Monetary Policy Design when Consumption Prices are Subsidized: The Case of Tunisia

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Abstract

Several theoretical studies suggest that price inflation targeting is the right design for a monetary policy. Experiences of several inflation targeters in the 1990s motivate this result. In particular, those countries attained substantial decline in output, inflation and interest rate fluctuations. Many other countries are adopting this monetary regime including emerging markets and developing countries despite their different historical experiences and economic environment. In fact, those countries face different market imperfections and government interventionism in setting prices or quantities in some markets. This paper uses structural general-equilibrium approach with price rigidity to test the premise that inflation targeting is welfare improving taking into consideration an environment where government subsidizes a share of private consumption expenditures. Our approach consists in estimating a dynamic stochastic general-equilibrium model for Tunisia with Bayesian techniques. Then, a second order approximation of the model is applied to compare several Taylor Rule's specifications based on different definitions of inflation rates (CPI and sectoral price indexes). Results show that strict CPI inflation targeting would worsen household's welfare compared to the historical monetary rule. Furthermore, CPI inflation targeting can be easily overcome by sectoral inflation targeting or by output gap stabilization.

JEL classification: F3, F4

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1 Introduction

Because inflation targeting has been a recent phenomenon, it has taken time to accumulate empirical evidence on its impact, especially for developing countries. What is the current state of the debate on whether inflation targeting is able to improve economic performance? The general conclusion from the empirical evidence is that inflation targeting is associated with an improvement in overall economic performance. This conclusion is derived from the following results: (i) inflation levels (and volatility), as well as interest rates, have declined after countries have adopted inflation targeting; (ii) output volatility has not worsened, and if anything, it has improved, after the adoption of inflation targeting; (iii) the drop in inflation levels and volatility, and in interest rates and output volatility, was part of a worldwide trend in the 1990s, and inflation targeters have not done better in terms of these variables or in terms of exchange rate pass-through than have non-inflation-targeting industrialized countries such as the United States or Germany. Evidence corroborating this result is reported by Mishkin and Schmidt-Hebbel (2005) who find that inflation targeters do experience significant improvements in performance relative to their own previous performance and relative to most non-targeters. From a theoretical perspective inflation targeting seems to overcome the distortions implied by market imperfections, such as price or wage rigidities (see Woodford 2003). In addition, it appears that inflation targeting has served to anchor expectations and hence to dampen the effect of shocks that might otherwise have initiated a persistent departure of inflation from its target value. For instance, Aoki (2001) shows that in a closed economy with a flexible-price sector and a sticky-price sector, the optimal monetary policy is to target sticky-price inflation only.

Although these results suggest that inflation targeting is beneficial, they are less conclusive than at first appears. Huang and Liu (2005) find welfare superior to target a combination of finished and intermediate goods inflation rates when both have nominal rigidities. In an important contribution to this literature, Erceg, Henderson and Levin (2000) show that strict inflation targeting is no longer optimal when wage inertia is added to price stickiness; the central bank should also respond to movements in the nominal wage or the output gap. The optimality of CPI inflation targeting could particularly be mitigated in the case of developing countries where the economic environment exhibits different intrinsic characteristics, namely through frictions. In particular, we focus in this paper on the heterogeneity in the processes of price setting between sectors through considering subsidized- and non-subsidized-goods productive sectors.

Our main objective is to characterize the simple Taylor-type monetary policy reaction function that would deliver highest welfare given the estimated model. To that end, we compare the welfare attained with the estimated historical rule (exogenous money supply rule) to that of alternative specifications of the nominal interest rate feedback rule (Taylor rule) that allows for different coefficients on CPI inflation as well as on sectoral inflation rates.

To the best of our knowledge, characterizing the welfare-maximizing simple inflation-targeting rule and evaluating the welfare gain of alternative specifications of the monetary policy reaction function have not yet been explored in the context of an estimated model for a developing economy like Tunisia. Therefore, the main innovation in this paper is twofold. First, this is the first paper where a dynamic stochastic general-equilibrium model was developed and estimated for Tunisia. Second, the paper is a first attempt to quantify the optimal monetary rule for this economy taking into account some of the specificities of the economic environment.

This paper uses structural, general-equilibrium approach to test the premise that inflation targeting is welfare improving taking into consideration an environment where: (i) there is monopolistic competition and staggered prices in the non-subsidized-goods market; and (ii) government subsidizes a share of private consumption expenditures. Our approach consists in estimating a dynamic stochastic general-equilibrium model for Tunisia using Bayesian techniques. Then, a second order approximation of the model is applied to compare several Taylor Rule's specifications based on different definitions of inflation rates (CPI and sectoral price indexes). Results show that strict CPI inflation targeting would worsen household's welfare compared to the historical monetary rule. Furthermore, CPI inflation targeting can be easily overcome by sectoral inflation targeting or by output gap stabilization

It is worth noting that the main objective of this paper is to tackle a very particular question related to the appropriate price index to be considered when inflation targeting is to be adopted. Therefore, issues like technical capabilities and central bank autonomy, albeit, severely lacking in most emerging market economies, are not explicitly considered in our context.[1]

The remainder of the paper is organized as follows. In section 2, we describe the model. In section 3, we outline the more relevant qualitative implications of the model in terms of optimal monetary policy using a class of modified Taylor rules. We describe the estimation method and discuss the parameter estimates in section 4. In section 5, we discuss the optimized parameterization for the monetary policy rule under alternative specifications of inflation-targeting Taylor-type rules, and we offer conclusions in section 6.

[1]See for example a discussion on the impact of monetary and fiscal policy independence in De Resende and Rebei (2008).

2 The Model

The economy consists of a representative household with an infinite planning horizon, a representative final good firm, a collection of monopolistically competitive firms that produce differentiated intermediate goods, and a monetary authority that sets the short-term nominal interest rate following a Taylor rule.

2.1 Households

The representative household maximizes expected utility given by:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left[u\left(C_t, C_{t-1}, \frac{M_t}{P_t}\right) - \eta v\left(H_t\right)\right], \tag{1}$$

where C_t is consumption, M_t is the nominal balances, P_t is the consumer price index, H_t is hours worked, $\beta \in (0,1)$ is a subjective discount factor, and η measure the relative importance of leisure in household's utility.[2] The functional form of period utility is given by:

$$u\left(C_t, C_{t-1}, \frac{M_t}{P_t}\right) = \log\left(C_t - aC_{t-1}\right) + b \log\left(\frac{M_t}{P_t}\right) \tag{2}$$

and

$$v\left(H_t\right) = \log\left(1 - H_t\right) \tag{3}$$

where the parameter a is the degree of habit formation for a typical household and b measures the weight of real balances in the utility function and defines the level of real money balances at the steady state.

The representative household's budget constraint in period t is:

$$P_tC_t + P_tI_t + M_t + P_tCAC_t + \frac{B_t}{R_t} \leq (1-\tau_t)W_tH_t + Q_tK_t + M_{t-1} + D_t + B_{t-1} + T_t, \tag{4}$$

where R_t is the gross nominal interest rate on debt between t and $t+1$, W_t is the nominal wage, Q_t is the nominal rental rate of capital, B_{t-1} denotes domestic non-state-contingent bonds, D_t denotes nominal dividend payments received from monopolistically competitive firms, τ_t is a distortionary tax on nominal labor revenues which is endogenously determined in each period given a fiscal rule, T_t corresponds to a lump-sum transfer from the government, I_t is real investment, K_t is the stock of capital, CAC_t is a capital adjustment cost, and R_t is the gross nominal interest rate on debt between t and $t+1$.

[2]The parameter η should affect the steady-state level of labor in the model.

