Price Stickiness Asymmetry, Industrial Transformation and the Great Moderation

Alessandro Flamini*

September 6, 2011

Abstract

In a two-sector New-Keynesian model, this paper shows that the dispersion in the degree of sectoral price stickiness plays a key role in the determination of the dynamics of aggregate inflation and, consequently, of the whole economy. The dispersion in price stickiness reduces the persistence of inflation and, to a smaller extent, of the interest rate. It also reduces the volatility of inflation, the interest rate and the output-gap. Thus two economies with the same average degree of price stickiness but a different variance may behave very differently, highlighting the relevance of sectoral data for economic estimations and forecasts. Furthermore, considering an industrial transformation of the type occurred in the last decades in several industrialized economies, the model offers a new and quantitatively relevant explanation for the Great Moderation, i.e. the decline in the volatility of output and inflation experienced since the ’80s by various developed countries.

JEL Classification: E31, E32, E37, E52.

Key Words: Sectoral asymmetries, price stickiness, New Keynesian model, persistence, volatility.

1 Introduction

A main feature of real-world economies is the presence of multi sectors. How sectoral asymmetry relates to the working of an economy is therefore a general issue potentially very important for the estimations and simulations of macro models. This paper focuses on sectoral asymmetry in price stickiness and asks how it affects the economic dynamics. Drawing on Benigno (2004) and Woodford (2003), the current

*I thank for comments Mustafa Caglayan, Alpay Filiztekin and Kostas Mouratidis, and for data the UK Office of National Statistics. I have also benefited from a useful discussion with Paul Levine and seminar participants at the University of Surrey. Any mistake is my responsibility.
work addresses this question presenting a two-sector New Keynesian model with the assumption of habit persistence¹.

Sectoral asymmetry in price stickiness in the New-Keynesian model with optimal monetary policy has been pioneered by Aoky (2001) and Benigno (2004). Both papers show that focusing the policy response on the sector with sticky or stickier price maximises welfare. Abstracting from optimal monetary policy and considering sectoral asymmetry in wage contracts, Dixon and Kara (2010a) show that in economies with the same average contract length, monetary shocks are more persistent in presence of longer contracts. They also show in Dixon and Kara (2010b) that accounting for the distribution of contract length substantially improves the ability of the model to replicate the inflation persistence found in the data.

With respect to the previous literature the contribution of this paper is twofold. First, it shows that sectoral asymmetry in price stickiness plays a key role in the determination of the aggregate inflation process and, via inflation, of the interest rate and aggregate output gap processes. Indeed, the analysis shows that the dispersion in sectoral price stickiness affects negatively the persistence of aggregate inflation and, to a minor extent, of the interest rate. It also affects negatively the variability of aggregate inflation, the interest rate and the output-gap. The analysis suggests that these results are quantitatively important too. Interestingly, these findings imply that two economies sharing the mean degree of price stickiness but not the variance may respond to exogenous disturbances very differently.

The second contribution is related to the decline in the volatility of output growth and inflation experienced by several industrialized countries since the ’80s, what has been called the Great Moderation whose determinants are highly debated and still unclear. In this regard, the model shows that when sectoral price stickiness is considered along with an expansion of the services sector and a contraction of the manufacturing sector, a new argument quantitatively relevant to explain the Great Moderation arises.

The intuition for these findings is the following. Breaking the symmetry in sectoral price stickiness introduces the relative price of sectoral goods into the picture which, affecting sectoral inflations in opposite ways, changes dramatically the shock transmission mechanism of the economy.

The plan of the paper is as follows. Section 2 presents the model where consumption habits are introduced into a two-sector New-Keynesian model. It derives the non-linear optimal conditions, shows the existence and uniqueness of the steady state, the log-linearized relations used in the following analysis, and the calibration of the structural parameters. Section 3 investigates the relation between sectoral asymmetry in price stickiness and the dynamics of the economy in presence of shocks.

¹Habit persistence tends to be a well accepted real friction in the New Keynesian model able to reproduce the hump-shaped response of real spending to various shocks. Although its inclusion is not necessary to obtain the results presented here, it is useful for comparisons with the previous literature.
to the price level, technology and the preferences of the household. Specifically, the analysis is carried out via impulse response functions, autocorrelations, and standard deviations of the endogenous variables. Section 4 studies the relation between sectoral price stickiness, the industrial transformation of the type occurred in numerous developed economies and the Great Moderation. It considers the impact of the transition from manufacturing to services on output, inflation and interest rate volatility for various degree of 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

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

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

$$C_t \equiv \left[ \left( n_s \right)^{1/\rho} \left( C_s^t \right)^{(\rho-1)/\rho} + \left( n_m \right)^{1/\rho} \left( C_m^t \right)^{(\rho-1)/\rho} \right]^{\rho/(\rho-1)}$$

of the goods $C_s^t$ and $C_m^t$ which are produced, respectively, by the s and m-sector, with $\rho$ 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:

$$C_s^t \equiv \left[ n_s^{-\frac{1}{\theta_s}} \int_0^{n_s} \left( C_s^t \left( i \right) \right)^{1-\frac{1}{\theta_s}} di \right]^{\frac{\theta_s}{\theta_s-1}}, \quad C_m^t \equiv \left[ n_m^{-\frac{1}{\theta_m}} \int_{n_s}^{1} \left( C_m^t \left( i \right) \right)^{1-\frac{1}{\theta_m}} di \right]^{\frac{\theta_m}{\theta_m-1}}$$

where $\theta_k > 1$, $k = s, m$, is the sectoral elasticity of substitution between any two differentiated goods. Period preferences on consumption and labour are modeled as CRRA functions

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

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

where $\overline{C}_t$ is an exogenous preference shock, $H_t \left( j \right)$ is the quantity supplied of labour of type $j$, and $\tilde{\sigma} > 0$ captures the intertemporal elasticity of substitution in consumption,
0 \leq \eta < 1 \text{ measures the degree of habit persistence, and } \nu > 0 \text{ is the inverse of the elasticity of goods production. The price index for the minimum cost of a unit of } C_t \text{ is given by}

\[ P_t \equiv \left[ n_s \left( P^s_t \right)^{1-\rho} + (n_m) \left( P^m_t \right)^{1-\rho} \right]^{1/(1-\rho)}, \tag{5} \]

