Heterogeneity in Sectoral Price Stickiness, Aggregate Dynamics and Monetary Policy Pitfalls with Real Shocks

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Abstract

Ample differences in sectoral price stickiness is a widely documented fact. This paper shows that in presence of *real* shocks, heterogeneity in sectoral price stickiness plays a key role in the determination of the aggregate dynamics. The larger price stickiness heterogeneity, the smaller the *persistence* of inflation and the *volatility* of inflation, interest rate and output-gap. Thus, two economies with the same average degree of sectoral price stickiness but unlike variance may behave very differently. In terms of monetary policy, they can require *interest rate paths* that substantially differ both qualitatively and quantitatively. Generally, with real shocks, disregarding the dispersion in sectoral price stickiness leads policymakers to overvalue the variation and persistence of inflation and output gap.

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Key Words: Price Stickiness Heterogeneity, Real Shocks, New Keynesian model, Persistence, Volatility, Monetary Policy Mistakes.

1 Introduction

This paper relates heterogeneity in sectoral price stickiness to aggregate macroeconomic dynamics and monetary policy mistakes in presence of real shocks. Real-world

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economies feature multiple sectors differing in terms of nominal rigidities (Altissimo et al. 2006, Blinder et al. 1998, Bils and Klenov, 2004, Dhyne et al. 2006, Nakamura and Steinsson 2008). Most of the research that embeds nominal rigidities, however, adopts a one-sector set up. This is not an innocuous assumption. Indeed, it has been shown both theoretically and empirically that the relation between heterogeneity in sectoral nominal rigidities and macroeconomic dynamics matters in a significant way with monetary shocks. Pioneering this relation, Carvalho (2006) found that the presence of sectoral differences in price stickiness in a New-Keynesian model leads to larger and more persistent real effects in response to monetary shocks. With sticky wage contracts in a Generalized Taylor Economy, Dixon and Kara (2010a) show that for economies with the same average contract length, monetary shocks are more persistent in presence of longer contracts. Empirically, Imbs et al. (2011) show that a Phillips curve based on sectoral estimates implies policy trade-offs remarkably different from one based on aggregate estimates. Focusing on inflation persistence instead of persistence in real variables, Sheedy (2007) finds that heterogeneity in price stickiness leads to less inflation persistence. On the other hand, Dixon and Kara (2010b) argue that considering the distribution of contract length substantially improves the ability of the model to replicate the inflation persistence found in the data.

This previous literature has related heterogeneity in sectoral nominal rigidities to the persistence of real effects caused by *monetary shock*, and to the model performance at reproducing the inflation persistence in the data. The current paper contributes to this literature by showing that in presence of *real shocks*, neglecting heterogeneity in sectoral price stickiness leads to a wrong assessment of the aggregate dynamics, and consequently, to important monetary policy mistakes.

The analysis shows that with real shocks, accounting for the dispersion in sectoral price stickiness, the *persistence* of aggregate inflation turns out to be smaller. The same result occurs with the *variability* of aggregate inflation, interest rate and output-gap. The investigation suggests that these findings are quantitatively important too. Interestingly, this implies that two economies sharing the mean degree of price stickiness but not the variance may respond to real disturbances very differently and thus deserve specific monetary policies. In particular, they can require paths for expected interest rates that remarkably differ both qualitatively and quantitatively. Generally, when real disturbances hit the economy, disregarding the dispersion in sectoral price stickiness leads policymakers to overvalue the variation and persistence of inflation and the variation of the output gap and the interest rate.

We believe that these implications pose serious problems to monetary policy decisions. In particular, the use of one-sector model would corrupt the projections of the target variables which are fundamental ingredients for the inflation targeting operating procedure in use at several central banks (Svensson 2010). Thus, this work questions the prominent use of one-sector models for economic estimations and forecasts, a view shared with Imbs et al. (2011).

The intuition for the current findings is the following. Heterogeneity in sectoral price stickiness introduces the relative price of sectoral goods into the picture. This variable, affecting sectoral inflations in opposite ways via the demand channel, acts as a buffering device attenuating the impact of aggregate real shocks on aggregate inflation. As a consequence, the whole transmission mechanism of the shock to the economy dramatically changes. Using a graphical AS-AD framework that exactly embeds expectations reveals that the role played by the relative price consists of contracting the shifts of the AS due to real shocks. As a result, aggregate inflation varies less affecting the rest of the economic dynamics.

Sectoral and regional heterogeneity in nominal rigidities have been also related by the previous literature to optimal monetary policy obtaining important results. Aoky (2001) and Benigno (2004), respectively in two-sector and two-region economies, show that focusing the policy response on the sector/region with sticky or stickier price maximizes welfare. A different result is obtained by Kara (2010) with a multiple-sector Generalized Taylor Economy where targeting economy-wide inflation results in almost the same welfare of the optimal monetary policy. With respect to this literature, the current paper is different in that abstracts from optimal monetary policy. What it does is a) focusing on the impact of heterogeneity in sectoral price stickiness on the macroeconomic dynamics driven by real shocks, and b) investigating how the path of the expected interest rate changes neglecting heterogeneity in price stickiness. This is carried out contrasting a *two-sector economy* featuring sectoral asymmetry with a *one-sector economy* featuring a degree of price stickiness equal to the average of the sectoral price stickiness in the two-sector economy.

The plan of the paper is as follows. Section 2 presents the model where consumption habits are introduced into an otherwise standard two-sector New-Keynesian model drawn on Benigno (2004) and Woodford (2011). It derives the non-linear optimal conditions, the log-linearized relations used in the following analysis, and reports the calibration of the structural parameters. Section 3 investigates the relation between sectoral heterogeneity in price stickiness and the dynamics of the economy in presence of cost-push, technology, and preferences shocks. First the main result is illustrated via impulse response functions. Next, the implications in terms of monetary policy mistakes are discussed. Then, the mechanics is explained. Here, the heterogeneity assumption is related to switches in sectoral demands and to their buffering role on aggregate inflation. After that, it is presented a complementary illustration using an appropriate AD-AS graphical framework for the New-Keynesian model. Finally, the analysis is completed looking at autocorrelations, and standard deviations of the endogenous variables. Although this paper focuses on real shocks, Section 4 also offers a parallel with Carvalho (2006) that considers monetary shocks. This comparison shows that introducing the heterogeneity assumption leads to opposite results with monetary and real shocks which, however, always obtain via a contraction in the shift of the AS following the shock. Section 4 also presents three general monetary policy pitfalls in terms wrong assessment of the persistence and volatility in inflation and real activity when policymakers disregard dispersion in sectoral price stickiness. Concluding remarks are in section 5.

2 The model

The economy is populated by a continuum of unit mass of identical infinite-lived households each seeking to maximize

$$U_t = E_t \sum_{T=t}^{\infty} \beta^{T-t} \left\{ \widetilde{u}\left(C_T - \eta C_{T-1}; \overline{C}_T\right) - \int_0^1 \widetilde{v}\left[H_T(j)\right] dj \right\},$$

where β is the intertemporal discount factor, C_t represents all interest-rate-sensitive expenditure including investments and is defined as a CES aggregate

$$C_t \equiv \left[(n_s)^{1/\rho} \left(C_t^s\right)^{(\rho-1)/\rho} + (n_m)^{1/\rho} \left(C_t^m\right)^{(\rho-1)/\rho} \right]^{\rho/(\rho-1)}, \tag{1}$$

of the goods C_t^s and C_t^m which are produced, respectively, by the s and m-sector, with ρ defining their elasticity of substitution and n_s and n_m ($n_s \equiv 1 - n_m$) denoting the number of goods of sector s and m in C_t, respectively. Each sectoral good is, in turn, a Dixit-Stiglitz aggregate of the continuum of differentiated goods produced in the sector

$$C_t^h \equiv \left[n_h^{-\frac{1}{\theta}} \int_{N_h} \left(C_t^h(i)\right)^{1-\frac{1}{\theta}} di \right]^{\frac{\theta}{\theta-1}}, \qquad h = s,\ m$$

where $\theta > 1$ is the sectoral elasticity of substitution between any two differentiated goods and $N_s \equiv [0, n_s]$, $N_m \equiv (n_s, 1]$. Period preferences on consumption and labour are modeled as CRRA functions

$$\widetilde{u}\left(C_t - \eta C_{t-1}; \overline{C}_t\right) = \overline{C}_t^{\frac{1}{\widetilde{\sigma}}} \frac{\left(C_t - \eta C_{t-1}\right)^{1-\frac{1}{\widetilde{\sigma}}} - 1}{1 - \frac{1}{\widetilde{\sigma}}}, \tag{2}$$

$$\widetilde{v}\left[H_t(j)\right] \equiv \frac{H_t^{1+\nu}(j)}{1+\nu}, \tag{3}$$

where $\overline{C}_t$ is an exogenous preference shock, $H_t(j)$ is the quantity supplied of labour of type j, $\widetilde{\sigma} > 0$ captures the intertemporal elasticity of substitution in consumption, $0 \leq \eta < 1$ measures the degree of habit persistence, and $\nu > 0$ is the inverse of the elasticity of goods production[1].

