The Cyclical Behavior of the Markups in the New Keynesian Models

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June 2015

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Abstract

Different methods have been used in the literature to mesure and analyze price markup cyclical behavior. We use a medium-scale DSGE Model with positive trend inflation, in which aggregate fluctuations are driven by neutral technology, MEI and monetary policy shocks and, where both price and wage markups vary. We find that when raising trend inflation from 0 to 4 percent, wage markup is more important than price markup in explaining the dynamics effects of shocks. Thus, the interactions between positive trend inflation and MEI shock have greater cyclical effects on wage markup than on price markup. These results put into question the focus on the price markup cyclicality in the literature which ignore the implications of trend inflation.

JEL classification: E31, E32.

Keywords: Markups, cyclicality, New Keynesian Models.

*I am grateful to my supervisor Louis Phaneuf for his kind advises

1 Introduction

Nominal price and wage rigidities are an important component of medium-scale DSGE models, with price and wage markups playing possibly a key role of the propagation mechanism. Measuring markups and estimating their cyclicality is one of the more challenging issues in modern dynamic macroeconomics literature.

Different methods [1] have been used to examine price markup cyclicality and its role for explaining the dynamic effects of shocks in the New Keynesian Models, with mixed results. Most of the papers have tended to find procyclical or acyclical price markup(Domowitz, Hubbard and Petersen, 1986; Haskel, Martin and Small, 1995; Morrison, 1994; Chirinko and Fazzari, 1994; Nekarda and Ramey, 2013). The others, however, find evidence supporting countercyclical price markup (Bils, 1987; Rotemberg and Woodford, 1999). In support of this evidence, modern theories predict that price markup should move in opposite directions in response to supply and demand shocks. This result is behind the stylized facts that are at the foundation of modern New Keynesian models (Erceg, Henderson and Levin, 2000; Smets and Wouters, 2003, 2007; Christiano, Eichenbaum and Evans, 2005).

Accordingly, in light of existing mixed results, Blanchard (2008) argues that : "How markups move, in response to what, and why, is however nearly terra incognita for macro. We have a number of theories. ... Some of these theories imply pro-cyclical markups, so that an increase in output leads to a larger increase in the desired price, and thus to more pressure on inflation. Some imply, however, counter-cyclical markups, with the opposite implication. ..... But we are a long way from having either a clear picture or convincing theories and this is clearly an area where research is urgently needed."

The literature on price markup[2] shows that it plays an important role for explaining the dynamic effects of shocks. Most of the work consider the framework where only price markup varies i.e a sticky price model with imperfect competition (Rotemberg, 1982). It's clear that with sticky prices, the price markup varies in response to shocks and that the wage markup varies with sticky wages. Our main question is what happen if both price and wage markups vary, assuming a non-zero steady state inflation?

[1] Nekarda and Ramey (2013) have surveyed four methods.

[2] To our knowledge, the literature on the identification of wage markup cyclicality is not available. The only exception is the seminal paper by Gali, Gertler and Lopez-Salido (2007).

To answer this question, we analyze price and wage markups cyclicality using an extended medium-scale DSGE model. Specifically, we aim to document the determinants of price and wage markups cyclicality in the presence of a positive trend inflation.

The proposed theoretical framework is inspired by Ascari, Phaneuf and Sims (2015) which builds upon earlier work by Christiano, Eichenbaum and Evans (2005). They extended this model along four important dimensions. First, they incorporate non-zero steady-state inflation. Second, they added real per capita output growth originating from two distinct sources of growth : trend growth in investment-specific technology (IST) and in neutral technology. Third, consistent with Justiniano, Primiceri and Tambalotti (2011), they assume that MEI shocks are the only investment shocks affecting the business cycle. Fourth, they added a roundabout production structure in the spirit of Basu (1995) and Huang, Liu and Phaneuf (2004).

They use this framework to address two main issues. First, the welfare costs of moderate trend inflation. Second, whether moderate trend inflation alters the business-cycle properties of a medium-scale macro model in non trivial ways.

We use the same class of model to assess how positive trend inflation affects the responses of price and wage markups cyclical behavior in explaining the dynamics effects of shocks.

Our main interest is to document sources of price and wage markups cyclicality in the presence of a non-zero steady-state inflation.

The baseline model nests a variety of different specifications of the New Keynesian Models, such as sticky price, sticky wage, and sticky price and sticky wage Model. In each case, alternative dimensions have been considered. Altogether, twelve stylized models have been analyzed in responses to neutral technology, MEI and monetary shocks.

We compare contemporaneous cross-correlations between markups (price and wage) and real output conditional to TFP, MEI and monetary shocks. We use first difference and HP filters, and set trend inflation to 0 and 4 percent. We find the following main results in our baseline model.

First, we find that when both wage and price markups vary, the wage markup is more important than the price markup for explaning the dynamics effects of shocks in the presence of non-zero steady-state inflation.

When raising trend inflation from 0 to 4 percent, wage markups change substantially from countercyclical to procyclical in responses to MEI shock[3], with significant increases in magnitude[4]. However, price markups remain either procyclical or countercyclical in responses to TFP and monetary shocks respectively (Bils, 1987; Rotemberg and Woodford, 1999; Nekarda and Ramey, 2013), with negligeable impact in magnitude. Thus, wage markup is more important than the price markup when positive trend inflation is considered.

Our results complement and qualify those of Ascari, Phaneuf and Sims (2015). These authors find that under zero trend inflation, the steady-state wage and price markups equal 1.2 percent. With a trend inflation of 3.52 percent, the price markup is only slightly higher at 1.201, while the wage markup is much higher at 1.28.

Second, The interactions between positive trend inflation and MEI shock is more important than the interaction with TFP shock, and have greater cyclical effects on wage markup than on price markup. This result is consistent with what is available in the literature as reported by Ascari, Phaneuf and Sims (2015).

The contribution of this paper is to document the determinants of price and wage markups cyclicality, using a medium-scale New Keynesian model with non-zero steady-state inflation.

The remainder of the paper proceeds as follows. In Section 2, we outline our baseline model specification. In Section 3, we discuss the calibration of the structural parameters.We present results in Section 4, and we conclude in Section 5.

[3]if first difference filter is considered
[4]if HP filter is considered, conditional to TFP and MEI shocks

2 Theoretical Framework

In this section, we outline our baseline model specification. More details on it description and on the inclusion of positive trend inflation, trend growth and roundabout production structure can be found in Ascari, Phaneuf and Sims (2015).

2.1 Firms and Price setting

2.1.1 Final Goods Producers

There are a continuum of firms, indexed by $j \in (0,1)$. They produce a gross output good, X_t from intermediate goods $X_t(j)$ that are imperfect substitutes with a constant elasticity of substitution (CES), $\theta > 1$. The composite gross output is given by :

$$X_t = \left(\int_0^1 X_t(j)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}} \tag{1}$$

Profit maximization leads to input-demand function for the intermediate good which depend on its relative prices $\frac{P_t(j)}{P_t}$ and aggregate gross output X_t :

$$X_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta} X_t, \quad \forall j, \tag{2}$$

The aggregate price indexe is given by :

$$P_t^{1-\theta} = \int_0^1 P_t(j)^{1-\theta} dj \tag{3}$$

2.1.2 Intermediate Producers

Intermediate producing firm j uses labor $L_t(j)$, capital services $\widehat{K}_t(j)$[5] and intermediate $\Gamma_t(j)$ inputs to produce $X_t(j)$ units of goods. The production function for a typical intermediate producer j is given by :

$$X_t(j) = \max\left\{A_t \Gamma_t(j)^{\phi}\left(\widehat{K}_t(j)^{\alpha} L_t(j)^{1-\alpha}\right)^{1-\phi} - \Upsilon_t F, 0\right\}, \tag{4}$$

where F is a fixed cost, and production is required to be non-negative. Υ_t is a growth factor. Given Υ_t, F is chosen to keep profits zero along a balanced growth path, so the entry and exit of firms can be ignored. $\phi \in (0,1)$ is the intermediate input share and $\alpha \in (0,1)$ and $1-\alpha$ are value-added share for capital services and labor inputs respectively.