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

\[ P^s_t \equiv \left( n_s \right)^{-1} \int_0^{n_s} p^s(i)^{1-\theta_s} \, di, \quad P^m_t \equiv \left( n_m \right)^{-1} \int_{n_s}^{1} p^m(i)^{1-\theta_m} \, di. \]

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

\[ C^s_t = n_s C_t \left( \frac{P^s_t}{P_t} \right)^{-\rho}, \tag{6} \]
\[ C^m_t = n_m C_t \left( \frac{P^m_t}{P_t} \right)^{-\rho}. \tag{7} \]

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

\[ \lambda_t = \beta E_t \left\{ \frac{\tilde{u}_c \left( C_{t+1} - \eta C_t; \overline{C}_{t+1} \right) - \beta \eta E_t \tilde{u}_c \left( C_{t+2} - \eta C_{t+1}; \overline{C}_{t+2} \right)}{\tilde{u}_c \left( C_t - \eta C_{t-1}; \overline{C}_t \right) - \beta \eta E_t \tilde{u}_c \left( C_{t+1} - \eta C_t; \overline{C}_{t+1} \right)} \right\} \frac{P_t}{P_{t+1}}, \tag{8} \]

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

\[ \Omega_t(j) = \Psi_t \left[ \tilde{u}_h \left( H_t \left( j \right) \right) \right. \frac{\tilde{u}_c \left( C_t - \eta C_{t-1}; \overline{C}_t \right) - \beta \eta E_t \tilde{u}_c \left( C_{t+1} - \eta C_t; \overline{C}_{t+1} \right)}{\tilde{u}_c \left( C_{t+1} - \eta C_{t+2}; \overline{C}_{t+2} \right) - \beta \eta E_t \tilde{u}_c \left( C_{t+2} - \eta C_{t+1}; \overline{C}_{t+2} \right)} \left( \frac{P_t}{P_{t+1}} \right)}, \tag{9} \]

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. Given (2), sectoral aggregate demands are

\[ Y^s_t \equiv \left[ \frac{1}{n_s} \int_0^{n_s} \left[ y^s_t(j) \right]^{a^s-1} \, dj \right]^{\frac{\rho^s}{\sigma^s-1}}, \quad Y^m_t \equiv \left[ \frac{1}{n_m} \int_0^{n_m} \left[ y^m_t(j) \right]^{a^m-1} \, dj \right]^{\frac{\rho^m}{\sigma^m-1}}. \]

Turning 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 and a sector-specific technology

\[
y^s_t(i) = A_t [H^s_t(i)]^{1/\phi_s},
\]

\[
y^m_t(i) = A_t [H^m_t(i)]^{1/\phi_m},
\]

where \( A_t \) is a technology shock, \( H^s_t(i) \), \( H^m_t(i) \) are the quantities of labour used by the representative firm \( i \) in the \( s \) and \( m \)-sector to produce good \( i \) respectively, and \( \phi^k > 1 \), \( k = s, m \) is the elasticity of sectoral output with respect to hours worked.

Thus the input requirement functions are

\[
H^s_t = \left[ \frac{y^s_t(i)}{A_t} \right]^{\phi_s}, \tag{10}
\]

\[
H^m_t = \left[ \frac{y^m_t(i)}{A_t} \right]^{\phi_m}, \tag{11}
\]

then, accounting for the preferences (1-2) the quantity demanded for each individual good in the manufacturing and services sector are, respectively,

\[
y^s_t(i) = C^s_t(i)
= C_t \left( \frac{p^s_t(i)}{P_t} \right)^{-\theta_s} \left( \frac{P^s_t}{P_t} \right)^{-\rho}, \tag{12}
\]

and

\[
y^m_t(i) = C^m_t(i)
= C_t \left( \frac{p^m_t(i)}{P_t} \right)^{-\theta_m} \left( \frac{P^m_t}{P_t} \right)^{-\rho}. \tag{13}
\]

In equilibrium, market clearing in the goods market requires

\[
Y^m_t = C^m_t, \tag{14}
\]

\[
Y^s_t = C^s_t; \tag{15}
\]

\[
Y_t = C_t, \tag{16}
\]

Then, combining (3), (8), and (16) we obtain the nonlinear version of the aggregate demand. 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 \(t, \tilde{p}_t^h\), to maximize the flow of expected profits:

\[
\max_{\tilde{p}_t^h} E_t \sum_{T=t}^{\infty} \alpha^{T-t} \lambda_{t,T} \left\{ \tilde{p}_t^h y_T^h (i) - \left[ \frac{y_T^h (i)}{A_T} \right]^\phi_h \frac{[y_T^h (j) / A_T]^\mu_{\phi_h} \Psi_T^h \left( \frac{\tilde{p}_t^h}{P_T^h} \right)^{-\phi_h \theta_h - \phi_h \theta_h - 1} \tilde{p}_t^h}{C_T^\frac{1}{\theta_h} (C_t - \eta C_{t-1})^{-\frac{1}{\theta_h}} - \eta \beta C_T^\frac{1}{\theta_h} (C_{t+1} - \eta C_t)^{-\frac{1}{\theta_h}}} P_T \right\},
\]

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

\[
0 = E_t \sum_{T=t}^{\infty} \alpha^{T-t} \lambda_{t,T} \left\{ C_T \left( \frac{\tilde{p}_t^h}{P_T^h} \right)^{-\theta_h} \left( \frac{P_T^h}{P_T} \right)^{-\rho} - \theta_h C_T \left( \frac{\tilde{p}_t^h}{P_T^h} \right)^{-\theta_h - 1} \frac{\tilde{p}_t^h}{P_T^h} \left( \frac{P_T^h}{P_T} \right)^{-\rho} - \frac{\psi_T^h}{C_T^\frac{1}{\theta_h} \left( C_T - \eta C_{t-1} \right)^{-\frac{1}{\theta_h}} - \eta \beta C_T^\frac{1}{\theta_h} \left( C_{t+1} - \eta C_t \right)^{-\frac{1}{\theta_h}}} P_T \right\}
\]

(17)

