.912 and -570.466 for Laplace approximation and Metropolis respectively. The literature explains and justifies the motivation to include inertia, by the fact that a proportion of companies has a retrospective price behavior. The integration of a lag in inflation increases the degree of persistence of inflation following a monetary shock. This Phillips curve is widely used in the study of monetary policy. For instance, the papers based on Maximum-Likelihood Estimation suggest that the estimated weights associated with the existence of backward-looking agents are the highest, while in other studies using the Full Information Maximum Likelihood technique, the author report that the inflation dynamics depends only on forward-looking behavior.

Our results complement the existing literature, which focused only on the integration of delayed elements as a factor in creating a high degree of persistence. However, it seems that the presence of delays alone is not sufficient to create a strong persistence. The underlying structure of price fixity also

[3] The aggregated real wage is mostly defined by an average real wage per worker times the number of workers. It can be calculated as the average wage per hour times the number of worked hours.

seems to play an important role. Some researchers, such as Ball *et* al. (2005), have criticized the models based on the assumption of a sticky price. These authors replaced this specification with sticky information contracts that prevent inflation from jumping immediately after replicas. However, with such pricing, the adjustment is small, and all expected inflation is integrated into the price trajectory, so the indexing scheme is of little interest. Also, extending the maximum age of expired information sets from s = 12 to s = 22 quarters does not significantly improve the performance of gooey information models. This shows that, in fixed-price models, the rigidity structure chosen is important for the degree to which inflation persists, more so than the presence or absence of lagged values of inflation in the dynamics.

4.2.2 Based on Posterior Information

Tables A.3.1 and A.3.2 (see Appendix A.3) present the posterior distributions of the two pricing models under different assumptions. Many of the estimated parameters are quite similar. The estimate of Calvo's parameter α_w for wage rigidity is evaluated at 0.7301 (Table A.3.1). This outcome, similar to Sánchez (2008), Smets and Wouters (2005) for the Euro area, implies that the average length of wage determination between two revisions is $1/(1-0.7301) \approx 3.705$, corresponding close to 1 year. However, under the sticky information model, the wage rigidity has a value of ~0.8124, which implies that the length of wage determination between two revisions is $1/(1-0.8124) \approx 5.330$, corresponding to 5 quarters and 1 month. This result can be explained by the imperfect information in the economy. Among other behavioral parameters, the labor supply parameter under Calvo's (sticky information) model is estimated to be 1.9579 (2.5456), which is below the average value 1.39 reported in Chetty et al. (2011b), Sánchez (2008), Rabanal and Rubio-Ramirez (2005a), and Smets and Wouters (2003). The standard deviation of wage markup is evaluated at 0.76 in the sticky information model, but only 0.21 in Calvo's model. The degree of inertia ρ_i is slightly higher under Calvo's model (0.87) than under the Sticky Information model (0.84). Consequently, the sticky information assumption has different implications for some key parameters, including those of the monetary policy instruments. This behavior arises because a fraction of firms does not receive the current information, therefore they cannot adjust their prices; instead, these firms wait until they get the price information from the markets.

4.2.3 Dynamics through the Impulse Responses

Simulations (Figures 1–4, Appendix A.2) serve to compare the impulse responses to one standard deviation shocks of the main selected variables. In fact, we calculated a first order approximation of the models and then simulated the responses of the inflation, output, real wage, and interest rate to one structural deviation shock (technological shock, monetary policy shock, price markup shock, and wage markup shock).

By focusing on the responses of the aggregates after a technology shock (figure 1). We can observe that the response of the product for both models is automatically positive and continues to accumulate gradually until reaching 0.5%. The real wages are indexed to productivity and following mimetically the evolution of production. As production grows less than potential output, the resulting negative output gap creates downward pressure on prices. The monetary authorities are then encouraged to reduce the interest rate (-0.07% for the SI model versus -0.1% Calvo model).The monetary policy becomes accommodative and prices vary very little. The response of inflation is negative and shows persistence. As opposed to the SI model that exhibits a slight hump-shaped curvature after the few initial impacts, Calvo models generate more persistence of inflation, so, after a technological shock and they bring down the policy instrument (interest rate) slightly longer below its stationary. Through Calvo's models, the propagation of the shocks appears consistent; the inflation doesn't display a hump-shaped curvature after the initial impact. In contrast to the sticky information model, Calvo's model can reduce the policy instrument to slightly below its steady-state level.

According to Figures 2, the responses of output and inflation to a monetary policy shock occur after the increase in the nominal interest rate about 0.12%. This reaction corresponds to a disruption of the monetary policy rule that triggers the correction mechanisms. The firms respond to interest rate changes by drastically reducing their capital expenditures, job demands and capital utilization rate, which lead to a significant drop in marginal cost. The decline in the investment sector can mostly explain the GDP growth about -0.4% for the Calvo model and -0.23% for the SI model. We verified that the inflation response after a monetary policy shock (figure 2) is hump-shaped under the specification with sticky information contracts but jump immediately after replicas in the Calvo's models.