The price index for the minimum cost of a unit of C_t is given by

$$P_t \equiv \left[n_s \left(P_t^s\right)^{1-\rho} + \left(n_m\right)\left(P_t^m\right)^{1-\rho}\right]^{1/(1-\rho)}, \tag{4}$$

with P^s, P^m denoting, respectively, the Dixit-Stiglitz price index for goods produced in the s and m sector.

Preferences captured by equation (1) imply that the optimal sectoral consumption levels are given by

$$C_t^h = n_h C_t \left(\frac{P_t^h}{P_t}\right)^{-\rho}, \qquad h = s,\ m. \tag{5}$$

Financial markets are assumed to be complete so that at any date all households face the same budget constraint and consume the same amount. Then, utility maximization subject to the budget constraint and the no-Ponzi scheme requirement yields the condition for optimal consumption

$$\lambda_t = \beta E_t \left\{ \frac{\left[\widetilde{u}_c\left(C_{t+1} - \eta C_t; \overline{C}_{t+1}\right) - \beta\eta E_t \widetilde{u}_c\left(C_{t+2} - \eta C_{t+1}; \overline{C}_{t+2}\right)\right]}{\widetilde{u}_c\left(C_t - \eta C_{t-1}; \overline{C}_t\right) - \beta\eta E_t \widetilde{u}_c\left(C_{t+1} - \eta C_t; \overline{C}_{t+1}\right)} \frac{P_t}{P_{t+1}} \right\}, \tag{6}$$

where $\lambda_t \equiv \frac{1}{1+i_t}$ is the price of a one-period nominal bond. Finally, utility maximization requires that the optimal supply of labour of type j is given by

$$\Omega_t(j) = \Psi_t \frac{\widetilde{v}_h\left[H_t(j)\right]}{\left[\widetilde{u}_c\left(C_t - \eta C_{t-1}; \overline{C}_t\right) - \eta\beta E_t \widetilde{u}_c\left(C_{t+1} - \eta C_t; \overline{C}_{t+1}\right)\right]}, \tag{7}$$

[1] It is worth noting that the assumption of habit persistence is not necessary to obtain the results shown below. Nevertheless, this real rigidity captures the gradual hump-shaped response of real spending to various shocks and thus is well accepted in the New-Kenesian literature.

where $\Omega_t(j)$ is the real wage demanded for labour of type j and $\Psi_t \geq 1$ is an exogenous markup factor in the labor market assuming that firms are wage-takers.

Moving to production, each household i is assumed to supply all type of labour and is a monopolistically competitive producer of one differentiated good, either $y^m(i)$ or $y^s(i)$. In this economy any firm i belongs to an industry j which, in turn, belongs either to sector s or m. Furthermore, there is a unit interval continuum of industries indexed by j and in each industry there is a unit interval continuum of good indexed by i so that the total number of goods is one. Since in equilibrium all the firms belonging to an industry will supply the same amount, they will also demand the same amount of labour. As a result the total demand of labour in an industry is equal to demand of labor of any differentiated firm in the industry. Next, we assume industry-specific labor as the only variable input

$$y_t^h(i) = A_t \left[H_t^h(i)\right]^{\frac{1}{\phi}}, \qquad h = s,\ m,$$

where A_t is a technology shock, $H_t^h(i)$, is the quantity of labour used by the representative firm i in the h-sector to produce good i, and $\phi > 1$, is the elasticity of sectoral output with respect to hours worked.

In equilibrium, market clearing in the goods market requires

$$Y_t^m = C_t^m, \qquad Y_t^s = C_t^s, \qquad Y_t = C_t. \tag{8}$$

Hence, combining (2), (6), and (8) we obtain the nonlinear version of the New-Keynesian IS relation. Turning to the producers' pricing behaviour, firms in both sectors fix their prices at random intervals following the Calvo (1983) staggered price model and have the opportunity to change their prices with probability $(1-\alpha)$. Thus, a producer i in the $h = m, s$ sector that is allowed to set its price in period t chooses its new price for the random period starting in t, $\widetilde{p}_t^h$, to maximize the flow of expected profits:

$$\max_{\widetilde{p}_t^h} E_t \sum_{T=t}^{\infty} \alpha^{T-t} \lambda_{t,T} \left\{ \widetilde{p}_t^h y_T^h(i) - \left[\frac{y_T^h(i)}{A_T}\right]^{\phi} \Psi_T^h \frac{\left[y_T^h(j)/A_T\right]^{\nu\phi} P_T}{\overline{C}_t^{\frac{1}{\sigma}} \left(C_t - \eta C_{t-1}\right)^{-\frac{1}{\sigma}} - \eta\beta \overline{C}_{t+1}^{\frac{1}{\sigma}} \left(C_{t+1} - \eta C_t\right)^{-\frac{1}{\sigma}}} \right\},$$

where $\lambda_{t,T}$ is the stochastic discount factor by which financial markets discount random nominal income in period T. Accounting for firm i demand function in sector h, and considering that the firm's pricing decision cannot change the real wage, the f.o.c. is

$$0 = E_t \sum_{T=t}^{\infty} \alpha^{T-t} \lambda_{t,T} \left\{ C_T \left(\frac{\widetilde{p}_t^h}{P_T^h}\right)^{-\theta} \left(\frac{P_T^h}{P_T}\right)^{-\rho} - \theta C_T \left(\frac{\widetilde{p}_t^h}{P_T^h}\right)^{-\theta-1} \frac{\widetilde{p}_t^h}{P_T^h} \left(\frac{P_T^h}{P_T}\right)^{-\rho} - \right.$$

$$\left[-\phi\theta\left(\frac{C_T}{A_T}\right)^{\phi}\left(\frac{\widetilde{p}_t^h}{P_T^h}\right)^{-\phi\theta-1}\frac{1}{P_T^h}\left(\frac{P_T^h}{P_T}\right)^{-\phi\rho}\right]\frac{\Psi_T^h\left[C_t\left(\frac{p_t^h(j)}{P_t^h}\right)^{-\theta}\left(\frac{P_t^h}{P_t}\right)^{-\rho}\frac{1}{A_T}\right]^{\nu\phi}P_T}{\overline{C}_T^{\frac{1}{\widetilde{\sigma}}}\left(C_T-\eta C_{T-1}\right)^{-\frac{1}{\widetilde{\sigma}}}-\eta\beta\overline{C}_{T+1}^{\frac{1}{\widetilde{\sigma}}}\left(C_{T+1}-\eta C_T\right)^{-\frac{1}{\widetilde{\sigma}}}}\right\} \tag{9}$$

2.1 Log-linearized relations

We now log-linearize the equilibrium conditions around the steady state where the variables $\left(Y_t^m, Y_t^s, Y_t, Q_t, \frac{P_{t+1}}{P_t}, \frac{P_{t+1}^s}{P_t^s}, \frac{P_{t+1}^m}{P_t^m}\right)$ are equal to $(Y^m, Y^s, Y, 1, 1, 1, 1)$ and all the shocks are equal to one. Loglinearizing the Euler equation, account being taken of the market clearing condition, leads to the IS relation

$$y_t = \frac{\eta}{1+\eta\left(1+\beta\eta\right)}y_{t-1} + \frac{1+\eta\beta\left(1+\eta\right)}{1+\eta\left(1+\beta\eta\right)}y_{t+1|t} - \frac{\eta\beta}{1+\eta\left(1+\beta\eta\right)}y_{t+2|t}$$

$$-\frac{\widetilde{\sigma}\left(1-\eta\right)\left(1-\eta\beta\right)}{\left(1+\eta+\beta\eta^2\right)}\left(\widehat{i}_t-\pi_{t+1|t}\right)+\frac{1-\eta}{1+\eta\left(1+\beta\eta\right)}\left[\overline{c}_t-\left(\eta\beta+1\right)\overline{c}_{t+1|t}+\eta\beta\overline{c}_{t+2|t}\right] \tag{10}$$