2.1 Existence and uniqueness of the steady state equilibrium

In presence of flexible prices, the monopolistic competitive representative firm \(i\) in sector \(m\) sets the optimal price \(\tilde{p}_t^m\) in any period to maximize the period profit

\[
\max_{\tilde{p}_t^m} \left\{ \tilde{p}_t^m y_t^m (i) - \left[ \frac{y_t^m (i)}{A_t^m} \right]^\phi_m \frac{\psi_t^m \left[ \tilde{v}_h \left[ H_t \left( \frac{y_t^m}{A_t^m} \right) \left( \frac{\tilde{p}_t^m}{P_t} \right)^{-\rho} \frac{\tilde{v}_h \left[ H_t \left( \frac{y_t^m}{A_t^m} \right) \right]}{C_t - \eta C_{t-1}; \bar{C}_t} - \eta \beta E_t \tilde{u}_e \left( C_{t+1} - \eta C_t; \bar{C}_{t+1} \right) \right]}{P_t} \right\},
\]

and the f.o.c. consists of setting the price as a mark-up on marginal costs

\[
\tilde{p}_t^m = \frac{\theta}{(\theta - 1)} \phi_m \left[ \frac{y_t^m (i)}{A_t^m} \right]^\phi_m \frac{\psi_t^m \left[ \tilde{v}_h \left[ H_t \left( \frac{y_t^m}{A_t^m} \right) \left( \frac{\tilde{p}_t^m}{P_t} \right)^{-\rho} \frac{\tilde{v}_h \left[ H_t \left( \frac{y_t^m}{A_t^m} \right) \right]}{C_t - \eta C_{t-1}; \bar{C}_t} - \eta \beta \tilde{u}_e \left( C_{t+1} - \eta C_t; \bar{C}_{t+1} \right) \right]}{P_t}.
\]

Let \(s_t^m\) be the real marginal cost in the \(m\)-sector

\[
s_t^m \left( y_t^m (i), C_t, \frac{P_t^s}{P_t^m}; \xi_t \right) = \phi_m \left[ \frac{y_t^m (i)}{A_t^m} \right]^\phi_m \frac{\psi_t^m \tilde{v}_h \left[ y_t^m (i) \right]}{\tilde{u}_e \left( C_t - \eta C_{t-1}; \bar{C}_t \right) - \eta \beta \tilde{u}_e \left( C_{t+1} - \eta C_t; \bar{C}_{t+1} \right) \left( P_t^m \right) P_t^m},
\]

(18)
where "real" is with respect to the price of the composite good in the $m$ sector. Notice that accounting for (5) we obtain

$$\frac{P_t}{P_t^m} = \left[ n_s \left( Q_t^{1-\rho} - 1 \right) + 1 \right]^{\frac{1}{1-\rho}}, \quad (19)$$

and

$$\frac{P_t}{P_t^m} = \left[ n_m \left( Q_t^{\rho-1} - 1 \right) + 1 \right]^{\frac{1}{1-\rho}}, \quad (20)$$

where $Q_t \equiv \frac{P_t^s}{P_t^m}$, so that $s^m$ turns out to be a function only of $(y_t^m (i), C_t, Q_t; \xi_t^m)$ where $\xi_t^m \equiv (A_t^m, \Psi_t^m, C_t)'$ is a vector of shocks. Then the f.o.c. can be rewritten as

$$\frac{\tilde{p}_t^m}{P_t^m} = \frac{\theta_m}{(\theta_m - 1)} s^m (y_t^m (i), C_t, Q_t; \xi_t^m). \quad (21)$$

Now, rearranging the demand for good $i$ in sector $m$ given by (13) we obtain

$$\frac{p_t^m (i)}{P_t^m} = \frac{[y_t^m (i)]^{-\frac{1}{\sigma_m}} \left( P_t^m \right)^{-\frac{\sigma_m}{\sigma_m}}}{C_t^{-\frac{1}{\sigma_m}}} \left( P_t \right)^{-\frac{\sigma_m}{\sigma_m}} = \frac{\theta_m}{(\theta_m - 1)} s^m (y_t^m (i), C_t, Q_t; \xi_t^m).$$

Then, accounting for (21) the supply of good $i$ must satisfy

$$\frac{[y_t^m (i)]^{-\frac{1}{\sigma_m}} \left( P_t^m \right)^{-\frac{\sigma_m}{\sigma_m}}}{C_t^{-\frac{1}{\sigma_m}}} \left( P_t \right)^{-\frac{\sigma_m}{\sigma_m}} = \frac{\theta_m}{(\theta_m - 1)} s^m (y_t^m (i), C_t, Q_t; \xi_t^m).$$

Now notice that the LHS and the RHS are, respectively, decreasing and increasing in $y_t^m (i)$. Thus there is only one value of $y_t^m (i)$ that satisfies the previous equation given $(C_t, Y_t^s, Q_t)$. In equilibrium all the firms in the $m$-sector produce the same quantity so that it must be that $y_t^m (i) = Y_t^m$. Hence

$$\frac{[Y_t^m]^{-\frac{1}{\sigma_m}} \left( P_t^m \right)^{-\frac{\sigma_m}{\sigma_m}}}{C_t^{-\frac{1}{\sigma_m}}} \left( P_t \right)^{-\frac{\sigma_m}{\sigma_m}} = \frac{\theta_m}{(\theta_m - 1)} s^m (Y_t^m, C_t, Q_t; \xi_t^m),$$

and accounting for (18) and (19) we obtain

$$\frac{[Y_t^m]^{-\frac{1}{\sigma_m}} \left( P_t^m \right)^{-\frac{\sigma_m}{\sigma_m}}}{C_t^{-\frac{1}{\sigma_m}}} \left( P_t \right)^{-\frac{\sigma_m}{\sigma_m}} = \frac{\theta_m}{(\theta_m - 1)} \phi_m \left[ Y_t^m \right]^{\phi_m-1} \left[ y_t^m (j) / A_t^m \right]^{\nu \phi_m} \left[ n_s \left( Q_t^{1-\rho} - 1 \right) + 1 \right]^{\frac{1}{1-\rho}} \left[ \frac{C_t^{\frac{1}{\sigma}} (C_t - \eta C_t) \left( \frac{1}{\phi_m (1 - \eta)} + \frac{1}{\gamma C_t} \right)}{\eta \beta C_t^{\frac{1}{\sigma}} (C_t + 1 | t - \eta C_t)} \right]^{\frac{1}{1-\rho}},$$