The assumption of price rigidity induces a persistent fall in inflation of -1%. Since wages are highly pro-cyclical, they fall according to a persistent dynamic by -0.2% for the Calvo model, but it is almost nil for the SI model. Mankiw and Reis (2002) criticize, in the fixed prices models, the absence of delay in the inflation reaction. While it is, a feature related to fixed prices forward-looking models.

4.3 Discussions

Firstly, the analysis of monetary policies running through Carlo and sticky information models, supposes that the Central Bank controls the short-term interest rate R_t. The monetary policy follows the generalized Taylor (1993) rule, which incorporates deviations of the lagged inflation and output gap. The credible policies have many targets to struggle against inflation and economic recession but should be sometimes announced before its running to avoid the negative anticipation of households and firms. By estimating the responses of inflation and output (see Figures 2) for the two models, we check whether they correctly reproduce the gradual and delayed responses of inflation as well as the loss of production related to the increase in the nominal interest rate.

For the Calvo pricing model, we can observe a higher persistence of inflation after a technological shock. Overall, the short-run responses show more variability under the sticky information pricing than under Calvo's model. This outcome is partly due to the Sources of inflation inertial are fundamentally different under both models and the nominal variable volatility of the sticky information pricing during the short-run dynamics. This reflects the stylized facts very badly because of the purely prospective behavior of the agents, which lack any friction that disturbs the immediate adjustment of the inflation rate. The inflation results from price changes made by firms when adjusting their contracts, jumps immediately to its new equilibrium value: the price level can be rigid but the rate of inflation cannot. However, the model of Mankiw and Reis (2003) does not generate an immediate jump of inflation similar to Calvo model, and the shocks display a hump-shaped response. Following a monetary policy shock, the past prices have a lower recall effect; therefore, the degree of persistence is lower.

About the output, we have mixed outcomes as in Caraiani 2013, the reactions of both models are very close, and then there is no specification being clearly better than the other ones. The two models do not generate an immediate jump and the shocks on the output are transmitted much less quickly. This lack of accurate results may come that from the fact the output dynamics are much more influenced by the different structural parameters and the rigidities. In the short-term, the inflation responses to monetary shocks exhibit larger and more volatile effects under the sticky information model than Calvo's model. This latter can explain the dynamic responses of the Tunisian macro-variables to monetary policy. It predicts negative hump-shaped output responses and shows smooth dynamic inflation responses. From the Calvo model, the inflation increases smoothly. In contrast, with the sticky information model, the inflation displays a hump-shaped response and indicates an increasing process after four quarters. This shape of response is also indicated in Trabandt (2007) that the sticky information generates hump shaped reaction to monetary policy shocks. This finding corresponds to the acceleration phenomenon observed by Mankiw and Reis (2002). From the sticky information model, there is an empirical correlation between the output and inflation as detected Dupor et al. 2010, Moro 2007, and Paustian and Pytlarczik 2006.

In the two models, the dynamics of output reactions to monetary shocks reflect their prices hypotheses leading to volatile persistence during the first quarters. Thus, the models react well to monetary policy shocks because the relative prices of the firms increase due to the rise in the interest rates. The more accentuated reactions in Calvo's model can be explained by the limited information of the firms about the variability in the credit prices. This point accounts for the volatile and dynamic properties of the output and inflation processes.

In the European economies, under the Calvo model, Smets and Wouters (2003) found that the positive price markup shocks have negative effects on inflation. Such reactions appear, in a small Tunisian economy, with a more accentuated hump-shaped form compared to the inflation reaction. In the sticky information models, the price markup shocks lead to persistent responses from the fourth quarter (see Figures 3 and 4). Under the sticky information behavior and after price markup shocks, the underlying processes return more quickly to their steady-state level than in Calvo's behavior.

These reactions can be explained by the presence of the structure of random acquisition of information to Calvo. Based on old expectations of the evolution of the interest rates, the firms fix these prices. Thus, the existence of real rigidities prevents the other firms from adjusting their prices to the level they want. Nevertheless, after wage markup shocks, the Calvo model returns to the steady-state level more quickly than the sticky information behavior. The price markup and wage markup shocks exhibit inverse output reaction behaviors between the two models. In the sticky information models, the output dynamic reacts to the wage markup shocks, leading to increases in the marginal costs and inflation, which indicate that the firms drive investment downs. This means that the increase in interest rates by the monetary authorities have negative impacts on the real economy and the inflation process. We agree with Mankiw and Reis (2002) that the absence of a delay in the inflation reaction in the fixed prices model implies its weakness. More evidently, we detected that the Calvo model is not appropriate, as it leads to quasi-null reactions of the output and inflation, as well as interest rates to wage markup shocks. Such responses are not supportable in the real world. In the sticky information model, the wage markup shocks would induce different reactions. Our empirical results of the markup (wage and price) shocks are different to the findings of Paustian and Pytlarczik (2006) results, but the responses of macroeconomic variables to monetary shocks are similar between these studies