Investment increases the household's stock of capital according to

$$K_{t+1} = (1-\delta)K_t + I_t, \tag{5}$$

where $\delta \in (0,1)$ is the depreciation rate of capital. Investment is subject to convex adjustment costs of the following form:

$$CAC_t = \Gamma\left(\frac{K_{t+1}}{K_t}\right)K_t, \tag{6}$$

where Γ is a function that has the following characteristics: $\Gamma(1)=0$, $\Gamma'(1)=0$, and $\Gamma''(1)=\varphi$.

2.2 Firms

2.2.1 Final-good producers

Firms in the final-good sector are perfectly competitive. They combine subsidizied and non-subsidized intermediate goods to produce a single homogenous good using the following constant elasticity of substitution (CES) technology:

$$y_t = \left[\phi^{\frac{1}{\nu}}\left(y_t^s\right)^{\frac{\nu-1}{\nu}} + (1-\phi)^{\frac{1}{\nu}}\left(y_t^{ns}\right)^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}}, \tag{7}$$

where $y_t^s \equiv \left(\int_0^1 y_t^s(i)^{(\theta-1)/\theta}di\right)^{\theta/(\theta-1)}$ and $y_t^{ns} \equiv \left(\int_0^1 y_t^{ns}(i)^{(\vartheta-1)/\vartheta}di\right)^{\vartheta/(\vartheta-1)}$ are composite indexes of subsidized and non-subsidized intermediate goods, respectively; θ (ϑ) > 1 is the elasticity of substitution between subsidized (non-subsidized) intermediate goods; $\phi > 0$ is the weight of the subsidized composite good; and $\nu > 0$ is the elasticity of substitution between subsidized and non-subsidized intermediate goods. Define $P_t^s \equiv \left(\int_0^1 P_t^s(i)^{1-\theta}di\right)^{1/(1-\theta)}$ and $P_t^{ns} \equiv \left(\int_0^1 P_t^{ns}(i)^{1-\vartheta}di\right)^{1/(1-\vartheta)}$ as the price indexes associated with the aggregators y_t^d and y_t^m. Then, demands for individual subsidized and non-subsidized intermediate goods are, respectively, given by

$$y_t^s(i) = \left(\frac{P_t^s(i)}{P_t^s}\right)^{-\theta} y_t^s, \qquad i \in (0,1),$$

and

$$y_t^{ns}(i) = \left(\frac{P_t^{ns}(i)}{P_t^{ns}}\right)^{-\vartheta} y_t^{ns}, \qquad i \in (0,1). \tag{8}$$

In addition, we assume that the government subsidizes one sector to keep prices stable following this rule:

$$\tilde{P}_t^s = \kappa\tilde{P}_{t-1}^s + (1-\kappa)P_t^s + \varepsilon_t^{P^s} \tag{9}$$

where the final price for subsidized goods is $\tilde{P}_t^s$ and κ represents the degree of intervention of the government and ε_t^{Ps} is an iid shock. If κ approaches the unit, the price of the subsidized good is completely fixed, however, if this parameter is set close to zero the price is totally set by the monopolistic firms.

The representative final-good producer solves

$$\max_{\{y_t^d, y_t^m\}} P_t y_t - \tilde{P}_t^s y_t^s - P_t^{ns} y_t^{ns}, \tag{10}$$

where y_t is given by (7). Profit maximization implies

$$y_t^s = \phi \left(\frac{\tilde{P}_t^s}{P_t} \right)^{-\nu} y_t, \tag{11}$$

and

$$y_t^{ns} = (1-\phi) \left(\frac{P_t^{ns}}{P_t} \right)^{-\nu} y_t. \tag{12}$$

The zero-profit condition implies that the price of the final good, P_t, is given by

$$P_t = \left[\phi (\tilde{P}_t^s)^{1-\nu} + (1-\phi) \left(P_t^{ns}\right)^{1-\nu} \right]^{\frac{1}{1-\nu}}. \tag{13}$$

2.2.2 Intermediate-good producers

Subsidized and non-subsidized intermediate-good producers have identical Cobb-Douglas production functions given by

$$y_t^j(i) = A_t^j k_t^j(i)^{\alpha^j} h_t^j(i)^{1-\alpha^j}, \tag{14}$$

where $j = s, ns$; $\alpha^j \in (0,1)$; $k_t^j(i)$ and $h_t^j(i)$ are capital and labour inputs used by firm i; and A_t^j is an aggregate technology shock that follows the stochastic process

$$\log(A_t^j) = (1-\rho_A^j)\log(A) + \rho_A^j \log(A_{t-1}^j) + \epsilon_t^j, \tag{15}$$

where ρ_A^j is strictly bounded between -1 and 1 and the innovation ϵ_t^j is a normally distributed, serially uncorrelated shock with zero mean and standard deviation σ_A^j.

Domestic intermediate-good producers are monopolistically competitive, and are thus price setters. They segment markets by setting different prices for different destinations. That is, firm i chooses a domestic-currency price $P_t^d(i)$ for its sales in the domestic market and a foreign-currency price $P_t^x(i)$ for its exports. Changing prices entails quadratic adjustment à la Rotemberg (1982):[3]

$$\frac{\psi^j}{2}\left(\frac{P_t^j(i)}{\pi^j P_{t-1}^j(i)}-1\right)^2,$$

where $j = s, ns$; $\psi^j \geq 0$; and π^j is the steady-state value of $\pi_t^j \equiv P_t^j/P_{t-1}^j$. Firm i solves the following dynamic problem:

$$\max_{\{h_t^j(i),k_t^j(i),P_t^j(i)\}} E_t \sum_{l=0}^{\infty} \beta^s \left(\frac{\lambda_{t+l}}{\lambda_t}\right) \frac{D_{t+l}^j(i)}{P_{t+l}}, \tag{16}$$

where

$$D_t^j(i) \equiv P_t^j(i)y_t^j(i) - W_t h_t^j(i) - Q_t k_t^j(i) - \frac{\psi^j}{2}\left(\frac{P_t^j(i)}{\pi^j P_{t-1}^j(i)}-1\right)^2 P_t^j(i)y_t^j(i).$$

Given the demand functions (11) or (12), the first-order conditions for firm i are:

$$w_t = (1-\alpha^j)\xi_t^j(i)\frac{y_t^j(i)}{h_t^j(i)}, \tag{17}$$

$$q_t = \alpha^j \xi_t^j(i)\frac{y_t^j(i)}{k_t^j(i)}, \tag{18}$$

$$\begin{aligned} -\theta\frac{\xi_t^j(i)}{p_t^j(i)} &= (1-\theta)\left[1-\frac{\psi^j}{2}\left(\frac{\pi_t^j(i)}{\pi^j}-1\right)^2\right] \\ &\quad - \psi_d\left[\frac{\pi_t^j(i)}{\pi^j}\left(\frac{\pi_t^j(i)}{\pi^j}-1\right) - \beta E_t\frac{\lambda_{t+1}}{\lambda_t}\frac{\left(\pi_{t+1}^j(i)\right)^2}{\pi_{t+1}\pi^j}\left(\frac{\pi_t^j(i)}{\pi^j}-1\right)\frac{y_{t+1}^j(i)}{y_t^j(i)}\right], \end{aligned} \tag{19}$$

where $\xi_t^j(i)$ is the Lagrange multiplier associated with equation (14) and is equal to the real marginal cost of firm i; $p_t^j(i) \equiv P_t^j(i)/P_t$; $\pi_t^j(i) \equiv P_t^j(i)/P_{t-1}^j(i)$; and $\pi_t \equiv P_t/P_{t-1}$.

2.3 Monetary and fiscal authorities

The monetary authority sets the short-term nominal money growth rate, $\zeta = \frac{M_t}{M_{t-1}}$, in accordance with the following exogenous rule:

$$\log(\zeta_t) = \rho_\zeta \log(\zeta_{t-1}) + \varepsilon_{\zeta,t}, \tag{20}$$

[3] As is well known, the pricing behaviour under the assumption of costly price adjustment is observationally equivalent to that resulting from a Calvo-type price setting (Calvo 1983), where firms are randomly selected to change their prices with a constant probability.

where $\rho_\zeta \in (0,1)$, and the stochastic shock term $\varepsilon_{\zeta,t}$ is i.i.d. normal with a zero mean and a standard deviation of σ_ζ.