which, assuming no shocks and accounting for (7) and (14-16) boils down to

$$\frac{(\theta_m - 1)}{\theta_m \phi_m} = \frac{[Y_t^m]^{\nu \phi_m + \phi - 1}}{(1 - \eta) [ (1 - \eta) Y ]^{-\frac{1}{\sigma}}} \left[ n_s Q_t^{1-\rho} + n_m \right]^{\frac{1}{1-\rho}}. \quad (22)$$
Similarly for the other sector

\[
\frac{(\theta_s - 1)}{\theta_s \phi_s} = \frac{[Y^s]^{\phi_s + \phi_s - 1}}{(1 - \eta \beta) [(1 - \eta) Y]^{-\frac{1}{\rho}}} \left[ n_s + n_m (Q)^{\rho - 1} \right]^{-\frac{1}{\rho}} .
\] (23)

Now accounting for (6-7) and the sectoral market clearing conditions (14-16) and (19-20) we obtain

\[
Y^m = n_m Y \left[ n_s (Q)^{1 - \rho} + n_m \right]^{-\frac{1}{\rho}} ,
\] (24)

\[
Y^s = n_s Y \left[ n_s + n_m (Q)^{\rho - 1} \right]^{-\frac{1}{\rho}} ,
\] (25)

thus we have to solve a system of four equations (22-25) in four unknowns \((Y^m, Y^s, Y, Q)\).

### 2.2 Log-linearized relations

I now log-linearize the equilibrium conditions around the steady state where the variables \((Y^m_t, Y^s_t, Y_t, Q_t, P_{t+1}, P_{t+1}^m, P_{t+1}^s, P_{t+1}^m)^t\) are equal to \((Y^m, Y^s, Y, Q, 1, 1, 1)\) and all the shocks are equal to one. Loglinearizing the Euler equation account being taken of the market clearing condition leads to the aggregate demand

\[
y_t = \frac{\eta}{1 + \eta (1 + \beta \eta)} y_{t-1} + \frac{1 + \eta \beta (1 + \eta)}{1 + \eta (1 + \beta \eta)} y_{t+1|t} - \frac{\eta \beta}{1 + \eta (1 + \beta \eta)} y_{t+2|t}
\]

\[
- \frac{\bar{\sigma} (1 - \eta) (1 - \eta \beta)}{(1 + \eta + \beta \eta^2)} \left( \bar{e}_t - \pi_{t+1|t} \right) + \frac{1 - \eta}{1 + \eta (1 + \beta \eta)} \left[ \bar{e}_t - (\eta \beta + 1) \bar{e}_{t+1|t} + \eta \beta \bar{e}_{t+2|t} \right]
\] (26)

where \(\bar{c}_t \equiv \log \bar{C}_t\) and loglinearizing the f.o.c. for the firm’s problem (17) with respect to sector \(m\) and \(s\) we obtain

\[
\pi_t^m = \kappa^m \left[ \omega_m + \varphi (1 + \eta^2 \beta) \right] y_t - \kappa^m \varphi \eta y_{t-1} - \kappa^m \varphi \eta \beta y_{t+1|t} + \kappa^m Q^s (\rho \omega_m + 1) q_t
\]

\[
- \kappa^m \left[ (1 + \omega_m) a_t + \varphi (1 - \eta) \left( \bar{e}_t - \eta \beta \bar{e}_{t+1|t} \right) - \psi^m_t \right] + \beta \pi_{t+1|t}^m
\] (27)

and

\[
\pi_t^s = \kappa^s \left[ \omega_s + \varphi (1 + \eta^2 \beta) \right] y_t - \kappa^s \varphi \eta y_{t-1} - \kappa^s \varphi \eta \beta y_{t+1|t} - \kappa^s Q^m (\rho \omega_s + 1) q_t
\]

\[
- \kappa^s \left[ (1 + \omega_s) a_t + \varphi (1 - \eta) \left( \bar{e}_t - \eta \beta \bar{e}_{t+1|t} \right) - \psi^s_t \right] + \beta \pi_{t+1|t}^s
\] (28)
where \( a_t \equiv \log A_t, \; \psi^h_t \equiv \Psi^h_t, \; h = s, m \) and
\[
\overline{Q}^s \equiv \frac{n_s Q^{1-\rho}}{n_s (Q^{1-\rho} - 1) + 1}, \quad \overline{Q}^m = 1 - \overline{Q}^s, \tag{29}
\]
\[
\omega_h \equiv \phi_h (v + 1) - 1, \tag{30}
\]
\[
\kappa^h \equiv \frac{(1 - \alpha^h) (1 - \alpha^h \beta)}{\alpha^h (1 + \omega_h \theta_h)}, \quad h = m, s, \tag{31}
\]
\[
\varphi \equiv \frac{1}{(1 - \eta) \bar{\sigma} (1 - \eta \beta)}, \tag{32}
\]

Notice that \( \overline{Q}^s \) and \( \overline{Q}^m \) are the only (composite) parameters in (27-28) that depend on \( n^s \). This implies that a first channel through which an industrial transformation affects the economy is the degree of impact of the relative price on sectoral inflations which depends on \( \overline{Q}^s \). This point will be examined below in the analysis of the relation between the industrial transformation and the Great Moderation.