5. CONCLUSION

By analyzing the monetary policy using Tunisian quarterly data, we consider two alternatives models with different nominal rigidities to compare inflation dynamics in the DSGE framework. Following Söderberg 2015, Dupor et al. 2010, Moro 2007, we evaluate the response functions of the output, inflation, real wage, and interest rate to shocks of monetary policy, price markup, and wage markup. The findings show that the sticky price models consistently and smoothly generate the dynamics of output and inflation to different shocks, except for the output responses to price markup and monetary policy shocks. However, the sticky information models display a hump-shaped behavioral shift of the output and inflation to various shocks, except for the output reactions to price markup shock. In Calvo's model, the dynamics of output reactions to shocks reflect its static prices hypothesis, which leads to a smooth persistence. Thus, the sticky prices model reacts well to monetary policy shock, but it is more accentuated compared to the output reaction in the sticky information model. This latter reflects the volatile and dynamic properties of the output and inflation processes.

Both hypotheses can produce an important degree of persistence, but they are unable to reproduce a sufficient persistence of inflation. In fixed-price models, indexation alone cannot add persistence to the two tested specifications, and the choice of rigidity structure appears to be more important than the presence or absence of lagged values of inflation in the dynamics. However, some factors tend to favor fixed prices rather than predetermined prices. Indeed, the assumption of fixed prices benefits from strong theoretical and empirical support, showing that firms change their prices more often when average inflation increases. This result is compatible with the existence of fixed prices and not with predetermined prices. If prices are fixed, and when inflation is high, firms want to keep their price constant for as short a time as possible. Thus, the average duration of the contracts is less. If prices are predetermined, the average level of inflation has no impact on firms' choices; because the prices are supposed to be perfectly flexible, firms can incorporate any predictable inflation. Overall, there is a theoretical and empirical implication of our research, for future research, consisting of producing models that incorporate the imperfect information, which is at least due to increasing uncertainty and loss of rationality. To overcome the specification weakness in the NKPC, the threshold modeling can improve the empirical outcomes by regime and leading to switch from Calvo to sticky information models depending on the threshold behavior.

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APPENDICES

A.1 Linearized equations

Equations (39) to (51), modeling the economy, are linearized around the logarithms of the steady state level. In the log-linearized system, the variables are expressed as percentage deviations from their steady state values.

- Euler equation

$$\lambda_t = \mathrm{E}_t\lambda_{t+1} + r_t - \mathrm{E}_t\pi_{t+1} \quad (39)$$

Where, $\lambda_t(1-\gamma)(1-\beta\gamma) = \sigma_C\left(\beta\mathrm{E}_t c_{t+1} + \gamma c_{t-1} - \left(1+\beta\gamma^2\right)c_t\right) + (1-\gamma)e_t^B - \beta(1-\gamma)\gamma\mathrm{E}_t e_{t+1}^B \quad (40)$

- Investment equation

$$i_t = \frac{1}{1+\beta}i_{t-1} + \frac{\beta}{1+\beta}\mathrm{E}_t i_{t+1} + \frac{1/\varphi}{(1+\beta)}\left(q_t + e_t^I\right) \quad (41)$$

Where $\varphi = \overline{S}''$

- Real price of capital equation

$$q_t = -\left(r_t - \mathrm{E}_t\pi_{t+1}\right) + \beta(1-\delta)\mathrm{E}_t q_{t+1} + \left[1-\beta(1-\delta)\right]\mathrm{E}_t r_{t+1}^k + \varepsilon_t^Q \quad (42)$$

- Capital accumulation equation

$$k_t = (1-\delta)k_{t-1} + \delta i_{t-1} + \delta e_t^I \quad (43)$$

- Aggregate production function

$$y_t = \mu\left[\alpha\left(k_{t-1} + 1/\phi r_t^k\right) + (1-\alpha)l_t + e_t^A\right] \quad (44)$$

where $\phi = \Phi''(1)/\Phi'(1)$ is the elasticity of the capital utilization cost function.

- Market clearing condition on goods market

$$y_t = \frac{\overline{\overline{C}}}{\overline{\overline{Y}}}c_t + \frac{\overline{\overline{I}}}{\overline{\overline{Y}}}i_t + \frac{\overline{\overline{G}}}{\overline{\overline{Y}}}e_t^G + \frac{\alpha(1-\tau)}{\phi}r_t^k \quad (45)$$

- Labor demands

$$l_t - k_{t-1} = -\left[w_t - (1+1/\phi)r_t^k\right] \quad (46)$$

- Real marginal cost (deflated by the interior producer price index):

$$mc_t = \alpha r_t^k + (1-\alpha)w_t - e_t^A + \varepsilon_t^P \quad (47)$$

- Monetary policy rule

$$r_t = \rho_i r_{t-1} + (1-\rho_i)\left[\psi_\pi\pi_{t-1} + \psi_y\left(y_{t-1} - \overline{y}_{t-1}\right)\right] + \psi_{\Delta\pi}\left(\pi_t - \pi_{t-1}\right) + \psi_{\Delta y}\left[\left(y_t - \overline{y}_t\right) - \left(y_{t-1} - \overline{y}_{t-1}\right)\right] + \varepsilon_t^R \quad (48)$$

where $\overline{y}_t$ stands for the flexible-price output.