The government's expenditures include the cost of subsidizing goods and households' transfers. These revenues are financed with tax collection on labor revenues and newly issued money. Hence, the government's budget constraint is given by

$$\left(\tilde{P}_t^s - P_t^s\right) Y_t^s + T_t = \tau_t W_t H_t + (M_t - M_{t-1}). \tag{21}$$

3 Optimal Monetary Rules

To assess the impact of alternative monetary policy rules on households' welfare, we use hybrid Taylor rule to reflect inflation targeting policies. This counterfactual exercise involves the following process for setting interest rates:

$$\log\left(\frac{R_t}{R}\right) = \rho_\pi \log\left(\frac{\pi_t}{\widetilde{\pi}}\right) + \rho_{\pi^s} \log\left(\frac{\pi_t^s}{\widetilde{\pi}^s}\right) + \rho_{\pi^{ns}} \log\left(\frac{\pi_t^{ns}}{\widetilde{\pi}^{ns}}\right) + \rho_y \log\left(\frac{Y_t}{Y}\right). \tag{22}$$

Variables without time subscripts denote deterministic steady-state values. The Taylor rule immediately implies that in the deterministic steady state the rate of inflation will be equal to $\widetilde{\pi}$. Therefore, it is natural to interpret $\widetilde{\pi}$ as the target level of inflation as well as its deterministic steady-state level.

3.1 Calibration

We calibrate the structural parameters of the model to values similar to those found in the literature. We performed sensitivity analysis on their calibrated values. The baseline model is calibrated at a quarterly frequency. The subjective discount factor, β, is set to 0.98, which implies that the annual real interest rate is equal to 8 per cent in the deterministic steady state. The preference parameter η is chosen so that the fraction of hours worked in the deterministic steady state is equal to 0.25. The capital's share in production, α, is set to 0.36, while the depreciation rate, δ, is chosen to be 0.025. These values, which have become quite standard in the literature, were used, for example, by Backus and Crucini 2000. The elasticity of substitution between subsidized intermediate goods, θ, and its analogous for non-subsidized goods, ϑ, are set to 8, implying a markup of 14 per cent in the deterministic steady state, which lie between the estimates of the empirical literature (see, for example, Basu 1995). The degree of nominal rigidity in the non-subsidized-goods (subsidized-goods) sector, in the form of price adjustment cost, is reflected in the parameter

ψ^{ns} (ψ^{s}) which is set to 80 (0). In order to have a better understanding of the interpretation of the the latter parameter, we use the commonly known result about the equivalence between the Calvo and Rotemberg pricing assumptions. Under our assumption, adjusting prices entails convex costs, as described by Rotemberg (1982). Once we assumes that prices adjust at random intervals of time in a staggered fashion, following the pricing mechanism introduced by Calvo (1983), one can derive a relation between the adjustment cost parameter, ψ, and the probability of keeping prices unchanged called ψ^{ns}_{Calvo}. In particular, imposing $\psi^{ns} = \frac{(\vartheta-1)\psi^{ns}_{Calvo}}{(1-\psi^{ns}_{Calvo})(1-\beta\psi^{ns}_{Calvo})}$ yields the same first-order dynamics in both models. Hence, an average prior price adjustment costs parameter of 80 implies a probability of not changing prices of 0.75, which corresponds to changing prices every four quarters on average. The parameters affecting the degree of price distortion in the subsidized-goods sector are calibrated as follows. first, the share of subsidized-goods, ϕ, is set to be 30 percent which is taken from the disaggregated data on price indexes and their corresponding weight in the aggregate price index. Second, the elasticity of substitution, ν, is simply set to be 1 so that it doesn't reflect per se neither complementarity or substitutability between sectoral goods in the consumption basket. Third, for the degree of intervention of the government, κ, we choose a value of 0.75 which sounds reasonable in a quarterly basis, however, sensitivity analysis is particularly conducted for this parameter.

Table 1: Calibrated Parameters

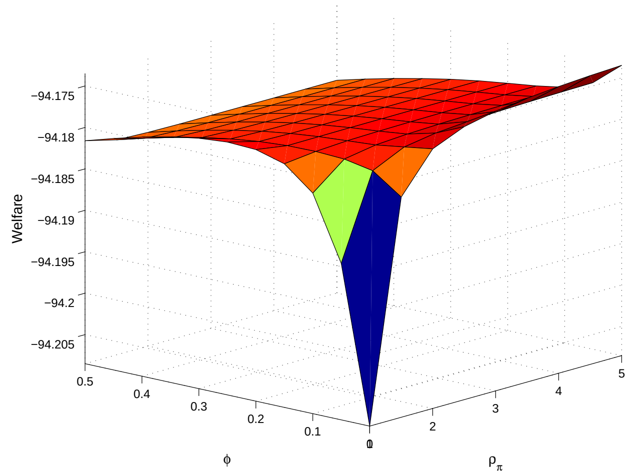
Parameter	Value	Description
β	$1.08^{\frac{1}{4}}$	Quarterly subjective discount factor
b	0.005	Wight of real balances in utility
a	0.5	Habit formation
η	*adjusted*	Weight of leisure in utility
δ	$1.1^{\frac{1}{4}} - 1$	Quarterly depreciation rate
φ	5	Capital adjustment cost parameter
$\alpha^{\{s,ns\}}$	0.35	Cost share of Capital
θ	8	Price elasticity of demand
ψ^{s}	0	Degree of nominal rigidity
ψ^{ns}	80	Degree of nominal rigidity
ν	1	elasticity of substitution between sectoral goods
ϕ	$\frac{1}{3}$	Share of subsidized goods
κ	0.75	Government price subsidy
$\rho_{\{A^s,A^{ns},\zeta\}}$	0.80	first-order serial correlations
$\sigma_{\{A^s,A^{ns}\}}$	0.01	Standard Deviation of technology shocks
σ_{ζ}	0.005	Standard Deviation of monetary shock
$\sigma_{\varepsilon^{P^s}}$	0.005	Standard Deviation of subsidized-goods price shock

3.2 CPI inflation targeting

Results of the second order approximation of the model and the evaluation of welfare conditional to alternative monetary policy are twofold. First, solely and aggressively reacting to CPI inflation when choosing the rate of interest is not optimal in the presence of flexible-price goods ($\varphi = 0.35$ and $\kappa = 0$). Furthermore, the friction reflecting the intervention of the government through subsidizing a share of consumption goods, does not advocate for an aggressive reaction to CPI inflation.

In the case where the only active imperfection is through the presence of price adjustment costs in the non-subsidized goods, the optimal policy is to fully stabilize inflation rate fluctuations in the same sector (i.e. $\rho_{\pi^{ns}} = \infty$). As shown in Figure 1, CPI inflation is the right variable to target in the situation where $\pi_t = \pi_t^{ns}$ corresponding to $\phi = 0$. Otherwise, targeting CPI inflation becomes suboptimal since impulse-response functions of the latter deviate from those if the non-subsidized inflation.

Figure 1: CPI inflation targeting



Although, household's welfare is lower due to the imperfection in the subsidized-goods sector, inflation targeting becomes suboptimal. In other words, the simultaneous presence of non-subsidized-goods sector imperfection, through price stickiness, and subsidized-goods sector imperfection, through the government intervention for smoothing prices, makes it impossible to reach the first-best equilibrium while having only the interest rate as an instrument for the monetary authority.