where $\overline{c}_t \equiv \log \overline{C}_t$ which, relaxing the habit persistence assumption, i.e. $\eta = 0$, boils down to the basic New Keynesian IS curve. Next, loglinearizing the f.o.c. for the firm's problem (9) with respect to sector m and s, we obtain

$$\pi_t^h = \kappa^h\left[\omega+\varphi\left(1+\eta^2\beta\right)\right]y_t - \kappa^h\varphi\eta y_{t-1} - \kappa^h\varphi\eta\beta y_{t+1|t} + \kappa^h\zeta_h\left(\rho\omega+1\right)q_t \tag{11}$$

$$-\kappa^h\left[\left(1+\omega\right)a_t+\varphi\left(1-\eta\right)\left(\overline{c}_t-\eta\beta\overline{c}_{t+1|t}\right)-\psi_t\right]+\beta\pi_{t+1|t}^h, \qquad h = s,\ m,$$

where $\omega \equiv \phi\left(v+1\right)-1$, $\varphi \equiv \frac{1}{(1-\eta)\widetilde{\sigma}(1-\eta\beta)}$, $q_t \equiv \log\frac{Q_t}{Q}$, $a_t \equiv \log A_t$, $\psi_t^h \equiv \log\Psi_t$, and

$$\kappa^h \equiv \frac{\left(1-\alpha^h\right)\left(1-\alpha^h\beta\right)}{\alpha^h\left(1+\omega_h\theta\right)}, \tag{12}$$

$$\zeta_h \equiv \begin{cases} n_s > 0, & \text{if } h = m \\ -\left(1-n_s\right) < 0, & \text{if } h = s \end{cases}. \tag{13}$$

It is worth noting that introducing heterogeneity in sectoral price stickiness the new variable q_t and the new relation between q_t, π_t^s, and π_t^m enter in the model. The latter is captured by both (11) and the low of motion for q_t given by

$$q_t = q_{t-1} + \pi_t^s - \pi_t^m. \quad (14)$$

At this point two remarks are in order. First, considering (12), the shock elasticity of sectoral inflation in (11) is decreasing in the degree of sectoral price stickiness. This implies a shock filtering device for real shocks which is increasing with stickiness as described in Ascari, Flamini and Rossi (2012). Thus, the shock elasticity in the sector whose prices are stickier is smaller. Second, accounting for ζ_h, the elasticities of sectoral inflations to the relative price q_t have opposite sign, and the sector whose prices are more flexible experiences (in absolute value) the larger elasticity. As it will be explained below, different sectoral shock elasticities and relative price elasticities activate a switching demand mechanism that buffers the impact of the symmetric shock on aggregate inflation.

Turning to the exogenous shocks, they are described by

$$\begin{aligned} a_{t+1} &= \gamma_a a_t + \varepsilon_{t+1}^a, \\ \bar{c}_{t+1} &= \gamma_c \bar{c}_t + \varepsilon_{t+1}^c, \\ \psi_{t+1} &= \gamma_\psi \psi_t + \varepsilon_{t+1}^\psi, \end{aligned}$$

where $E_t\left(\varepsilon_{t+1}^h\right) = 0$, $h = a,\ c,\ \psi$. Log-linearizing the price index (4) we obtain aggregate inflation

$$\pi_t = n_s \pi_t^s + n_s \pi_t^m, \quad (15)$$

and substituting the sectoral inflations we obtain aggregate inflation in terms of lagged, current, and expected output gap, the relative price, expected inflation, and the exogenous shocks

$$\begin{aligned} \pi_t = {} & \left[\omega + \varphi\left(1 + \eta^2 \beta\right)\right]\left(n_s \kappa^s + n_m \kappa^m\right) y_t - \varphi \eta \left(n_s \kappa^s + n_m \kappa^m\right) y_{t-1} + \beta \pi_{t+1|t} \quad (16) \\ & - \varphi \eta \beta \left(n_s \kappa^s + n_m \kappa^m\right) y_{t+1|t} - n_s n_m \left(\kappa^s - \kappa^m\right)\left(\rho \omega + 1\right) q_t \\ & - \left(n_s \kappa^s + n_m \kappa^m\right)\left[\left(1 + \omega\right) a_t - \psi_t\right] - \varphi\left(1 - \eta\right)\left(n_s \kappa^s + n_m \kappa^m\right)\left(\bar{c}_t - \eta \beta \bar{c}_{t+1|t}\right). \end{aligned}$$

This aggregate New-Keynesian Phillips curve based on sectoral inflations boils down to the standard New-Kenesian Phillips curve with habit persistence when sectoral symmetry is imposed[2], i.e. $\alpha^s = \alpha^m$. Finally, the model is closed with a Taylor rule

[2] Assuming also no habit persistence, i.e. $\eta = 0$, we obtain the basic New-Keynesian Phillips curve.

describing the behaviour of the central bank

$$i_t = \delta_0 i_{t-1} + (1-\delta_0)\,\delta_1 \pi_t + (1-\delta_0)\,\delta_2 y_t. \tag{17}$$

2.2 Calibration

Table 1a reports the calibration for the structural parameters based on the previous literature. The degree of habits persistence η is set to 0.7; the elasticity of intertemporal substitution in consumption is $\widetilde{\sigma} = 2/3$; the intertemporal discount factor is $\beta = 0.9975$ (3% per year); the coefficients of the Taylor rule are $\delta_0 = 0.8$; $\delta_1 = 1.5$; $\delta_2 = 0.5/4$. These values configure a quite standard calibration consistent, for example, with Smets and Wouters (2007). Let us now turn to the remaining parameters. The inverse of the elasticity of goods production (the inverse of Frish elasticity) ν is set to 1.17 as estimated by Fernández-Villaverde, Guerrón-Quintana and Rubio-Ramírez (2010)[3]. Following Rotemberg and Woodford (1997), the elasticity of sectoral output with respect to hours worked, $1/\phi$, is set to 0.75 and the sectoral elasticity of substitution between any two differentiated goods θ is set to 7.88 (average markup $< 15\%$). The elasticity of substitution between C_t^s and C_t^m in the CES consumption aggregate, ρ, is difficult to calibrate without specifying the type of industry the sectors belong to. We then assume that the m and the s sector refer to the manufacturing and services sectors respectively, and set ρ to 1 (Cobb-Douglas aggregator). Since this work aims to insulate the impact of the asymmetry in sectoral price stickiness on economic dynamics in presence of real shocks, sectors size is set to be equal, i.e. the number of firms in the s-sector is $n_s = 0.5$; and in the m-sector is $n_m = 1 - n_s$. Finally, the AR coefficients of the exogenous processes are $\gamma_a = \gamma_\psi = \gamma_c = 0.95$, for any shock the variance is $\sigma_\varepsilon^2 = 0.009^2$, and the sectoral degree of price stickiness $\alpha_h,\ h = s, m$ is let free to vary in the range $\{0.5, 0.6, 0.7, 0.8, 0.9\}$ as described in the analysis below.

Robustness To check for the robustness of the results, we experimented an alternative calibration which is as close as possible to the one in Carvalho (2006)[4]. Table

[3] This source for ν is motivated by the fact that these authors use a set of priors nearly identical to the one proposed by Smets and Wouters (2007) in a similar DSGE model but specify the relation between the utility and labor in the same way of the current paper, which differs from Smets and Wouters (2007).

[4] Carvalho (2006) considers two alternative calibrations for ν and θ: either $1/\nu = 0.5$ and $\theta = 11$ or $1/\nu = 1.5$ and $\theta = 5$. Here, for sake of simplicity but without loss in generality, we take the

$1b$ only reports the parameters value of this second calibration which differ from the first calibration. Here there are no habits in consumption, i.e. $\eta = 0$, the elasticity of intertemporal substitution in consumption is $\widetilde{\sigma} = 1$, the elasticity of sectoral output with respect to hours worked is $1/\phi = 1$ (linear technology), and the inverse of the elasticity of goods production is $\nu = 1$. Finally, the sectoral elasticity of substitution between any two differentiated goods θ and the elasticity of substitution between C_t^s and C_t^m in the CES consumption aggregate ρ are both set equal to 8.

