Competitiveness, inflation, and monetary policy

Hashmat Khan[*]

and

Richhild Moessner [**]

Working Paper no. 246

[*] Structural Economic Analysis Division, Bank of England.
hashmat.khan@bankofengland.co.uk

[**] Structural Economic Analysis Division, Bank of England.
richhild.moessner@bankofengland.co.uk

We would like to thank Charlie Bean, Ian Bond, Jennifer Greenslade, Charlotta Groth, Richard Harrison, Jens Larsen, Lavan Mahadeva, Katharine Neiss, Ed Nelson, Argia Sbordone and anonymous referees of the Bank of England working paper series for helpful comments and discussions. The views in this paper are our own and do not necessarily reflect those of the Bank of England.

Copies of working papers may be obtained from Publications Group, Bank of England, Threadneedle Street, London, EC2R 8AH; telephone 020 7601 4030, fax 020 7601 3298, e-mail mapublications@bankofengland.co.uk

Working papers are also available at www.bankofengland.co.uk/wp/index.html

The Bank of England's working paper series is externally refereed.

ISSN 1368-5562

Contents

Abstract

This paper examines the way in which structural changes in the level of steady-state competitiveness and the trend rate of inflation affect inflation responses to monetary policy shocks, in scenarios chosen to capture broadly the conditions of the UK economy in the early 1990s and more recently. Cyclical changes in competitiveness are also considered, since it is not clear empirically whether changes in competitiveness have been predominantly structural or cyclical. A model based on work by Woodford is used, allowing for positive trend inflation and cyclical variations in competitiveness in a tractable manner. This extension enables the separate quantification of the impact of differences in the steady-state level of and cyclical changes in competitiveness on inflation in the short term, in high and low inflation environments. The paper quantifies the extent to which procyclical (countercyclical) changes in competitiveness dampen (amplify) the impulse responses of inflation to a given monetary policy shock. In the calibration used, the inflation response to monetary policy shocks in a low inflation/high competitiveness environment is dampened compared with a high inflation/low competitiveness environment. By contrast, inflation responses to monetary policy shocks in a low inflation/low competitiveness environment are similar to those in a high inflation/high competitiveness environment.

Key words: Competitiveness, trend inflation, structural change.

JEL classification: E31, E32.

Summary

Differences in the degree of competition among firms - ‘competitiveness’ - may affect the rate of inflation in the short term and the monetary transmission mechanism. In addition, cyclical variations in competitiveness may affect inflation dynamics and the transmission mechanism. It follows that the examination of both types of changes is potentially important for monetary policy makers.

We examine how differences in the level of steady-state competitiveness and the trend rate of inflation might affect inflation responses to monetary policy shocks, using a standard New Keynesian model. We extend the model to allow for positive trend inflation and cyclical variations in competitiveness. This allows us to quantify separately the impact of differences in steady-state levels of and cyclical changes in competitiveness on inflation dynamics, in high and low inflation environments. We apply this model to scenarios chosen to capture broadly the conditions in the UK economy in the early 1990s and more recently.

We show that in a low inflation/high competitiveness environment, the higher degree of price stickiness implied by the low inflation environment, and the higher degree of steady-state competitiveness both have the effect of dampening the inflation response to monetary policy shocks, compared with the high inflation/low competitiveness scenario. By contrast, in the low inflation/low competitiveness environment, we find that the effect of lower steady-state competitiveness partially offsets the effect of the higher degree of price stickiness in the low inflation environment, so that the inflation responses in the high and low inflation environments are similar to each other. Moreover, we quantify the extent to which procyclical changes in competitiveness dampen the impulse response of inflation to a given monetary policy shock, and the extent to which countercyclical changes amplify it.

1 Introduction

Differences in the degree of competition among firms - ‘competitiveness’ - may affect the level of inflation in the short term and the monetary transmission mechanism. In addition, cyclical variations in competitiveness may affect inflation dynamics and the transmission mechanism. Therefore, examining both types of changes is important for monetary policy makers.

Empirically, there is little consensus on how competitiveness in industrialised countries has changed over the past 20 years. In general, it is hard to distinguish between structural (steady-state) differences in competitiveness, and changes over the business cycle. Because of these empirical difficulties, we consider inflation dynamics within a model that incorporates both differences in steady-state levels and cyclical changes in competitiveness. One of the advantages of our model is that we can quantify the effects of structural and cyclical changes on inflation dynamics separately. Monetary policy makers could use our model to inform their judgement about the possible impact of both differences in steady-state levels and cyclical changes in competitiveness on inflation dynamics in the past, or given what they expect to hold in the future. Also, if more reliable empirical evidence on changes in competitiveness should become available in future, the impact of such changes on inflation dynamics could be analysed within our model.

We consider a dynamic general equilibrium model that incorporates nominal and real rigidities, which is widely used in monetary policy analysis (see Woodford (2003)). However, unlike the standard set-up, we allow for positive trend inflation.[1] The supply side of the model consists of monopolistically competitive firms that have sticky nominal prices. The Dixit-Stiglitz elasticity of substitution between goods captures the degree of competition, or competitiveness. The higher the elasticity of substitution, the greater is competitiveness. The nominal rigidity leads monetary policy to have real effects on output. The model also incorporates real rigidities, which provide some incentive to firms not to change their relative prices, and thereby amplify the effect of nominal rigidities (as in Ball and Romer (1990)). Nominal rigidities are modelled within the Calvo (1983) framework where firms have a constant and exogenous probability of being able to adjust their prices in each quarter. In our calibration, however, firms adjust their prices more frequently at higher levels of trend inflation. This aspect reflects the notion that at higher trend inflation

(1) Trend inflation refers to the rate of inflation that is expected in the absence of shocks. It is determined by the monetary policy regime. Sometimes the term ‘trend inflation’ is used interchangeably with other terms such as steady-state inflation, long-run anchor of inflation expectations, nominal anchor, or the inflation target. Empirically, the average inflation rate can serve as an informative proxy for the underlying trend inflation rate.

levels, firms with sticky nominal prices have stronger incentives to adjust their prices. We examine how these supply-side rigidities and trend inflation, together with differences in steady-state levels of and cyclical changes in competitiveness affect inflation dynamics. The demand side is characterised by intertemporal optimisation by households. We model monetary policy by a modified Taylor rule with interest rate smoothing.