3.3 Second-best scenario: Non-subsidized-goods inflation targeting

In this section we assess the performance of the monetary rule that overcome the imperfection linked to the price dispersion in the non-subsidized sector. Note that in the framework where the government does not intervene in the goods market, $\kappa = 0$ (and $\forall\phi$), the first best is recovered with a full stabilization of the non-subsidized goods inflation rate, π^{ns}. This is quite obvious since the only imperfection left is the adjustment cost for adjusting non-subsidized-goods prices.[4]

[4] A small caveat is the presence of capital adjustment costs, however, they barely affect the level of welfare in this class of models.

Figure 2: Second-best scenario

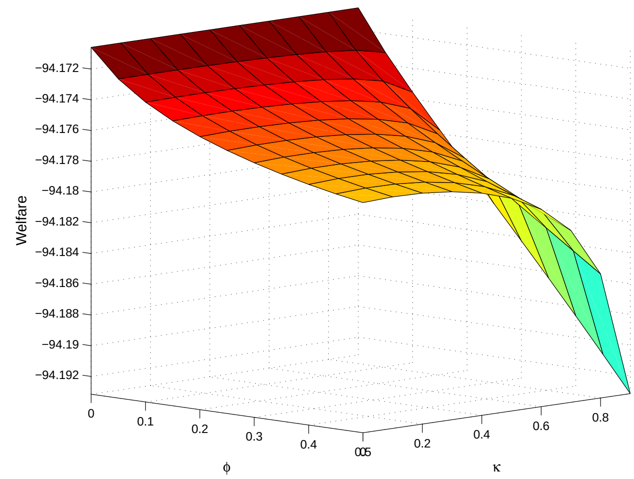


Figure 2 shows that the introduction of government subsidies substantially alters the picture of the optimality of the non-subsidized-goods inflation targeting. In particular, the tradeoff generated by the presence of price rigidity and goods purchase subsidizing is apparent in the negative relationship between non-subsidized-goods inflation volatility on the one hand and subsidized-goods inflation volatility on the other. This suggests, in turn, a decrease... Obviously, welfare losses are substantial for high degree of government interventionism and for substantive weight on the subsidized-good sector. Therefore, in this framework there is no rationale for subsidizing expenditures in purchasing final goods if households' utility metric is considered.[5]

3.4 Which inflation to target?

The above-mentioned results show that despite the presence of nominal frictions through price stickiness, we find welfare losses if the central bank were to target consumer price index (CPI) rather than sectoral inflation. However, a substantial welfare gain is made from targeting subsidized-goods inflation rather than non-subsidized-goods inflation, particularly from targeting only inflation deviations from target in the most frictional sector, i.e., subsidized goods (see Figure 3). Note however that the latter does not correspond to the largest of the production sectors.

One other way to understand the result is by studying the log-linearized versions of the equations (9) and (19):

[5] Notwithstanding, this is beyond he scope of the present study which takes the government behavior as given and only highlights the conduct of the monetary policy in such an environment.

$$\hat{\pi}_t^s = \frac{1-\kappa}{\kappa}\left(\hat{p}_t^s - \hat{\hat{p}}_t^s\right)$$

and

$$\hat{\pi}_t^{ns} = \beta\hat{\pi}_{t+1|t}^{ns} + \frac{\vartheta - 1}{\psi^{ns}}\hat{\xi}_t^{ns}$$

Note that the hatted variables correspond to the relative deviation of each variable from its steady state.[6] The first equation, which summarizes the price setting in the subsidized-goods sector, shows that price inflation stabilization is possible if and only if the government gives up intervening in the price setting process ($\hat{\pi}_t^s = \hat{\pi}_{t+1|t}^s$ if and only if $\hat{p}_t^s = \hat{\hat{p}}_t^s$). Similarly, from the second equation, which reflects the price level setting in by the firms in the non-subsidized-goods sector, price inflation remains constant if and only if firms are continuously equalizing the prices to marginal costs (that is $\hat{\pi}_t^{ns} = \hat{\pi}_{t+1|t}^{ns}$ if and only if $\hat{\xi}_t^{ns} = 0$).

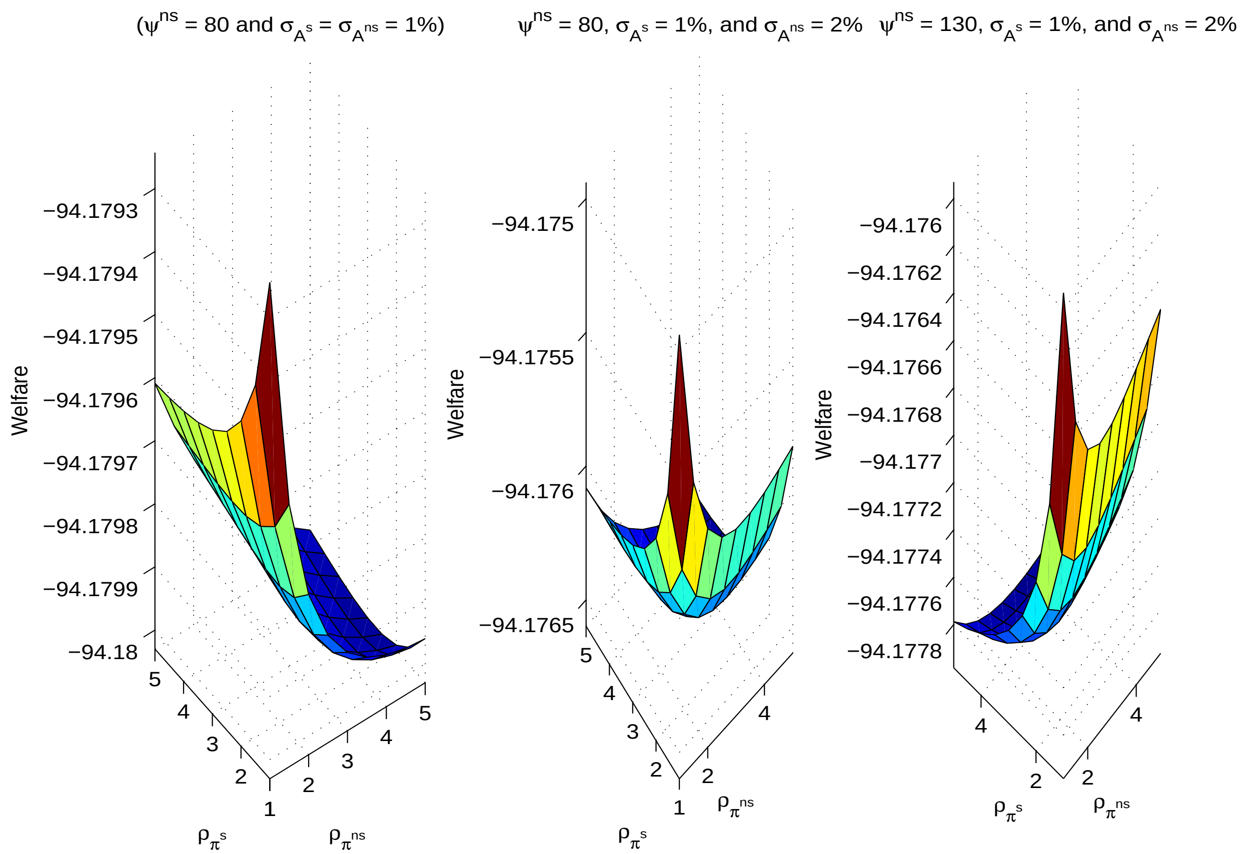
In short, there is clearly a tradeoff between stabilizing sectoral inflation rates and the output gap in the presence of the two price setting frictions.[7] Consequently, the monetary authority cannot achieve a Pareto-optimal level of social welfare under this framework.

In the presence of multiple market imperfections it turns out that the monetary policy that should be undertaken depends on the relative importance of the frictions in the model.