Finally, the exogenous shocks follow
\[
\begin{align*}
\Delta a_{t+1} &= \gamma_a a_t + \varepsilon^a_{t+1}, \\
\Delta \tilde{c}_{t+1} &= \gamma_{c} \tilde{c}_t + \varepsilon^c_{t+1}, \\
\psi^s_{t+1} &= \gamma_{s} \psi^s_t + \varepsilon^{s}_{t+1}, \\
\psi^m_{t+1} &= \gamma_{m} \psi^m_t + \varepsilon^{m}_{t+1},
\end{align*}
\]
where \( E_t (\varepsilon_{t+1}^h) = 0, \; h = a, c, \psi^s, \psi^m \). Log-linearizing the price index (5) we obtain aggregate inflation
\[
\pi_t = (1 - \tilde{n}) \pi^s_t + \tilde{n} \pi^m_t, \tag{33}
\]
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
\[
\pi_t = \left\{(1 - \tilde{n}) \kappa^s \left[ \omega_s + \varphi (1 + \eta^2 \beta) \right] + \tilde{n} \kappa^m \left[ \omega_m + \varphi (1 + \eta^2 \beta) \right]\right\} y_t - \varphi \eta \left[ (1 - \tilde{n}) \kappa^s + \tilde{n} \kappa^m \right] y_{t-1} - \varphi \eta \left[ (1 - \tilde{n}) \kappa^s + \tilde{n} \kappa^m \right] y_{t+1|t} - \left[ (1 - \tilde{n}) \kappa^s \overline{Q}^m (\rho \omega_s + 1) - \tilde{n} \kappa^m \overline{Q}^s (\rho \omega_m + 1) \right] q_t \\
- (1 - \tilde{n}) \kappa^s \left[ (1 + \omega_s) a_t - \psi^s_t \right] - \tilde{n} \kappa^m \left[ (1 + \omega_m) a_t - \psi^m_t \right] \\
- \varphi (1 - \eta) \left[ (1 - \tilde{n}) \kappa^s + \tilde{n} \kappa^m \right] \left( \tilde{c}_t - \eta \tilde{c}_{t+1|t} \right) + \beta \pi_{t+1|t}
\]
Finally, defining \( q_t \equiv \log \frac{Q_t}{Q} \), the law of motion for the log deviation of the relative price from its steady state value is given by

\[
q_t = q_{t-1} + \pi^s_t - \pi^m_t. \tag{35}
\]

The model is closed with a Taylor rule describing the behaviour of the central bank

\[
i_t = \delta_0 i_{t-1} + (1 - \delta_0) \delta_1 \pi_t + (1 - \delta_0) \delta_2 y_t.
\]

### 2.3 Calibration

The degree of habits persistence is \( \eta = 0.8 \); the elasticity of intertemporal substitution in consumption is \( \bar{\sigma} = 0.638 \); the elasticity of substitution between \( C^s_t \) and \( C^m_t \) in the CES consumption aggregate is \( \rho = 3 \); the number of firms in the s-sector is \( n_s = 0.5 \); and in the m-sector is \( n_m = 1 - n_s \); the elasticity of sectoral output with respect to hours worked is \( \phi_h = 1.333 \), \( h = s, m \); the inverse of the elasticity of goods production is \( \nu = 1 \); the sectoral elasticity of substitution between any two differentiated goods is \( \theta_h = 7.88 \), \( h = s, m \); the intertemporal discount factor is \( \beta = 0.99 \); the coefficients of the Taylor rule are \( \delta_0 = 0.8 \); \( \delta_1 = 1.5 \); \( \delta_2 = 0.5/4 \); the AR coefficients of the exogenous processes are \( \gamma_a = \gamma_\psi = \gamma_c = 0.95 \) and for any shock the variance is \( \sigma^2 = 0.009^2 \). Finally, 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.

### 3 Sectoral asymmetry in price stickiness and economic dynamics

This section studies the relation between sectoral asymmetry in price stickiness and the dynamics of the economy in presence of exogenous positive shocks to the price level, technology and the preferences of the household. All the shocks are supposed to hit symmetrically both sectors. Through impulse response functions, autocorrelations, and variances of the endogenous variables, the analysis combines three perspectives to investigate qualitatively and quantitatively the relation at issue.

#### 3.1 IRFs analysis

Figures 1-3 show the impulse response functions to a preference shock and to symmetric cost-push and technology shocks in presence of sectoral symmetry and asymmetry in the degree of price stickiness. Starting with Panels 1a-3a, each figure reports the symmetric case, first row \( (\alpha_s = \alpha_m = 0.5) \), and two asymmetric cases differing in the degree of sectoral asymmetry, second and third row \( (\alpha_s = 0.7, \ \alpha_m = 0.5 \ \text{and} \ \alpha_s = 0.9, \ \alpha_m = 0.5) \). 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 stated as follows:

**Result 1: Price Stickiness Asymmetries and Aggregate Inflation.** For any shock considered, the larger the asymmetry in price stickiness, the lower the deviation of aggregate 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.

This result has significant implications on the behaviour of the interest rate. To describe them, it is important to note that the cost-push shock and the technology shock affect the economy only from the supply side, while the preference shock also from the demand side\(^2\). Furthermore, the impact of the preference shock on the demand and supply side goes in opposite directions\(^3\). This, as explained below, implies that sectoral asymmetry, via inflation, play a different role on the dynamics of the interest rate with a preference shock and with a cost-push or technology shock.

Starting with the preference shock, panel 1a shows a positive and negative impact of the shock on the output gap and inflation, respectively. Now, under symmetry, first row, the fall in inflation affects the interest rate via the Taylor rule more than the increase in the output gap. As a result the interest rate falls considerably in the initial periods. Yet, breaking the symmetry, second and third row, Result 1 implies that 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 and consequently the monetary policy turns out to be more active in the subsequent periods.

On the other hand, in presence of a cost-push or technology shock (panel 2a and 3a respectively), the shock hits the economy only through the supply side. Thus Result 1 implies that the larger the asymmetry, the less the shock passes through to the rest of the economy, specifically, the lower the deviations of the output-gap from its steady state value, and the less active the monetary policy.

Summing up, Result 1 implies that sectoral asymmetry plays a key role in amplifying or attenuating the deviations of the interest rate from its long run equilibrium according to the type of the shock that hits the economy.

The analysis based on Panels 1a-3a provides a useful starting point to illustrate how sectoral asymmetry affect the behaviour of aggregate inflation and Result 1 helps to fix the ideas. Yet, it does not disentangle the impact of the mean and the variance in the degree of sectoral price stickiness on aggregate inflation. Indeed,

\(^2\)The latter has this peculiarity as shocks to the utility function affect on the one hand the Euler equation and therefore the aggregate demand and, on the other hand, they affect the marginal rate of substitution between labour and consumption entering in the optimal supply of labour, and therefore the aggregate supply.