In this paper, we study the combined impact of structural changes in competitiveness and trend inflation on impulse responses to monetary policy shocks, within the framework of Woodford (2003). In addition, we consider cyclical changes in competitiveness. Positive trend inflation has previously been considered for example in King and Wolman (1996), Ascari (2004), Rotemberg (2002), and Bakhshi, Burriel-Llombart, Khan and Rudolf (2003), but without time variation in competitiveness. The latter is considered in Steinsson (2003), but under the assumption of zero trend inflation.[(2)]

We apply our model to scenarios chosen to broadly represent conditions in the United Kingdom in the early 1990s and 2000s. We consider two scenarios, one with a high level of trend inflation equal to the average of RPIX inflation from 1990 to 1992 of 6.5%, and another with low trend inflation equal to the average of RPIX inflation from 2000 to 2002, of 2.1%. It is not clear, however, how the degree of competition has changed between the early 1990s and 2000s, and we therefore consider both high and low levels of steady-state competitiveness. Factors such as increased globalisation and the expansion of the use of new technologies might have led to an increase in the degree of competition, and an associated structural change in aggregate pricing behaviour. In the November 1999 *Inflation Report* (Bank of England), it was noted that ‘Competitive forces appeared to be intensifying in a number of sectors, linked to factors such as greater international penetration of domestic markets, as barriers to trade and to market entry have declined, and to information technology advances which were offering savings on distribution networks, more transparent pricing, and encouraging new business opportunities.’ A survey-based measure from the Euler Trade Industry Indemnity survey appears to point to an increase in perceived competitive pressures in product markets in the United Kingdom between 1994 and 2000 (see Wadhwani (2000)). Factors such as privatisation and deregulation may also have contributed to an increase in the level of competition; on the other hand, these factors, as well as declining trade barriers, may also have led to some restructuring, with the effect of sustaining and concentrating market power in some cases (see Nickell (2001)).

We quantify the extent to which a structural increase in steady-state competitiveness

(2) Smets and Wouters (2003) and Ireland (2004) also consider time variation in competitiveness, or ‘cost-push’ shocks in the terminology of Clarida, Galí and Gertler (1999). Blanchard and Giavazzi (2003) consider the impact of deregulation on competitiveness and its macroeconomic implications.

dampens the response of inflation to a given monetary policy shock, for a given level of trend inflation. For a given level of steady-state competitiveness, a decrease in the level of trend inflation dampens the response of inflation to monetary policy shocks, due to a higher degree of price stickiness at lower levels of trend inflation. We examine the combined effect of a structural change in steady-state competitiveness and trend inflation on inflation responses to monetary policy shocks. We show that in a low inflation/high competitiveness environment, the higher degree of price stickiness implied by the low inflation environment, and the higher degree of competitiveness both have the effect of dampening the inflation response to monetary policy shocks, compared to the high inflation/low competitiveness scenario. By contrast, in the low inflation/low competitiveness environment, we find that the effect of lower competitiveness partially offsets the effect of the higher degree of price stickiness in the low inflation environment, so that the inflation responses in the high and low inflation environments are similar to each other.

We also compare impulse responses to monetary policy shocks for different forms of cyclical variations in competitiveness. We quantify the extent to which procyclical (countercyclical) changes in competitiveness dampen (amplify) the impulse response of inflation to a given monetary policy shock, in the above scenarios.

The paper is organised as follows. In Section 2 we describe some key features of the model. In Section 3, we describe the general equilibrium model, and derive the New Keynesian Phillips Curve (NKPC) in the presence of trend inflation and cyclical variations in competitiveness. In Section 4 we discuss some of the model properties in more detail. In Section 5, we describe the scenarios that reflect some aspects of the UK economy in the early 1990s and more recently. We examine impulse responses to monetary policy shocks within these scenarios, which are characterised by different levels of steady-state competitiveness and trend inflation. In addition, we consider the effect of cyclical variations in competitiveness. Finally, Section 6 concludes.

2 Key features of the model

In this section we describe three features of the model: namely, imperfect competition, rigidities (real and nominal), and positive trend inflation. In particular, we discuss how competitiveness interacts with these features.

2.1 Sources of imperfect competition and competitiveness

In our model, firms operate in an imperfectly competitive environment and are able to set prices as mark-ups over marginal cost. A common source for firms' market power is that they sell differentiated products, leading to a limited degree of substitutability between products.[3] In the Dixit-Stiglitz framework the elasticity of substitution between goods characterises the degree of monopolistic competition, and determines the desired mark-up that firms may charge. We refer to this elasticity as competitiveness in the model. It is inversely related to the desired mark-up. The higher the substitutability between products, the greater competitiveness, and the smaller the desired mark-up.

There are several other potential determinants of the level of competitiveness. Firms may have locational advantages, engage in strategic interactions to sustain market power, and face foreign competition. Moreover, new firms may face fixed costs of entry in excess of their expected profits, and institutional regulations may offer advantages to incumbent firms. Some or all of these features may characterise the competitive environment in which firms operate and determine the size of their desired mark-ups.[4] In the model, we consider different steady-state levels of and cyclical changes in competitiveness - or the degree of substitutability between goods. We interpret these as potentially arising from the factors mentioned above.

Since changes in the level of competition may arise from different sources, it is difficult to determine empirically whether they are structural or cyclical. Our model therefore allows to examine the effects of both differences in steady-state levels and cyclical changes on inflation responses to monetary policy shocks.

2.2 Monetary policy transmission, competitiveness, and real rigidities

In the presence of imperfect competition, we can consider price stickiness, which in turn leads to short-run effects of monetary policy on output. 'Real-rigidities' - that is, the incentive for firms not to change their relative price - will further amplify these short-run effects (see Ball and Romer (1990) and Kimball (1995)).[5] Here we present an intuitive

(3) Although several products in the economy are complements to each other, for the discussion and the ease of modelling, one could assume substitutability across product baskets that may also contain goods that are complements.

(4) A large body of industrial organisation literature examines different sources of imperfect competition and their implications for the market structure (see, for example, Tirole (1988)).

(5) Kimball (1995) and Woodford (2003) use the game-theoretic terminology of 'strategic complementarities' to describe the implications of real rigidities. They also consider various market interactions that imply strategic complementarities.

discussion of circumstances under which the level of competitiveness may influence the incentives of firms to change their relative prices, and consequently the monetary policy transmission mechanism.

Consider a decrease in nominal interest rates that causes aggregate demand to rise. Firms that do not change prices will experience an increase in their sales. To produce the extra output they will hire more labour which will bid up wages. Firms that choose to reset their prices, however, will choose higher prices since their costs have increased. How high a price a firm will charge depends on how much its cost has risen. That in turn depends on the assumptions made about the structure of labour markets: if there is an economy-wide labour market with a common wage, the bidding for labour by sticky-price firms may increase the wage (and hence marginal costs) substantially. That, in turn, will cause the price-setting firms to choose a relatively high price. Even if the proportion of price-setting firms is small (or the degree of nominal inertia is small), the relative price can rise quite sharply in response to the rise in wage such that the aggregate price level adjusts upwards. Therefore, expansionary monetary policy affects mainly prices rather than output.