[6] Since price levels are non-stationary by definition we first divide them by the CPI price level, P_t, and the new price indexes are denoted in lowercases.

[7] The output gap referred to in this section corresponds to the difference between the production considering all the assumptions of the model and the one realized when all the friction generated by the processes of price setting are taken away.

Figure 3: Subsidized-goods versus non-subsidized-goods inflation targeting



As the figure makes clear, it is crucial for countries planning for the adoption of inflation targeting policies to be very cautious since the outcome is tributary to the definition of the inflation to be stabilized. A careful attention should be addressed towards (i) sectoral specificities and weights; (ii) the relative importance of sectoral fluctuations; and (iii) the relative importance of the main frictions in action. Following a standard calibration of the parameters of the model, the presence of subsidized goods financed through distortionary taxation is relatively more welfare deteriorating than price stickiness in the non-subsidized-goods sector.[8] This challenges the commonly recommended monetary policy arguing for the reduction of CPI inflation short run fluctuations.

[8] Interestingly, despite the relatively small size of the subsidized-goods sector, $\frac{1}{3}$, solely stabilizing inflation in this sector remains the best practice a monetary authority could adopt if the policy choice is inflation targeting.

3.5 Optimal policy

The optimized Taylor rule implies a rigorous choice for parameters reflecting the reaction of the monetary authority to changes in sectoral inflation rates as well as output gap.

Figure 4: Optimal policy

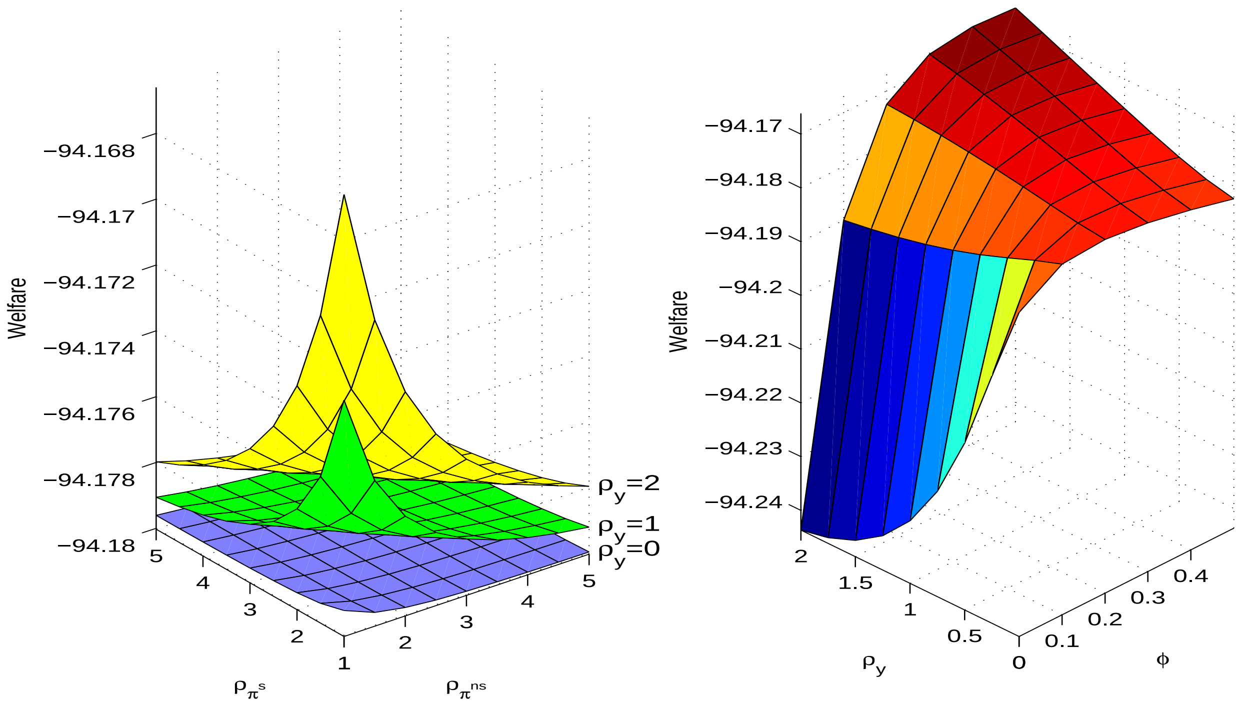


Figure 4 shows that the welfare cost of strict inflation targeting can be extremely high when the coefficient of output gap different from zero. In other terms, the hybrid rule (in which the interest rate responds to both price inflation and the output gap) does not perform well in terms of reducing the welfare costs. However, the relation between the parameter multiplying output gap in the Taylor rule and welfare is not linear. For instance, fully stabilizing output gap is not the best rule. But, strict output gap targeting performs quite well conditional to simultaneously reacting to sectoral inflation rates. Besides, one can read form the right panel of figure 4 that the higher the share of subsidized-goods in the consumption basket the more welfare improving is output gap targeting. This is again tributary to the conflict between stabilizing both sectoral inflation rates.

4 Estimation

4.1 Estimation strategy

The above model is estimated using Bayesian estimation techniques that update prior distributions for the deep parameters of the model, which are defined according to a reasonable calibration, using the actual data. The estimation is done using recursive simulation methods, more specifically the Metropolis-Hastings algorithm, which has been applied to estimate similar dynamic stochastic general-equilibrium models in the literature, such as Schorfheide (2000) and Smets and Wouters (2003). More specifically, let Y^T be a set of observable data. Once the model is log-linearized and solved, its state-space representation can be derived and the likelihood function, $L(\theta|Y^T)$, can be evaluated using the Kalman filter. The Bayesian approach places a prior distribution $p(\theta)$ on parameters and updates the prior through the likelihood function. Bayes' Theorem provides the posterior distribution of θ:

$$p(\theta|Y^T) = \frac{L(\theta|Y^T)p(\theta)}{\int L(\theta|Y^T)p(\theta)d\theta}$$

Markov Chain Monte Carlo methods are used to generate the draws from the posterior distribution. Based on the posterior draws, we can make inference on the parameters. The marginal data density, which assesses the overall fit of the model, is given by:[9]

$$p(Y^T) = \int L(\theta|Y^T)p(\theta)d\theta$$

The model has four shock processes: two sector-specific technology shocks—to the subsidized-goods sector, $\varepsilon_{A^s,t}$, and the non-subsidized-goods sector, $\varepsilon_{A^{ns},t}$; a monetary policy shock-, $\varepsilon_{R,t}$; and a shock on the degree of subsidizing, $\varepsilon_{\kappa,t}$. To identify them in the estimation process, we need to use at most the same number of actual series. We choose the observables to be as informative as possible.

4.2 Data and summary statistics

We use seasonally adjusted quarterly series for Tunisia for the period 1990Q1–2008Q4.[10] The series are growth rate of real output, subsidized-goods inflation rate, and non-subsidized-goods inflation

[9] The marginal data densities are approximated using the harmonic mean estimator that is proposed by Geweke (1999).

[10] Compared to other studies estimating DSGE models, the sample size is relatively short, 72 observations. This motivates the adoption of the Bayesian estimation techniques to compensate for the limited information extracted from the observed variables.

rate. Since the quarterly data on Tunisian GDP are available only since 2000 onwards, we derived the quarterly data for the earlier sub-sample from annual values using the variation in the quarterly data on industrial production. The CPI quarterly series are obtained from the unweighted average of monthly series. The total weight of subsidized goods in the Tunisian CPI corresponds to 32.19 percent. This share is divided between food components of consumption basket, 8.14 percent, and non-food products, 24.05 percent.[11] Looking at a more disaggregated level, cereals' subsidies dominate food subsidies followed by dairy products and derivatives with weights of 3.81 percent and 1.71 percent, respectively. In the subgroup of non-food products, most subsidies are targeting medical and pharmaceutical costs with 5.52 percent followed by energy costs with 4.59 percent.

