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ABSTRACT

The Case for Inflation Stability*

We evaluate the case for perfect price (inflation) stabilization in a New Keynesian (NNS) model that includes capital accumulation, a variety of shocks, a monetary and an imperfect competition distortion. In such a model, price rigidity may provide the monetary authorities with an opportunity to improve upon the inefficient flexible price equilibrium via the suitable cyclical manipulation of real marginal costs. We find that such an opportunity is of limited value. With only the imperfect competition friction present (in the 'cashless' version of the model), inflation variability is costly independent of the level of capital adjustment costs, the degree of price rigidity, the size of mark-ups, the degree of risk aversion and the type of the shock. A small amount of inflation variability may become desirable when prices are fairly flexible and capital adjustment costs low if the model includes both frictions.

JEL Classification: E32 and E52
Keywords: distortions, inflation stabilization, investment and price rigidity

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Introduction

The recent literature on optimal monetary policy has studied extensively the welfare properties of price (inflation) targeting within the New Neoclassical Synthesis, NNS (or, new Keynesian, NK) model. Broadly speaking, one can identify two main strands in this literature. The first a) abstracts from capital accumulation; b) ignores any direct services provided by money (a "cashless" economy); c) eliminates the imperfect competition distortion via a production subsidy; d) uses a separable utility function and e) works with a log–linear approximation to the policy functions and employees a quadratic approximation to the utility function in order to evaluate welfare (Clarida, Galì and Gertler, 1999, Woodford, 2000). Assumptions (b) and (c) imply that the flexible price equilibrium is efficient. Consequently, with price rigidity being the only distortion present, the optimal policy is to perfectly stabilize the price level.[1] This eliminates the relative price distortion and results in an allocation that is identical to that under flexible prices.

The situation is more complicated when the economy under consideration does not satisfy assumption (b) above, that is, when it is not "cashless" (for instance, when money enters the utility function or, when, as in this paper, the household incurs a transaction cost). In this case, Friedman's zero interest rate rule prescribes sustained deflation in order to eliminate the distortion associated with money demand. Furthermore, optimal monetary policy may also entail the systematic variation of the price level with the various shocks in order to stabilize the nominal interest rate and real balances. Both of these considerations suggest that some deviations from perfect price stabilization may be optimal (Woodford, 2000, ch. 6).

The second strand of the NNS literature typically includes capital accumulation, it has an explicit role for money, it assumes nonseparable utility and, most importantly, does not eliminate the monopolistic competition distortion (Ireland, 1996, Goodfriend and King, 1997, 2001). The last assumption implies that the flexible price equilibrium would not be first best even in the cashless case. Consequently, there no longer exists a presumption that a policy that replicates the flexible price equilibrium by perfectly stabilizing prices is optimal.

What type of monetary policy is optimal in this class of models? In a model with *one period* price contracts and no capital, Adao, Correia and Teles (2000) show that the Friedman rule is optimal. And that this rule may be implementable in fixed but not flexible price equilibria for reasons related to the zero nominal interest rate bound.

[1] Or the inflation rate when there exists price indexation as in Collard and Dellas, 2001.

However, Khan, King and Wolman (2000) show that this result depends critically on the assumption of one period contracts. With overlapping contracts there exists a tension between eliminating the relative price and the money demand distortion. Optimal policy may still involve sustained deflation at a rate that depends on the interest elasticity of the demand for money. Nevertheless, optimal *price variation* in response to various shocks seems negligible.

Goodfriend and King (2001) undertake a more general analysis of the optimality of price stability that draws on public finance, optimal taxation principles. Observing that the markup acts as a tax on inputs they argue that markup constancy, and hence perfect price stability, is optimal when tax rate constancy is optimal. Abstracting from the monetary distortion, they identify the elasticity of labor as well as the type of the shock as the key factors in this. Nevertheless, they argue that, for commonly employed specifications of preferences, even in cases where optimal policy might depart from markup constancy and price stability (for instance, in the presence of fiscal shocks or of variable labor elasticity), such departures are likely to be minor.

The existing NNS based literature thus makes a very strong case for — perfect — price stability[2], independent of whether fiscal policy is utilized to eliminate the imperfect competition distortion or not. Nevertheless, the generality and practical relevance of this result remains unknown due to an important omission. With no exception, the works mentioned above abstract from investment decisions when studying optimal monetary policy. The inclusion of investment, however, may affect the properties of optimal monetary policy for the reasons emphasized by Goodfriend and King (2001). First, the presence of investment may amplify the response of employment to the shocks, weakening the case for uniform taxation. And second, including an additional aggregate demand component affects both the incentives and the ability of the policymakers to manipulate consumption and employment over the business cycle by manipulating cyclical markups. While Goodfriend and King speculate, based on Chari and Kehoe (1999) who argue that optimal labor income taxes fluctuate little in an RBC model, that price stability would remain optimal in the NNS model even with capital included, this remains still an unverified conjecture[3].

[2] The same arguments can be used to support perfect inflation rather than perfect price targeting if the relative price distortion is eliminated in the steady state. That is, if long term money neutrality is restored. This can be easily accomplished via the "indexation" scheme suggested by Erceg, Henderson and Levin, 1999. See below for details.

[3] There seems also to exist an important difference between the standard tax smoothing argument and that of markup constancy. In the former, both the average tax rate and its variation are optimally selected. In the latter, the steady state tax rate (markup) is exogenous and only its cyclical variation is selected.

Our objective in this paper is to study how the presence of capital accumulation affects the welfare properties of inflation stabilization when the flexible price equilibrium is inefficient. We address this question within the general NNS model in which money is introduced via a transaction cost approach and there exists shocks to technology, government expenditures and the demand for money. The solution uses a second order approximation to the policy functions and the computation of welfare relies on a high order approximation to the utility function. We follow this procedure because Woodford's suggested second order approximation to utility (with linear policy rules) may be inapplicable in this case. We do not attempt to characterize the globally optimal policy (a computationally demanding strategy) but instead restrict ourselves to a simpler but equally valuable task. Namely, to the investigation of whether commonly studied policies that entail substantial price variability, such as a Henderson-McKibbin-Taylor rule with imperfect inflation targeting or M– or R–targeting, outperform perfect price stabilization.

Our main finding is that the presence of investment does not undermine the case for perfect price stabilization. When the monetary friction is negligible (a "cashless" economy) any inflation variability is harmful. And this is true even when the flexible price equilibrium exhibits large inefficiency (large markups) and also independently of the level of capital adjustment costs, the degree of price rigidity, the level of risk aversion and the type of the shock. The same is true when the only distortion present in the model is the monetary one. Only when *both* of these two distortions are present simultaneously, price flexibility is very large (a contract length less of one and a half quarter) and capital adjustment costs are very low can *some* inflation variability prove welfare improving.

What seems to lie behind this result is the fact that the wedge between the natural rate and the efficient level of output is either constant (with the monopolistic distortion) or varies little (with the monetary friction). With little time variation in the gap between the flexible price and the efficient equilibrium, the presence of investment does not induce a quantitatively significant deviation from perfect price stability (as conjectured by Goodfiend and King, 2001, and Woodford, 2000).