3 Sectoral heterogeneity in price stickiness and economic dynamics

We now focus on the relation between sectoral heterogeneity in price stickiness and the dynamics of the economy in presence of positive cost-push, technology and household preferences shocks. All the shocks are supposed to hit symmetrically both sectors of the economy. The analysis first shows qualitatively via impulse response functions how dispersion in sectoral price stickiness affects the economic dynamics. Next, it assesses the policy mistakes for a central bank that ignores the presence of dispersion in sectoral price stickiness. Then the mechanics is explained focusing on the impact of the asymmetry assumption on the sectoral and aggregate AS. The mechanism at work is also illustrated using an appropriate AD-AS diagram for the New-Keynesian model. Finally, the investigation is completed looking at autocorrelations, and standard deviations of the endogenous variables.

3.1 Impulse responses to real shocks

Figures 1 shows the impulse response functions to a preference shock (Panel a), and to symmetric cost-push (Panel b) and technology shocks (Panel c) in presence of sectoral symmetry and asymmetry in the degree of price stickiness.

[INSERT FIGURE 1 HERE]

average values over these two calibrations, that is $1/\nu = 1$ and $\theta = 8$. It is worth noting that in Carvalho (2006) ρ is set equal to the sectoral elasticity of substitution θ, and it is reported that alternative calibrations for ρ including the case in which the CES is a Cobb-Douglas do not change the substantive findings.

The first row of each Panel considers a two-sector economy under the *symmetry* assumption, i.e. price stickiness is the same in both sectors. Here the probability that a firm does not have the opportunity to optimize its price in a given period captured by α_s and α_m is set to 0.7. This value implies that, on average, firms revise their prices a bit less than every 3.5 quarters, which is consistent with Fernández-Villaverde, Guerrón-Quintana and Rubio-Ramírez (2010) and seems a natural benchmark of longer and shorter pricing cycle for firms belonging to different sectors. The second row, instead, considers the same economy under the *asymmetry* assumption but with the same mean of the symmetric economy. Specifically, the sectoral price stickiness are $\alpha_s = 0.9$, $\alpha_m = 0.5$, resulting in the mean of 0.7 over the two sectors[5]. What is interesting here is that each panel reveals a common behaviour of aggregate inflation in response to an increasing degree of price stickiness asymmetry. This behaviour can be described as follows:

Variance of sectoral price stickiness and aggregate inflation. *For any shock considered, for a given mean value of price stickiness, the larger the variance (i.e. the larger the asymmetry), the lower the deviation of inflation from its steady state value, the lower the initial impact of the shock and the lower the persistence of the response to the shock*[6].

Before explaining the mechanism that generates this result, we describe its implications on the behaviour of the interest rate and then on the economic dynamics. Starting with the preference shock, Panel a, it is worth noticing that this shock impacts on both the demand and supply side of the economy[7], and these impacts go in opposite directions[8]. Plots for y and π then illustrate these effects, positive on the output gap and negative on inflation. Thus, two contrasting forces act on the

[5] The measure of price stickiness captured by α in the Calvo's (1987) scheme varies a lot in the empirical litterature ranging from 0.35 in Christiano et al. (2005) to 0.91 in Smets and Wouters (2003).

[6] Further analysis available upon request shows that this result is independent on the mean and the variance of sectoral price stickiness.

[7] The preference shock is a shock to the utility function so that it affects, on the one hand, the Euler equation and therefore the aggregate demand and, on the other hand, the marginal rate of substitution between labour and consumption entering in the optimal supply of labour, and therefore the aggregate supply.

[8] Indeed in equation (10) the coefficient of the preference shock is positive and in equation (16) it is negative.

interest rate via the Taylor rule. Now, under symmetry, first row, it occurs that the fall in inflation affects the interest rate more than the increase in the output gap leading the interest rate to fall in the initial periods. Yet, breaking the symmetry, second row, inflation is less affected by the shock and, therefore the negative impact on the interest rate is attenuated. This leaves the interest rate more exposed to the positive impact of the output gap. Consequently, the monetary policy turns out to be more active in the subsequent periods in order to focus on the stabilization of the output gap. Hence, given the relation between the variance of sectoral price stickiness and aggregate inflation, monetary policy can better stabilize the output gap under asymmetry.

Moving to a cost-push or technology shock, the economy turns out to be hit only through the supply side. Thus the larger the asymmetry, the less the shock affects aggregate inflation. This implies that the interest rate has to respond less via the Taylor rule and thus that the shock propagates less to the output gap. Accordingly, Panels b and c show that the policy response in the asymmetric economy tends to be remarkably milder than in the symmetric one. Similarly, the deviations of output-gap and inflation from their steady state values in the asymmetric economy tend to be remarkably smaller than in the symmetric economy. Summing up, with supply shocks, heterogeneity in sectoral price stickiness tends to buffer exogenous disturbances requiring a less active monetary policy.

3.2 Monetary policy mistakes ignoring sectoral price stickiness heterogeneity

The previous findings imply that two two-sector economies sharing the same mean degree of price stickiness but not the same variance respond differently to exogenous real disturbances and therefore require specific monetary policies. This implication poses serious problems in terms of monetary policy mistakes for central banks that neglects sector price stickiness heterogeneity. To illustrate this point, we can consider, for instance, a two-sector economy where $\alpha_s = 0.9$ and $\alpha_m = 0.5$ so that the average degree of price stickiness is $\alpha = 0.7$. In this economy, we let the central bank assume that $\alpha_s = \alpha_m = 0.7$, or, equivalently for what is shown below, only consider the average price stickiness value disregarding the dispersion across sectors. Then, exogenous shocks hit and the central bank responds. Yet, the actual response will be different from the response that would occur if the central bank considered heterogeneity in sectoral price stickiness, i.e. the correct response. To develop this argument, let us define as *monetary policy* the current and expected interest rate decisions, that is the interest rate path following the shock[9]. There are, then, two monetary policies: the actual and the correct one, and we can ask what the policy mistakes are for the central bank that neglects the dispersion in sectoral price stickiness.

Figure 2 provides a *prima facie* answer contrasting in each panel the IRFs of the interest rate capturing the actual (dashed) and the correct policy (solid). Here each panel lies on a row referring to a calibration and on a column referring to a shock.

[INSERT FIGURE 2 HERE]

Figure 2 shows that asymmetry in price stickiness always makes monetary policy remarkably different. With a cost-push shock, ε^{ψ}, the actual policy is uniformly *tighter* than the correct one, while with a technology shock, ε^{a}, the actual is uniformly *easier* than the correct; these results holding with both calibrations. Left with a preference shock, ε^{c}, under the first calibration the actual policy is *less tight* than the correct one, except for the initial three periods. Under the second calibration the actual policy is fully wrong: it is *easy* instead of *tight* as required by the correct policy.

Visual inspection thus reveals that neglecting asymmetry in price stickiness leads to quantitative and qualitative policy mistakes. At this point, to sharp our evaluation of these policy mistakes we need to measure the policy error. For this purpose, let us introduce a policy error statistic in two steps: first computing the distance between the interest rate path under symmetry and asymmetry at each point in time. Then dividing this distance by the value of the policy under asymmetry at each point in time. What results is therefore the *percentage deviation of the actual policy from the correct policy.* Figure 3 reports this statistic for the policy errors. As before, each panel lies on a row that refers to a calibration and to a column that refers to a shock.

[INSERT FIGURE 3 HERE]

In addition, now, each panel shows for every point in time the measure (in percentage terms) and the type of the error (e.g. policy tighter, easier, etc.). To fix the ideas, we can consider the policy errors with a cost-push shock under the first

[9] This definition is introduced to avoid confusion between the *monetary policy rule*, which here is the Taylor rule and is invariant to the symmetry/asymmetry case, and the *monetary policy,* that is the decisions (current and expected) taken by the central bank using the policy rule.

calibration (row1, column 1). Looking at the tenth period subsequent to the shock, the actual policy turns out to be 100% tighter than the correct one. Now, what Figure 3 reveals is that the policy errors are generally very large, with actual policies that compared to the correct ones can be easier (black), tighter (blue/dark grey), less tight (white) between 40% and 145% over the first ten periods. Or with policies that are easy instead of tight (yellow/light grey), with a distance between the two which is no less than 150% of the (absolute) value of the correct tight policy. Summing up, Table 2 reports that the percentage deviation of the actual policy from the correct policy averaged over the first ten periods is between 50% and 100% for the cost-push and technology shock, and between 60% and 180% for the preference shock.

Now, before deepening the investigation with a quantitative assessment of the implications of this policy mistakes, it is worth stopping for a natural question: what drives these findings?