4.3 Choice of prior distributions

Table 1 shows the prior distributions we have imposed for the deep parameters of the model, as well as the median and 90 per cent confidence interval for the posterior distributions. Figures 1 and 2 convey the same information by drawing the prior distributions, in thick lines, together with the posterior ones, in thin lines.

Some parameter values are taken as fixed rather than given a prior distribution that will be updated with the data; we calibrate them to values similar to those found in the literature. We performed sensitivity analysis on their calibrated values and observed that the estimates of the remaining model parameters were unchanged. These parameters are: the subjective discount rate, $\beta = 0.98$, which implies an annual real interest rate of 8 per cent; the steady state rate of inflation π is taken equal to 1; the weight of leisure in the utility function, η, is calibrated to yield a steady-state share of time devoted to market activities of 30 per cent; the quarterly depreciation rate of capital, $\delta = 0.025$; the gross steady-state markups in all sectors, $\frac{\vartheta}{\vartheta-1} = 1.14$.

It turns out that simultaneously estimating parameters related to price setting in the subsidized-goods sector, ϕ and κ, is very difficult. Different values are plausible given the flat shape of the likelihood function in the neighborhood of the first parameters. Hence, we calibrate the share of subsidized goods since it is easy to identify using the disaggregated database on CPI components. We find a share of about 30 per cent in the total consumption basket.

The set of estimated parameters we estimate is: $\{\rho_{A^s}, \rho_{A^{ns}}, \rho_\zeta, \sigma_{A^s}, \sigma_{A^{ns}}, \sigma_\zeta, \sigma_\kappa, \alpha^s, \alpha^{ns}, a, \varphi, \psi, \kappa\}$. For these parameters we have borrowed some of the prior distributions from the literature, but for those for which we had no references we used common sense while trying to construct the least

[11] Note that the share of subsidized goods is comparable with other similar countries. For instance, the total weight of subsidized goods in the Moroccan CPI amounts to 31.06 percent.

restrictive priors possible. We selected beta distributions for those coefficients that we wanted to restrict to lie between 0 and 1, such as the autocorrelation coefficients of the shock processes or the share parameters. Gamma and Inverted Gamma distributions are imposed, when required, to guarantee real positive values.

Both sectors—subsidized- and non-subsidized-goods—are treated symmetrically a priori. They are given the same share of capital, $\alpha^{\{s,ns\}}$, of 0.35. Similarly, we calibrate for both sectors the same technology autocorrelation and shock volatility, $\rho_{A^{\{s,ns\}}}$ and $\sigma_{A^{\{s,ns\}}}$, of 0.8 and 0.005, respectively.

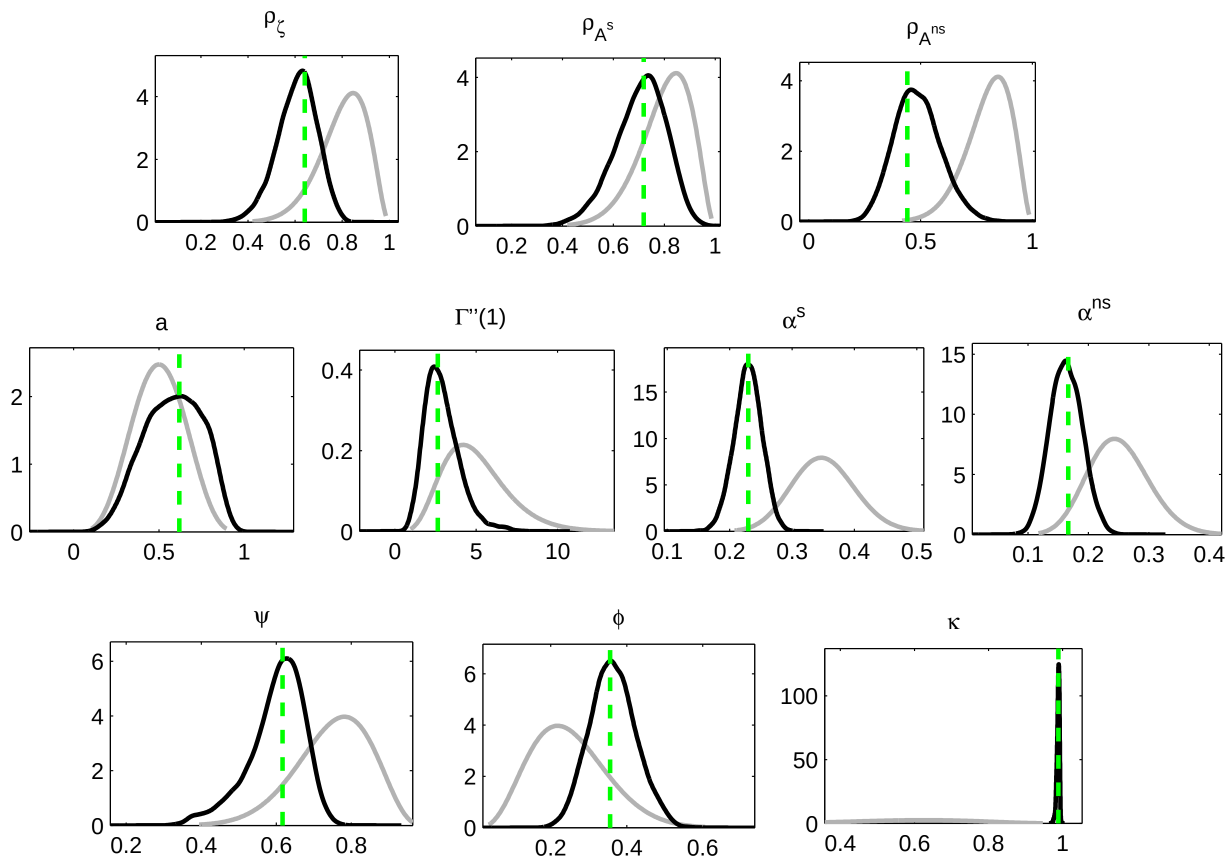
The price-adjustment-cost parameter ψ is calibrated so that, up to a first-order approximation, the resulting nominal rigidity is equivalent to that implied by a Calvo-type staggered price setting with an average duration of price contracts of 4 quarters. The degree of habit formation, a, was estimated mainly for developing countries and results are diverging, therefore, we fix the mean of the distribution to 0.5. Capital adjustment costs are generally introduced to match the ratio of investment and output volatilities. The prior average level of the parameter, ϕ, reflecting the extent to which changes in capital stock are delayed, is set to 5.

4.4 Estimation results

Through Bayesian simulation techniques described in detail in Schorfheide (2000), $200,000$ draws from the posterior are generated. Columns 5 and 6 in Table 2 show the mean and 90 percent probability intervals for the estimated parameters. Overall the parameters are precisely estimated and are economically meaningful.

As shown in the first row of Figure 5, data are most informative for the adequate parameterization of the shocks processes and the price distortions, since those are the parameters for which posterior distributions differ more from their prior ones. In particular, posterior estimates indicate that non-subsidized-goods supply shocks are the more volatile ($\sigma_{A^{ns}} = 0.0101$) followed by shocks to subsidized-goods price ($\sigma_{\varepsilon^{P^s}} = 0.0077$). This would imply their importance in explaining business cycles fluctuations. Specific subsidized-goods technology shocks are less volatile ($\sigma_{A^{ns}} = 0.0024$) but reflect higher persistence ($\sigma_{A^{ns}} = 0.7047$). The prices of non-subsidized goods are estimated to have a posterior median duration of two and a half quarters (prices are unchanged for 7.5 months in average). This duration is in line with the estimates found in the literature covering developing countries in general (see for instance Gali and Gertler 1999; Christiano, Eichenbaum, and Evans 2001; Smets and Wouters 2002; Bils and Klenov 2004, among many others).