The remaining of the paper is organized as follows. Section 1 presents the model economy. Section 2 discusses parameter selection. The main findings are presented n section 3.

1 The model

The setup is the standard NNS model. The economy is populated by a large number of identical infinitely–lived households and consists of two sectors: one producing intermediate goods and the other a final good. The intermediate good is produced with capital and labor and the final good with intermediate goods. The final good is homogeneous and can be used for consumption (private and public) and investment purposes.

1.1 The Household

Household preferences are characterized by the lifetime utility function:[4]

$$E_t \sum_{\tau=0}^{\infty} \beta^{\tau} U\left(C_{t+\tau}, \ell_{t+\tau}\right) \tag{1}$$

where $0 < \beta < 1$ is a constant discount factor, C denotes consumption and ℓ leisure. The utility function, $U\left(C, \ell\right) : \mathbb{R}_{+} \times [0,1] \longrightarrow \mathbb{R}$ is increasing and concave in its arguments.

The household is subject to the following time constraint

$$\ell_t + h_t = 1 \tag{2}$$

where h denotes hours worked. The total time endowment is normalized to unity.

In each and every period, the representative household faces a budget constraint of the form

$$\begin{aligned} B_t + M_t + P_t(C_t + I_t + T_t) + P_t\tau(v_t;\zeta_t)C_t \quad &\leq \quad P_tW_th_t + P_tz_tK_t + \Pi_t + \ldots \\ &\quad +R_{t-1}B_{t-1} + M_{t-1} + N_t \end{aligned} \tag{3}$$

where B_t and M_t are nominal bonds and money acquired during period t, P_t is the nominal price of the final good, R_t is the nominal interest rate, W_t and z_t are the real wage rate and real rental rate of capital. The household owns K_t units of physical capital, makes an additional investment of I_t, consumes C_t and supplies h_t units of labor. It pays lump sum taxes T_t, receives a transfer of money N_t from the government and finally claims the profits, Π_t, earned by the firms. $\tau(v_t;\zeta_t)$ denotes a proportional transaction cost that depends on the household's money–to–nominal consumption ratio

$$v_t = \frac{P_tC_t}{M_t}$$

[4] $E_t(.)$ denotes mathematical conditional expectations. Expectations are conditional on information available at the beginning of period t.

The function $\tau(.)$ is borrowed from Schmidt–Grohe and Uribe, 2002.

$$\tau(v_t;\zeta_t)=\zeta_t\left(Av_t+\frac{B}{v_t}-2\sqrt{AB}\right)$$

ζ_t is a money demand shock whose properties will be defined later. Note however that setting its mean to 1, we recover Schmidt–Grohe and Uribe's specification in the steady state. Letting ζ tend toward zero,[5] we get close to a "cashless" economy.

Capital accumulation is subject to adjustment costs. It follows

$$K_{t+1}=I_t-\frac{\varphi}{2}\left(\frac{I_t}{K_t}-\delta\right)^2K_t+(1-\delta)K_t \tag{4}$$

where $\delta\in[0,1]$ denotes the rate of depreciation and $\varphi\geqslant 0$ is the capital adjustment cost parameter.

The household determines her consumption/savings, money holdings and leisure plans by maximizing utility (1) subject to the time (2), the budget (3) and the capital accumulation (4) constraints.

1.2 Final sector

The final good is produced by combining intermediate goods according to a technology described by the following CES function

$$Y_t=\left(\int_0^1 X_t(i)^\theta \mathrm{d}i\right)^{\frac{1}{\theta}} \tag{5}$$

where $\theta\in(-\infty,1)$. θ determines the elasticity of substitution between the various intermediate goods. The producers in this sector are assumed to behave competitively and to determine their demand for each good, $X_t(i)$, $i\in(0,1)$ by maximizing the static profit equation

$$\max_{\{X_t(i);i\in(0,1)\}} P_tY_t-\int_0^1 P_t(i)X_t(i)\mathrm{d}i \tag{6}$$

subject to (5), where $P_t(i)$ denotes the price of intermediate good i. This yields demand functions of the form:

$$X_t(i)=\left(\frac{P_t(i)}{P_t}\right)^{\frac{1}{\theta-1}}Y_t \tag{7}$$

and the following general price index

$$P_t=\left(\int_0^1 P_t(i)^{\frac{\theta}{\theta-1}}\mathrm{d}i\right)^{\frac{\theta-1}{\theta}} \tag{8}$$

The final good may be used for consumption — private or public — and investment purposes.

[5] In the practical implementation of the model we set $\zeta=$`1e-12`

1.3 Intermediate goods producers

Each firm i, $i \in (0,1)$, produces an intermediate good by means of capital and labor according to a constant returns–to–scale technology, represented by the production function

$$X_t(i) = A_t K_t(i)^{\alpha} h_t(i)^{1-\alpha} \text{ with } \alpha \in (0,1) \tag{9}$$

where $K_t(i)$ and $h_t(i)$ respectively denote the physical capital and the labor input used by firm i in the production process. A_t is an exogenous stationary stochastic technology shock, whose properties will be defined later. Assuming that each firm i operates under perfect competition in the input markets, the firm determines its production plan so as to minimize its total cost

$$\min_{\{K_t(i),h_t(i)\}} P_t W_t h_t(i) + P_t z_t K_t(i)$$

subject to (9). This leads to the following expression for total costs:

$$P_t S_t X_t(i)$$

where the real marginal cost, S, is given by $\frac{W_t^{1-\alpha} z_t^{\alpha}}{\chi A_t}$ with $\chi = \alpha^{\alpha}(1-\alpha)^{1-\alpha}$

Intermediate goods producers are monopolistically competitive, and therefore set prices for the good they produce. We follow Calvo (1983) in assuming that firms set their prices for a stochastic number of periods. In each and every period, a firm either gets the chance to adjust its price (an event occurring with probability γ) or it does not. In order to maintain long term money neutrality (in the absence of monetary frictions) we also assume that the price set by the firm grows at the steady state rate of inflation and therefore have a nominal growth component, Ξ_t. A firm i sets its price, $\widetilde{p}_t(i)$, in period t in order to maximize its discounted profit flow:

$$\max_{\widetilde{p}_t(i)} \widetilde{\Pi}_t(i) + E_t \sum_{\tau=1}^{\infty} \Phi_{t+\tau}(1-\gamma)^{\tau-1} \left(\gamma \widetilde{\Pi}_{t+\tau}(i) + (1-\gamma)\Pi_{t+\tau}(i)\right)$$

subject to the total demand it faces

$$X_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{\frac{1}{\theta-1}} Y_t$$

and where $\widetilde{\Pi}_{t+\tau}(i) = (\widetilde{p}_{t+\tau}(i) - P_{t+\tau}S_{t+\tau})X(i, s^{t+\tau})$ is the profit attained when the price is reset, while $\Pi_{t+\tau}(i) = (\Xi_{t+\tau}\widetilde{p}_t(i) - P_{t+\tau}S_{t+\tau})X_{t+\tau}(i)$ is the profit attained when the price is maintained. $\Phi_{t+\tau}$ is an appropriate discount factor related to the way the household values future as opposed to current consumption. This leads to the price setting equation

$$\widetilde{p}_t(i) = \frac{1}{\theta}\frac{E_t\sum_{\tau=0}^{\infty}(1-\gamma)^\tau \Phi_{t+\tau}\Xi_{t+\tau}^{\frac{1}{\theta-1}}P_{t+\tau}^{\frac{2-\theta}{1-\theta}}S_{t+\tau}Y_{t+\tau}}{E_t\sum_{\tau=0}^{\infty}(1-\gamma)^\tau \Phi_{t+\tau}\Xi_{t+\tau}^{\frac{\theta}{\theta-1}}P_{t+\tau}^{\frac{1}{\theta-1}}Y_{t+\tau}} \tag{10}$$

Since the price setting scheme is independent of any firm specific characteristic, all firms that reset their prices will choose the same price.