3.3 Mechanics

When sectors differ in terms of stickiness, sectoral inflations differ after a shock and the stickier sector experiences a smaller change in inflation[10]. As a result the relative price between sectors kicks in as shown by equation (14) and tends to divert the demand from the sector whose goods are relatively more expensive to the sector whose goods are relatively cheaper. As expected, in the former sector inflation falls while in the latter increases. Yet, these sectoral inflation changes caused by q, beyond differing in direction, differ also size wise because the change in marginal costs caused by the demand change impacts less inflation in the stickier sector. This is due to the fact that the elasticity of sectoral inflation to the relative price is decreasing in sectoral stickiness as shown in (11) and therefore is smaller in the stickier sector. Such a difference in the impact of the relative price on sectoral inflations implies a fall in aggregate inflation and therefore a buffering role played by the switching demand mechanism. It is worth noting that the sector where prices are more flexible, while exposing aggregate inflation more to the shocks, is also the one through which the switching demand mechanism acts the most to buffer the shock.

The buffering device activated by heterogeneity in price stickiness can be conveniently illustrated with a New Keynesian AS-AD framework that gives special atten-

[10] This holds no matter what the shock is: with a supply shock through the shock filtering mechanism and with a demand shock through a different slope of the Phillips curve.

tion to the role played by expectations.

3.3.1 A New Keynesian AS-AD graphical illustration of the role of price stickiness dispersion

The AD-AS diagram is presented in the $(\pi_t,\ y_t)$ space. For sake of simplicity but without loss in generality the assumptions of habit persistence and interest rate smoothing are relaxed, i.e. $\eta = 0$ and $\delta_0 = 0$. Drawing the diagram, it is worth recalling that in steady state all the expectations terms are zero.

To obtain the AD we join the Euler equation and the Taylor rule and solve for current inflation as a function of the current output gap given the output gap and inflation expectations

$$\pi_t = -\left(\frac{1+\widetilde{\sigma}\delta_2}{\widetilde{\sigma}\delta_1}\right) y_t + \frac{1}{\widetilde{\sigma}\delta_1} y_{t+1|t} + \frac{1}{\delta_1}\pi_{t+1|t}. \tag{18}$$

Solving this equation forward leads to

$$\pi_t = -\left(\frac{1+\widetilde{\sigma}\delta_2}{\widetilde{\sigma}\delta_1}\right) y_t + \frac{\delta_1 - 1 - \widetilde{\sigma}\delta_2}{\widetilde{\sigma}\delta_1}\sum_{\tau=1}^{\infty}\delta_1^{-\tau} y_{t+\tau|t}. \tag{19}$$

Equation (19) shows that the relation between current inflation and output gap shifts in the $(\pi_t,\ y_t)$ space according to the expected path of the output gap. Thus, if breaking the symmetry changes this expected path there will be a shift of the AD with respect to its position under symmetry.

Regarding the AS, equation (16) can be solved forward to obtain

$$\pi_t = (\omega+\varphi)\frac{1}{2}(\kappa_s+\kappa_m)\, y_t + \frac{1}{2}(\omega+\varphi)(\kappa_s+\kappa_m)\sum_{\tau=1}^{\infty}\beta^{\tau} y_{t+\tau|t} \tag{20}$$
$$-\frac{1}{4}(\rho\omega+1)(\kappa_s-\kappa_m)\sum_{\tau=0}^{\infty}\beta^{\tau} q_{t+\tau|t} + \frac{1}{2}(\kappa_s+\kappa_m)\sum_{\tau=0}^{\infty}\beta^{\tau}\psi_{t+\tau|t},$$

which under symmetry boils down to

$$\pi_t = (\omega+\varphi)\frac{1}{2}\kappa y_t + \frac{1}{2}(\omega+\varphi)\kappa\sum_{\tau=1}^{\infty}\beta^{\tau} y_{t+\tau|t} + \frac{1}{2}\kappa\sum_{\tau=0}^{\infty}\beta^{\tau}\psi_{t+\tau|t}, \tag{21}$$

where $\kappa = \kappa_s = \kappa_m$. For a given expected path of the cost-push shock, equation (20) shows that current inflation depends on the expected paths of the output gap and the relative price, while equation (21) shows that it depends only on the expected path of the output gap.

3.3.2 Cost-push shock case

Figure 4 reports the *steady state equilibrium* A and the *off-steady state equilibria* in presence of a cost-push shock under symmetry B $(\alpha_m = \alpha_s = 0.7)$, and asymmetry C $(\alpha_m = 0.6,\ \alpha_s = 0.8)$ and D $(\alpha_m = 0.5,\ \alpha_s = 0.9)$.

[INSERT FIGURE 4 HERE]

Off the steady state, Figure 4 takes a snapshot of π_t and y_t in the initial period in which the shock hits the economy. It does not leaves aside the subsequent periods though. Indeed, expectations on the economic dynamics determine the position of the AD and AS (not their slopes) as shown by equations (19-21). Describing the Figure, the red/grey and the black color refer to symmetry and asymmetry respectively, while the solid lines refer to the steady state equilibrium, and the dash and dots lines refer to off-steady state equilibria. It is worth noting that in steady state the AD (downward sloped) under symmetry and asymmetry coincide, while the AS (upward sloped) is steeper under asymmetry[11].

Figure 4 shows that under symmetry, when the shock hits the economy the equilibrium is no longer A but B. What happens is that with the shock the expected path for inflation becomes positive so that, via the Taylor rule, the expected path for the output gap becomes negative. As shown by equations (21 and 19), this leads the AD to shift left and the AS to shift up (the impact of the shock prevails on the deflationary path for the output gap). Breaking the symmetry the economy moves either to C (low asymmetry) or to D (high asymmetry). With respect to equilibrium B, equilibria C and D feature a smaller increase in inflation and a smaller fall in output. Furthermore, the larger the asymmetry, the larger the departure from B and the larger these effects. Indeed, regarding the AS, for a given current value and expected path of the shock, under asymmetry the shift is determined by the expected path of the output gap and the relative price, summarized in (20) by the terms $\sum_{\tau=1}^{\infty}\beta^{\tau} y_{t+\tau|t}$ and $\sum_{\tau=0}^{\infty}\beta^{\tau} q_{t+\tau|t}$ respectively. In contrast, given the shock, under symmetry the shift is determined only by the expected path of the output gap. Thus, in buffering the shock the *deflating mechanism* provided by the output gap is supported by the *switching*

[11] Breaking the symmetry, the elasticity of inflation to the output gap and the shock increases. This effect, visible in the AS steeper under asymmetry and due to the convexity of the relation between κ and α, exerts a minor impact on the macroeconomic dynamics.

demand mechanism provided by the relative price. This is shown by the *negative* expected path for q reported in Panel b of Figure 1 associated with the positive elasticity of aggregate inflation to the relative price in equation (20). Thus the expected path of the relative price buffers the shock in addition to the expected path for the output gap in (20). As a result of the presence of the switching demand mechanism, the AS shifts up less under asymmetry.

Regarding the AD, the smaller shift to the left under asymmetry is always due to the presence of the relative price. Indeed, the smaller impact of the shock on inflation due to the switching demand mechanism implies, via the policy response, a smaller deflating role imposed to the output gap, which is captured by a smaller value of the term $\sum_{\tau=1}^{\infty} \beta^{\tau} y_{t+\tau|t}$ in (19). Summing up, breaking the symmetry results in different impacts of the cost-push shock on sectoral inflations which, activating the relative price, allows a partial return of both AS and AD to their pre-shock positions. Hence breaking the symmetry results in lower output and inflation volatility.

3.4 Persistence and volatility of the macrovariables vs sectoral price stickiness heterogeneity

The Impulse Response analysis has signalled two consequences of the presence of sectoral price stickiness asymmetry in the working of the economy. On the one hand it affects the macroeconomic dynamics. On the other hand, if it is neglected in monetary policy decisions, it leads to quantitative and qualitative policy mistakes. In order to further characterize these consequences, it is useful to focus on the *persistence* and *volatility* of y, i, and π and studying how they change as a function of sectoral price stickiness asymmetry.

Starting with persistence, this feature of the dynamics is here measured using, for each variable, the sum of the first five autocorrelation coefficients[12]. Figure 5, Panel a, shows that the persistence of y, i, and in particular π, monotonically decreases for increasing degrees of sectoral price stickiness asymmetry.