Figure 5: Prior versus posterior distributions of the estimated parameters



Looking at the other parameters that are not directly affecting the monetary policy conduct, one can find similarities with the literature. The degree of habit formation for consumption is not very high in Tunisia ($a = 0.5809$) reflecting low welfare cost following changes in the level of consumption in developing countries. Although, the magnitude of habit formation is still consistent with the values of 0.63, reported by Christiano et al. (2005) and 0.73, reported by Boldrin et al. (2001). The capital adjustment cost parameter estimate, $\varphi = 2.8946$, is consistent with the traditionally very low values which have been used to calibrate RBC models. In addition, data used to estimate the model suggest plausible value for the share of capital in production of subsidized and non-subsidized goods of 0.2291 and 0.1629, respectively.

Table 2: Parameter Estimation Results

	Prior distribution			Posterior distribution			
				With subsidy (H_1)		Without subsidy (H_0)	
Parameter	Type	Mean	S.E.	Median	90% interval	Median	90% interval
ρ_{A^s}	Beta	0.80	0.10	**0.7047**	[0.5442 , 0.8681]	0.9236	[0.9180 , 0.9294]
$\rho_{A^{ns}}$	Beta	0.80	0.10	**0.4859**	[0.3139 , 0.6532]	0.8386	[0.8078 , 0.8675]
ρ_ζ	Beta	0.80	0.10	**0.6062**	[0.4754 , 0.7504]	0.6734	[0.5417 , 0.7906]
σ_{A^s}	InvGamma	0.005	∞	**0.0024**	[0.0017 , 0.0030]	0.0100	[0.0076 , 0.0124]
$\sigma_{A^{ns}}$	InvGamma	0.005	∞	**0.0101**	[0.0035 , 0.0155]	0.0145	[0.0109 , 0.0176]
σ_ζ	InvGamma	0.0025	∞	**0.0008**	[0.0005 , 0.0010]	0.0012	[0.0007 , 0.0017]
$\sigma_{\varepsilon^{P^s}}$	InvGamma	0.0025	∞	**0.0077**	[0.0064 , 0.0090]	0.0259	[0.0151 , 0.0361]
a	Beta	0.50	0.15	**0.5809**	[0.3227 , 0.8588]	0.3333	[0.1657 , 0.4943]
φ	Gamma	5.00	2.00	**2.8946**	[1.2514 , 4.5322]	0.9841	[0.4710 , 1.5450]
α^s	Beta	0.35	0.05	**0.2291**	[0.1924 , 0.2650]	0.2565	[0.2445 , 0.2705]
α^{ns}	Beta	0.35	0.05	**0.1629**	[0.1214 , 0.2079]	0.2190	[0.1644 , 0.2749]
ψ	Beta	0.75	0.10	**0.5994**	[0.4781 , 0.7133]	0.8185	[0.8036 , 0.8360]
ϕ	Beta	0.25	0.10	**0.3630**	[0.2624 , 0.4625]	0.8899	[0.8889 , 0.8906]
κ	Beta	0.60	0.15	**0.9879**	[0.9825 , 0.9934]	− − −	− − −
Marginal Data Densities				−861.4672		−782.5323	

For the Tunisian economy, κ is precisely estimated to be around 0.98 meaning that the government is actively intervening to stabilize the fluctuations of a subset of commodities' prices. This represents a substantive deviation from the flexible price equilibrium. The share of subsidized goods in the overall consumption basket is estimated to be around 36 percent with a 90 percent interval of [0.2624 , 0.4625] which is consistent with the initial calibration of 30 percent taken from the disaggregated data on prices used for the construction of the CPI. Together with the degree of price stickiness, ψ, these two parameters are quite important in terms of the conduct of the monetary policy in Tunisia and the definition of the right inflation to be targeted.[12]

One issue that we are interested in is whether fiscal authorities are really intervening to stabilize prices. We test this hypothesis by estimating the model separately under the restrictions $\kappa > 0$ and $\kappa = 0$. We reject one model specification in favor of the other by evaluating the posterior odds ratio corresponding to the assumptions $H_0 : \kappa = 0$ and $H_1 : \kappa > 0$. Let's define $\pi_{0,0}$ as the prior probability associated with this hypothesis. The posterior odds of H_0 versus H_1 are given by :

$$\frac{\pi_{0,T}}{\pi_{1,T}} = \left(\frac{\pi_{0,0}}{\pi_{1,0}}\right)\left(\frac{p(Y^T|H_0)}{p(Y^T|H_1)}\right)$$

As shown in this equation, posterior odds are the ratio between the marginal data likelihood of the model under H_0 and H_1, $\left(\frac{p(Y^T|H_0)}{p(Y^T|H_1)}\right)$, multiplied by a prior model odds ratio, $\left(\frac{\pi_{0,0}}{\pi_{1,0}}\right)$.

Large values of the posterior odds ratio provide evidence in favor of H_0 over H_1 while small values provide evidence in favor of H_1 over H_0.[13]

The odds ratios are below 1 and thus do not indicate any evidence in favor of $\kappa = 0$.[14] While the estimates for the two models are reasonable and broadly similar, a closer inspection reveals some notable differences. For instance, the weight of subsidized-goods sector becomes unreasonably high assuming that $\kappa = 0$ which reveals the importance of the government intervention assumption for matching the observed variables. Also, the structure of sectoral shocks is very tributary to the presence of subsidy.

[12] In addition to the parameters defining the degree of price deviation from the one in the frictionless version of the model, the sectoral shock processes play an important role in finding the optimal policy.

[13] In the literature (e.g., Jeffereys, 1961) we can find that the odds ratio can be assessed using the following rule of thumb: if $1 < \frac{\pi_{0,T}}{\pi_{1,T}} < 3$ there is only a weak evidence for H_0. If $3 < \frac{\pi_{0,T}}{\pi_{1,T}} < 12$ there is weak to moderate evidence for H_0. If $12 < \frac{\pi_{0,T}}{\pi_{1,T}} < 148$ there is moderate to strong evidence for H_0. Finally, if $\frac{\pi_{0,T}}{\pi_{1,T}} > 148$, there is decisive evidence for H_0.

[14] Assuming that prior model preferences are not imposed, i.e. $\frac{\pi_{0,0}}{\pi_{1,0}} = 1$, the odds ratio simplifies into the Bayes factor comparing two marginal data densities.

5 Quantitative Implications of the Model

In this section, we search for the parameterization of alternative feedback Taylor-type interest rate rules similar to equation (22) that maximize household welfare given our estimated model. We evaluate the welfare gain they represent with respect to the estimated monetary policy reaction function (or "historical rule"), as well as their implications in terms of aggregate fluctuations.