\(^3\)Indeed in equation (??) the coefficient of the preference shock is negative and in equation (26) it is positive.
both moments increases when $\alpha_s$ increases. This issue leads to ask to what extent, if any, two economies sharing the same mean degree of price stickiness but differing in terms of variance respond differently to exogenous disturbances. Panels 1b-3b, address this question reporting on the first row an economy with symmetric sectors where price stickiness is the same in both sectors, specifically $\alpha_s = \alpha_m = 0.7$, and in the second row an economy with asymmetric sectors with the same mean of the symmetric economy, i.e. $\alpha = 0.7$, but different sectoral price stickiness, specifically $\alpha_s = 0.9$, $\alpha_m = 0.5$. Interestingly, the analysis reveals an important relation between the variance of sectoral price stickiness and the behavior of aggregate inflation that can be stated as follows

**Corollary 1: 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.

What are the implications of Corollary 1 on the behaviour of the two economies? Panel 1b refers to the response of the two economies to a preference shock. In the asymmetric case the initial and subsequent response of the interest rate is, respectively, lower and higher than in the symmetric case. This is due to the fact that breaking the symmetry the impact of the shock on inflation is attenuated. Consequently, a minor initial decrease of the interest rate is required to stabilize inflation and thus monetary policy can focus more on the stabilization of the output gap by increasing the interest rate. In term of the output gap, this policy results in a better stabilization for the asymmetric economy.

Panel 2b and 2c refer to the response of the two economies to a cost-push and a technology shock respectively. They show that the policy response in the asymmetric economy is half as active as in the symmetric one and, similarly, that the deviations of output-gap and inflation from their steady state values in the asymmetric economy tend to be half as large as in the symmetric economy.

Summing up, the economy featuring higher dispersion in sectoral price stickiness is less perturbed by exogenous disturbances and tends to exhibit a less active policy. These findings will be assessed quantitatively in the following analysis yet, before deepening the investigation with the study of the autocorrelation and standard deviation of the endogenous variables, it is worth stopping for a natural question: what drives these findings?

3.1.1 **Mechanics**

To explain the mechanism at work we first notice that breaking the symmetry introduces a new variable and a new relation into the working of the economy. The new variable is the relative price of the sectoral goods which appears, as a log-deviation,
in the second and third row of Figures 1a-3a and in the second row of Figures 1b-3b. The new relation is a relation between the relative price and sectoral inflations. With symmetry, sectoral inflations coincide and thus the relative price $Q_t$ is constant and equal to its steady state value $Q$ so that $q_t = 0$. Breaking the symmetry, a symmetric shock hits sectoral inflations differently: the stickier the sectoral price, the smaller the impact of the shock\(^4\). Thus sectoral inflations start to differ and $q_t$ enters the picture driven by its low of motion (35). But the relation between $q_t$ and sectoral inflations works in the other direction too. Indeed, the presence of the relative price activates a switching demand mechanism that, in presence of a symmetric shock, acts asymmetrically on the sectoral inflations: it offsets the shock in the sector hit more and strengthens it in the sector hit less\(^5\). Since the offsetting action outpaces the magnifying action, this mechanism reduces the difference between sectoral inflations caused by the shock. Yet, given the law of motion of $q_t$, as long as the sign of the difference between sectoral inflations generated by the shock does not change, the relative price continues to increase its deviation from the steady state amplifying the switching demand mechanism. This process inexorably leads to a turning point for $q_t$ where the impact of the switching demand mechanism exceeds the impact of the shock. As a result, the difference in sectoral inflations changes sign, and $q_t$ starts to go in the opposite direction converging to its steady state value. This is illustrated by the hump-shaped path of $q_t$ shown in Figure 1-3. To conclude, the relation between $q_t$ and sectoral inflations results in different paths for the latter which, in turn, affect the behaviour of aggregate inflation and the rest of the economy.

### 3.2 Autocorrelation analysis: sectoral asymmetry in price stickiness and the persistence of $y$, $i$, and $\pi$

The Impulse Response analysis has signalled an important impact of sectoral asymmetry in the degree of price stickiness on the dynamics of the economy. In order to characterize this impact further, it is useful to focus on the persistence of $y$, $i$, and $\pi$. Adopting as persistence measure the sum of the first five autocorrelation coefficients, Figure 4 illustrates the case of sectoral symmetry and plots the persistence of the endogenous variables against price stickiness. The graphic shows that when the average degree of price stickiness increases from 0.5 to 0.9, the persistence of the inflation variables (which is the same in the symmetric case as sectoral and aggregate inflation coincide) increases too. This is due to the price stickiness mechanism itself that buffering changes in marginal costs caused by exogenous disturbances tends to insu-

\(^4\)This can be seen in the sectoral AS, equations (27-28) noting that $\kappa$ in the coefficient of the shocks is inversely related to the degree of price stickiness $\alpha$.

\(^5\)This can be seen in the equations for sectoral inflations (27-28) where the coefficients for $q_t$ have opposite signs.
late inflation generating more persistence. The increase in inflation persistence leads in turn to an increase in the interest rate persistence. Interestingly, these findings starkly contrast with the ones provided by the sectoral asymmetry case illustrated in Figure 5. Here the graphic plots the persistence of the endogenous variables against the degree of price stickiness in the s-sector keeping constant the degree of price stickiness in the m-sector at $\alpha_m = 0.5$. Due to the mechanism that generates Results 1 explained above, the persistence of the m-sector inflation falls, and falls more than the increase in the persistence in the s-sector. Thus, the persistence of aggregate inflation up to $\alpha_s = 0.7$ rises faintly and then falls more and more markedly. As in the symmetric case, the interest rate persistence tends to mirror the aggregate inflation persistence.

This analysis has shown that sectoral asymmetry in price stickiness is a key factor determining the persistence of inflation and the interest rate. Disentangling the variance effect from the mean effect we consider two economies that share the same mean degree of sectoral asymmetry but a different variance. Setting the mean degree of sectoral asymmetry equal to 0.7, Figure 4, for $\alpha_s = \alpha_m = 0.7$, provides the persistence of the endogenous variables for an economy with zero variance and Figure 5 for, $\alpha_s = 0.9$ and $\alpha_m = 0.5$, provides the persistence of the endogenous variables for an economy with positive variance equal to 0.04. Then the persistence measures reveal that increasing the dispersion in sectoral price stickiness, but keeping the same mean value, leads to a significant reduction in the persistence of aggregate inflation and to a modest reduction in the persistence of the interest rate. Specifically, inflation and interest rate persistence falls, respectively, of 23.3% and 5.5%.