[INSERT FIGURE 5 HERE]

Specifically, moving from $\alpha_m = \alpha_s = 0.7$ to $\alpha_m = 0.5$, $\alpha_s = 0.9$, the persistence of y, i and π decreases of 2.6%, 6.9%, and 24% respectively. Noting that in the two

[12] The autocorrelation coefficients have been computed in presence of the whole set of considered shocks.

sectors inflation persistence exhibits opposite behaviors, the stark fall in aggregate inflation persistence depends on the major role played by the sector where prices are more flexible, i.e. the m-sector. Indeed, the larger the asymmetry, the more the m-sector is exposed to the destabilizing impact of the shock and to the stabilizing impact of the switching demand mechanism; both factors contracting persistence. In contrast, the larger the asymmetry, the less the s-sector is exposed to the destabilizing impact of the shock and to the stabilizing impact of the switching demand mechanism[13]. The decrease in inflation persistence leads, in turn, to a decrease in the interest rate persistence via the Taylor rule.

The finding that heterogeneity in price stickiness leads to less inflation persistence questions the ability of the standard New Keynesian Phillips curve in fitting the macroeconomic evidence on inflation persistence, a view that this work shares with Sheedy's (2007).

Let us now turn to the volatility of y, i, and π as a function of the asymmetry in sectoral price stickiness. The impulse response analysis signalled that introducing sectoral asymmetry in price stickiness tends to reduce the deviations of these variables from their long run values. Consistently, Figure 5, Panel b shows that the unconditional standard deviations of these variables monotonically fall when the asymmetry in sectoral price stickiness increases[14]. In particular, the variability of π and i decreases of 38.2% leading to a decrease of the variability of y of the 31.3%. This finding matters as indicates that sectoral asymmetry in price stickiness plays a key role in determining the variability of the endogenous variables.

These results also imply that two economies that share the average but not the variance of the sectoral price stickiness exhibit very different persistence and variability of the endogenous variables.

At this point it is interesting to relate the current results to the inflation targeting operating procedure in use at several central bank (Svensson 2010). Sketching this procedure, first the staff computes alternative distribution forecasts associated with different interest rate paths minimizing a standard loss function. Then the Board selects the policy associated with the specific distribution forecast that suits best its preferences. The current results thus suggest that one-sector models are not suitable to obtain projections of the target variables since they can be highly misleading as

[13]This depends on the elasticities of sectoral inflations to real shocks and the relative price as explained above.

[14]In the Figure, the inflation and the interest rate volatility curve tend to overlap so that the inflation curve is hidden.

to their persistence and volatility.

Finally, these theoretical results are in line with the empirical evidence related to French data found by Imbs et al. (2011). Indeed, they show that in presence of sectoral heterogeneity in price stickiness, sectoral estimates imply policies associated with volatilities in output gap and inflation that halve the ones implied by aggregate data.

4 Shocks and policy pitfalls of one-sector model with price stickiness heterogeneity

The role played by price stickiness heterogeneity in the transmission of monetary shocks has been pioneered by Carvalho (2006). Therein the important result has been to show that the presence of sectoral differences results in *larger* and *more persistent* effects of monetary shocks on the output gap. Comparing the current findings with Carvalho's we observe that they tend to be opposite: with real shocks the presence of sectoral differences in prices stickiness results in *smaller* effects on the output gap[15].

Two questions then naturally arise: why does this happen? and is there any general result holding for *any* exogenous shock that can be useful for policy analysis? To address the first question we simulate the response of the current model to a monetary shock and illustrate the result using the previous AD-AS graphical framework.

Adding a monetary shock to the Taylor rule specified as $m_{t+1} = \gamma_m m_t + \varepsilon^m_{t+1}$ the forward solution of the AD given by (19) is replaced by

$$\pi_t = -\left(\frac{1+\widetilde{\sigma}\delta_2}{\widetilde{\sigma}\delta_1}\right) y_t + \frac{\delta_1 - 1 - \widetilde{\sigma}\delta_2}{\widetilde{\sigma}\delta_1} \sum_{\tau=1}^{\infty} \delta_1^{-\tau} y_{t+\tau|t} - \frac{1}{\delta_1} \sum_{\tau=0}^{\infty} \left(\frac{1}{\delta_1}\right)^{\tau} m_{t+\tau|t}. \qquad (22)$$

Equation (22) shows that a monetary policy shock shifts the AD in the (π_t, y_t) space. Since the position of the AD depends also on the expected path of the output gap, if breaking the symmetry changes this path then there will be a different impact of the monetary shock. To illustrate the relevant role played by the asymmetry assumption, Figure 6 considers a contractionary monetary policy shock.

[INSERT FIGURE 6 HERE]

[15] Previous analysis has shown that output gap persistence falls too, but to a minor extent.

With both symmetry and asymmetry, the shock leads to a *negative* expected path for the output gap which, in turn, leads to a *negative* expected path for inflation. This leads the AD to shift left and the AS to shift down, point B. What happens when we break the symmetry? breaking the symmetry the AS shifts up and the AD shifts further left, point C (low asymmetry) or D (high asymmetry). Starting with the AS, the deflationary impact of the contractionary monetary policy will be smaller in the sector with stickier prices. Thus, the relative price q leaves the steady state and increases. This, in turn, exerts a positive effect on aggregate inflation contrasting the shift down of the AS determined by the negative expected output gap[16].

Turning to the AD, why does it shift further left when we break the symmetry? Because, as explained above the switching demand mechanism prevents the expected inflation path from deviating from its steady state value as much as with symmetry. This implies that the policy response via the Taylor rule to inflation is smaller than under symmetry. As a result, the initial impact of the shock on the output gap is larger and the subsequent path to its steady state takes longer.

Let us now turn to the second question: is there any general result useful for policy analysis that we can apply to any exogenous shocks in presence of sectoral differences in price stickiness? Drawing on the AS-AD illustrations for the cost-push and monetary shock, Figures 4 and 6, we can note that, independently on the nature of the shock, breaking the symmetry contracts the outward shift of the AS. This contraction is due to the buffering device activated by the switching demand mechanism[17]. It is easy to show that this result is general in that applies to technology and preference shocks too. Thus, with any shock, sectoral differences in price stickiness lead to smaller and less persistent effects on inflation. This suggests three policy pitfalls for policy makers grounding policy decisions on one-sector model when the actual economy features sectoral differences in price stickiness. First, with *any* shock the one-sector model will *overvalue* the variation and persistence of inflation. Second, with real shocks the one-sector model will *overvalue* the variation of the output gap.

[16]Since the elasticity of current inflation to q is positive due to the fact that with asymmetry $\kappa_s < \kappa_m$, the q effect on aggregate inflation is positive.

[17]Formally, in both cases the shock leads to an expected path for q whose sign is opposite to the sign of the elasticity of π_t with respect to the shock at issue. Indeed, with a cost-push shock that has a direct positive impact on π_t it happens that q exhibits a negative path. With a monetary shock that has an indirect negative impact on π_t (via the expected path for the output gap), it happens that q exhibits a positive path.

Third, with monetary shocks the one-sector model will *undervalue* the variation and persistence of the output gap. Table 3 reports these policy pitfalls.

5 Concluding remarks

Using a two-sector New-keynesian model, this paper investigates how sectoral heterogeneity in price stickiness affects the dynamics of the economy in presence of real shocks.

When sectoral symmetry is broken, the relative price between sectoral goods appears into the working of economy and significantly alters its response to exogenous shocks via the demand channel. As a result, asymmetry in sectoral price stickiness on the one hand leads to an important fall in the persistence of aggregate inflation and to a moderate fall in the persistence of the interest rate. On the other hand, it leads to an important fall in the volatility of inflation, the interest rate and the output gap. Thus, two economies differing in the dispersion of sectoral asymmetry but not in the mean may exhibit very unlike volatility and persistence.

This finding has important monetary policy implications. Disregarding the dispersion in sectoral price stickiness leads policymakers first to overvalue the variation and persistence of inflation; second, to overvalue the variation of the output gap. We show that this wrong evaluation of the aggregate dynamics can lead policymakers to relevant mistakes in presence of real shocks. They can follow over the first ten quarters subsequent the shock a policy that is qualitatively different from the correct one, or a policy that is up to 150% tighter or easier than the correct one. These implications suggests that policy decisions should seriously account for the presence of sectoral price stickiness. Moreover, they highlight the relevance of sectoral data for economic estimations and forecasts.

Considering a country or monetary union where regions or states feature different degree of price stickiness, the current findings question the appropriateness of a monetary policy based on the average degree of price stickiness. Further analysis will investigate this point as well as how sectoral size and strategic complementarities affect the relation between sectoral asymmetry in price stickiness and the dynamics of the economy.