In each period, a fraction γ of contracts ends, so there are $\gamma(1-\gamma)$ contracts surviving from period $t-1$, and therefore $\gamma(1-\gamma)^j$ from period $t-j$. Hence, from (8), the aggregate intermediate price index is given by

$$P_t = \left(\sum_{i=0}^{\infty}\gamma(1-\gamma)^i\left(\Xi_{t-i}\widetilde{p}_{t-i}\right)^{\frac{\theta}{\theta-1}}\right)^{\frac{\theta-1}{\theta}} \tag{11}$$

1.4 The monetary authorities

We have mentioned before that our objective is not to characterize the globally optimal policy. But rather to examine whether the case for price stability is undermined by the presence of investment. The simplest way to accomplish this is by examining whether various popular policy rules that allow for "large" deviations from perfect inflation stability outperform perfect inflation targeting. We study four such rules.

(i) Targeting of the growth rate of the money supply:

$$\mu_t = \overline{\mu} \tag{12}$$

The nominal interest rate then adjusts to clear the money market.

(ii) Targeting of the nominal interest rate.[6]

$$R_t = \overline{R} \tag{13}$$

In this case, the money supply adjusts in order to clear the money market.

[6] In order to avoid the well known indeterminacy problems, we have specified this rule as follows in the practical implementation

$$\widehat{R}_t = \rho\widehat{R}_{t-1} + (1-\rho)k_\pi\widehat{\pi}_t \text{ with } \rho = 0.999 \text{ and } k_\pi = 1.001$$

where π_t is the rate of inflation and a ˆ stands for log–deviations from the deterministic steady state.

(iii) Perfect inflation targeting. In this case, we consider a rule à la Henderson-McKibbin-Taylor that takes the form

$$\widehat{R}_t = \kappa_\pi \widehat{\pi}_t \tag{14}$$

Perfect inflation targeting obtains when $\kappa_\pi = \infty$.[7] In this case, as under interest rate targeting, money supply adjusts to clear the money market.

(iv) Imperfect inflation targeting. Under this rule we use a "small" value of κ_π in rule (14). In most of the simulations run involving imperfect inflation targeting we used $\kappa_\pi = 1.5$.

1.5 The government

The government finances government expenditures on the domestic final good using lump sum taxes. The stationary component of government expenditures is assumed to follow an exogenous stochastic process, whose properties are defined below in section 2.

1.6 The equilibrium

We now turn to the description of the equilibrium of the economy.

Definition 1 *An equilibrium of this economy is a sequence of prices* $\{\mathcal{P}_t\}_{t=0}^{\infty} = \{W_t, z_t, P_t, R_t, P_t(i), i \in (0,1)\}_{t=0}^{\infty}$ *and a sequence of quantities* $\{\mathcal{Q}_t\}_{t=0}^{\infty} = \{\{\mathcal{Q}_t^H\}_{t=0}^{\infty}, \{\mathcal{Q}_t^F\}_{t=0}^{\infty}\}$ *with*

$$\begin{aligned}
\{\mathcal{Q}_t^H\}_{t=0}^{\infty} &= \{C_t, I_t, B_t, K_{t+1}, h_t, M_t\} \\
\{\mathcal{Q}_t^H\}_{t=0}^{\infty} &= \{Y_t, X_t(i), K_t(i), h_t(i); i \in (0,1)\}_{t=0}^{\infty}
\end{aligned}$$

such that:

(i) given a sequence of prices $\{\mathcal{P}_t\}_{t=0}^{\infty}$ *and a sequence of shocks,* $\{\mathcal{Q}_t^H\}_{t=0}^{\infty}$ *is a solution to the representative household's problem;*

(ii) given a sequence of prices $\{\mathcal{P}_t\}_{t=0}^{\infty}$ *and a sequence of shocks,* $\{\mathcal{Q}_t^F\}_{t=0}^{\infty}$ *is a solution to the representative firms' problem;*

(iii) given a sequence of quantities $\{\mathcal{Q}_t\}_{t=0}^{\infty}$ *and a sequence of shocks,* $\{\mathcal{P}_t\}_{t=0}^{\infty}$ *clears the*

[7] In our experiments, perfect inflation targeting will be approximated by setting $\kappa_\pi = 10000$. Using greater values for κ_π does not affect our results.

markets

$$
\begin{aligned}
Y_t &= C_t + I_t + G_t && (15)\\
h_t &= \int_0^1 h_t(i)\,di && (16)\\
K_t &= \int_0^1 K_t(i)\,di && (17)\\
G_t &= T_t && (18)
\end{aligned}
$$

and the money market.

(iv) Prices satisfy (10) and (11).

2 Parametrization of the model

The model is parameterized on US quarterly data for the period 1960:1–2000:4. The data are taken from the Federal Reserve Database.[8] The baseline parameters are reported in table 1.

Table 1: Calibration: Benchmark case

Technology		
Capital elasticity of intermediate output	α	0.2500
Capital adjustment costs parameter	φ	10.0000
Depreciation rate	δ	0.0250
Parameter of markup	θ	0.8000
Probability of price resetting	q	0.2500
Preferences		
Discount factor	β	0.9880
Relative risk aversion	σ	1.5000
CES weight in utility function	ν	0.3405
Parameter of transaction cost (linear)	A	0.0111
Parameter of transaction cost (constant)	B	0.0752
Shocks		
Persistence of technology shock	ρ_a	0.9500
Standard deviation of technology shock	σ_a	0.0079
Persistence of government spending shock	ρ_g	0.9696
Volatility of government spending shock	σ_g	0.0098
Persistence of money demand shock	ρ_ζ	0.9500
Volatility of money demand shock	σ_ζ	0.0180

The nominal growth of the economy is set equal to the sample average of the rate of growth of M1 over the period, implying $\overline{\mu} = 2.6\%$ per quarter. The quarterly depreciation

[8] URL: `http://research.stlouisfed.org/fred/`

rate, δ, is 0.025 implying an annual depreciation of about 10%. The value of the capital adjustment cost parameter, φ, is set to 10 in our benchmark experiment. We vary it in our sensitivity analysis from 0.1 to 100. θ in the benchmark case is set such that the level of markup in the steady state is 20%. α, the elasticity of the production function to physical capital, is set such that the model reproduces the US labor share — defined as the ratio of labor compensation to GDP — over the sample period (0.575). $a_t = \log(A_t/\overline{A})$ is assumed to follow a stationary AR(1) process of the form

$$a_t = \rho_a a_{t-1} + \varepsilon_{a,t}$$

with $|\rho_a| < 1$ and $\varepsilon_{a,t} \rightsquigarrow \mathcal{N}(0, \sigma_a^2)$. We set $\sigma_a = 0.0079$ and $\rho_a = 0.95$.