Next, consider short-run constraints on the mobility of factors (labour and/or capital). In that case, the increase in factor prices in one sector of the economy does not transmit immediately to other sectors, since factors do not move instantaneously to equalise those prices. For example, labour markets may be specific to different sectors of the economy, due perhaps to the skill-specific nature of production. Alternatively, the capital stock for a firm may be fixed in the short run (see Sbordone (2002)). In the model we consider both of these sources. The level of competitiveness is related to both sources, and hence has an effect on the monetary transmission mechanism *via* the slope of the Phillips curve.

This characterisation implies that marginal costs of production are also influenced by firms' own relative prices. When price-setting firms increase their relative prices, they experience a fall in their sales, and therefore reduce employment. This channel leads to a fall in their marginal costs and creates an incentive to reduce their relative prices and increase their sales. In order to maintain its sales, therefore, a price-setting firm has an incentive not to have its price too different from firms that are not changing their prices. This reluctance to have large differences in relative prices amplifies the nominal rigidity and consequently the effect of monetary policy on output.

How strong an incentive firms have not to change their relative prices in turn depends on competitiveness. If competitiveness is high (*ie* the degree of substitutability between products is high), the effect of relative price differences on sales will be larger. This mechanism implies that in the presence of real rigidity, competitiveness influences the monetary policy transmission mechanism via the slope of the NKPC based on Calvo (1983). An increase in competitiveness decreases the slope of the Phillips curve. When real rigidities are absent (for example, when common economy-wide factor markets are considered), a firm's marginal cost depends on aggregate output alone. In that case, the level of competitiveness does not have any implications for relative price adjustment, and therefore does not influence the slope of the NKPC.(6)

2.3 *Positive trend inflation and sticky prices*

The inflation environment in the UK economy has changed substantially over the past few decades from the high-inflation periods of the 1970s to the low-inflation period since the late 1990s. One way to broadly characterise this change is that the underlying trend inflation rate has fallen. In empirical work, the average inflation rate over sufficiently long periods is often used as a proxy for trend inflation. The average inflation rate in the United Kingdom over the past 40 years (including subperiods of ten years' duration) has been positive. Our model accounts for this aspect of the UK economy, and considers, in particular, the interaction of competitiveness with positive trend inflation.

In the presence of positive trend inflation, firms with sticky nominal prices experience an erosion in their relative prices over time, and consequently see their sales rise. In an imperfectly competitive environment with prices set above marginal costs, firms are able to increase their supply. The extent to which the erosion of relative prices causes firms' sale to increase depends on the degree of competitiveness. The higher the level of competitiveness, the greater is the demand that a sticky-price firm has to meet. The presence of real rigidities enhances this effect.

Higher trend inflation may also affect the frequency with which firms adjust their prices. If the underlying rationale for the existence of nominal price stickiness is that firms face small fixed costs of adjusting prices ('menu costs'), then prices ought to be adjusted more frequently when trend inflation is high (see Romer (1990)); that is, the degree of price stickiness depends on the level of trend inflation.(7) Since we incorporate positive trend inflation in our model, we allow the degree of nominal price stickiness to decrease as trend inflation rises (Section 4.1 gives more details).

(6) Moreover, if nominal price stickiness is introduced using Rotemberg (1982)'s quadratic price-adjustment-cost model, a higher level of competitiveness *increases* the slope of the Phillips curve. Khan (2004) examines the consequences of Rotemberg and Calvo price-setting assumptions and the effects of mark-up shocks within the New Keynesian model.

(7) Ball, Mankiw and Romer (1988) find empirical support for an implication of this hypothesis, namely that the Phillips curve should be steeper in high-inflation environments.

3 Model

In this section we present the microfoundations for the dynamic general equilibrium model. The characterisation of the model economy follows Woodford (2003). The model incorporates both nominal rigidities and real rigidity; it allows for diminishing returns to labour in production and firm-specificity of labour. These assumptions capture the short-run constraints on the mobility of capital and labour. Typically, capital is not reallocated instantaneously, labour is not mobile or worker-skills are firm-specific in the short run. Although constraints on the short-run reallocation of capital can give rise to strategic complementarity (as in Sbordone (2002)), the model has relatively stronger strategic complementarity by allowing labour to be firm-specific as well. We allow for both positive trend inflation and cyclical variations in competitiveness.

3.1 Households

The representative household maximises the discounted sum of expected utility

$$E_t \sum_{j=0}^{\infty} \beta^j \left(\frac{C_{t+j}^{1-\sigma^{-1}}}{1-\sigma^{-1}} - \int_0^1 \frac{H_{t+j}(i)^{1+\phi}}{1+\phi} di \right) \quad \textbf{(1)}$$

subject to the standard budget constraint. In **(1)**, C_t is the Dixit-Stiglitz constant elasticity of substitution aggregate of consumption, $H_t(i)$ the firm-specific labour input, $\sigma > 0$ the intertemporal elasticity of substitution of expenditure, $0 < \beta < 1$ is the subjective discount factor, and $\phi > 0$ the inverse of the labour supply elasticity with respect to real wages.

The first-order conditions for the optimal choice of consumption and labour supply are

$$E_t \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma^{-1}} \frac{P_t}{P_{t+1}} R_t \right] = 1 \quad \textbf{(2)}$$

and

$$\frac{W_t(i)}{P_t} = \frac{H_t(i)^{\phi}}{C_t^{-\sigma^{-1}}} \quad \textbf{(3)}$$

where R_t denotes the gross nominal interest rate, P_t the aggregate price level, and $W_t(i)$ the nominal wage paid by firm i.

3.2 Aggregate demand

Using **(2)** and the market-clearing condition ($C_t = Y_t$), the standard IS-curve which represents the aggregate demand side of the model, in log-linearised form is

$$y_t = E_t y_{t+1} - \sigma(i_t - E_t \hat{\pi}_{t+1}) \quad \textbf{(4)}$$

where i_t is the log-deviation in the gross nominal interest rate from its steady state of $\frac{\pi}{\beta}$.[8]

3.3 Firms and aggregate supply

Each monopolistically competitive firm (indexed by i) faces a demand curve

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta_t} Y_t \tag{5}$$

where $Y_t(i)$ and Y_t denote firm i's and aggregate demand, respectively. θ_t denotes the elasticity of substitution between goods. The higher the elasticity of substitution θ_t, the more competitive is the economy. Similarly, $P_t(i)$ is firm i's price. Each firm's production function is given by

$$Y_t(i) = A_t H_t(i)^a \tag{6}$$

where the labour income share, a, satisfies $0 < a < 1$, and capital is assumed to be fixed. A_t is the productivity shock. Total real cost then follows as $TC_t(i) = \frac{W_t(i)}{P_t}\left(\frac{Y_t(i)}{A_t}\right)^{\frac{1}{a}}$, and marginal cost is given by

$$MC_t(i) = \frac{1}{a}\frac{W_t(i)}{P_t}\left(\frac{Y_t(i)}{A_t}\right)^{\frac{1}{a}-1}\frac{1}{A_t} \tag{7}$$

Using the equation for market clearing, $C_t = Y_t$ in **(3)**, the real marginal cost is

$$MC_t(i) = \frac{1}{a}Y_t(i)^{\omega}Y_t^{\sigma^{-1}}A_t^{-(\frac{\phi+1}{a})} = \frac{1}{a}\left(\frac{P_t(i)}{P_t}\right)^{-\omega\theta_t}Y_t^{\omega+\sigma^{-1}}A_t^{-(\frac{\phi+1}{a})} \tag{8}$$

where $\omega = \phi/a + 1/a - 1$ denotes the elasticity of marginal cost with respect to a firm's own output. Due to the presence of specific-factor markets, marginal cost depends on a firm's own relative price, as well as aggregate output. In the following, we set $A_t = 1$.