- Wage setting: common framework

$$w_t = \frac{1}{1+\beta}w_{t-1} + \frac{\beta}{1+\beta}\mathrm{E}_t w_{t+1} + \frac{\beta}{1+\beta}\mathrm{E}_t(\pi_{t+1}) - \frac{1+\beta\xi_w}{1+\beta}(\pi_t) + \frac{1+\beta\xi_w}{1+\beta}(\pi_{t-1}) - \frac{\beta}{1+\beta}\frac{(1-\alpha_w\beta)(1-\alpha_w)}{\alpha_w\left(1+\frac{\mu_w\sigma_L}{\mu_w-1}\right)}(w_t - \sigma_L l_t - e_t^L + \lambda_t) \quad (49)$$

- Price setting (**Sticky Price**)

$$\pi_t = \frac{\beta}{1+\beta\xi_p}\mathrm{E}_t\pi_{t+1} + \frac{\xi_p}{1+\beta\xi_p}\pi_{t-1} + \frac{(1-\alpha_p\beta)(1-\alpha_p)}{\alpha_p}\frac{(1-\alpha_p)(\mu_p-1)}{\mu_p+\alpha_p-1}\left(w_t - \frac{e_t^A}{1-\alpha_P} + \frac{\alpha_p}{A-\alpha_p}y_t + \varepsilon_t^P\right) \quad (50)$$

The log-linearization of the aggregate price index under the sticky information pricing gives.

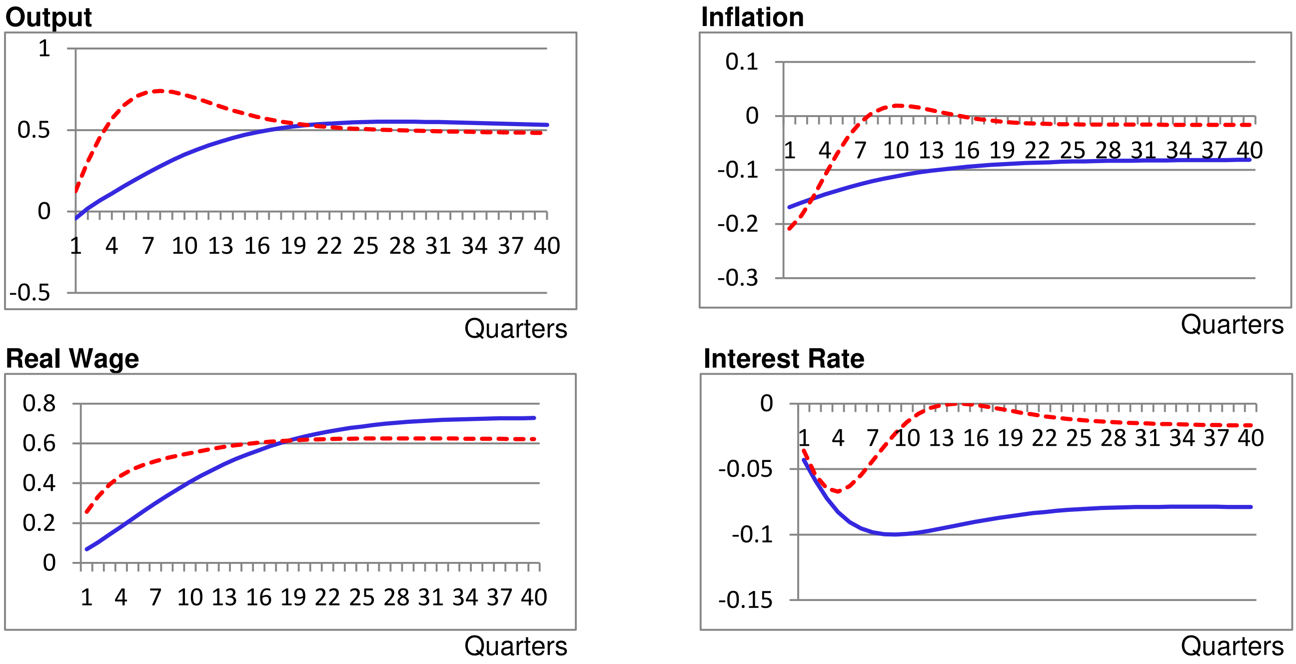
- Price setting (**Sticky information**)

$$\sum_{s=0}^{J-1}\Pi_{t-s} = \alpha_p\left(\sum_{s=1}^{J-1}\Pi_{t-s} + \xi_p\Pi_{t-1}\right) + (1-\alpha_p)\alpha\mu\sum_{s=0}^{+\infty}(1-\alpha)^s E_{t-s}\left(MC_t + \sum_{s=0}^{J-1}\Pi_{t-s} - (1-\tau_t)\right) \quad (51)$$