The government spending shock[9] is assumed to follow an AR(1) process

$$\log(g_t) = \rho_g \log(g_{t-1}) + (1 - \rho_g) \log(\overline{g}) + \varepsilon_{g,t}$$

with $|\rho_g| < 1$ and $\varepsilon_{g,t} \sim \mathcal{N}(0, \sigma_g^2)$. Estimating this process over the sample period leads to a persistence parameter, ρ_g, of 0.9696 and a standard deviation of innovations of $\sigma_g = 0.0098$. The government spending to output ratio is set to its observed sample average, 0.22.

The instantaneous utility function takes the form

$$U(C_t, \ell_t) = \frac{1}{1-\sigma}\left[\left(C_t^{\nu}\ell_t^{1-\nu}\right)^{1-\sigma} - 1\right]$$

σ, the coefficient ruling risk aversion, is set equal to 1.5 in the benchmark case. ν is set such that the model generates a total fraction of time devoted to market activities of 31%. β, the discount factor is set such that households discount the future at a 4% annual rate.

The two parameters, A and B, defining the properties of the transaction cost function, are borrowed from Schmidt–Grohe and Uribe (2002). This led us to set A=0.0111 and B=0.0752. The money demand shock also follows an AR(1) process

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

with $|\rho_\zeta| < 1$ and $\varepsilon_{\zeta,t} \sim \mathcal{N}(0, \sigma_\zeta^2)$. We use parameter values estimated by Ireland [2001], namely, $\rho_\zeta = 0.95$ and $\sigma_\zeta = 0.018$. In the cashless economy the average value of ζ is

[9] The logarithm of the government expenditures are first detrended using a linear trend.

set to `1e-12`.[10]. In the non–cashless economy, $\overline{\zeta}$ is set to 1, implying that we recover Schmidt–Grohe and Uribe's specification in this case.

γ, the probability of price resetting is set in the benchmark case at 0.25, implying that the average length of price contracts is 4 quarters.

In the simulations, we vary capital adjustment costs, φ, relative risk aversion σ, the markup θ, the degree of monetary friction, ζ, and the probability of price resetting, γ.

3 The results

The model is solved using a second order perturbation method as described in Sims (1998) and Schmitt–Grohe and Uribe (2001). An attractive feature of this approach is that it breaks the certainty equivalence property that characterizes the standard log–linear approximation. This allows the volatility terms — which do matter for welfare — to enter the decision rules[11]. The method is therefore more likely to deliver accurate welfare results. The level of welfare is computed taking a high order approximation to the utility function.[12] We simulate series for consumption, $\{c_t\}_{t=0}^{T}$, and leisure, $\{\ell_t\}_{t=0}^{T}$, and compute high order moments from the series. These moments are then feeded into the approximation of the utility function in order to compute welfare. Each series has a length T=5000[13] Each experiment is repeated 1000 times and the results are averaged.

Tables 2-17 contain the main results. We examine separately the effects of the two frictions (imperfect competition and monetary) in order to determine their relative contribution to the desirability of inflation variability. The first set of tables (tables 2-9) corresponds to the "cashless" version of the model (ζ =`1e-12`, see section 2). And the second set (tables 10-17) to the case when the monetary distortion is "non–negligible" ($\zeta = 1$, see section 2). We report both volatility and welfare measures for three of the four rules considered under a variety of parameterizations. For the sake of space we have left out the nominal interest rate targeting procedure as it was uniformly and significantly dominated by the other rules.[14]

If the flexible price equilibrium were optimal, then a policy of perfect price stabilization

[10] Considering smaller values of ζ does not affect the results.

[11] Our solution method takes into account the fact that, unlike the case of a log-linear approximation, there is a non-trivial aggregation problem. Namely, that the "Solow residual" type of term that aggregation introduces into the production function is no longer a constant (see Christiano, Evans and Eichnebaum, 2001).

[12] We report results with a 8th order approximation. The results do not differ when we considered higher orders.

[13] Simulating longer series does not affect our welfare ranking.

[14] Results are available from the authors upon request.

that replicated that equilibrium would be optimal also. In our case, the flexible price equilibrium is not efficient because of the existence of the imperfect competition and the monetary distortion (in the non–cashless version of the model). A key question is then whether the monetary authorities can take advantage of price rigidities in order to improve upon the inefficient flexible price allocation. The way to accomplish this is via the cyclical manipulation of markups. However, in our setting, manipulating markups over the business cycle involves a tradeoff. On the one hand, the management of markups could in theory reduce the volatility of consumption, employment and/or bring about a more favorable covariance between these two variables. On the other hand, letting the markups vary carries a cost because it leaves the relative price distortion in place. One cannot tell a priori how the costs and benefits of imperfect price stabilization vary with the degree of price rigidity. The greater the degree of price rigidity the higher the cost of imperfect price targeting, but at the same time, the greater the ability of the monetary authorities to influence markups. The importance of our results precisely lies in their providing information about the net effect of these two opposing factors.

The main pattern that emerges in the "cashless" version of the model (ζ =`1e-12`) is that the presence of investment does not weaken the case for inflation (price) stability. Remarkably, this is independent of all the important parameters of the model; namely, of the type of the shock, the degree of price rigidity (see table 2), the degree of capital adjustment costs (see table 3), the markup (see table 4) and the coefficient of risk aversion (see table 5).

These finding are interesting because one might have thought that the parameters determining the strength of the distortions would have played a major role for the welfare rankings of the monetary policies considered. In particular, one may have presumed that the greater the inefficiency of the flexible price economy (the lower the θ), the weaker the incentive to replicate the flexible price equilibrium would have been. Similarly, one may have thought that price stability would lose its appeal if the relative price distortion were small. Apparently, our results suggest that, as prices become more flexible, the ability to manipulate markups decreases faster than the cost of the relative price distortion.

We now investigate the role of investment and capital adjustment costs in the ranking of alternative policies. Indeed, this issue, although raised in several papers (see Goodfriend and King (2001)), has not been addressed quantitatively. The general validity of perfect price stabilization remains uncertain. As can be seen from table 3, the presence of investment weakens — but does not undermine — the case for price stability. As adjustment costs increase, the welfare difference between perfect and imperfect inflation targeting becomes larger. This finding confirms Goodfriend and King's (2001) conjecture on the effect of investment fluctuations on optimal markups. Goodfriend and King argue that, while substantial investment volatility increases the monetary authority's incentive to stabilize employment–consumption by manipulating cyclical markups, which would actually strengthen the case for perfect price stabilization, it opens at the same time an intertemporal smoothing channel for the households that makes it more difficult for the central bank to produce transitory variations in consumption via markup manipulation. Hence, although its case is somewhat weakened, price stabilization is still worth pursuing.