3.4 Optimal relative price and aggregate inflation under positive trend inflation and variable competitiveness

In this section we present the derivation of the the optimal relative price and aggregate inflation under positive trend inflation in the case of variable competitiveness. We allow the elasticity of substitution to vary over the business cycle, but assume that firms take it as given in their optimisation problem. Variable competitiveness in the presence of trend inflation introduces additional terms in the New Keynesian Phillips Curve, which are absent when trend inflation is zero (as in Steinsson (2003)). Within the Calvo (1983) framework, each firm receives an exogenous signal with probability $(1-\alpha)$ to adjust its price in each period. A firm chooses its price $P_t(i)$ to maximise current and discounted

(8) We denote log-linearised deviations from steady state by lower-case Roman letters, and by Greek letters with hats.

future (real) profits

$$\max_{P_t(i)} E_t \sum_{j=0}^{\infty} \alpha^j Q_{t,t+j} \left[\left(\frac{P_t(i)}{P_{t+j}} \right)^{1-\theta_{t+j}} Y_{t+j} - \frac{W_{t+j}(i)}{P_{t+j}} \left(\left(\frac{P_t(i)}{P_{t+j}} \right)^{-\theta_{t+j}} Y_{t+j} \right)^{\frac{1}{a}} \right] \quad \textbf{(9)}$$

where $Q_{t,t+j} = \beta^j \left(\frac{C_t}{C_{t+j}} \right)^{-\sigma}$ is the real stochastic discount factor, $P_t^*/P_t \equiv X_t$ is the firm's optimal relative price, $P_t/P_{t+j} = 1/\prod_{k=1}^{j} \Pi_{t+k}$, and Π_t is the gross inflation rate. The first-order condition from **(9)** is

$$E_t \sum_{j=0}^{\infty} \alpha^j Q_{t,t+j} (\theta_{t+j} - 1) X_t^{1-\theta_{t+j}} \left[\prod_{k=1}^{j} \Pi_{t+k} \right]^{\theta_{t+j}-1} Y_{t+j} =$$

$$E_t \sum_{j=0}^{\infty} \alpha^j Q_{t,t+j} \theta_{t+j} \frac{1}{a} X_t^{-\theta_{t+j}(1+\omega)} \left[\prod_{k=1}^{j} \Pi_{t+k} \right]^{\theta_{t+j}(1+\omega)} Y_{t+j}^{1+\omega+\sigma^{-1}} \quad \textbf{(10)}$$

We log-linearise **(10)** around the steady state to get the optimal relative price[9]

$$\begin{aligned} x_t = \quad & \left(\frac{1 - \beta\alpha\pi^{(\theta+\omega\theta)}}{1+\omega\theta} \right) * \\ & E_t \sum_{j=0}^{\infty} \beta^j \alpha^j \pi^{j(\theta+\omega\theta)} \left(\left[1 + (1+\omega)\theta \ln(\frac{\pi^j}{X}) \right] \hat{\theta}_{t+j} + (\theta+\omega\theta) \sum_{k=1}^{j} \hat{\pi}_{t+k} + (\omega + \sigma^{-1} + 1) y_{t+j} \right) \\ & - \frac{1 - \beta\alpha\pi^{(\theta-1)}}{1+\omega\theta} E_t \sum_{j=0}^{\infty} \beta^j \alpha^j \pi^{j(\theta-1)} \left(\left[\frac{\theta}{\theta-1} + \theta \ln(\frac{\pi^j}{X}) \right] \hat{\theta}_{t+j} + (\theta-1) \sum_{k=1}^{j} \hat{\pi}_{t+k} + y_{t+j} \right) \end{aligned} \quad \textbf{(11)}$$

The aggregate price level in the model is

$$P_t = \left[(1-\alpha) P_t^{*1-\theta_t} + \alpha P_{t-1}^{1-\theta_t} \right]^{\frac{1}{1-\theta_t}} \quad \textbf{(12)}$$

Rewriting **(12)** we obtain

$$(1-\alpha) X_t^{(1-\theta_t)} + \alpha \Pi_t^{\theta_t - 1} = 1 \quad \textbf{(13)}$$

In the steady state, the presence of trend inflation erodes relative prices chosen by firms in the past. Therefore, $X > 1$ when $\pi > 1$. The mechanical erosion of prices is reflected in

$$\ln X = \frac{1}{\theta - 1} \ln \left(\frac{1-\alpha}{1 - \alpha\pi^{(\theta-1)}} \right) \quad \textbf{(14)}$$

(9) As noted in Bakhshi *et al* (2003), unlike the zero trend inflation case, the variations in the real stochastic discount factor do not cancel out in the log-linearisation of the optimal relative price in **(11)**. Additional terms involving output perturbations appear in the log-linearisation. We ignore this potential source of variation in the NKPC for simplicity.

which is the 'price adjustment gap' in the terminology of King and Wolman (1996). Log-linearising **(13)** we obtain

$$\hat{\pi}_t = \frac{1-\gamma}{\gamma}x_t + \frac{\theta}{\theta-1}\left[\frac{1-\gamma}{\gamma}\frac{1}{\theta-1}\ln\left(\frac{1-\alpha}{1-\gamma}\right) - \ln\pi\right]\hat{\theta}_t \qquad \textbf{(15)}$$

where $\gamma = \alpha\pi^{\theta-1}$.

The log-linearised aggregate price level, **(15)**, indicates that inflation depends on the optimal price set by firms in the current period (given by **(11)**), and a second term proportional to log-deviations in competitiveness. This second term is present only if trend inflation is non-zero. The magnitude of the coefficient depends on the level of trend inflation and other parameters of the model. In the presence of trend inflation, the coefficient is negative (for the calibration considered here). Variations in competitiveness also affect inflation *via* the firm's optimal price. In **(11)**, the terms $\ln(\frac{\pi^j}{X})$ disappear if trend inflation is zero, since $\pi = 1$, and therefore, $X = 1$, in that case. However, variations in competitiveness still have an effect on the optimal price in the absence of trend inflation. In that case, the coefficients for each of the θ_{t+j}-terms are negative, while the coefficients of each of the y_{t+j}-terms are positive. This implies that procyclical variations in the elasticity of substitution between goods lead to smaller changes in the optimal relative prices set by firms than in the absence of such procyclical variations. Since firms' optimal prices affect inflation *via* equation **(15)**, this translates into a dampening of inflation responses. The form for cyclical variations in competitiveness is discussed in Section 5.3.