The neutral technology A_t follows a process with both a trending and stationary component :

$$A_t = A_t^{\tau} \widetilde{A}_t, \tag{5}$$

where the deterministic trend component A_t^{τ} grows at the gross rate $g_A \geq 1$ in each period[6] such that :

$$A_t^{\tau} = g_A A_{t-1}^{\tau}. \tag{6}$$

The stochastic process driving the detrended level of technology $\widetilde{A}_t$ is given by

$$\widetilde{A}_t = \left(\widetilde{A}_{t-1}\right)^{\rho_A} \exp\left(s_A u_t^A\right), \tag{7}$$

which, taking its natural logarithm, yields

$$\ln \widetilde{A}_t = \rho_A \ln \widetilde{A}_{t-1} + s_A u_t^A, \quad u_t^A \sim iid\,(0,1). \tag{8}$$

[5]It is the product of utilization and physical capital

[6]With the implicit normalization that it begins at 1 in period 0 i.e $A_0^{\tau} = 1$

The autoregressive parameter ρ_A governs the persistence of the process and satisfies $0 \leq \rho_A < 1$. The shock is scaled by the known standard deviation equal to s_A and u_t^A is the innovation, drawn from a mean zero normal distribution.

Cost Minimization

Producer of differentiated goods j is assumed to set its price, $P_t(j)$, according to Calvo pricing(Calvo, 1983) and decide in every period its quantities of intermediates, capital services, and labor input. The cost of intermediate is just the aggregate price level, P_t. The cost of capital and labor are R_t^k and W_t (in nominal terms) respectively.

The cost-minimization problem of a typical firm choosing its inputs is given by :

$$\min \quad P_t \Gamma_t(j) + R_t^k \widehat{K}_t + W_t L_t(j) \tag{9}$$

subject to

$$A_t \Gamma_t(j)^{\phi} \left(\widehat{K}_t(j)^{\alpha} L_t(j)^{1-\alpha} \right)^{1-\phi} - \Upsilon_t F \geq \left(\frac{P_t(j)}{P_t} \right)^{-\theta} X_t$$

The first order conditions yield the following marginal cost and conditional demand functions for the inputs used in the production of $X_t(j)$:

$$\Gamma_t(j) = \phi mc_t \left(X_t(j) + \Upsilon_t F \right), \tag{10}$$

$$\widehat{K}_t(j) = \alpha(1-\phi) \frac{mc_t}{r_t^k} \left(X_t(j) + \Upsilon_t F \right), \tag{11}$$

$$L_t(j) = (1-\alpha)(1-\phi) \frac{mc_t}{w_t} \left(X_t(j) + \Upsilon_t F \right). \tag{12}$$

Profit Maximization and Price Setting

Each intermediate producing firm[7] chooses its price $P_t(j)$ that maximizes the expected present discount value of its future profit. The firm problem is given by :

$$\max_{P_t(j)} \quad E_t \sum_{h=0}^{\infty} (\xi_p)^h \, D_{t,t+h} \left(P_t(j) X_{t+h}(j) - V(X_{t+h}(j)) \right) \tag{13}$$

subject to

$$X_{t+h}(j) = \left(\frac{P_t(j)}{P_{t+h}} \right)^{-\theta} X_{t+h}$$

where $D_{t,t+h}$ is the discount rate for future profits and $V(X_t(j))$ is the total cost of producing good $X_t(j)$. The first-order condition for $p_t^*(j)$ is :

$$p_t^*(j) = \frac{\theta}{\theta-1} \frac{\sum_{h=0}^{\infty} (\xi_p \beta)^h \lambda_{t+h}^r \nu_{t+h}(j) \pi_{t+1,t+h}^{\theta} X_{t+h}}{\sum_{h=0}^{\infty} (\xi_p \beta)^h \lambda_{t+h}^r \pi_{t+1,t+h}^{\theta-1} X_{t+h}}, \tag{14}$$

where $p_t^*(j) = \frac{P_t(j)}{P_t}$ is the real optimal price and ν_t the real marginal cost.

Since all updating firms will choose the same reset price, the optimal reset price relative to the aggregate price index becomes $p_t^* \equiv \frac{P_t^*}{P_t}$. Then the optimal pricing condition (15) can be rewritten:

$$p_t^* = \frac{\theta}{\theta-1} \frac{x_{1,t}}{x_{2,t}}. \tag{15}$$

The auxiliary variables $x_{1,t}$ and $x_{2,t}$ can be written recursively:

$$x_{1,t} = \lambda_t^r \nu_t X_t + \beta \xi_p E_t (\pi_{t+1})^{\theta} x_{1,t+1}, \tag{16}$$

[7] The fraction $(1-\xi_p)$ of the one that can adjust its price optimally(Calvo, 1983)

$$x_{2,t} = \lambda_t^r X_t + \beta \xi_p E_t (\pi_{t+1})^{\theta-1} x_{1,t+1}. \tag{17}$$

2.2 Households and wage setting

2.2.1 Labor aggregators

There are a continuum of households, indexed by $i \in (0,1)$. Households supply $L_t(i)$ units of differentiated labor to labour aggregators. These firms assemble composite labor from differentiated, individual-specific labour according to the following aggregation function :

$$L_t = \left(\int_0^1 L_t(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \tag{18}$$

where θ denotes the constant elasticity of substitution (CES) between labor types, with $\theta > 1$. Labor aggregators are pricetakers in both their output and input markets. They sell composite labor to intermediate producers at the aggregate wage, W_t while each unit of differentiated labor costs, $W_t(i)$. Thus, input demand for labor of type-i gives :

$$L_t(i) = \left(\frac{W_t(i)}{W_t} \right)^{-\sigma} L_t \tag{19}$$

The aggregate wage indexe is :

$$W_t^{1-\sigma} = \int_0^1 W_t(i)^{1-\sigma} di \tag{20}$$

2.2.2 Households

In this economy, households are monopoly suppliers of differentiated labor services. The representative household has the following expected lifetime utility[8] :

$$\max_{C_t, L_t(i), K_{t+1}, B_{t+1}, I_t, Z_t} \quad E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln\left(C_t - bC_{t-1}\right) - \eta \frac{L_t(i)^{1+\chi}}{1+\chi} \right),$$

subject to

$$P_t\left(C_t + I_t + \frac{a(Z_t)K_t}{\varepsilon_t^{I,\tau}}\right) + \frac{B_{t+1}}{1+i_t} \leq W_t(i)L_t(i) + R_t^k Z_t K_t + \Pi_t + B_t + T_t, \tag{21}$$

and

$$K_{t+1} = \vartheta_t \varepsilon_t^I \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t + (1-\delta)K_t, \tag{22}$$

with

$$a(Z_t) = \gamma_1(Z_t - 1) + \frac{\gamma_2}{2}(Z_t - 1)^2,$$

and

$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - g_I\right)^2.$$

where $0 < \beta < 1$ is a discount factor, $0 < \delta < 1$ a depreciation rate, and $0 \leq b < 1$ measures internal habit formation. χ is the inverse of the Frisch-labor-supply elasticity. γ_1 and γ_2 are parameters to be calibrated. κ is an investment adjustment cost parameter that is strictly positive. B_{t+1} is a stock of nominal governmental bonds in t+1. Π_t is distributed dividends from firms, and T_t is lump-sum transfer from the government net of taxes. Z_t is the level of capital utilization and $a(Z_t)$ is the utilization adjustment cost function,with $a(1) = 0$, $a'(1) = 0$, and $a''(1) > 0$. $S\left(\frac{I_t}{I_{t-1}}\right)$ is an investment adjustment cost, satisfying $S\left(g_I\right) = 0$, $S'\left(g_I\right) = 0$, and $S''\left(g_I\right) > 0$, where $g_I \geq 1$ is the steady state (gross) growth rate of investment.