The results differ somewhat when we consider the version of the model that also allows for a "non-negligible" monetary distortion ($\zeta = 1$). Perfect inflation stabilization still outperforms rules that do not target inflation directly (such as M– and R–targeting) independent of the shock, the degree of price rigidity (see table 10), the imperfect competition distortion (see table 12) and so on. But it may fare worse relative to an imperfect inflation targeting rule when prices are relatively *flexible*, even when such rules tolerate a substantial degree of inflation volatility (table 10). For instance, the rule given by equation 14 ($k_\pi = 1.5$) dominates perfect inflation stabilization under supply shocks when capital adjustment costs are low (say, $\varphi = 0.1$), prices are set for — approximately — one and a half quarters (or less) and the remaining parameter values correspond to the benchmark case. Note, that in this case the standard deviation of inflation is 0.19[15]. For perfect inflation stability to be dominated by imperfect inflation targeting, it is important that both distortions are in place and that they are also significant. That is, this result arises from the interaction of the two frictions. For instance, having a large monetary distortion alongside a negligible imperfect competition is not sufficient to undermine the supremacy of perfect stabilization.

A caveat is in order. It should not be forgotten that the practical relevance of large fluctuations in the inflation rate is limited when prices are relatively flexible (unless the monetary distortion is quantitatively very large, which seems rather unlikely). This is due to the fact that, in this case, money does not matter much for real economic activity and hence the welfare differences across different policy rules are negligible. Consequently, our view is that one should not see the results as significantly weakening the case for perfect price stability in the NNS model.

What is the explanation for these findings? We think that the reason that both distortions are needed in order for some inflation variability to be desirable is related to the

[15] In order to get a feeling of how large this volatility is, note that the corresponding standard deviation of inflation under M–Targeting is 0.68.

behavior of the gap between the natural rate and the efficient equilibrium. This wedge is constant with the monopolistic distortion but variable with the monetary friction. Nevertheless, as the time variation in this wedge is quite limited due to the small role played by real balances for economic activity in models such as hours, the deviation from perfect price stability is not quantitatively significant even in the presence of investment (as conjectured by Goodfiend and King, 2001, and Woodford, 2000).

4 Conclusions

The modern NNS literature has presented a very strong case for perfect price (inflation) stabilization. Nevertheless, the general applicability of this result has remained unknown because of the exclusion of investment from the models that have been used to analyze optimal monetary policy. The present paper has confirmed and extended Goodfriend and King's (2001) conjecture that the inclusion of capital accumulation might not by itself undermine the case for price (inflation) stabilization.

We have shown that this conjecture is valid independent of the values of the key parameters of the model (the degree of price rigidity, the size of mark ups, the size of capital adjustment costs and the degree of risk aversion). The intuition for this result is that our model exhibits limited variation in the gap between the natural and the efficient level of output. In particular, the monopolistic distortion induces a constant wedge between these two quantities while the monetary friction's influence on that wedge is weak. As a result, in the presence of both the monopolistic competition and the monetary distortion, a policy of imperfect inflation targeting that tolerates a small amount of inflation variability is preferable when the degree of price rigidity is very low and capital adjustment costs are not too high. But in this case, such a deviation from perfect price stability is of rather small welfare value.

An important and yet relatively unexplored question is whether and by *how much* the case for strict price stability is undermined when there exists substantial time variation in the degree of inefficiency of the flexible-price equilibrium. For instance, when there is significant variation in the level of distorting taxes, in the degree of market power of firms or workers and so on. And how the presence of investment might strengthen or weaken the case for price stability under such circumstances. We are currently exploring this issue.

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A Second–order Perturbation Method: A brief summary

In this section, we provide a short description of the model solution. Further details can be found in Schmitt–Grohé and Uribe (2001). Our model may be written as

$$E_t F(y_{t+1}, y_t, x_{t+1}, x_t) = 0$$

where x_t denotes the $(n_x \times 1)$ state vector x_t and y_t is a $(n_y \times 1)$ containing all co–state and measurement variables. Therefore, $F : \mathbb{R}^{n_y} \times \mathbb{R}^{n_y} \times \mathbb{R}^{n_x} \times \mathbb{R}^{n_x} \longrightarrow \mathbb{R}^n$ denotes the model. The total number of variables is given by $n = n_x + n_y$. We assume that the state vector may be partitioned as $x_t = [x_t^1; x_t^2]$, where x^1 consists of endogenous state variables, whereas x^2 consists of exogenous state variables. In order to simplify, let us assume that x^2 follows the process

$$x_{t+1}^2 = M x_t^2 + \eta \Sigma \varepsilon_{t+1}$$

where ε_{t+1} is $(n_\varepsilon \times 1)$ and is distributed as a $\mathcal{N}(0, I)$. All eigenvalues of M are assumed to have modulus less than one.

The solution to this model is of the form:

$$y_t = g(x_t, \eta) \tag{19}$$

$$x_{t+1} = h(x_t, \eta) + \eta \Omega \varepsilon_{t+1} \text{ with } \Omega = \begin{pmatrix} 0 \\ \Sigma \end{pmatrix} \tag{20}$$

where g maps $\mathbb{R}^{n_x} \times \mathbb{R}_+$ into $\mathbb{R}^{n_y}$ and h maps $\mathbb{R}^{n_x} \times \mathbb{R}_+$ into $\mathbb{R}^{n_x}$. Making use of the solution, the model can be rewritten as (a prime denotes $t + 1$)

$$E_t \mathcal{F}(x, \eta) = 0$$

where

$$\mathcal{F}(x, \eta) \equiv F\left(g\left(h(x, \eta) + \eta \Omega \varepsilon', \eta\right), g(x, \eta), h(x, \eta) + \eta \Omega \varepsilon', x\right)$$

Since neither $g(.)$ nor $h(.)$ can be computed analytically, we take advantage of their properties to infer the properties of their slopes and curvatures. The second–order approximation is given by

$$\begin{aligned} E_t \mathcal{F}^i(x, \eta) \simeq\ & E_t\Bigg(\mathcal{F}^i(x^\star, 0) + \nabla_x \mathcal{F}^i(x^\star, 0)(x - x^\star) + \nabla_\eta \mathcal{F}^i(x^\star, 0)\eta \\ & + \frac{1}{2}(x - x^\star, \eta)\mathcal{H}_{\mathcal{F}}^i \begin{pmatrix} x - x^\star \\ \eta \end{pmatrix}\Bigg) = 0 \end{aligned}$$

for all $i = 1 \ldots, n$.