3.5 No cyclical variations in competitiveness

To examine the implications of structural changes in the level of steady-state competitiveness alone, we abstract from cyclical variations in competitiveness in this section. Using **(11)** and **(15)**, the reduced-form expression for the NKPC in the presence of positive trend inflation (NKPC-PI) is (see Appendix A for details)

$$\hat{\pi}_t = a_1^{\pi}E_t\hat{\pi}_{t+1} + a_2^{\pi}E_t\hat{\pi}_{t+2} + S_{PI}y_t + a_1^{y}E_ty_{t+1} \qquad \textbf{(16)}$$

where the coefficients a_1^{π}, a_2^{π}, S_{PI} and a_1^{y} are all functions of the underlying parameters ω, θ, β, σ, α and π.[10] The slope of the NKPC-PI is given by

$$S_{PI} = \left[\frac{(1-\alpha\pi^{\theta-1})(1-\alpha\beta\pi^{\theta+\omega\theta})}{\alpha\pi^{\theta-1}}\left(\frac{\omega+\sigma^{-1}}{1+\omega\theta}\right) + \frac{\beta(1-\alpha\pi^{\theta-1})(1-\pi^{1+\omega\theta})}{1+\omega\theta}\right] \qquad \textbf{(17)}$$

The steady-state level of competitiveness influences the slope *via* two distinct channels, as described below.

[10] When $\pi = 1$ in **(16)**, the Phillips curve specification becomes identical to the standard case, $\pi_t = \beta E_t\pi_{t+1} + \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}\left(\frac{\omega+\sigma^{-1}}{1+\omega\theta}\right)y_t$. To obtain **(16)**, we quasi-difference twice, so that the one-period ahead NKPC is embedded in such a way that it is cancelled out for $\pi = 1$. A similar nesting of NKPCs within the state-dependent Phillips curve is shown in Bakhshi, Khan and Rudolf (2004).

RELATIVE PRICE CHANNEL: The relative price channel is captured by the term $\omega\theta$, which is present even when there is zero trend inflation (π =1). A higher level of steady-state competitiveness, ie a higher elasticity of substitution between goods, implies that firms' sales are more sensitive to their relative prices. Therefore, when demand increases, firms that are able to adjust their prices are more reluctant to do so because they will lose more sales to firms that do not adjust their prices, due to their higher relative price. Thus, higher steady-state competitiveness makes firms more reluctant to change their relative prices, thereby increasing real rigidity in the model. Consequently, a given current demand pressure has a smaller impact on current inflation.

TREND INFLATION EFFECTS: In the presence of positive trend inflation ($\pi > 1$), there are additional forward-looking variables in firms' price-setting decision relative to the zero trend inflation case. Firms' mark-ups, which are established when current prices are chosen optimally, are eroded until the signal to reoptimise arrives. For a given level of trend inflation, a higher level of competitiveness implies that firms will have to supply a greater amount of output in order to meet demand in the presence of falling relative prices, which are eroded by trend inflation. The higher the level of steady-state competitiveness, the greater this effect. Consequently, firms pay less attention to current marginal cost in their price-setting, and in aggregate, this implies a smaller weight on current output.

For a given level of trend inflation, an increase in the steady-state level of competitiveness decreases the slope of the NKPC *via* both channels, implying a smaller response of inflation to a monetary policy shock. For a given level of steady-state competitiveness and degree of nominal price stickiness, an increase in trend inflation decreases the slope of the NKPC.

3.6 Monetary policy rule

The final element of our model is a characterisation of monetary policy. The central bank is assumed to follow a modified Taylor rule of the form

$$i_t = \rho_\pi \hat{\pi}_t + \rho_1 i_{t-1} + \epsilon_t^i \tag{18}$$

Here, variables are log-deviations from steady state, ie $\hat{\pi}_t$ = (ln π_t - ln π) where π takes the different values π_H and π_L (see Table B), and ϵ_t^i is a serially uncorrelated monetary policy shock whose impact on inflation dynamics we will study by calculating impulse responses. As discussed in Woodford (2003), solutions to general equilibrium models including a Taylor rule for the central bank's reaction can be indeterminate. In order to obtain determinate solutions, we choose $\rho_\pi = \rho_1 = 0.9$, as in Rotemberg (2002).

In **(18)**, we do not include a reaction in the Taylor rule to deviations in output from steady state, since the concept of an appropriate theoretical output gap is complicated by the presence of non-zero trend inflation. The absence of an output gap in the Taylor rule requires a relatively larger value of ρ_π in order to achieve determinacy of the model solutions.

The specification of the Taylor rule in **(18)** implies that the long-run multiplier for the response of nominal interest rates to inflation deviations is $\rho_\pi/(1-\rho_1)$. For our calibration, it implies a relatively large long-run multiplier of 9. One advantage of using this calibration is that, within the framework of positive trend inflation and strategic complementarity, it ensures determinacy of the model solutions for higher levels of competitiveness, so that we can explore a wider range of competitiveness scenarios in this paper. An alternative specification for the Taylor rule, $i_t = (1-\rho_1)1.5\hat{\pi}_t + \rho_1 i_{t-1} + \epsilon_t^i$, would imply a smaller long-run multiplier of 1.5 for $\rho_1 = 0.9$ (in line with empirical studies), implying a smaller calibration for ρ_π of 0.15 in **(18)**. While the magnitude of impulse responses changes for the latter specification, the relative pattern of the inflation impact responses to monetary policy shocks for different levels of competitiveness is similar to the pattern obtained with our calibration (see Chart 1 and Section 5 below).

Monetary policy is modelled as a modified Taylor rule, rather than in a fully optimal way. The model's dynamic responses to shocks would be modified in the case of optimal monetary policy. The characterisation of optimal monetary policy in the case of positive trend inflation, however, is beyond the scope of the paper.

4 Model properties

In this section, we discuss some key properties of the model in greater detail in order to provide some intuition for the interactions between trend inflation and competitiveness. The model properties help to understand the impulse responses presented in Section 5.

4.1 Positive trend inflation and Calvo pricing

Our focus is on the short-run effects of monetary policy, and we take the level of trend inflation as determined outside the model, assuming that it is a consequence of the monetary policy regime.