The equation noted (50) and (51) measures the dispersion of prices, we can show that the main difference between two Phillips (50) and (51) curves is the presence of different expectation terms. As equation (50) shows, in the sticky price model, that the inflation depends on the current expectation of future inflations because the current information used by firms drives to change prices. The sticky-information Phillips curve (51) contains all past expectations of current inflation reflecting that a fraction of firms changes prices based on obsolete information of different age. Three types of shocks give the autoregressive exogenous processes driving the economy. We suppose that all the shocks follow an AR (1) process and have an independent and identically innovation.

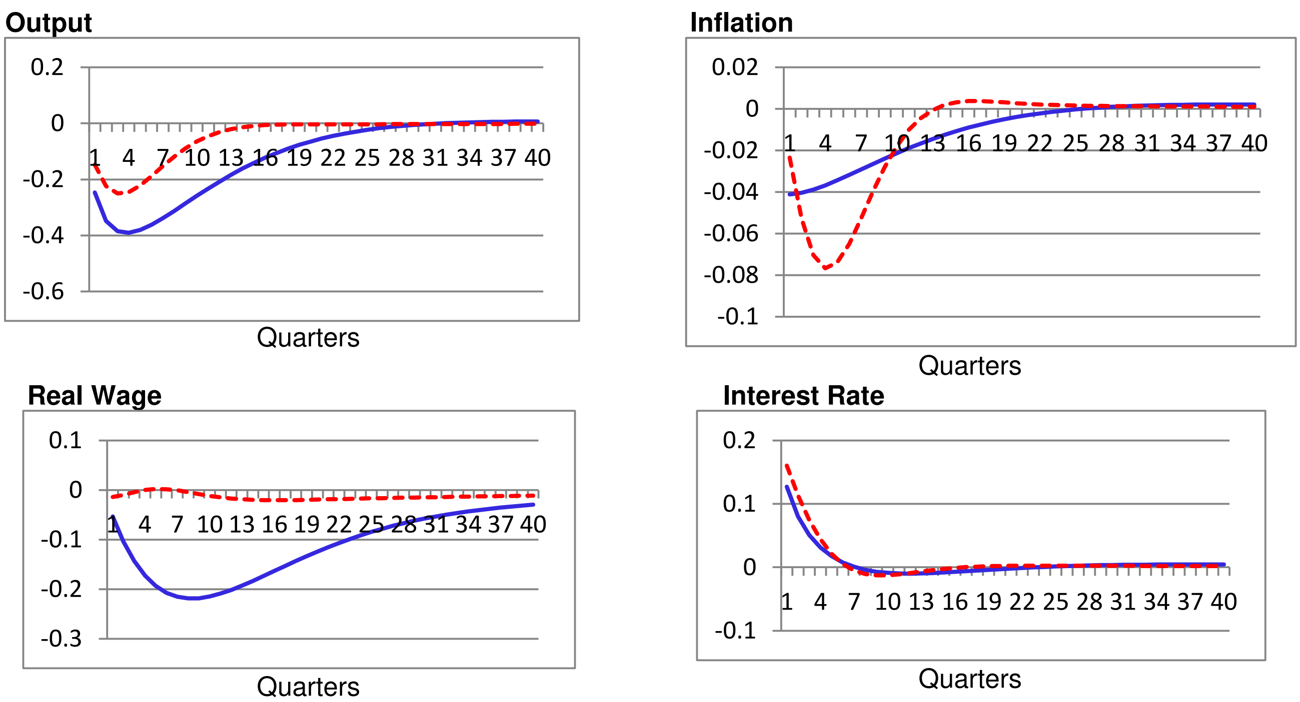
A.2 Figures

Figures 1: Dynamic responses to a technological shock



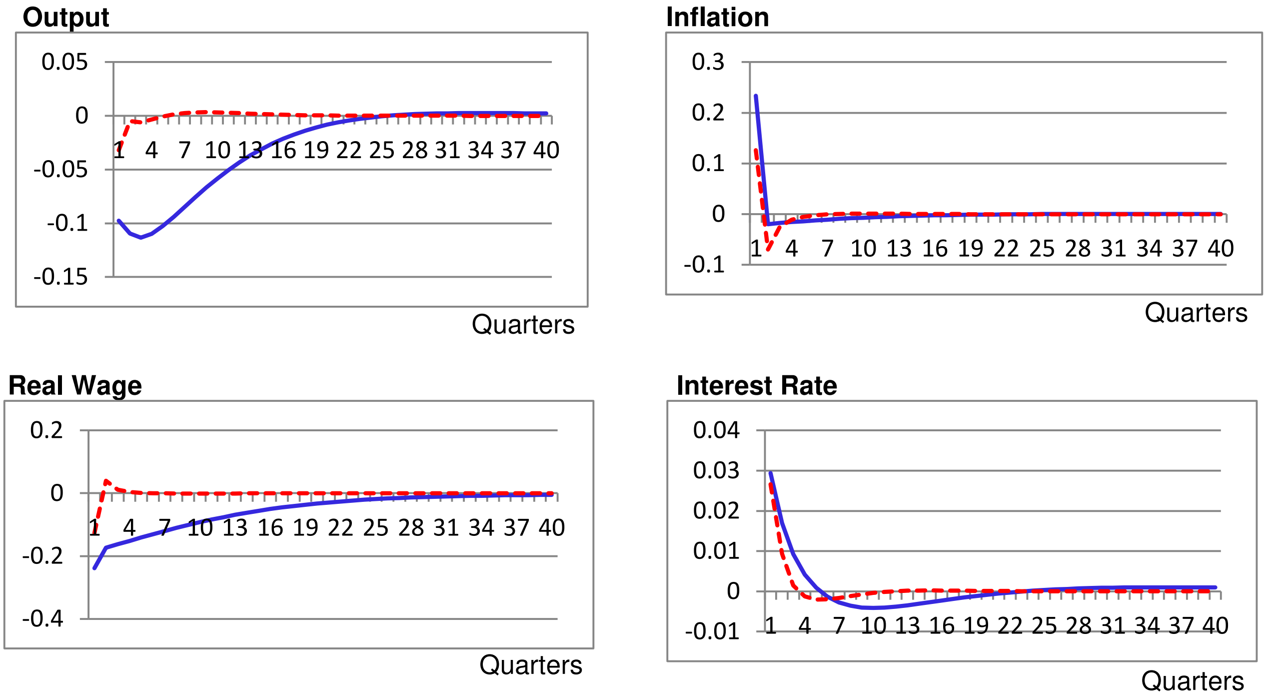
Blue line (Calvo) model; Red dashed line (Sticky information) model.

Figures 2. Dynamic responses to a Monetary Policy shock



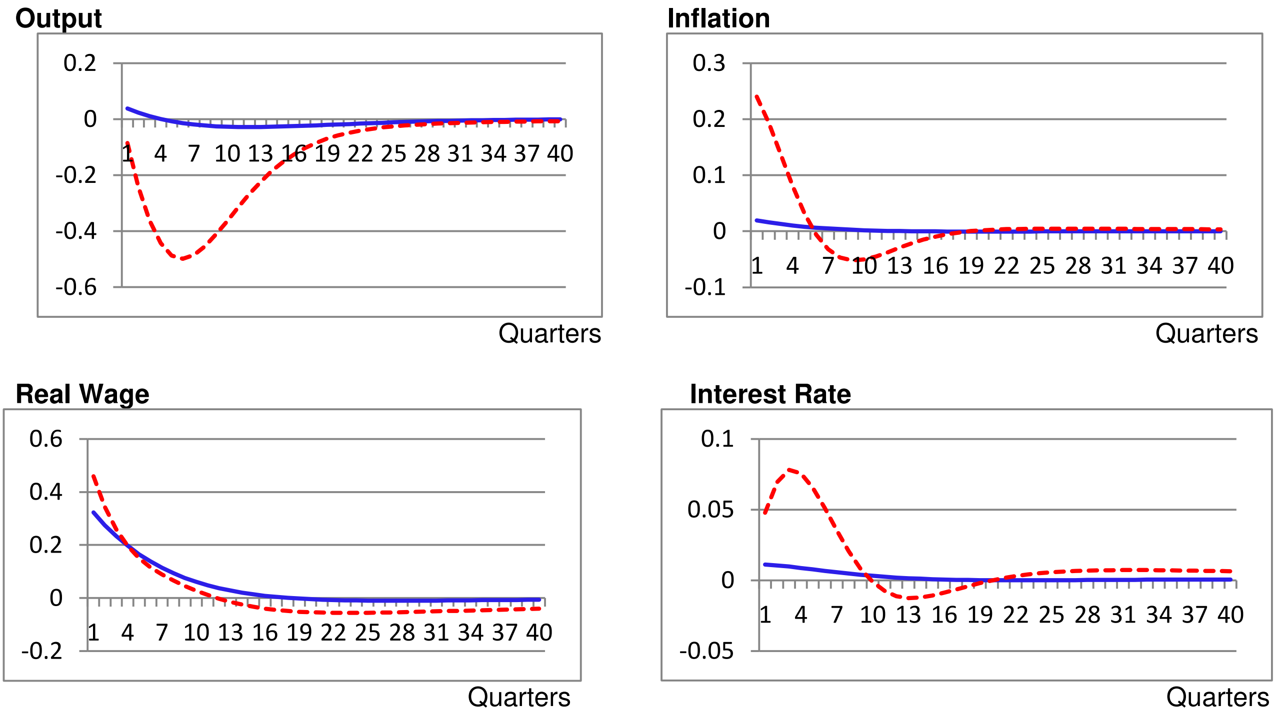
Blue line (Calvo) model, Red dashed line (Sticky information) model