The constant terms,$g(x^\star, 0)$ and $h(x^\star, 0)$, correspond to the deterministic steady state of the model. The first order terms ($g_x(x^\star, 0)$ and $h_x(x^\star, 0)$) can be obtained by solving a matrix polynomial equation and imposing the requirement that the system returns asymptotically to equilibrium in the absence of other future shocks. This essentially amounts to solving a linear RE model, so any method of the Blanchard and Kahn (1980) type can be used. Furthermore, Schmitt–Grohé and Uribe (2001) show that both $g_\eta(x^\star, 0)$ and $h_\eta(x^\star, 0)$ are zero. The second order terms, $g_{xx}(x^\star, 0)$ and $h_{xx}(x^\star, 0)$, can be obtained by solving a linear system and the same procedure applies to $g_{\eta\eta}(x^\star, 0)$ and $h_{\eta\eta}(x^\star, 0)$. As both $g_{x\eta}(x^\star, 0)$ and $h_{x\eta}(x^\star, 0)$ are zero the approximated decision rule, used to simulate the model, take the form

$$g(x^\star, 0) + g_x(x^\star, 0)(x_t - x^\star) + \frac{1}{2}(x_t - x^\star)' g_{xx}(x^\star, 0)(x_t - x^\star) + \frac{1}{2} g_{\eta\eta}(x^\star, 0)\eta^2$$
$$h(x^\star, 0) + h_x(x^\star, 0)(x_t - x^\star) + \frac{1}{2}(x_t - x^\star)' h_{xx}(x^\star, 0)(x_t - x^\star) + \frac{1}{2} h_{\eta\eta}(x^\star, 0)\eta^2$$

Table 2: The role of price rigidity (Cashless economy, φ=10, σ=1.5, θ=0.80)

		M–Targeting				Pπ–Targeting				Iπ–Targeting			
γ	Shock	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W
	Supply	1.14	0.38	0.19	-53.36180671	1.32	0.12	0.11	-53.34710932	1.30	0.13	0.13	-53.35038293
0.25	Fiscal	0.19	0.26	0.04	-53.35508896	0.22	0.23	0.05	-53.35445311	0.21	0.23	0.05	-53.35460250
	Money	0.21	0.26	-0.05	-53.35132923	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355
	Supply	1.26	0.20	0.15	-53.35209959	1.32	0.12	0.11	-53.34710931	1.31	0.12	0.11	-53.34764236
0.50	Fiscal	0.21	0.24	0.05	-53.35467123	0.22	0.23	0.05	-53.35445311	0.22	0.23	0.05	-53.35447768
	Money	0.09	0.12	-0.01	-53.34769641	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355
	Supply	1.30	0.13	0.13	-53.34868186	1.32	0.12	0.11	-53.34710930	1.32	0.12	0.11	-53.34722727
0.75	Fiscal	0.21	0.23	0.05	-53.35452195	0.22	0.23	0.05	-53.35445311	0.22	0.23	0.05	-53.35445855
	Money	0.04	0.04	-0.00	-53.34629720	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355
	Supply	1.32	0.12	0.11	-53.34710973	1.32	0.12	0.11	-53.34710930	1.32	0.12	0.11	-53.34710933
1	Fiscal	0.22	0.23	0.05	-53.35445313	0.22	0.23	0.05	-53.35445311	0.22	0.23	0.05	-53.35445311
	Money	0.00	0.00	-0.00	-53.34562374	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect (k_π = 1.5) inflation stabilization respectively.

Table 3: The role of capital adjustment costs (Cashless economy, γ=0.25, σ=1.5, θ=0.80)

		M–Targeting				Pπ–Targeting				Iπ–Targeting			
φ	Shock	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W
	Supply	1.20	0.87	0.04	-53.37083476	1.42	0.25	0.06	-53.33712271	1.47	0.33	0.01	-53.33950193
0.1	Fiscal	0.16	0.39	0.03	-53.35719414	0.22	0.23	0.05	-53.35444010	0.21	0.23	0.05	-53.35458336
	Money	0.34	1.07	-0.26	-53.38272545	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355
	Supply	1.14	0.38	0.19	-53.36180671	1.32	0.12	0.11	-53.34710932	1.30	0.13	0.13	-53.35038293
10	Fiscal	0.19	0.26	0.04	-53.35508896	0.22	0.23	0.05	-53.35445311	0.21	0.23	0.05	-53.35460250
	Money	0.21	0.26	-0.05	-53.35132923	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355
	Supply	1.05	0.44	0.29	-53.37393704	1.24	0.20	0.24	-53.36057374	1.19	0.24	0.28	-53.36706358
100	Fiscal	0.19	0.25	0.04	-53.35496010	0.21	0.23	0.05	-53.35446832	0.21	0.23	0.05	-53.35461978
	Money	0.21	0.16	-0.03	-53.34979830	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect (k_π = 1.5) inflation stabilization respectively.

Table 4: The role of the markup (Cashless economy, γ=0.25, σ=1.5, φ=10)

		M–Targeting				Pπ–Targeting				Iπ–Targeting			
θ	Shock	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W
	Supply	0.54	0.33	0.11	-79.18432017	0.65	0.12	0.08	-79.17664530	0.62	0.16	0.10	-79.18003755
0.6	Fiscal	0.06	0.22	0.01	-79.17825057	0.07	0.20	0.02	-79.17808366	0.07	0.21	0.01	-79.17813046
	Money	0.13	0.15	-0.02	-79.17225734	0.00	0.00	-0.00	-79.16985384	0.00	0.00	-0.00	-79.16985384
	Supply	0.74	0.35	0.13	-68.40581093	0.87	0.11	0.08	-68.39499567	0.85	0.13	0.10	-68.39821180
0.7	Fiscal	0.10	0.24	0.02	-68.40025033	0.12	0.22	0.03	-68.39990536	0.12	0.22	0.03	-68.39999362
	Money	0.15	0.20	-0.03	-68.39489251	0.00	0.00	-0.00	-68.39130669	0.00	0.00	-0.00	-68.39130669
	Supply	1.14	0.38	0.19	-53.36180671	1.32	0.12	0.11	-53.34710932	1.30	0.13	0.13	-53.35038293
0.8	Fiscal	0.19	0.26	0.04	-53.35508896	0.22	0.23	0.05	-53.35445311	0.21	0.23	0.05	-53.35460250
	Money	0.21	0.26	-0.05	-53.35132923	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355
	Supply	1.86	0.41	0.29	-38.69599622	2.10	0.14	0.17	-38.67123608	2.08	0.15	0.19	-38.67595596
0.9	Fiscal	0.34	0.29	0.08	-38.68153489	0.39	0.24	0.09	-38.68018628	0.38	0.24	0.09	-38.68050856
	Money	0.32	0.31	-0.09	-38.68238837	0.00	0.00	-0.00	-38.67106504	0.00	0.00	-0.00	-38.67106504

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect (k_π = 1.5) inflation stabilization respectively.

Table 5: The role of risk aversion (Cashless economy, γ=0.25, φ=10, θ=0.80)

		M–Targeting				Pπ–Targeting				Iπ–Targeting			
σ	Shock	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W
	Supply	1.12	0.37	0.22	-40.41568697	1.30	0.13	0.14	-40.40892523	1.28	0.14	0.16	-40.41008393
0.5	Fiscal	0.18	0.27	0.05	-40.41607274	0.21	0.24	0.05	-40.41582511	0.21	0.24	0.05	-40.41585544
	Money	0.19	0.24	-0.04	-40.41402406	0.00	0.00	-0.00	-40.41109363	0.00	0.00	-0.00	-40.41109363
	Supply	1.14	0.38	0.19	-53.36180671	1.32	0.12	0.11	-53.34710932	1.30	0.13	0.13	-53.35038293
1.5	Fiscal	0.19	0.26	0.04	-53.35508896	0.22	0.23	0.05	-53.35445311	0.21	0.23	0.05	-53.35460250
	Money	0.21	0.26	-0.05	-53.35132923	0.00	0.00	-0.00	-53.34562355	0.00	0.00	-0.00	-53.34562355
	Supply	1.19	0.40	0.12	-100.37492926	1.36	0.10	0.07	-100.31509840	1.34	0.12	0.09	-100.33297311
3.5	Fiscal	0.20	0.26	0.04	-100.31851875	0.23	0.21	0.05	-100.31544652	0.23	0.22	0.05	-100.31661797
	Money	0.25	0.27	-0.07	-100.30632317	0.00	0.00	-0.00	-100.28612487	0.00	0.00	-0.00	-100.28612487

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect (k_π = 1.5) inflation stabilization respectively.