In the presence of trend inflation, price-setters experience faster erosion of their relative prices, and would hence prefer to adjust their nominal prices more frequently. The Calvo

(1983) price-setting assumption, widely used due to its tractability, does not capture this aspect of price-setting behaviour. Moreover, Calvo pricing can be quite restrictive even for low single-digit trend inflation rates (the optimal relative price in the steady state becomes infinite). Bakhshi *et al* (2003) suggest that if the Calvo price signal is elastic with respect to trend inflation, indicating more frequent price adjustments at higher trend inflation levels, then the restrictive aspect can be avoided. Motivated by Romer (1990), we consider a simple functional form,

$$\alpha = \bar{\alpha}\left(\frac{\pi}{1.01}\right)^{-b} \qquad \textbf{(19)}$$

where π is the quarterly gross trend inflation rate, b is the elasticity of price stickiness with respect to trend inflation, and $\bar{\alpha}$ measures the degree of price stickiness for $\pi = 1.01$ (corresponding to an annual trend inflation rate of π^a of 4%).(11) We consider values of $\bar{\alpha} = \frac{2}{3}$ and $b = 25$, which imply an average duration of price stickiness of approximately three quarters for an annual inflation rate of 4%. This calibration ensures that the steady-state optimal relative price is defined when trend inflation rises.(12)

5 Scenarios of structural change in competitiveness and trend inflation for monetary policy

Here we consider four possible scenarios that broadly characterise actual and potential structural changes in competitiveness and trend inflation in the United Kingdom between the early 1990s and 2000s. Table A summarises the different scenarios; π_H and π_L refer to the high and low trend inflation environments associated with the early 1990s and 2000s, respectively; θ_H and θ_L refer to the high and low competitive environments that can potentially characterise each period.

The move of the UK economy to a low inflation environment is a clear structural change (ie a shift to the right column in the scenario matrix). Average RPIX inflation, which is one proxy of trend inflation, fell from 6.5% in the early 1990s to 2.1% in the early 2000s. However, there is no consensus whether the current UK economy is better characterised by a scenario of low trend inflation and high competitiveness (π_L,θ_H), or low trend inflation and low competitiveness (π_L,θ_L). There are two reasons for this lack of consensus. First, there is no clear empirical evidence that the degree of competition has either increased or decreased in the UK economy between these two periods.

(11) We assume that at the micro level, the Calvo frequency of price adjustment is exogenous with respect to firms' pricing decision. At the macro level, however, the proportion of firms that keep their prices unchanged falls with trend inflation. The main advantage of this formulation is that it simplifies the analysis.

(12) Additionally, as in Bakhshi *et al* (2003), this calibration also ensures that the slope of the NKPC under positive trend inflation $rises$ with trend inflation.

Table A: Summary of scenarios of structural changes

(π_H,θ_H)	(π_L,θ_H)
(π_H,θ_L)	(π_L,θ_L)

Second, both the (π_L,θ_H) and (π_L,θ_L) scenarios are possible on theoretical grounds. For example, Benabou (1992a) suggests that price rigidity in the presence of higher trend inflation leads to greater price dispersion, which in turn makes search more valuable to consumers, causing an increase in the elasticity of demand faced by firms, if search costs are sufficiently small. This theory may therefore rationalise the scenario (π_L,θ_L). Benabou (1992b) finds evidence for a negative relationship between mark-ups and inflation for the retail trade sector in the United States. Since competitiveness is inversely related to the mark-up, this implies a positive relation between competitiveness and inflation.

On the other hand, Ball and Romer (2003) present a theory that may rationalise scenario (π_L,θ_H). Their theory suggests that since higher inflation leads to greater price dispersion, firms' prices are less informative for consumers when inflation is high. This allows firms to charge higher mark-ups and reduces competitiveness. Ball and Romer (2003)'s theory assumes that consumers establish a long-term relationship with firms. They find that their results are robust to the inclusion of search.

In addition, these scenarios may be modified to incorporate cyclical variations in competitiveness. In Section 5.2, we examine within these scenarios the transmission from monetary policy shocks to inflation in the short term for different levels of competitiveness, for a given level of trend inflation. Second, we examine how the transmission depends on different levels of trend inflation, for a given level of competitiveness. In Section 5.3, we examine how cyclical variations in competitiveness influence inflation responses to monetary policy shocks, for different levels of steady-state competitiveness and trend inflation.

5.1 Model calibration and solution

Our calibration for the scenarios in Table A and all other parameters in the model is summarised in Table B. Note that the calibration for β, ω, and σ is standard in the literature and taken from Woodford (2003).[13] The values for θ of 4, 7.88 and 10 correspond to desired mark-ups of 33%, 15% and 11%, respectively.[14]

We transform equation **(11)** to obtain **(A-7)** for a firm's optimal relative price.[15] This transforms the infinite number of forward-looking terms in **(11)** into a finite number of terms. A similar transformation has been used in Rotemberg (2002), who considers time variation in the frequency of price adjustment in a positive trend inflation environment. We then use the algorithm by Sims (2002) for solving **(4)**, **(15)**, **(21)**, **(18)**, and **(A-7)** after writing them in a form suitable for application of the algorithm. We study the impact of a 1% monetary policy shock on inflation, output and the nominal interest rate. Results for the impulse responses of all three variables are reported in terms of percentage deviations from steady state, for the quarterly variables.

Table B: Calibration of scenarios and summary of model parameters

High trend inflation	π_H	1.016 (6.5%)*
Low trend inflation	π_L	1.005 (2.1%)*
High competitiveness	θ_H	10 (11%)**
Benchmark competitiveness	θ	7.88 (15%)**
Low competitiveness	θ_L	4 (33%)**
Discount factor	β	0.99
Elasticity of intertemporal substitution	σ	1
Real rigidity parameter	ω	1.25
Elasticity of price stickiness	b	25
Nominal rigidity at π^a of 4%	$\bar{\alpha}$	0.67
Elasticity of cyclical competitiveness	b_θ^y	{1, 0, -1}
Weight on current inflation in the Taylor rule	ρ_π	0.9
Interest rate smoothing parameter	ρ_1	0.9

* Annualised net trend inflation rate, π^a, in brackets (%)

** Implied desired mark-up in brackets (%)

(13) The calibration of $\omega = 1.25$ is consistent with a labour share parameter of $a = 0.7$ and a labour supply elasticity parameter of $\phi = 1.73$, and these values are considered plausible in the literature.

(14) The value of 7.88 is taken from Rotemberg and Woodford (1997).

(15) The appendix provides further details.

5.2 *Inflation dynamics and structural changes in trend inflation and steady-state competitiveness*

This section considers impulse responses of inflation to a 1% monetary policy shock in the scenarios for different values of trend inflation and steady-state competitiveness described above. Here, we first consider different steady-state levels, while excluding cyclical variations in competitiveness.