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TABLE 1 Alternative calibrations

Panel a -benchmark				Panel b -robustness	
η	0.7	n_s	0.5	η	0
$\widetilde{\sigma}$	2/3	n_m	0.5	$\widetilde{\sigma}$	1
β	0.9975	γ_a	0.95		
ρ	1	γ_ψ	0.95	ρ	8
ν	1.17	γ_c	0.95	ν	1
$1/\phi$	0.75	σ_ε^2	0.009^2	$1/\phi$	1
θ	7.88			θ	8
δ_0	0.8				
δ_1	1.5				
δ_2	0.5/4				

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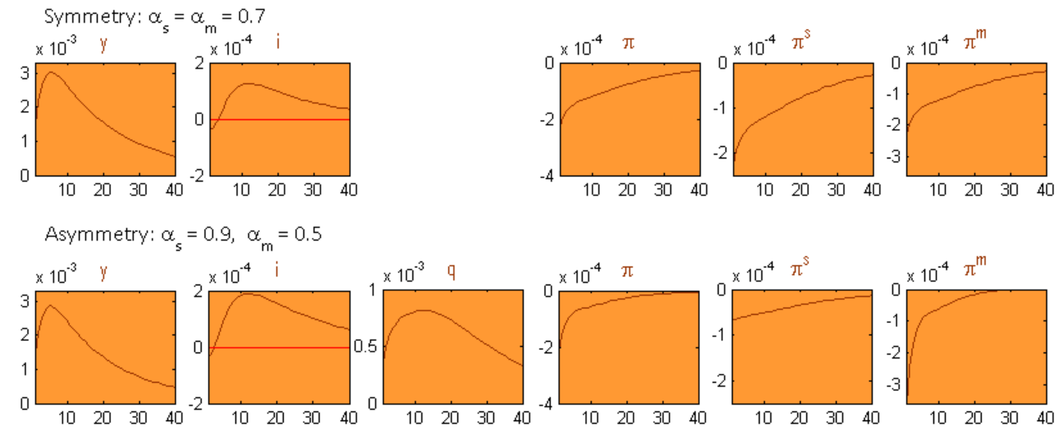
TABLE 2. Average Policy Error for the First Ten Periods

	Shock		
Calibration	ε_ψ	ε_a	ε_c
1	50%	50%	60%
2	100%	100%	180%

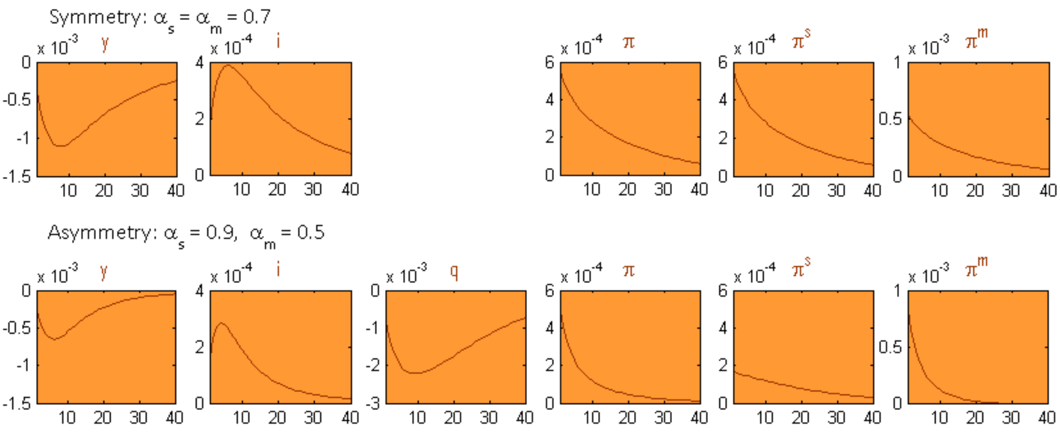
TABLE 3. Policy pitfalls using one-sector models in presence of price stickiness asymmetry

	Shock	
	Real	Monetary
π	Overvaluation of persistence and variation	Overvaluation of persistence and variation
y	Overvaluation of variation	Undervaluation of persistence and variation

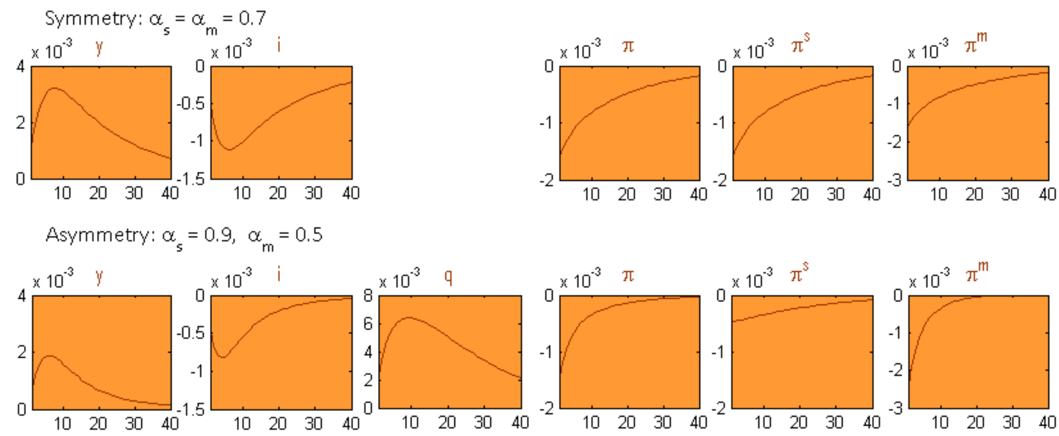
Figure 1. IRFs to real shocks in presence of symmetry and asymmetry in sectoral price stickiness



Panel a, IRFs to a preference shock ε_c



Panel b, IRFs to a cost-push shock ε_ψ



Panel c, IRFs to a technology shock ε_a

Figure 2. IRFs of the interest rate to real shocks under sectoral price stickiness symmetry (actual policy) and asymmetry (correct policy)

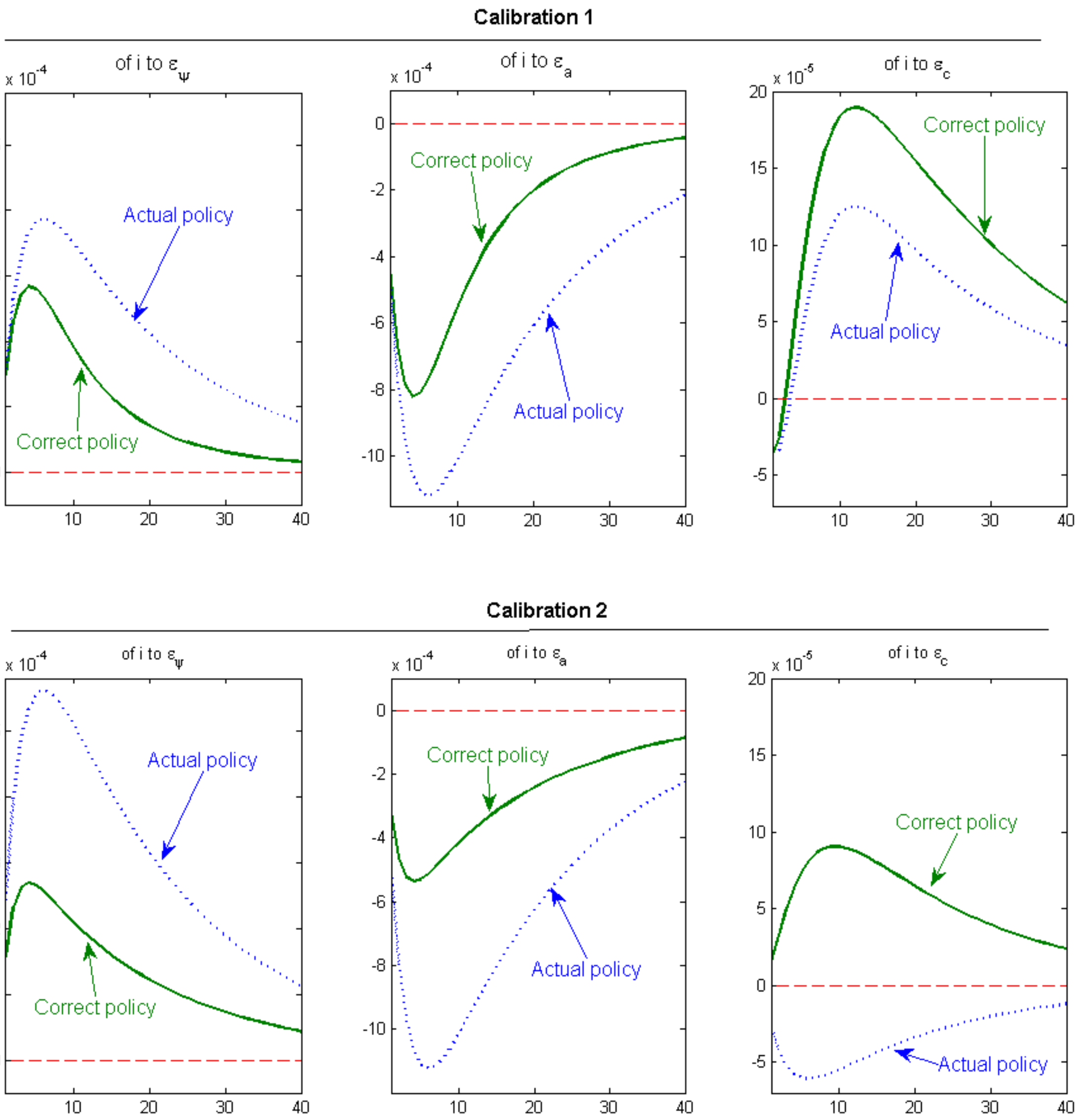
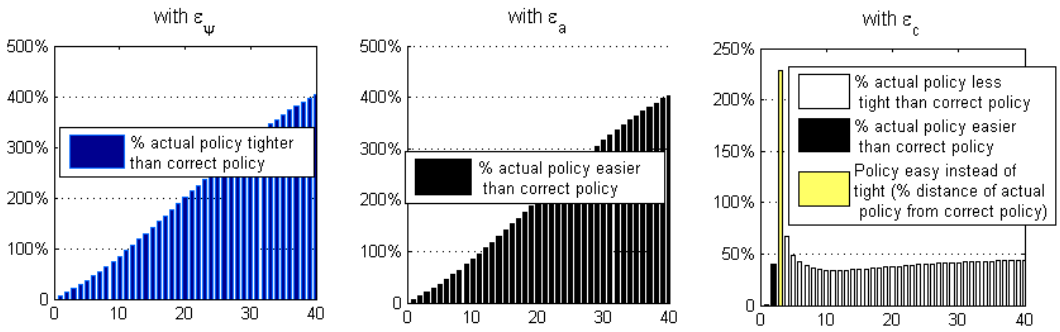