The search for the welfare-maximizing feedback monetary policy rules is set out as follows. We maximize the unconditional expectation of lifetime utility[15] of households over the parameters of the Taylor rule. This implies:

$$\max_{\rho_{\pi^s},\rho_{\pi^{ns}},\rho_y} E\left\{u(c_t,m_t,h_t)\right\}.$$

We measure the welfare gain associated with a particular monetary policy in terms of its compensating variation. That is, we calculate the percentage of lifetime consumption, ω, that should be added to that obtained under the estimated Taylor rule in order to give households the same unconditional expected utility as under the new monetary policy rule scenario:

$$E\left\{u((1+\omega)c_t,m_t,h_t)\right\} = E\left\{u(\tilde{c}_t,\tilde{m}_t,\tilde{h}_t)\right\},$$

where variables without tildes are obtained under the estimated rule described before, and variables with tildes are under the optimized Taylor rule. Based on the results found in Kim and Kim (2003) and subsequent literature, we compute the long-run average utility by means of a second-order approximation around the steady-state utility. In particular, we follow the approach of Schmitt-Grohé and Uribe (2004a):

$$E\left(u\left(\tilde{c}_t,\tilde{m}_t,\tilde{h}_t\right)\right) = u(c,m,h) + u'E\left(\widehat{\tilde{c}}_t,\widehat{\tilde{m}}_t,\widehat{\tilde{h}}_t\right) + \frac{1}{2}E\left(\widehat{\tilde{c}}_t,\widehat{\tilde{m}}_t,\widehat{\tilde{h}}_t\right)' u''\left(\widehat{\tilde{c}}_t,\widehat{\tilde{m}}_t,\widehat{\tilde{h}}_t\right) + \mathcal{O},$$

where u'_t and u'' are the first and second derivatives, respectively, of the utility function with respect to its arguments, evaluated at their deterministic steady-state values, and variables with hats measure deviations from their levels in the deterministic steady state. The compensating

[15] Schmitt-Grohé and Uribe (2004b) adopt the conditional welfare optimization in their framework and they consider the non-stochastic steady state as an initial state of the economy. By computing the unconditional long-run utility, we do not consider the effect of the initial state. Transition costs are crucially dependent on that initial state, especially if the real state of the economy is never at the deterministic level. In addition, Schmitt-Grohé and Uribe (2004b) show that the optimal rule is robust to these definitions of welfare, but that the welfare improvement could be different in the sense that it is higher in the case of unconditional welfare given that no short-term transition costs are incurred.

variation in consumption can therefore be decomposed into a first-level effect and a second-level or stabilization effect, i.e., into the welfare gains of the new parameterization of the monetary policy owing to its effect on the average levels of consumption, real balances, and leisure and into those due to its effect on their volatilities. The first-level effect is defined as:

$$E\left\{u\left((1+\omega^1)c_t, m_t, h_t\right)\right\} = u\left(c, m, h\right) + u' E\left(\widehat{\tilde{c}}_t, \widehat{\tilde{m}_t}, \widehat{\tilde{h}}_t\right),$$

and the second-level effect as:

$$E\left\{u\left((1+\omega^2)c_t, m_t, h_t\right)\right\} = u\left(c, m, h\right) + \frac{1}{2} E\left(\widehat{\tilde{c}}_t, \widehat{\tilde{m}_t}, \widehat{\tilde{h}}_t\right)' u'' \left(\widehat{\tilde{c}}_t, \widehat{\tilde{m}_t}, \widehat{\tilde{h}}_t\right).$$

The overall effect in all cases is such that, approximately, $(1+\omega) \approx (1+\omega^1)(1+\omega^2)$. Table 3 reports the welfare gains, together with the unconditional long-run average values of the arguments of the utility function, as well as that of the utility itself.

In what follows, we limit our attention to the Taylor-type rules that guarantee the existence of a unique and stable equilibrium in the neighborhood of the deterministic steady state.

First, we consider the case where the central bank targets the contemporaneous CPI inflation rate, π_t, which correspond to a completely different policy than the historical one. This result is mainly driven by the destabilization effect on welfare arguments (mainly consumption) Although, this rule contributes to permanently increase the level of consumption. Despite the distortions in price determination in different sectors entering the consumer goods basket, the new policy generate a welfare cost of 0.0048 percent in terms of consumption. This is mainly driven by a negative second order effect of -0.0229.

Table 3: Optimized Taylor rules versus historical rule

Monetary rule	Parameters	First-order effect* (ω^1)	Second-order effect* (ω^2)	Welfare gain* (ω)
CPI inflation stabilization	$\rho_\pi = \infty$	0.0181	-0.0229	-0.0048
Subsidized-goods inflation stabilization	$\rho_{\pi^s} = \infty$	-0.0482	0.0964	0.0482
Non-subsidized-goods inflation stabilization	$\rho_{\pi^{ns}} = \infty$	-0.0236	-0.0092	-0.0328
Optimal Rule	$\rho_{\pi^s} = 1$ $\rho_{\pi^{ns}} = 1$ $\rho_y = 0.4122$	1.3933	-0.0292	1.3641

* Note: All welfare gain/cost numbers are in percentage

As shown earlier, the right policy if one has to commit to only price inflation targeting is to focus on subsidized-goods inflation and discard the one in the subsidized-goods sector. The historical rule entails a welfare cost of 0.0482 per cent of the lifetime consumption associated with the optimized subsidized-goods inflation-targeting rule (see second row in Table 3). Most of the welfare improvement of choosing $\rho_{\pi^s} = \infty$ rather than the estimated parameters comes from the first-level effect or improvement in long-run average utility, which amounts to a 0.0964 percent increase in lifetime consumption. This is consistent with previous findings in the literature whereby the optimal monetary policy is to target exclusively the inflation rate of the sector that has more nominal inertia, which in our case is the subsidized-goods sector. As we reported earlier, the idea behind targeting inflation in this sector is motivated by its importance in the economy we estimate for Tunisia.

As reported by Erceg et al. (2000) we find evidence for output gap targeting in the present model. In some sense the two models have similarities in terms of the presence of multiple sources of price distortion. In Erceg et al.'s paper, output gap targeting results from the competing effects motivated by price and wage rigidities; however, in the present model sectoral inflation rates dynamics yield the result. For technical reasons inflation has to be targeted, although mildly. This guaranties the existence and uniqueness of a stable equilibrium (the Taylor principle). On the other hand, output gap perfect stabilization is not feasible because of the destabilizing effect of high values of ρ_y on nominal interest rates.[16] Hence, the interest rate setting is summarized through the following reaction equation:

$$\log\left(\frac{R_t}{R}\right) = 1\log\left(\frac{\pi_t^s}{\widetilde{\pi}^s}\right) + 1\log\left(\frac{\pi_t^{ns}}{\widetilde{\pi}^{ns}}\right) + 0.4122\log\left(\frac{Y_t}{Y}\right).$$

The latter produces a substantive welfare gain of 1.3641 percent increase in lifetime consumption despite the destabilizing impact which materializes through a loss of 0.0292 percent compared to the historical money supply rule. On the other hand, this policy is very close to the zero bound region on nominal interest rates. In practice, this policy is to be applied very cautiously especially when a monetary authority is newly implementing this policy. Indeed, the risk of hitting the zero bound would negatively affect the reputation of a central bank and alter the responsiveness of the private sector to the announcements of the monetary authority.

6 Conclusion

We analyze welfare-improving monetary policy reaction functions in the context of a New Keynesian developing economy model with a subsidized- and a non-subsidized-goods sectors where the latter exhibits sticky prices. The model is estimated for the case of Tunisia and is used to evaluate the welfare gains of alternative specifications of the feedback nominal interest rate rule.

The model is estimated using Bayesian techniques for quarterly Tunisian data. The estimation shows the importance of the subsidized-goods sector. We also find statistically significant importance in competing frictions across sectors in price determination. We explore what would have been the optimal parametrization of a Taylor rule such as the standard one, where the central bank targets aggregate inflation (CPI inflation). We find welfare losses in responding aggressively to aggregate inflation deviations from target compared to the exogenous money supply rule. We find welfare gains in targeting sectoral rather than aggregate inflation. In particular, the gains are highest if the monetary authority reacts aggressively to subsidized-goods inflation, since price distortions are substantive in that production sector.

We find that the higher welfare is achieved when central bank reacts minimally to inflation deviations from the target combined with output gap stabilization. But the implications in terms of business cycle fluctuations of such a policy rule are discouraging—high volatility is induced in the system, including a high probability of large deviations of CPI inflation from target as well as

[16]To avoid regions of high fluctuations of interest rate we restrict our optimization procedure to values of the Taylor rule parameters that do not generate a high risk of hitting the zero bound interest rate ($R - 2std(R_t) > 0$)

important probability of hitting the zero bound on nominal interest rates for a realization of shocks similar to that observed in the past.

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