Summing up, the autocorrelation analysis suggests that the relation between the dispersion in price stickiness asymmetry and the persistence of inflation and the interest rate, which was revealed by the impulse response function analysis, is quantitatively important.

### 3.3 Unconditional Variances analysis: sectoral asymmetry in price stickiness and economic stability

As shown in the impulse response analysis, the introduction of sectoral asymmetry in price stickiness tends to reduce the deviations of $\pi$, $i$, and $y$ from their long run values. A convenient way to measure these deviations consists of computing the unconditional standard deviations of the endogenous variables. Starting with the symmetric case, Figure 6 plots the standard deviation of $\pi$, $i$, and $y$ against the degree of price stickiness shared by the sectors. The graphic shows that the stickier the price level, the more stable the endogenous variables. As explained above, the sticky price mechanism itself tends to filter out the exogenous disturbances delivering more stability. Moving to the asymmetric case, Figure 7 plots standard deviations against

---

6 This can be observed in the inflation equations noticing that the composite coefficient $\kappa$ is inversely related to the degree of price stickiness $\alpha$. 

14
the degree of price stickiness in the s-sector keeping the degree of price stickiness in
the other sector constant. Comparing the figures, two economies that in terms of price
stickiness share the average but not the variance exhibit very different variability of
the endogenous variables. Indeed, keeping the average price stickiness equal to 0.7
and breaking the sectoral symmetry the variability of $y$, $i$, and $\pi$ decrease of the
32.6%, 48.9% and 48.9%, respectively. Thus sectoral asymmetry in price stickiness
plays a key role in determining the variability of the endogenous variables.

4 Sectoral asymmetry in price stickiness, industrial transformation, and the Great Moderation

Since the '80s in several industrialized countries the volatility of the output gap and
inflation has remarkably decreased. For the UK this process is illustrated by Figure
8.

What has ultimately caused this change, called the Great Moderation, is still un-
clear and several factors can likely have played a role. Structural change in inventory
management, better macro-economic policies and good luck are, so far, the most ac-
credited explanations given to this phenomenon. Reasonably, all of them matter but
there is no consensus on their relative importance\(^7\). Since the '80s another important
change occurred in numerous developed economies: a massive industrial transfor-
mation consisting in a contraction of the manufacturing sector accompanied by an
expansion of the services sector\(^8\). Black and Dowd (2009) and Moro (2009) related
these two changes from the empirical and theoretical standpoint respectively. The
former found a positive and significant relationship between the manufacturing-to-
services ratio and output variability in US, and interpreted this relation with services
being less cyclical than manufacturing. The latter, using a two-sector manufacturing
and services model calibrated for the US, found that the reduction in output volatil-
ity can be associated to the industrial transformation via the volatility in aggregate
factor productivity since this depends on the relative size of the two sectors.

The current model corroborates the view that the industrial transformation played
a significant role in the determination of the Great Moderation. The model presents a
novel argument based on sectoral asymmetry in price stickiness and offers an explana-
tion that is not limited to output volatility, as in the previous literature, but accounts

\(^7\)Other interesting explanations are better financial instruments and a decline in aggregate total
factor productivity.

\(^8\)For some countries, this industrial transformation started before the '80s but what is interesting
here is that the '80s witnessed an acceleration of this phenomenon.
for inflation and interest rate volatility too. The story is based on the working of two channels that are activated by variations in $n^s$ and the first is the following\textsuperscript{9}. The services sector features a degree of price stickiness higher than the manufacturing sector\textsuperscript{10}. With the industrial transformation $n^s$ increases and $n^m$ declines. The larger $n^s$, the more services inflation weights in aggregate inflation as shown in equation (33)\textsuperscript{11}. Since the services sector features an higher degree of price stickiness than the manufacturing sector, it follows that it dissipates any shock more than the manufacturing sector\textsuperscript{12}. Then, the larger $n^s$ the less the shock impact on aggregate inflation and, subsequently, given the Taylor rule, the less the monetary policy response to the shock and the final propagation to real activity\textsuperscript{13}.

The second channel works via an increase in the efficiency of the switching demand mechanism in absorbing the shock when the size of the stickier price sector increases. Indeed, the larger $n^s$, the larger (smaller) the degree of impact of $q_t$ on inflation in the manufacturing (service) sector\textsuperscript{14}. Thus, after that i. a symmetric shock hits the economy, ii. sectoral inflations depart from their steady state values, and iii. also the relative price departs from its steady state value according to its law of motion (35) due to sectoral price stickiness, the larger (smaller) the degree of impact of $q_t$ on manufacturing (services) inflation, the faster is the switching demand mechanism.

As described before, this mechanism acts \textit{asymmetrically} on sectoral inflations: it offsets the shock in the sector hit more (manufacturing) and magnifies it in the sector hit less (services). Since the offsetting action outpaces the magnifying action, this mechanism allows to absorb the shock. Now, when $n^s$ increases it happens that the offsetting action increases while the magnifying action declines so that the switching demand mechanism becomes more efficient in absorbing the shock\textsuperscript{15}.

\textsuperscript{9}In this section the superscripts $s$ and $m$ refers, respectively, to the services and manufacturing sector.

\textsuperscript{10}This is a well established fact documented for example in ECB (2006).

\textsuperscript{11}Note that $\bar{n}$ is decreasing in $n^s$.

\textsuperscript{12}This is clear considering (27-28) and noting that given the definition of $\kappa^h$, $h = s, m$ reported in (31), $\frac{\partial \kappa^h}{\partial n^s} < 0$.

\textsuperscript{13}Impulse response function analysis to illustrate this mechanism is available upon request.

\textsuperscript{14}This is shown by the sectoral aggregate supplies (27-28) where $\partial \pi^s_1 / \partial q_t$ and $\partial \pi^s_1 / \partial q_t$ depend respectively on $\bar{Q}^s$ and $\bar{Q}^m$, and account being taken of (29) and the fact that $\partial Q / \partial n^s > 0$, it turns out that $\partial \bar{Q}^s / \partial n^s > 0$ and $\partial \bar{Q}^m / \partial n^s = -\partial \bar{Q}^s / \partial n^s < 0$.