Slope of the NKPC-PI under different scenarios

$S(\pi_H, \theta_H)$ (1990s)	$S(\pi_L, \theta_H)$ (2000s)
$S(\pi_H, \theta_L)$ (1990s)	$S(\pi_L, \theta_L)$ (2000s)

Our model specification and calibration implies

$$S(\pi_H, \theta_L) > S(\pi_H, \theta_H) > S(\pi_L, \theta_L) > S(\pi_L, \theta_H) \quad \textbf{(20)}$$

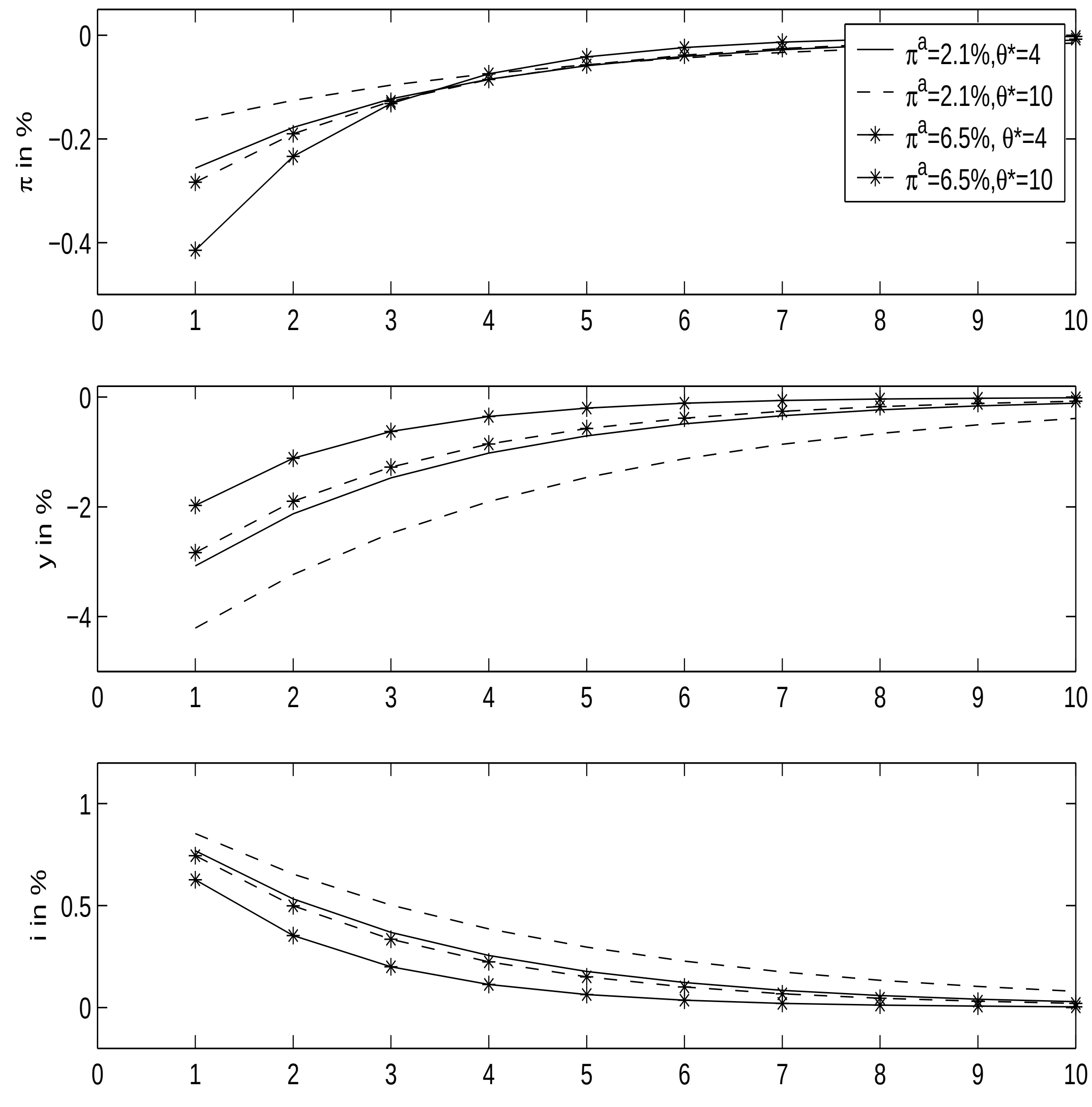
Chart 1 shows that for a given level of trend inflation, a higher level of competitiveness relative to the benchmark dampens the inflation response to a given monetary policy shock.[16] The mechanisms are reflected in the slope of the NKPC in **(17)**. The higher competitiveness, the stronger the effect of real rigidity, and the smaller the slope of the NKPC.

Chart 1 also shows impulse responses to monetary policy shocks for different levels of trend inflation chosen to match the averages for RPIX inflation in the early 1990s and 2000s of 6.5% and 2.1%, as described above. Under our calibration, the average duration of price stickiness for these trend inflation scenarios are 2.4 quarters and 4 quarters, respectively. We compare θ_H and θ_L relative to the benchmark value of $\theta =$ 7.88 (see Table B).

For a given level of competitiveness, the inflation response to a 1% monetary policy shock is larger for higher trend inflation. This happens mainly since the degree of price stickiness

[16] Impulse responses of inflation, output and the nominal interest rate are to a 1% monetary policy shock, for different levels of competitiveness and trend inflation. Percentage deviations from steady state for the quarterly variables are shown.

Chart 1: Responses to a 1% monetary policy shock for different scenarios



is smaller for higher trend inflation, and the model behaves more like a flexible-price model with an associated greater responsiveness of inflation.

Chart 1 also illustrates the range of differences in inflation responses to monetary policy shocks for the different scenarios of structural change considered here. The largest difference in inflation responses between the high and low inflation environments occurs if steady-state competitiveness is higher in the low inflation environment. In that case, the initial inflation response to the monetary policy shock is -0.41% for the high inflation scenario with low competitiveness of $\theta = 4$, compared with -0.16% for the low inflation scenario with $\theta = 10$ (see Chart 1). This happens since both the higher degree of price stickiness in the lower inflation environment, and the higher degree of competitiveness have the effect of dampening the inflation response, compared with the scenario of high inflation and low competitiveness.

For the other scenario where competitiveness is lower in the low inflation period, the inflation responses in the high and low inflation periods are more similar. In that case, the initial inflation response to the monetary policy shock is -0.28% for the high inflation scenario with high competitiveness of $\theta = 10$, compared with -0.26% for the low inflation scenario with $\theta = 4$ (see Chart 1). This happens since the change in trend inflation and thereby the degree of price stickiness, and the change in competitiveness have partly offsetting effects. While the higher degree of price stickiness due to lower trend inflation dampens the inflation response, the lower degree of competitiveness amplifies it.

Output falls in response to a 1% monetary policy shock. For a given level of trend inflation, the impact effect is larger in the scenario of higher competitiveness. The reason is that for higher competitiveness the effect of real rigidity is stronger, which increases the inertia in price adjustment. So firms reduce output in response to the fall in demand. For a given level of competitiveness, a lower level of trend inflation increases nominal price inertia *via* **(19)**, and so the impact effect on output is larger.