Table 6: Price rigidity and inflation volatility (Cashless economy, φ=10, σ=1.5, θ=0.80)

γ	Shock	M–Targeting	Pπ–Targeting	Iπ–Targeting
0.25	Supply	0.3413	0.0000	0.2004
	Fiscal	0.0606	0.0000	0.0407
	Money	0.2183	0.0000	0.0000
0.50	Supply	0.5440	0.0000	0.1996
	Fiscal	0.0975	0.0000	0.0407
	Money	0.3639	0.0000	0.0000
0.75	Supply	0.6982	0.0000	0.1994
	Fiscal	0.1254	0.0000	0.0407
	Money	0.4738	0.0000	0.0000
1	Supply	0.8095	0.0000	0.1994
	Fiscal	0.1456	0.0000	0.0407
	Money	0.5528	0.0000	0.0000

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 7: Capital adjustment costs and inflation volatility (Cashless economy, γ=0.25, σ=1.5, θ=0.80)

φ	Shock	M–Targeting	Pπ–Targeting	Iπ–Targeting
0.1	Supply	0.3258	0.0000	0.2020
	Fiscal	0.0788	0.0000	0.0397
	Money	0.3000	0.0000	0.0000
10	Supply	0.3413	0.0000	0.2004
	Fiscal	0.0606	0.0000	0.0407
	Money	0.2183	0.0000	0.0000
100	Supply	0.3749	0.0000	0.2979
	Fiscal	0.0577	0.0000	0.0416
	Money	0.2029	0.0000	0.0000

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

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Table 8: The markup and inflation volatility (Cashless economy, γ=0.25, φ=10, σ=1.5)

θ	Shock	M–Targeting	Pπ–Targeting	Iπ–Targeting
0.6	Supply	0.3164	0.0000	0.2747
	Fiscal	0.0331	0.0000	0.0271
	Money	0.1879	0.0000	0.0000
0.7	Supply	0.3313	0.0000	0.2367
	Fiscal	0.0469	0.0000	0.0354
	Money	0.2016	0.0000	0.0000
0.8	Supply	0.3413	0.0000	0.2004
	Fiscal	0.0606	0.0000	0.0407
	Money	0.2183	0.0000	0.0000
0.9	Supply	0.3482	0.0000	0.1698
	Fiscal	0.0743	0.0000	0.0441
	Money	0.2365	0.0000	0.0000

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 9: Risk aversion and inflation volatility (Cashless economy, γ=0.25, φ=10, θ=0.80)

σ	Shock	M–Targeting	Pπ–Targeting	Iπ–Targeting
0.5	Supply	0.3111	0.0000	0.1567
	Fiscal	0.0497	0.0000	0.0225
	Money	0.2095	0.0000	0.0000
1.5	Supply	0.3413	0.0000	0.2004
	Fiscal	0.0606	0.0000	0.0407
	Money	0.2183	0.0000	0.0000
3.5	Supply	0.3841	0.0000	0.2678
	Fiscal	0.0761	0.0000	0.0678
	Money	0.2310	0.0000	0.0000

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 10: The role of nominal rigidity (φ=10, σ=1.5, $\zeta = 1$, θ=0.80)

		M–Targeting				Pπ–Targeting				Iπ–Targeting			
γ	Shock	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W
	Supply	1.15	0.37	0.19	-53.56099016	1.33	0.11	0.11	-53.54700273	1.32	0.12	0.12	-53.55000215
0.25	Fiscal	0.19	0.26	0.04	-53.55506585	0.22	0.23	0.05	-53.55448700	0.22	0.23	0.05	-53.55462893
	Money	0.10	0.11	-0.01	-53.54675920	0.00	0.00	-0.00	-53.54565595	0.00	0.00	-0.00	-53.54565605
	Supply	1.26	0.19	0.15	-53.55185073	1.33	0.11	0.11	-53.54700272	1.34	0.11	0.10	-53.54733192
0.50	Fiscal	0.21	0.24	0.05	-53.55468831	0.22	0.23	0.05	-53.55448700	0.22	0.23	0.05	-53.55450706
	Money	0.04	0.05	-0.00	-53.54604404	0.00	0.00	-0.00	-53.54565595	0.00	0.00	-0.00	-53.54565600
	Supply	1.30	0.13	0.12	-53.54861611	1.33	0.11	0.11	-53.54700272	1.34	0.11	0.10	-53.54692744
0.75	Fiscal	0.21	0.23	0.05	-53.55455291	0.22	0.23	0.05	-53.55448700	0.22	0.23	0.05	-53.55448839
	Money	0.02	0.02	-0.00	-53.54577016	0.00	0.00	-0.00	-53.54565595	0.00	0.00	-0.00	-53.54565600
	Supply	1.32	0.11	0.11	-53.54712557	1.33	0.11	0.11	-53.54700272	1.34	0.11	0.10	-53.54681252
1	Fiscal	0.22	0.23	0.05	-53.55449043	0.22	0.23	0.05	-53.55448700	0.22	0.23	0.05	-53.55448308
	Money	0.00	0.00	-0.00	-53.54563947	0.00	0.00	-0.00	-53.54565595	0.00	0.00	-0.00	-53.54565599

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 11: The role of capital adjustment costs (ζ=1,γ=0.25, σ=1.5, $\theta = 0.8$)

		M–Targeting				Pπ–Targeting				Iπ–Targeting			
φ	Shock	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W
	Supply	1.20	0.78	0.07	-53.56654161	1.42	0.25	0.05	-53.53695306	1.49	0.32	0.00	-53.53909785
0.1	Fiscal	0.16	0.35	0.03	-53.55658360	0.22	0.23	0.05	-53.55447380	0.22	0.23	0.05	-53.55460941
	Money	0.14	0.43	-0.04	-53.55146752	0.00	0.00	-0.00	-53.54565589	0.00	0.00	-0.00	-53.54565597
	Supply	1.15	0.37	0.19	-53.56099016	1.33	0.11	0.11	-53.54700273	1.32	0.12	0.12	-53.55000215
10	Fiscal	0.19	0.26	0.04	-53.55506585	0.22	0.23	0.05	-53.55448700	0.22	0.23	0.05	-53.55462893
	Money	0.10	0.11	-0.01	-53.54675920	0.00	0.00	-0.00	-53.54565595	0.00	0.00	-0.00	-53.54565605
	Supply	1.06	0.43	0.29	-53.57300442	1.25	0.19	0.24	-53.56051818	1.23	0.22	0.26	-53.56648970
100	Fiscal	0.19	0.25	0.04	-53.55495568	0.22	0.23	0.05	-53.55450242	0.21	0.23	0.05	-53.55464646
	Money	0.09	0.07	-0.01	-53.54646964	0.00	0.00	-0.00	-53.54565602	0.00	0.00	-0.00	-53.54565611