Figure 3. Monetary policy mistakes in presence of real shocks: percentage deviation of the actual policy from the correct policy

Panel a. Calibration 1



Panel b. Calibration 2

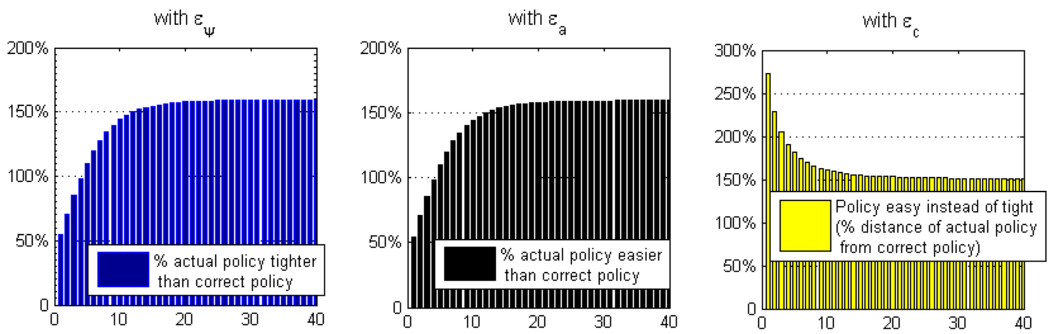


Figure 4. Steady state equilibrium and off-steady state equilibria after a cost-push shock with symmetry and asymmetry in sectoral price stickiness.

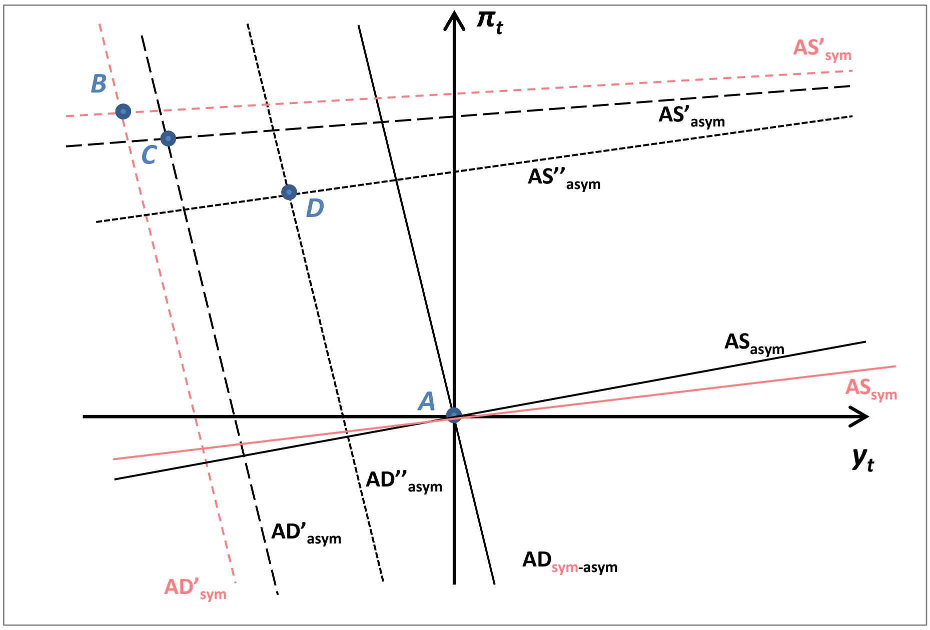
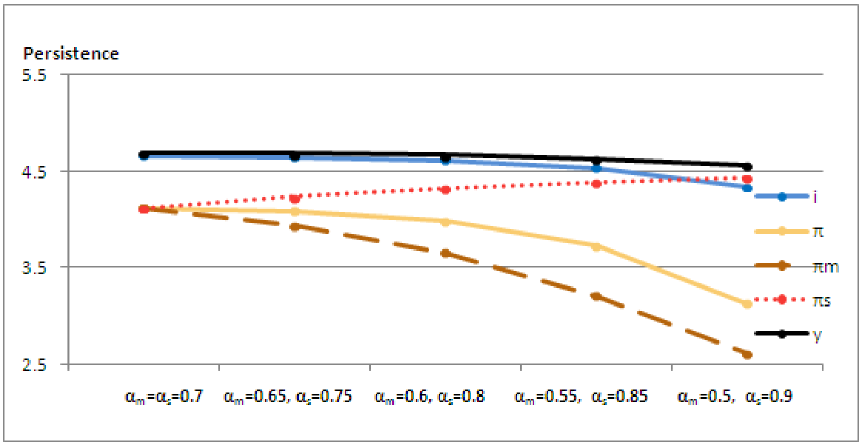
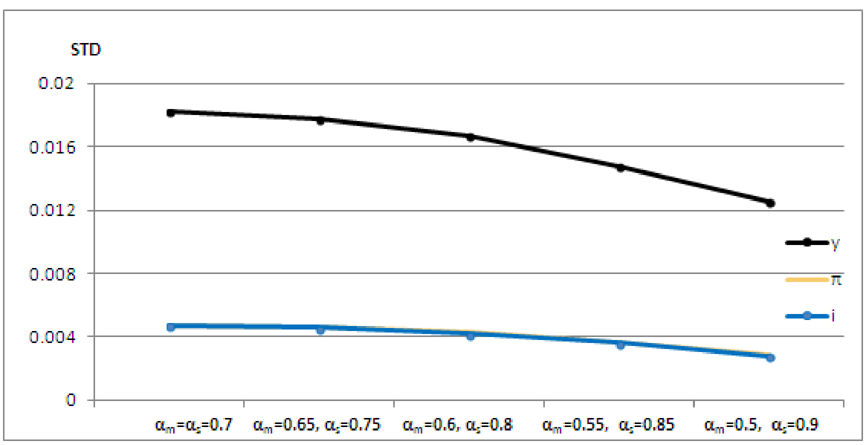


Figure 5. Persistence and volatility of the macrovariables vs asymmetry in sectoral price stickiness



Panel a. Persistence vs asymmetry in sectoral price stickiness



Panel b. Volatility vs asymmetry in sectoral price stickiness

Figure 6. Steady state equilibrium and off-steady state equilibria after a monetary shock with symmetry and asymmetry in sectoral price stickiness.