[8] Utility is separable and we assume that households are identical with respect to non-labor choices; hence we drop the i subscripts. For details, see Erceg, Henderson and Levin (2000).

The investment-specific term follows the deterministic trend :

$$\varepsilon_t^{I,\tau} = g_{\varepsilon^I} \varepsilon_{t-1}^{I,\tau} \tag{23}$$

where g_{ε^I} is the gross growth rate and grows at the gross rate $g_{\varepsilon^I} \geq 1$ in each period[9].

The exogenous variable ϑ_t captures the stochastic marginal efficiency of investment shock :

$$\vartheta_t = (\vartheta_{t-1})^{\rho_I} \exp\left(s_I u_t^I\right) \mathit{with}\ \ u_t^I \sim iid\,(0,1)\,. \tag{24}$$

The autoregressive parameter ρ_I governs the persistence of the process and satisfies $0 \leq \rho_I < 1$. The shock is scaled by the known standard deviation equal to s_I and u_t^I is the innovation drawn from a mean zero normal distribution.

The first-order conditions for consumption, capital utilization, investment, capital and bonds are respectively :

$$\lambda_t^r = \frac{1}{C_t - bC_{t-1}} - E_t \frac{\beta b}{C_{t+1} - bC_t}, \tag{25}$$

where $\lambda_t^r = P_t \lambda_t$, which is the marginal utility of an extra good;

$$r_t^k = \frac{a'(Z_t)}{\varepsilon_t^{I,\tau}}; \tag{26}$$

$$\lambda_t^r = \mu_t \varepsilon_t^{I,\tau} \vartheta_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\right] + \beta E_t \mu_{t+1} \varepsilon_{t+1}^{I,\tau} \vartheta_{t+1} S'\left(\frac{I_{t+1}}{I_t}\right)\left[\frac{I_{t+1}}{I_t}\right]^2; \tag{27}$$

$$\mu_t = \beta E_t \lambda_{t+1}^r \left(r_{t+1}^k Z_{t+1} - \frac{a(Z_{t+1})}{\varepsilon_{t+1}^{I,\tau}}\right) + \beta(1-\delta) E_t \mu_{t+1}; \tag{28}$$

$$\lambda_t^r = \beta E_t \lambda_{t+1}^r (1 + i_t) \pi_{t+1}^{-1}. \tag{29}$$

[9] With the implicit normalization that it begins at 1 in period 0 i.e $\varepsilon_0^{I,\tau} = 1$

2.2.3 Wage setting

Households get to update their wages each period with the probability $(1-\xi_w)$. The optimal wage $W_t(i)$ is obtained by maximizing :

$$E_t \sum_{h=0}^{\infty} (\beta\xi_w)^h \left(-\frac{\eta}{1+\chi} \left(L_{t+h}(i)\right)^{-\sigma(1+\chi)} + \lambda_{t+h} W_t(i) L_{t+h}(i) \right). \tag{30}$$

subject to,

$$L_{t+h}(i) = \left(\frac{W_t(i)}{W_{t+h}}\right)^{-\sigma} L_{t+h}$$

The first order condition gives :

$$w_t^* = \frac{\sigma}{\sigma-1}\frac{f_{1,t}}{f_{2,t}}. \tag{31}$$

Recursively the terms $f_{1,t}$ and $f_{2,t}$ give the following :

$$f_{1,t} = \eta \left(\frac{w_t}{w_t^*}\right)^{\sigma(1+\chi)} L_t^{1+\chi} + \beta\xi_w E_t (\pi_{t+1})^{\sigma(1+\chi)} \left(\frac{w_{t+1}^*}{w_t^*}\right)^{\sigma(1+\chi)} f_{1,t+1}, \tag{32}$$

and

$$f_{2,t} = \lambda_t^r \left(\frac{w_t}{w_t^*}\right)^{\sigma} L_t + \beta\xi_w E_t (\pi_{t+1})^{\sigma-1} \left(\frac{w_{t+1}^*}{w_t^*}\right)^{\sigma} f_{2,t+1}. \tag{33}$$

2.3 Monetary Policy

Monetary policy consists of a talor-type rule. It responds to deviations of inflation from an exogenous steady state target, π, and to deviations of output growth from its trend level, g_Y, and is of the form :

$$\frac{1+i_t}{1+i} = \left(\frac{1+i_{t-1}}{1+i}\right)^{\rho_i} \left[\left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi} \left(\frac{Y_t}{Y_{t-1}} g_Y^{-1}\right)^{\alpha_y}\right]^{1-\rho_i} \varepsilon_t^r. \tag{34}$$

with i_t and i the nominal and steady state interest rate respectevely, $\frac{\pi_t}{\pi}$ the inflation gap, $\frac{Y_t}{Y}$ the output gap, ρ_i the interest rate smooting, α_π and α_y the control parameters, and ε_t^r an exogenous shock to the policy rule, where $\varepsilon_t^r \sim N\left(0, \sigma_{\varepsilon^r}^2\right)$. To ensure determinacy, we assume that $0 \leq \rho_i < 1$, $\alpha_\pi > 1$ and $\alpha_y \geq 0$.

2.4 Aggregation

The aggregate price level and wage evolve according to :

$$1 = \xi_p (\pi_t)^{\theta-1} + (1-\xi_p)\left(p_t^*\right)^{1-\theta}, \tag{35}$$

$$w_t^{1-\sigma} = \xi_w \left(\frac{w_{t-1}}{\pi_t}\right)^{1-\sigma} + (1-\xi_w)\left(w_t^*\right)^{1-\sigma}. \tag{36}$$

With real GDP being the aggregate production of the goods, X_t, minus the aggregate production of intermediate inputs, Γ_t, where $\Gamma_t = \int_0^1 \Gamma_t(j)dj = \phi \frac{\widetilde{V}_t}{P_t}\left(s_t \frac{X_t}{A_t} + \frac{\Upsilon_t}{A_t} F\right)$, where $s_t = \int_0^1 \left(\frac{P_t(j)}{P_t}\right)^{-\theta} dj$, is a measure of price dispersion. Hence, the real GDP or aggregate net output, Y_t is given by :

$$Y_t = X_t - \Gamma_t \tag{37}$$

Market-clearing requires that $\int_0^1 \widehat{K}_t(j)dj = \widehat{K}_t$ and $\int_0^1 L_t(j)dj = L_t$ respectively for capital services and labor inputs. Hence, aggregate gross output can be written as

$$s_t X_t = A_t \Gamma_t^{\phi} \left(\widehat{K}_t^{\alpha} L_t^{1-\alpha} \right)^{1-\phi} - \Upsilon_t F, \tag{38}$$

We know that $\int_0^1 X_t(j)dj = s_t X_t$, hence the aggregate input demands can be written as

$$\Gamma_t(j) = \phi mc_t \left(s_t X_t(j) + \Upsilon_t F \right), \tag{39}$$

$$\widehat{K}_t(j) = \alpha(1-\phi) \frac{mc_t}{r_t^k} \left(s_t X_t(j) + \Upsilon_t F \right), \tag{40}$$

$$L_t(j) = (1-\alpha)(1-\phi) \frac{mc_t}{w_t} \left(s_t X_t(j) + \Upsilon_t F \right). \tag{41}$$

The aggregate resource constraint is therefore given by :

$$Y_t = C_t + I_t + \frac{a(Z_t)}{\varepsilon_t^{I,\tau}} K_t \tag{42}$$

2.5 Balanced Growth

Trend growth from the deterministic trends in neutral and investment-specific productivity, implies that a balanced-growth path exists where Output, consumption, investment, intermediate inputs, and the real wage will all grow at the same rate : $g_Y = g_I = g_\Gamma = g_w = g_\Upsilon = \frac{\Upsilon_t}{\Upsilon_{t-1}}$. In order to induce stationarity in these variables, they are scaled by the deterministic growth rate Υ_t , e.g $\widetilde{m}_t \equiv \frac{m_t}{\Upsilon_t}$. Meanwhile, there are some exceptions, the capital stock, with $\widetilde{K}_t = \frac{K_t}{\Upsilon_{t-1}\varepsilon_{t-1}^{I,\tau}}$ being stationary; also the rental rate, with $\widetilde{r}_t^k = r_t^k \varepsilon_t^I$, and the marginal utility of income $\widetilde{\lambda}_t^r = \lambda_t^r \Upsilon_t$.