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 12: The role of the markup ($\gamma = 0.25$, φ=10, σ=1.5, ζ=1)

		M–Targeting				Pπ–Targeting				Iπ–Targeting			
θ	Shock	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W
	Supply	0.54	0.32	0.11	-79.60026588	0.66	0.11	0.07	-79.59280418	0.64	0.14	0.09	-79.59575273
0.6	Fiscal	0.07	0.22	0.01	-79.59460674	0.08	0.20	0.02	-79.59444985	0.07	0.21	0.02	-79.59449196
	Money	0.06	0.07	-0.00	-79.58667371	0.00	0.00	-0.00	-79.58620251	0.00	0.00	-0.00	-79.58620254
	Supply	0.74	0.34	0.13	-68.73309092	0.88	0.10	0.08	-68.72270254	0.87	0.12	0.09	-68.72555948
0.7	Fiscal	0.11	0.24	0.02	-68.72810805	0.12	0.22	0.03	-68.72778831	0.12	0.22	0.03	-68.72787016
	Money	0.07	0.09	-0.01	-68.71988140	0.00	0.00	-0.00	-68.71917939	0.00	0.00	-0.00	-68.71917946
	Supply	1.15	0.37	0.19	-53.56099016	1.33	0.11	0.11	-53.54700273	1.32	0.12	0.12	-53.55000215
0.8	Fiscal	0.19	0.26	0.04	-53.55506585	0.22	0.23	0.05	-53.55448700	0.22	0.23	0.05	-53.55462893
	Money	0.10	0.11	-0.01	-53.54675920	0.00	0.00	-0.00	-53.54565595	0.00	0.00	-0.00	-53.54565605
	Supply	1.86	0.40	0.29	-38.76946845	2.11	0.14	0.16	-38.74602404	2.11	0.14	0.17	-38.75050408
0.9	Fiscal	0.34	0.28	0.08	-38.75628585	0.39	0.24	0.09	-38.75508231	0.39	0.24	0.09	-38.75539362
	Money	0.14	0.14	-0.02	-38.74813138	0.00	0.00	-0.00	-38.74596854	0.00	0.00	-0.00	-38.74596865

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 13: The role of risk aversion (γ=0.25, φ=10, $\zeta = 1$, θ=0.80)

		M–Targeting				Pπ–Targeting				Iπ–Targeting			
σ	Shock	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W	σ_c	σ_ℓ	$\sigma_{c\ell}$	W
	Supply	1.12	0.38	0.22	-40.53072797	1.30	0.13	0.14	-40.52351523	1.29	0.13	0.15	-40.52454750
0.5	Fiscal	0.18	0.27	0.04	-40.53078794	0.21	0.24	0.05	-40.53050448	0.21	0.24	0.05	-40.53053269
	Money	0.09	0.11	-0.01	-40.52636275	0.00	0.00	-0.00	-40.52577935	0.00	0.00	-0.00	-40.52577940
	Supply	1.15	0.37	0.19	-53.56099016	1.33	0.11	0.11	-53.54700273	1.32	0.12	0.12	-53.55000215
1.5	Fiscal	0.19	0.26	0.04	-53.55506585	0.22	0.23	0.05	-53.55448700	0.22	0.23	0.05	-53.55462893
	Money	0.10	0.11	-0.01	-53.54675920	0.00	0.00	-0.00	-53.54565595	0.00	0.00	-0.00	-53.54565605
	Supply	1.20	0.35	0.14	-100.97247717	1.37	0.10	0.06	-100.92332210	1.37	0.11	0.07	-100.94005631
3.5	Fiscal	0.21	0.24	0.04	-100.92621751	0.24	0.21	0.05	-100.92405814	0.23	0.21	0.05	-100.92517909
	Money	0.11	0.12	-0.01	-100.89839200	0.00	0.00	-0.00	-100.89465577	0.00	0.00	-0.00	-100.89465611

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 14: Price rigidity and inflation volatility (φ=10, $\zeta = 1$,θ=0.80)

γ	Shock	M–Targeting	Pπ–Targeting	Iπ–Targeting
0.25	Supply	0.3326	0.0000	0.1992
	Fiscal	0.0572	0.0000	0.0404
	Money	0.0964	0.0000	0.0004
0.50	Supply	0.5312	0.0000	0.1984
	Fiscal	0.0920	0.0000	0.0404
	Money	0.1610	0.0000	0.0004
0.75	Supply	0.6828	0.0000	0.1983
	Fiscal	0.1185	0.0000	0.0404
	Money	0.2100	0.0000	0.0004
1	Supply	0.7927	0.0000	0.1983
	Fiscal	0.1377	0.0000	0.0404
	Money	0.2454	0.0000	0.0004

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 15: Capital adjustment costs and inflation volatility (γ=0.25, σ=1.5, $\zeta = 1$,θ=0.80)

φ	Shock	M–Targeting	Pπ–Targeting	Iπ–Targeting
0.1	Supply	0.3211	0.0000	0.2019
	Fiscal	0.0723	0.0000	0.0394
	Money	0.1286	0.0000	0.0003
10	Supply	0.3326	0.0000	0.1992
	Fiscal	0.0572	0.0000	0.0404
	Money	0.0964	0.0000	0.0004
100	Supply	0.3616	0.0000	0.2950
	Fiscal	0.0546	0.0000	0.0413
	Money	0.0902	0.0000	0.0004

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 16: The markup and inflation volatility (γ=0.25, $\zeta = 1$, σ=1.5, φ=10)

θ	Shock	M–Targeting	Pπ–Targeting	Iπ–Targeting
	Supply	0.3057	0.0000	0.2733
0.6	Fiscal	0.0310	0.0000	0.0270
	Money	0.0836	0.0000	0.0003
	Supply	0.3217	0.0000	0.2352
0.7	Fiscal	0.0442	0.0000	0.0352
	Money	0.0895	0.0000	0.0004
	Supply	0.3326	0.0000	0.1992
0.8	Fiscal	0.0572	0.0000	0.0404
	Money	0.0964	0.0000	0.0004
	Supply	0.3404	0.0000	0.1690
0.9	Fiscal	0.0700	0.0000	0.0438
	Money	0.1038	0.0000	0.0004

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.

Table 17: Risk aversion and inflation volatility (γ=0.25, ζ=1, φ=10, θ=0.80)

σ	Shock	M–Targeting	Pπ–Targeting	Iπ–Targeting
	Supply	0.3206	0.0000	0.1551
0.5	Fiscal	0.0536	0.0000	0.0222
	Money	0.0934	0.0000	0.0003
	Supply	0.3326	0.0000	0.1992
1.5	Fiscal	0.0572	0.0000	0.0404
	Money	0.0964	0.0000	0.0004
	Supply	0.3475	0.0000	0.2672
3.5	Fiscal	0.0615	0.0000	0.0675
	Money	0.1007	0.0000	0.0004

Pπ–Targeting and Iπ–Targeting correspond to perfect and imperfect ($k_\pi = 1.5$) inflation stabilization respectively.