Figures 3. Dynamic responses to a Price Markup shock



Blue line (Calvo) model, Red dashed line (Sticky information) model

Figures 4. Dynamic responses to a Wage Markup shock



Blue line (Calvo) model, Red dashed line (Sticky information) model
Note: For Figures 1 to 4, the impulse responses are calculated at the posterior mode.

A.3 Tables

Table A.3.1. The results of the Bayesian Estimation for Sticky Prices Model

Parameters		Prior distribution	Prior mean	Standard deviation	Posterior mode	Posterior mean	Confidence interval	
							HPD Inf.[4]	HPD Sup.
Elasticity of substitution	σ_c	Normal	0.75	0.252	2.003	2.027	1.606	2.456
Inverse elasticity of labor supply	σ_L	Normal	2.00	0.784	1.957	2.049	0.840	3.171
Habit persistence	γ	Beta	0.70	0.062	0.421	0.436	0.319	0.541
constant fraction of firms	α_e	Beta	0.75	0.009	0.861	0.861	0.844	0.877
Elasticity of the capital utilization cost function.	ϕ	Gamma	0.20	0.203	0.941	0.997	0.665	0.342
Cost adjustment	φ	Normal	4.00	0.443	4.736	4.792	4.072	5.515
Probability that allows to change the prices	α_p	Beta	0.5	0.008	0.893	0.892	0.877	0.907
Probability that allows to change the wage	α_w	Beta	0.75	0.025	0.730	0.771	0.725	0.816
Wage indexation parameter to past prices	ξ_w	Beta	0.50	0.084	0.213	0.236	0.100	0.372
Indexation parameter to past inflation	ξ_p	Beta	0.50	0.088	0.253	0.325	0.110	0.298
Intensity responses to inflation	ψ_π	Normal	1.50	0.010	1.583	1.600	1.464	1.742
Intensity responses to output gap	ψ_y	Normal	0.12	0.125	0.098	0.102	0.056	0.148
Responds to deviation to the inflation target	$\psi_{\Delta\pi}$	Gamma	0.30	0.036	0.205	0.207	0.145	0.266
Responds to output gap deviation to its natural value	$\psi_{\Delta y}$	Gamma	0.06	0.027	0.189	0.187	0.143	0.234
smoothing parameter of the interest rate	ρ_i	Beta	0.75	0.014	0.873	0.871	0.847	0.897
Persistent parameter of technology shocks	ρ_A	Beta	0.85	0.002	0.997	0.993	0.986	0.999
Persistent parameter of Exogenous premium in the return to bonds	ρ_B	Beta	0.85	0.033	0.876	0.869	0.811	0.931
Persistent parameter of public expenditures shocks	ρ_G	Beta	0.85	0.012	0.975	0.963	0.935	0.990
Persistent parameter of labor supply shocks	ρ_L	Beta	0.85	0.008	0.967	0.961	0.945	0.976
Persistent parameter of investment shocks	ρ_I	Beta	4.12	0.024	0.949	0.934	0.889	0.980
S.D of technological shock ε_t^A	σ_A	*Inv. gamma*[5]	0.65	*Inf.*	0.668	0.693	0.579	0.800
S.D of consumption preferences shock ε_t^B	σ_B	*Inv. gamma*	1.13	*Inf.*	2.129	2.326	1.724	2.901
S.D of public expenditures shock ε_t^G	σ_G	*Inv. gamma*	3.00	*Inf.*	1.820	1.835	1.644	2.027
S.D of labor supply shock ε_t^L	σ_L	*Inv. gamma*	5.00	*Inf.*	5.302	5.847	3.162	8.610
S.D of investment shock ε_t^I	σ_I	*Inv. gamma*	3.00	*Inf.*	1.045	1.141	0.792	1.499
S.D of Monetary Policy shock ε_t^R	σ_R	*Inv. gamma*	2.00	*Inf.*	0.185	0.185	1.163	0.208

[4] The acronym HPD stands for Highest Posteriori Density in Table A.3.1 and Table A.3.2.

[5] For the inverted Gamma function, we consider 2 as degree of freedom of an estimated parameter in Tables A.3.1 and A.3.2.