\textsuperscript{15}As the services sector is stickier than the manufacturing sector, $\kappa^s < \kappa^m$, the derivative with respect of $n^s$ of the degree of impact of the relative price on services inflation is (in absolute value) smaller than the derivative with respect of $n^s$ of the degree of impact of the relative price on manufacturing inflation, i.e.

$$
\left| \frac{\partial \kappa^s}{\partial n^s} (\rho \omega_s + 1) \right| = \left| -\frac{\partial \kappa^s}{\partial n^s} (\rho \omega_s + 1) \right| < \left| \frac{\partial \kappa^m}{\partial n^s} (\rho \omega_m + 1) \right|.
$$

This implies that when $n^s$ increases the magnifying action declines while the offseting action increases so that the switching demand mechanism becomes more efficient in absorbing the shock.
To what extent sectoral price stickiness and the industrial transformation can account for the Great Moderation? The analysis shows that in a manufacturing and services economy, letting the industrial share of the services sector expand from 30% to 70% leads to a decline in output volatility ranging from 2% to 9% and in inflation and interest rate volatility ranging from 3 to 30%. This decline depends directly on the degree of sectoral asymmetry in price stickiness. Interestingly, the previous figures show that the fall in inflation volatility exceeds the one in output gap volatility. This is consistent with Blanchard and Simon (2001) which found that the standard deviation of output growth and inflation declined, respectively, by one-half and two-thirds.

Describing the methodology, this results has been obtained considering various cases of sectoral price stickiness with the following criterion: set a benchmark for the mean price stickiness computed assuming equally sized sectors. Then investigate the impact of the industrial transformation on output and inflation volatility by letting the sectoral price stickiness depart from the mean price stickiness in a symmetric way up to ±20 percentage points. To start the analysis we need some benchmark value for the mean price stickiness. Noting that a common calibrated value for this structural parameter in the one-sector model is $\alpha = 0.66$ as reported in Rotemberg and Woodford (1997) and, subsequently, by several other authors, we focus on two values for the mean price stickiness, specifically $\alpha \in \{0.6, 0.7\}$. The results of the analysis are illustrated in Figure 9.

5 Concluding remarks

This paper investigates how sectoral asymmetry in price stickiness affect the dynamics of the economy in a two-sector New Keynesian model.

When sectoral symmetry is broken, the relative price between sectoral inflations appears into the New Keynesian economy and significantly alters its response to exogenous shocks. As a result, asymmetry in sectoral price stickiness leads to an important fall in the persistence of inflation and in the volatility of inflation, the interest rate and the output gap. It also leads to a moderate fall in the persistence of the interest rate. Thus, two economies differing in the dispersion of sectoral asymmetry but not in the mean may exhibit very unlike volatility and persistence.

The model also shows that when asymmetry in sectoral price stickiness is considered along with an expansion of the sector with stickier prices, a possibility often occurred in the industrial transformations experienced since the ’80s by several developed economies, asymmetry in sectoral price stickiness offers a quantitatively relevant argument to explain the Great Moderation.
Further analysis will take the model to the data and investigate how sectoral size and strategic complementarities affect the relation between sectoral asymmetry in price stickiness and the dynamics of the economy.

References


Blanchard and Simon (2001)


Figure 1a. IRFs to a preferences shock under symmetry and asymmetry in sectoral price stickiness.

Symmetry: $\alpha_s = \alpha_m = 0.5$

Asymmetry: $\alpha_s = 0.7$, $\alpha_m = 0.5$

Asymmetry: $\alpha_s = 0.9$, $\alpha_m = 0.5$

Figure 1b. IRFs to a preference shock in two economies with the same mean degree of sectoral price stickiness but a different variance.

Symmetry: $\alpha_s = \alpha_m = 0.7$

Asymmetry: $\alpha_s = 0.9$, $\alpha_m = 0.5$
Figure 2a. IRFs to a cost-push shock under symmetry and asymmetry in sectoral price stickiness

Symmetry: $\alpha_s = \alpha_m = 0.5$

Asymmetry: $\alpha_s = 0.7, \alpha_m = 0.5$

Asymmetry: $\alpha_s = 0.9, \alpha_m = 0.5$

Figure 2b. IRFs to a cost-push shock in two economies with the same mean degree of sectoral price stickiness but a different variance.

Symmetry: $\alpha_s = \alpha_m = 0.7$

Asymmetry: $\alpha_s = 0.9, \alpha_m = 0.5$
Figure 3a. IRFs to a technology shock under symmetry and asymmetry in sectoral price stickiness.

Symmetry: $\alpha_s = \alpha_m = 0.5$

Asymmetry: $\alpha_s = 0.7$, $\alpha_m = 0.5$

Asymmetry: $\alpha_s = 0.9$, $\alpha_m = 0.5$

Figure 3b. IRFs to a technology shock in two economies with the same mean degree of sectoral price stickiness but a different variance.

Symmetry: $\alpha_s = \alpha_m = 0.7$

Asymmetry: $\alpha_s = 0.9$, $\alpha_m = 0.5$
Figure 4. Persistence in terms of the sum of the first five autocorrelation coefficients and symmetric price stickiness.

Figure 5. Persistence in terms of the sum of the first five autocorrelation coefficients and asymmetric price stickiness under $\alpha_m = 0.5$ and $0.5 \leq \alpha_s \leq 0.9$. 
Figure 6. Standard deviation and symmetric price stickiness.

Figure 7. Standard deviation and asymmetric price stickiness under $\alpha_m = 0.5$ and $0.5 \leq \alpha_s \leq 0.9$. 
Figure 8. Manufacturing and Services Shares of GDP in UK. Source ONS.
Industrial Transformation, Sectoral Price Stickiness and the Great Moderation

$\alpha_s = 0.65$ and $\alpha_m = 0.55$

$\alpha_s = 0.7$ and $\alpha_m = 0.5$

$\alpha_s = 0.75$ and $\alpha_m = 0.45$

$\alpha_s = 0.8$ and $\alpha_m = 0.4$

$\alpha_s = 0.75$, $\alpha_m = 0.65$

$\alpha_s = 0.8$, $\alpha_m = 0.6$

$\alpha_s = 0.85$, $\alpha_m = 0.55$

$\alpha_s = 0.9$, $\alpha_m = 0.5$