Labor hours, capital utilization and real marginal cost will be stationary, as will inflation rate and the relative reset price.

3 Calibration

In order to generate quantitative results, a calibration of model parameters need to be settled. Table1 summarizes our baseline model parameter values into non-shock and shock parameters (Ascari, Phaneuf and Sims, 2015).

3.1 Non-shock Parameters

We set our non-shock parameters which are standard in the literature, as follows : The discount factor is set to $\beta = 0.99$. The capital depreciation rate is set to $\delta = 0.025$, corresponding to an annual capital depreciation of 10 percent. The capital services share is set to 1/3. $\eta = 6$ is a scaling parameter on disutility from labor and the inverse Frish elasticity of labor supply to $\chi = 1$. Consumption habit formation is set at $b = 0.7$ (Fuhrer, 2000). The investment adjustment cost is set to $\kappa = 3$ (Christiano, Eichenbaum and Evans, 2005). We choose the utilization cost γ_2 equals to 0.05 to match a capital utilization elasticity equal to 1.5 (Basu ad Kimball,1997; Dotsey and King, 2006).

The elasticity parameters for goods and labor are set to a uniform value $\sigma = \theta = 6$, implying a steady-state price and wage markups of 20 percent (Liu and Phaneuf, 2007). With $\theta = 6$, this implies an intermediate inputs share ϕ of 0.61.

The Calvo price and wage parameters are set to $\xi_p = 0.66$ and $\xi_w = 0.75$ respectively. The Calvo price is consistent with the evidence reported in Bils and Klenow (2004) and the value assigned to the Calvo probability of wage with the evidence reported in Barattieri, Basu and Gottschalk (2010).

For the parameters of the monetary policy rule, we set the smoothing coefficient to $\rho_i = 0.75$, $\alpha_\pi = 1.5$ for the coefficient on inflation and $\alpha_y = 0.2$ for the coefficient on output growth. These values are standard in the literature.

3.2 Shock Parameters

Three types of shocks are included in our baseline model : neutral technology, investment-specific technology and monetary policy shocks. The AR(1) parameters of the neutral and investment shock are set to a uniform value of 0.95 ($\rho_A = \rho_I = 0.95$) with the resulting shock variances: $s_I = 0.0176$, $s_A = 0.0022$ and $s_r = 0.0019$. The magnitude of the three shocks are chosen to genrate volatility of output growth of 0.0078, with MEI shocks contributing to 50 percent of this output volatility, the neutral technology shock 35 percent,and the monetary policy shock 15 percent (Justiniano, Primiceri and Tambalotti, 2010).

The average growth rate of the price index over the period 1960:I-2007:III gives 0.008675. This implies $\pi^* = 1.008675$. The average growth rate of the Real GDP over this period is 0.005712 implying $g_Y = 1.005712$ and $g_I = 1.00472$. To generate the appropriate output volatility, we set $g_A^{1-\phi} = 1.0022$.

3.3 Moments

Table 2 reports the selected moments taken from APS (2015). Some statistics implied by the model, match the data : the mean value of real per capita output growth, the variability of inflation and the volatility of output growth at 0.0057, 0.0064 and 0.0078 respectively. The others are either very close (e.g. the volatility of consumption, Inflation persistence) or slightly higher (e.g. the volatility of output) if not somewhat higher (e.g. the volatility of investment, positive autocorrelation in output growth) in the model relative to the data.

Therefore, the model delivers an exact match of the average growth rate of real per capita output, the volatility of output growth and the variability of inflation during the postwar era and thus performs very well along usual business-cycle dimensions

4 Results

In this section, we examine the cyclical behavior of price and wage markups in the baseline model. We analyze the markups role for explaining the dynamic effects of TFP, MEI and monetary shocks, when trend inflation raises from 0 to 4 percent.

It should be noted that the wage markup is related to the discount factor, the elasticity of susbstitution between differentiated labor skills, trend inflation, trend growth rates in IST and neutral technology and the Frisch elasticity of labor supply. The price markup depends to the discount factor, the elasticity of substitution between differentiated goods and the level of trend inflation. Also that an increase in the price markup acts as a negative shifter of the labor demand schedule, whereas a higher wage markup induces a negative shift in the labor supply schedule (Ascari, Phaneuf and Sims, 2015).

Tables 3 to 8 report the contemporaneous cross-correlations between markups and output across alternative models. These correlations are either negative (countercyclical) or positive (procyclical) conditional to individual shock. Figures report the impulse-responses of variables of interest.

4.1 Neutral technology shock

Figures 1,4 and 7 report the impulse-responses of our variables of interest. They reveal that, under zero trend inflation, hours (output and real wage) fall on impact in responses to a positive TFP shock. This causes the marginal product of labor (hereafter MPL) to increase (or the marginal cost to decrease). Because of the sticky price, price cannot adjust immediately; this gives rise to procyclical movements in price markup in the short run to nearly acyclical movements in the medium run.

From tables 4,7 and 8, we see that raising trend inflation from 0 to 4 percent has no significant impact on the magnitude of price markup cyclicality following a positive TFP shock. The main raison is that whether trend inflation is 0 or 4 percent, the responses of price level and inflation are approximately the same i.e the TFP shock has little effects on inflation.

Our results complement and qualify several other contributions in the literature regarding the effects of TFP shock on the price markup cyclicality (Bils, 1987; Rotemberg and Woodford, 1999; Nekarda and Ramey, 2013; Ascari, Phaneuf and Sims, 2015).

However, the wage markup comoves negatively with real output in responses to TFP shock under zero trend inflation (Tables 5 to 8). It becomes more countercyclical as trend inflation passes from 0 to 4 percent. With higher labor demand in medium term, the marginal disutility of working rises; with higher consumption, the marginal utility of consumption falls. In consequence, the MRS rises further. From the efficiency equilibrium condition, as the MPL and price markup go unresponsive consecutive to positive trend inflation and the MRS rises, the wage markup becomes more negative to adjust.

Thus, the interaction between positive trend inflation and TFP shock has significant impact on MRS and wage markup.

4.2 Marginal Efficiency of Investment shock

Tables 7 and 8 and figure 8 summarize the contemporaneous cross-correlations and impulse-responses of the main variables consecutive to MEI shock. Under zero trend inflation, a positive MEI shock leads to a fall in the MPL consecutive to an increase in hours. With the fall of the

MPL, the marginal cost rises. Because of price rigidity, price markup falls but comoves negatively with output. Following the rise in the hours and consumption response on impact, the MRS also increases. In consequence, wage markup falls but comoves negatively with real output.

When raising trend inflation from 0 to 4 percent, price markup remain countercyclical with no significant changes in magnitude whereas wage markup change from countercyclical to procyclical (table 7) and with significant changes in magnitude (table 8). The interaction between trend inflation and MEI shock has stronger distorting effects as the response of wage dispersion is much stronger than the price dispersion. It leads to the threads of wage erosion. In consequence, households set higher wage markup with a higher trend inflation.

Thus, the interplay between non-zero steady-state inflation and MEI shock has greater impact on wage markup than on price markup.