S.D of equity premium shock ε_t^Q	σ_Q	*Inv. gamma*	5.00	*Inf.*	6.460	6.587	5.355	7.809
S.D of price Markup shock ε_t^P	σ_P	*Inv. gamma*	2.00	*Inf.*	0.255	0.264	0.224	0.306
S.D of Wage Markup shock ε_t^W	σ_W	*inv. gamma*	2.00	*Inf.*	0.191	0.200	0.163	0.236

Notes**.** The choice of priors and estimation methodology adopted the empirical approach outlined in Smets and Wouters (2005, 2007), Haider and Drissi (2009) and Lajmi and El Khadhraoui (2014). Also, we estimate the DSGE models with Bayesian methods of Geweke (1999), and DeJong et al. (2000). Such methodology involves obtaining the posterior distribution of the parameters of the model based on its log-linear state-space representation and assessing its empirical performance in terms of its marginal likelihood. SD stands for standard deviation**.**

Table A.3.2: The results of the Bayesian Estimation for Sticky Information

Parameters		Prior distribution	Prior mean	Standard deviation	Posterior mode	Posterior mean	Confidence interval	
							HPD Inf.	HPD Sup.
Elasticity of substitution	σ_c	Normal	1.00	0.257	1.632	1.553	1.098	1.979
Inverse elasticity of labor supply	σ_L	Normal	2.00	0.646	2.545	2.421	1.495	3.254
Habit persistence	γ	Beta	0.70	0.044	0.765	0.777	0.706	0.850
constant fraction of firms	α_e	Beta	0.75	0.008	0.899	0.898	0.884	0.912
Elasticity of the capital utilization cost function.	ϕ	Gamma	0.20	0.182	0.865	0.958	0.645	1.281
Cost adjustment	φ	Normal	4.00	0.443	4.919	5.008	4.244	5.696
Probability to receive new information	α	Beta	0.75	0.051	0.400	0.386	0.300	0.476
Probability that allows to change the wage	α_w	Beta	0.75	0.025	0.812	0.802	0.764	0.842
Wage indexation parameter to past prices	ξ_w	Beta	0.50	0.087	0.768	0.763	0.633	0.900
Intensity responses to inflation	ψ_π	Normal	1.50	0.090	1.571	1.595	1.443	1.738
Intensity responses to output gap	ψ_y	Normal	0.12	0.007	0.019	0.020	0.009	0.034
Responds to deviation to the inflation target	$\psi_{\Delta\pi}$	Gamma	0.30	0.036	0.239	0.247	0.184	0.308
Responds to output gap deviation to its natural value	$\psi_{\Delta y}$	Gamma	0.06	0.022	0.114	0.109	0.069	0.147
smoothing parameter of the interest rate	ρ_i	Beta	0.75	0.016	0.844	0.839	0.813	0.865
Persistent parameter of technology shocks	ρ_A	Beta	0.85	0.003	0.998	0.996	0.992	0.999
Persistent parameter of Exogenous premium in the return to bonds	ρ_B	Beta	0.85	0.064	0.233	0.267	0.159	0.378
Persistent parameter of public expenditures shocks	ρ_G	Beta	0.85	0.005	0.990	0.974	0.946	0.998
Persistent parameter of labor supply shocks	ρ_L	Beta	0.85	0.008	0.972	0.975	0.964	0.988
Persistent parameter of investment shocks	ρ_I	Beta	0.85	0.028	0.918	0.898	0.838	0.961
S.D of technological shock ε_t^A	σ_A	*Inv. gamma*	2.00	*Inf.*	0.466	0.496	0.393	0.590
S.D of consumption preferences shock ε_t^B	σ_B	*Inv. gamma*	5.00	*Inf.*	3.321	3.621	2.497	4.722
S.D of public expenditures shock ε_t^G	σ_G	*Inv. gamma*	3.00	*Inf.*	1.694	1.703	1.524	1.882
S.D of labor supply shock ε_t^L	σ_L	*Inv. gamma*	5.00	*Inf.*	9.348	8.374	6.676	10.19
S.D of investment shock ε_t^I	σ_I	*Inv. gamma*	3.00	*Inf.*	1.069	1.149	0.675	1.579
S.D of Monetary Policy shock ε_t^R	σ_R	*Inv. gamma*	2.00	*Inf.*	0.182	0.187	1.166	0.209
S.D of equity premium shock ε_t^Q	σ_Q	*Inv. gamma*	5.00	*Inf.*	6.153	6.328	5.063	7.609
S.D of price Markup shock ε_t^P	σ_P	*Inv. gamma*	2.00	*Inf.*	0.2974	0.323	0.186	0.449
S.D of Wage Markup shock ε_t^W	σ_W	*inv. gamma*	2.00	*Inf.*	0.407	0.421	0.667	0.475

Notes. For Sticky Information, we suppose the same prior of the previous parameters in Calvo model, and we considered that α is the opportunity to update the information is similar to Calvo model. During every period, only a random fraction of firms receives new information about the state of the economy. For that, the obtained Phillips curves are fundamentally different.