4.3 Monetary Policy shock

In our baseline model, monetary policy shock indirectly impacts on the MPL and labor demand schedules through its effects on intermediate inputs and capital utilization. Figure 9 gives the impulse-responses of variables consecutive to a positive monetary policy shock. It leads to lower real output (MPL, intermediate inputs, capital utilization,...) and consumption. Meanwhile, the lower demand for good pushes down the demand for labor input. With lower labor demand, the marginal disutility of working falls; with lower consumption, the marginal utility of consumption rises. Thus, MRS falls so does the real wage. Since the real wage is part of the real marginal cost, the later falls so the price markup rises but comoves negatively with real output. From the efficiency equilibrium condition, as MPL and MRS fall, price markup rises so the wage markup rises to adjust (Tables 7 and 8).

When raising trend inflation from 0 to 4 percent there is relatively small impact on MPL, MRS, price and wage markups. Thus, the interaction between positive trend inflation and monetary policy shock has no significant impact on price and wage markups i.e trend inflation has little distorting effects on the effciency equilibrium condition (Figure 9). Our results are consistent with findings reported by APS (2015).

5 Conclusion

This paper examines the cyclical behavior of price and wage markups in the News Keynesians Models and their role for explaining the dynamics effects of shocks, when positive trend inflation is considered.

In the literature much more attention has been putted on price markup cyclicality (Bils, 1987; Rotemberg and Woodford, 1999; Nekarda and Ramey, 2013).

We use an extended medium-scale DSGE model, where both price and wage markup vary in the presence of a non-zero trend inflation. In this framework, aggregate fluctuations are driven by TFP, MEI and monetary shocks.

The results show that when raising trend inflation from 0 to 4 percent, wage markup is more important than price markup in explaining the dynamics effects of shocks. We also find that the interactions between positive trend inflation and MEI shock are more important than the one with TFP shock and have greater cyclical effects on wage markup than on price markup.

Our results complement and qualify those of Ascari, Phaneuf and Sims (2015). Thus, the focus on price markup cyclicality in the literature ignore positive trend inflation implications.

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Table 1: Model calibration

Parameter	Description	Value
Non-Shock :		
β	Time discount factor	0.99
δ	Depreciation rate on physical capital	0.025
α	Capital services share	1/3
η	Weight on labor disutility	6
χ	Inverse Frisch elasticity	1
b	Habit formation parameter	0.7
κ	Investment adjustment cost parameter	3
γ_2	Capital utilization elasticity	0.05
θ	Elasticity of substitution between differentiated goods	6
σ	Elasticity of substitution between differentiated labor types	6
ξ_p	Calvo price probability	2/3
ξ_w	Calvo wage probability	2/3
ϕ	Intermediate inputs share	0.61
ρ_i	Taylor rule smoothing coefficient	0.75
α_π	Taylor rule inflation coefficient	1.5
α_y	Taylor rule output growth coefficient	0.2
Shock :		
ρ_r	Monetary policy shock, error term autocorrelation	0
s_r	Standard deviation of the monetary shock	0.0019
g_A	Neutral productivity growth in trend output	$1.0025^{1-\phi}$
ρ_A	Neutral productivity shock, error term autocorrelation	0.95
s_A	Standard deviation of the neutral shock	0.0022
g_I	Investment-specific productivity growth in trend output	1.0025
ρ_I	Investment productivity shock, error term autocorrelation	0.95
s_I	Standard deviation of the MEI shock	0.0176

Source : APS (2015)

Table 2: Moments

	$E(\Delta Y)$	$\sigma(\Delta Y)$	$\sigma(\Delta I)$	$\sigma(\Delta C)$	$\rho_1(\Delta Y)$
Model	0.0057	0.0078	0.0247	0.0048	0.539
Data	(0.0057)	(0.0078)	(0.0202)	(0.0047)	(0.363)
	$\sigma(Y^{hp})$	$\sigma(C^{hp})$	$\sigma(I^{hp})$	$\sigma(\pi)$	$\rho_1(\pi)$
Model	0.0169	0.0089	0.0555	0.0064	0.892
Data	(0.0162)	(0.0086)	(0.0386)	(0.0064)	(0.907)

Source : APS (2015)

Table 3: Cross Correlation Across Models with Staggered Price-Setting (First Difference - filtered)

π^*=1.00

	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SP	-0.0325	–	-0.0325	-0.1198	–	-0.1198	-0.9446	–	-0.9446
SPRP	0.0718	–	0.0718	-0.8204	–	-0.8204	-0.8863	–	-0.8863
SPG	-0.0620	–	-0.0620	-0.6017	-	-0.6017	-0.9487	–	-0.9487
SPRPG	0.0505	–	0.0505	-0.9438	–	-0.9438	-0.8923	–	-0.8923

π^*=1.04

	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SP	-0.0583	–	-0.0583	0.0205	–	0.0205	-0.9530	–	-0.9530
SPRP	0.0601	–	0.0601	-0.5762	–	-0.5762	-0.9020	–	-0.9020
SPG	-0.0921	–	-0.0921	-0.4161	-	-0.4161	-0.9556	–	-0.9556
SPRPG	0.0349	–	0.0349	-0.9604	–	-0.9604	-0.9059	–	-0.9059

Table 4: Cross Correlation Across Models with Staggered Price-Setting (HP-filtered)

	π^*=1.00								
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SP	0.7445	–	0.7445	0.3594	–	0.3594	-0.7122	–	-0.7122
SPRP	0.8626	–	0.8626	-0.1024	–	-0.1024	-0.7374	–	-0.7374
SPG	0.7203	–	0.7203	-0.1279	-	-0.1279	-0.7011	–	-0.7011
SPRPG	0.8458	–	0.8458	-3807	–	-3807	-0.7252	–	-0.7252

	π^*=1.04								
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SP	0.7413	–	0.7413	0.5757	–	0.5757	-0.6704	–	-0.6704
SPRP	0.8657	–	0.8657	0.0797	–	0.797	-0.6937	–	-0.6937
SPG	0.7125	–	0.7125	0.0308	-	0.0308	-0.6621	–	-0.6621
SPRPG	0.8460	–	0.8460	-3033	–	-3033	-0.6842	–	-0.6842

Table 5: Cross Correlation Across Models with Staggered Wage -Setting (First Difference - filtered)

	π^*=1.00								
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SW	-	-0.6093	-0.6093	-	-0.1932	-0.1932	-	-0.8286	-0.8286
SWRP	-	-0.6472	-0.6472	-	-0.5249	-0.5249	-	-0.8054	-0.8054
SWG	-	-0.7447	-0.7447	-	-0.0140	-0.0140	-	-0.8303	-0.8303
SWRPG	-	-0.7836	-0.7836	-	-0.4968	-0.4968	-	-0.8070	-0.8070

	π^*=1.04								
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SW	-	-0.6601	-0.6601	-	0.4738	0.4738	-	-0.8280	-0.8280
SWRP	-	-0.7131	-0.7131	-	0.4598	0.4598	-	-0.8049	-0.8049
SWG	-	-0.8252	-0.8252	-	0.6441	0.6441	-	-0.8297	-0.8297
SWRPG	-	-0.8663	-0.8663	-	0.5994	0.5994	-	-0.8067	-0.8067

Table 6: Cross Correlation Across Models with Staggered Wage -Setting (HP-filtered)

	π^*=1.00								
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SW	-	-0.3865	-0.3865	-	0.5892	0.5892	-	-0.7854	-0.7854
SWRP	-	-0.5255	-0.5255	-	0.4112	0.4112	-	-0.8133	-0.8133
SWG	-	-0.4319	-0.4319	-	0.6826	0.6826	-	-0.7779	-0.7779
SWRPG	-	-0.5611	-0.5611	-	0.4202	0.4202	-	-0.8065	-0.8065

	π^*=1.04								
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SW	-	-0.3668	-0.3668	-	0.8792	0.8792	-	-0.7862	-0.7862
SWRP	-	-0.5148	-0.5148	-	0.8334	0.8334	-	-0.8143	-0.8143
SWG	-	-0.4072	-0.4072	-	0.5305	0.5305	-	-0.7796	-0.7796
SWRPG	-	-0.5362	-0.5362	-	0.4724	0.4724	-	-0.8083	-0.8083

Table 7: Cross Correlation Across Models with Staggered Price and Wage Setting (First Difference - filtered)

π^*=1.00									
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SPSW	0.1318	-0.4184	-0.0826	-0.8959	-0.4240	-0.6022	-0.9926	-0.8078	-0.8314
SPSWRP	0.1585	-0.6161	-0.2016	-0.9533	-0.9752	-0.9817	-0.9941	-0.7513	-0.7670
SPSWG	0.1128	-0.5558	-0.1458	-0.8707	-0.7200	0.4361	-0.9930	-0.8107	-0.8327
SPSWRPG	0.1408	-0.8248	-0.3329	-0.9425	-0.8806	-0.9148	-0.9953	-0.7558	-0.7705

π^*=1.04									
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SPSW	0.1151	-0.3577	-0.0673	-0.8623	0.4254	0.2883	-0.9905	-0.8124	-0.8371
SPSWRP	0.1443	-0.5318	-0.1464	-0.9395	0.1596	-0.1418	-0.9914	-0.7603	-0.7764
SPSWG	0.0948	-0.5584	-0.1507	-0.8878	0.6289	-0.9304	-0.9914	-0.8149	-0.8377
SPSWRPG	0.1250	-0.9066	-0.3487	-0.9318	0.0007	-0.4133	-0.9936	-0.7644	-0.7792

Table 8: Cross Correlation Across Models with Staggered Price and Wage Setting (HP-filtered)

	π^*=1.00								
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SPSW	0.8937	0.0582	0.6418	-0.4462	0.3771	0.2034	-0.2755	-0.7844	-0.7500
SPSWRP	0.9267	-0.2246	0.4495	-0.3247	-0.0797	-0.1233	-0.2174	-0.8405	-0.8189
SPSWG	0.8799	-0.0331	0.5819	-0.4682	0.1754	-0.0914	-0.2924	-0.7728	-0.7409
SPSWRPG	0.9135	-0.3371	0.3242	-0.3572	-0.4330	-0.4201	-0.2375	-0.8272	-0.8068

	π^*=1.04								
	Neutral Shock			MEI Shock			Monetary Shock		
Model	μ_p	μ_w	μ	μ_p	μ_w	μ	μ_p	μ_w	μ
SPSW	0.8900	0.2974	0.7201	-0.4161	0.9200	0.9141	-0.2462	-0.7719	-0.7342
SPSWRP	0.9224	0.1396	0.6584	-0.3074	0.7962	0.5626	-0.1945	-0.8254	-0.8022
SPSWG	0.8739	0.1596	0.6514	-0.3973	0.4278	0.3856	-0.2744	-0.7602	-0.7262
SPSWRPG	0.9072	-0.0997	0.4981	-0.3114	-0.0919	-0.3975	-0.2286	-0.8111	-0.7899

Figure 1: TFP shock, SPRPG Model

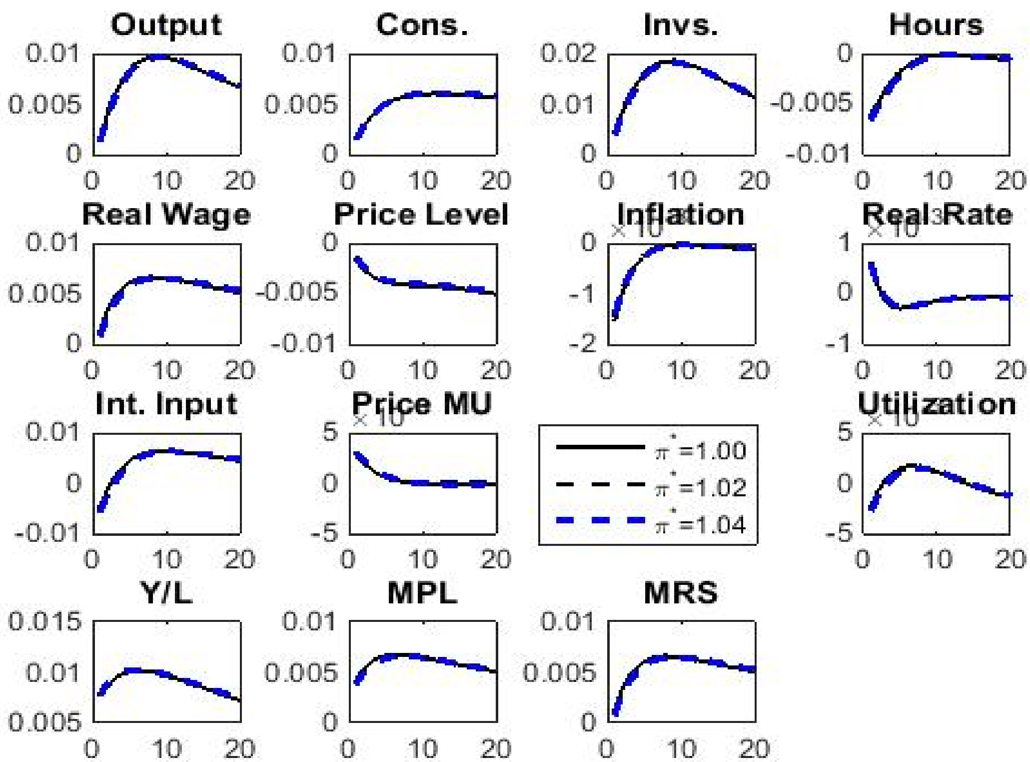

Figure 2: MEI shock, SPRPG Model

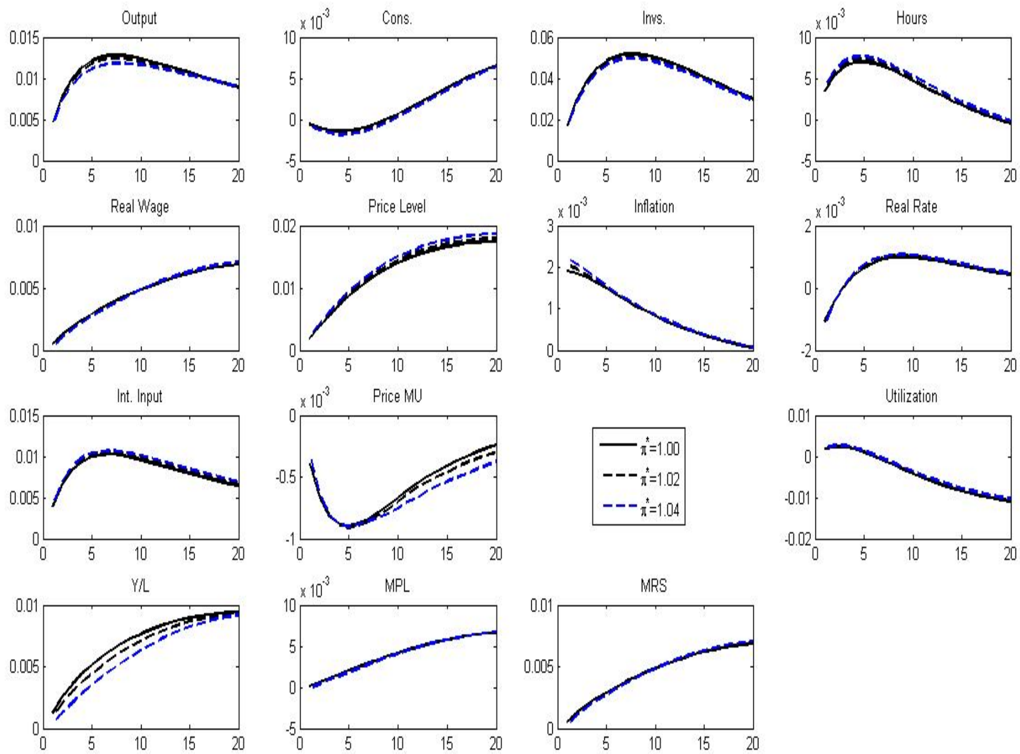

Figure 3: Monetary shock, SPRPG Model

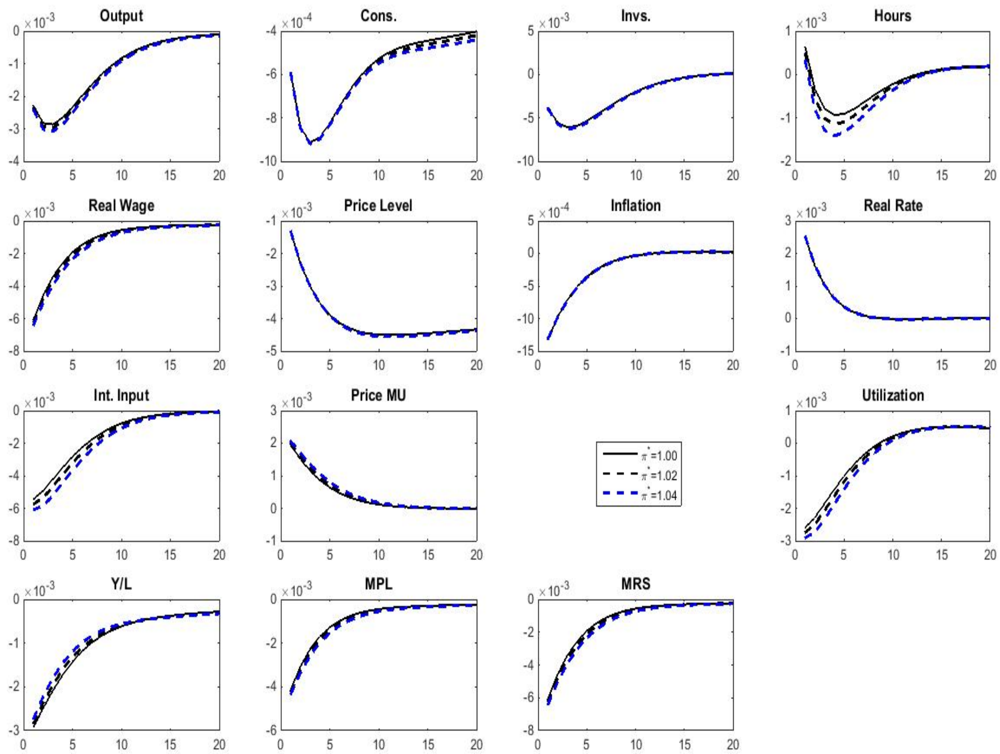

Figure 4: TFP shock, SWRPG Model

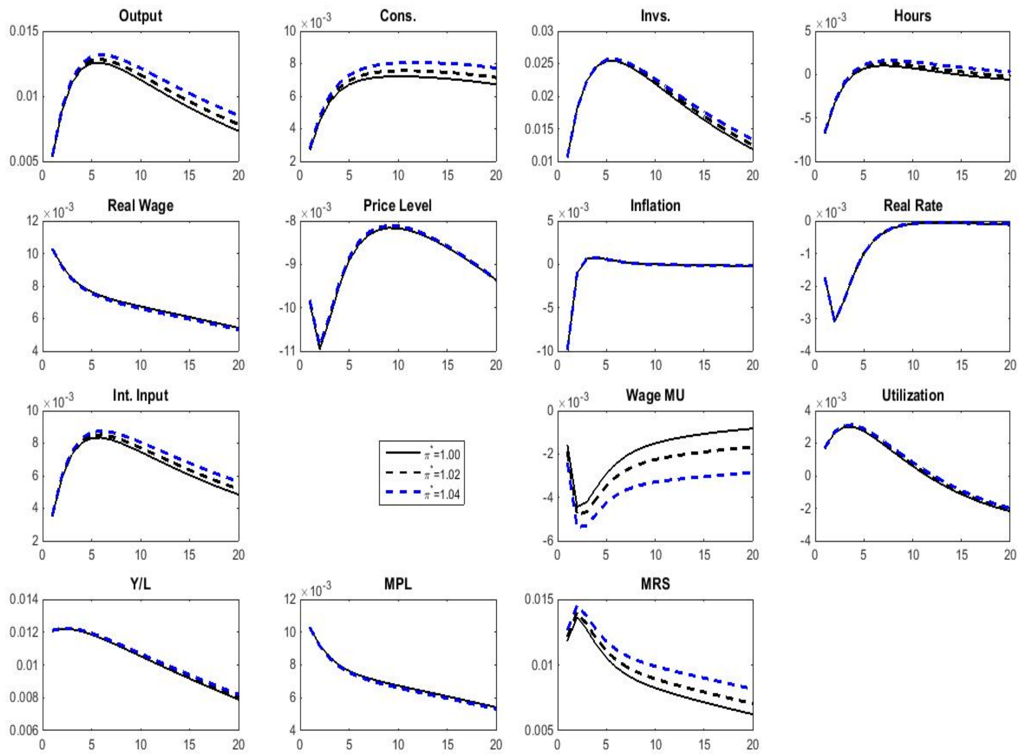

Figure 5: MEI shock, SWRPG Model

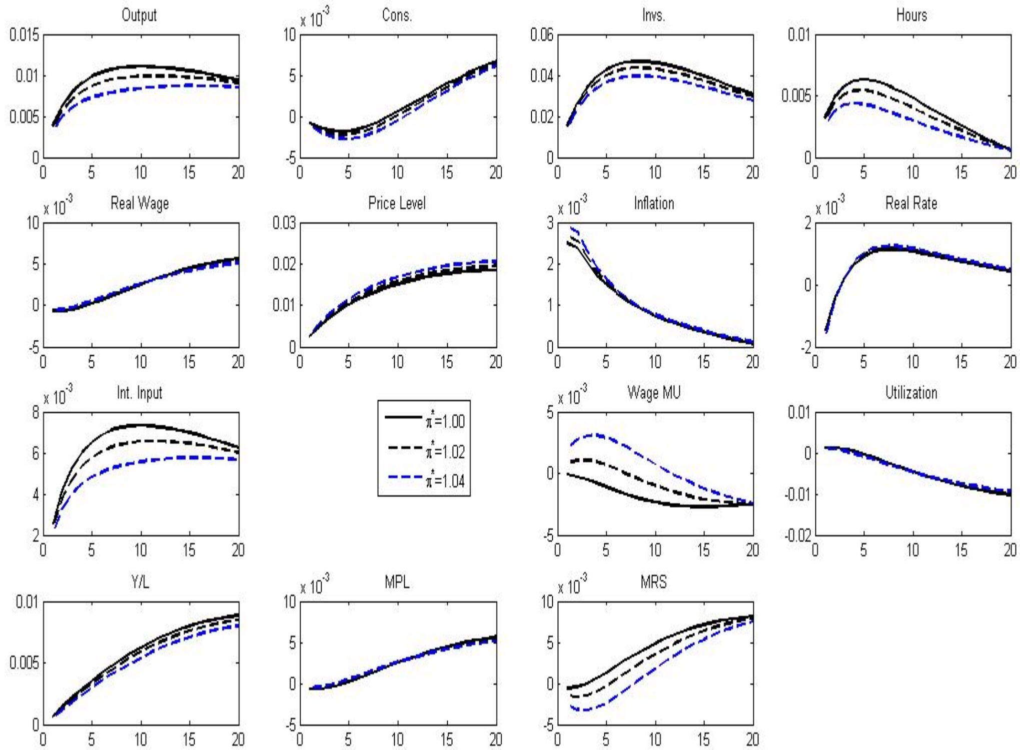

Figure 6: Monetary shock, SWRPG Model

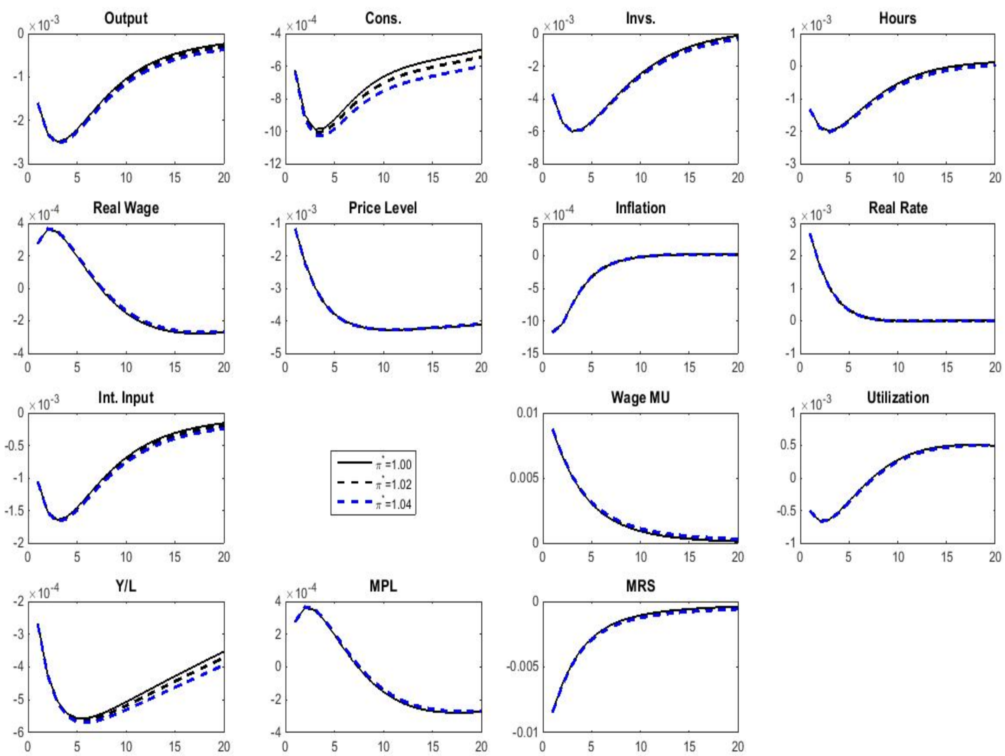

Figure 7: TFP shock, SPSWRPG Model

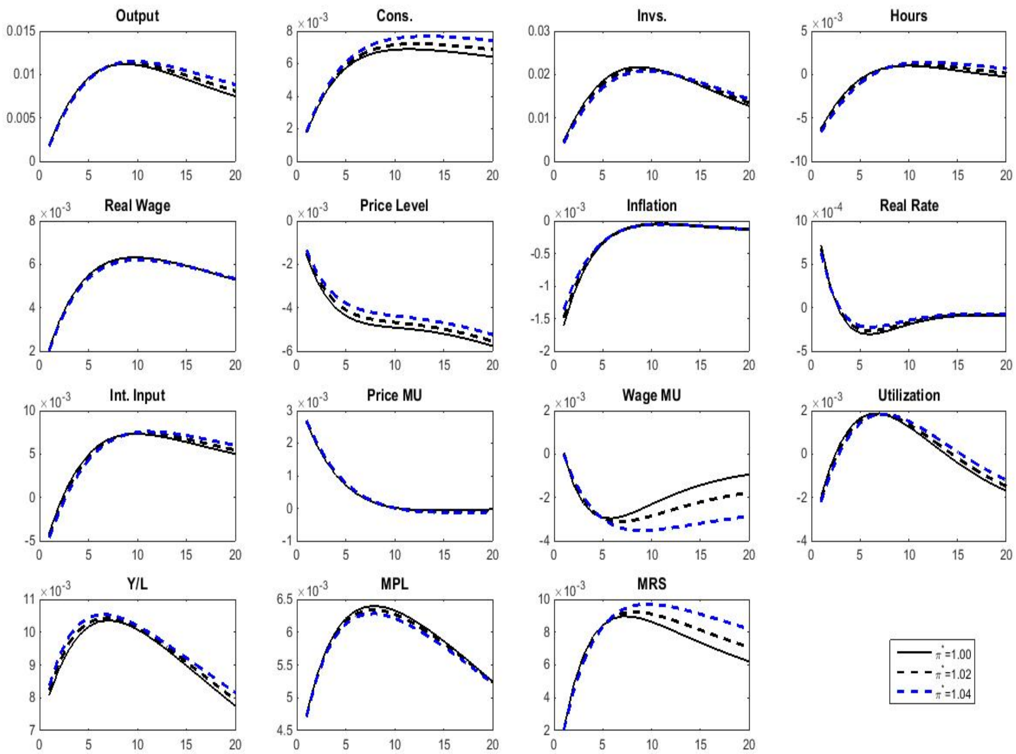

Figure 8: MEI shock, SPSWRPG Model

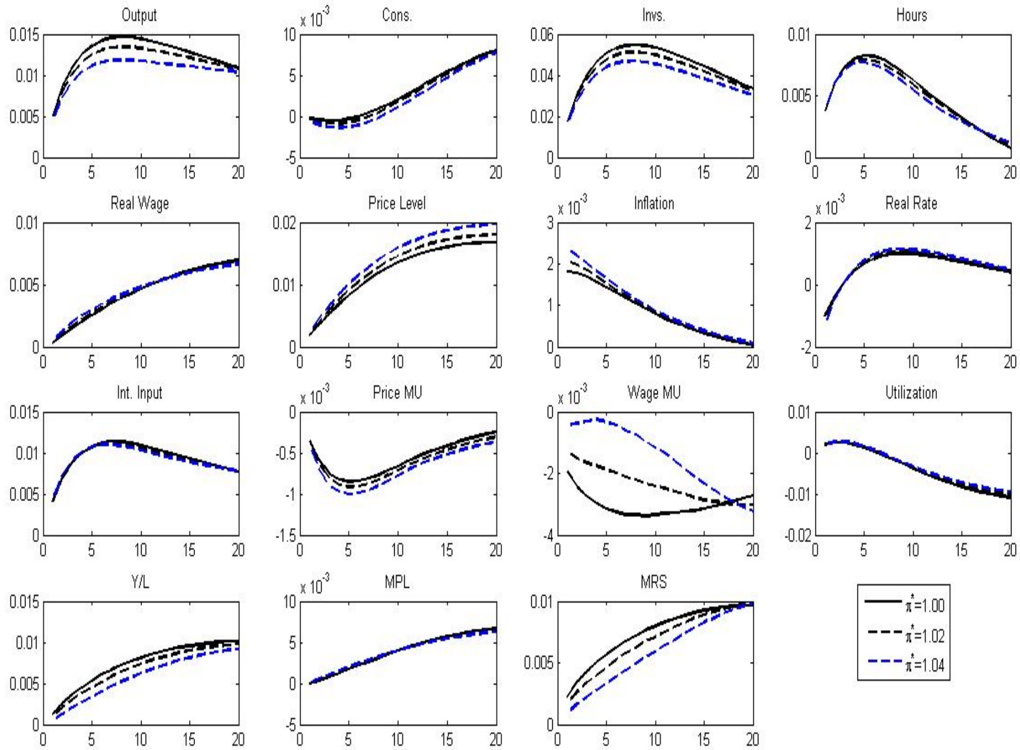

Figure 9: Monetary shock, SPSWRPG Model