As noted in Section 3.6, monetary policy is modelled as a modified Taylor rule in this paper, rather than in a fully optimal way. The impulse responses to monetary policy shocks would be modified for the case of optimal monetary policy.

5.3 Steady-state changes and cyclical variations in competitiveness

In this section we examine how different forms for the cyclical variation in competitiveness affect impulse responses to monetary policy shocks, for given levels of steady-state competitiveness and trend inflation.

We consider variations in competitiveness with output over the cycle, but as mentioned earlier assume that firms take θ_t as given in their profit maximisation problem. Since a firm's desired mark-up, μ_t, is given by $\mu_t = \frac{\theta_t}{\theta_t - 1}$, variations in θ_t imply changes in the desired mark-up. Procyclical changes in θ_t will imply countercyclical changes in μ_t, and *vice versa*. A large body of literature provides a theoretical rationale for endogenous movements (see Rotemberg and Woodford (1999) and references therein) in desired mark-ups. Britton, Larsen and Small (2000) investigate the behaviour of the mark-up of prices over marginal costs under two different assumptions about market structure, a customer market model and an implicit collusion model, and find that the customer market model generates predictions consistent with UK evidence. Although evidence from aggregate US data indicates that mark-ups are countercyclical (see Bils (1987), Rotemberg and Woodford (1991)), the evidence for the United Kingdom suggests that mark-ups are procyclical (see Small (1997)). We therefore consider both cases.

We model competitiveness as varying with output over the cycle,

$$\hat{\theta}_t = b_\theta^y y_t \quad \textbf{(21)}$$

where b_θ^y denotes the elasticity of competitiveness with respect to deviations in output from steady state. Positive or negative values for this elasticity imply procyclical or countercyclical variation in competitiveness, respectively. An advantage of the formulation in **(21)** is that it captures, in a simple manner, the essence of the theoretical studies that emphasise movements in desired mark-ups over the business cycle, including the notion that cyclical movements in desired mark-ups may amplify inflationary fluctuations. We assume that firms form their expectations about cyclical variations in competitiveness based on **(21)**.[17]

Cyclical variations are treated as shocks in the model, which are assumed to be exogenous to the firm's pricing decisions. This simplifying assumption is made in order for the model to remain tractable.

[17] To examine the role of shocks to competitiveness that are not cyclical, we can postulate an exogenous shock process

$$\hat{\theta}_t = b_\theta^y \hat{\theta}_{t-1} + \epsilon_t^\theta \quad \textbf{(22)}$$

where $\epsilon_t^\theta \sim N(0, \sigma_\theta^2)$ and calibrate the two additional parameters governing its persistence, b_θ^y, and volatility, σ_θ, respectively.

Chart 2: Responses to a 1% monetary policy shock with cyclical variations in competitiveness

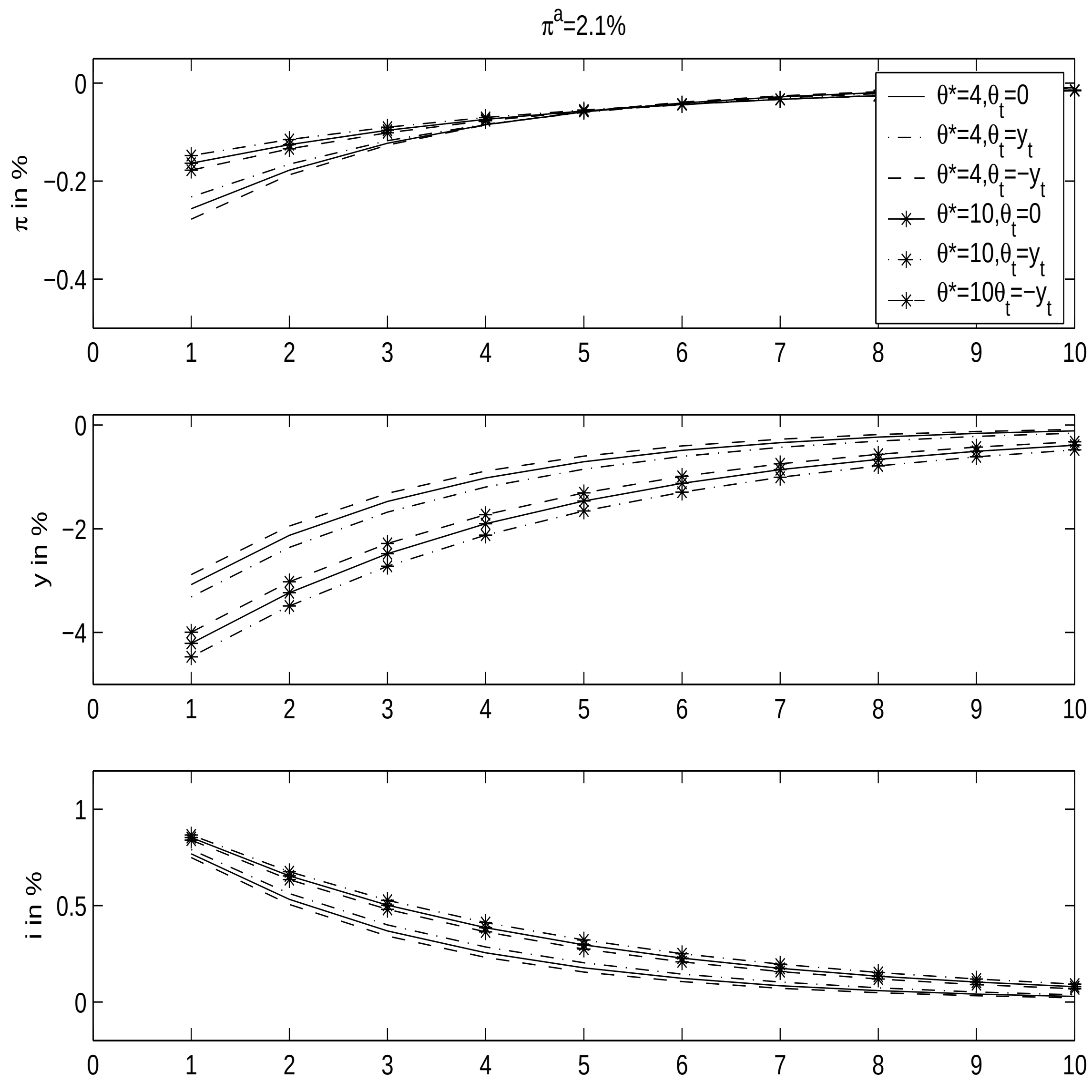


Chart 3: Responses to a 1% monetary policy shock with cyclical variations in competitiveness

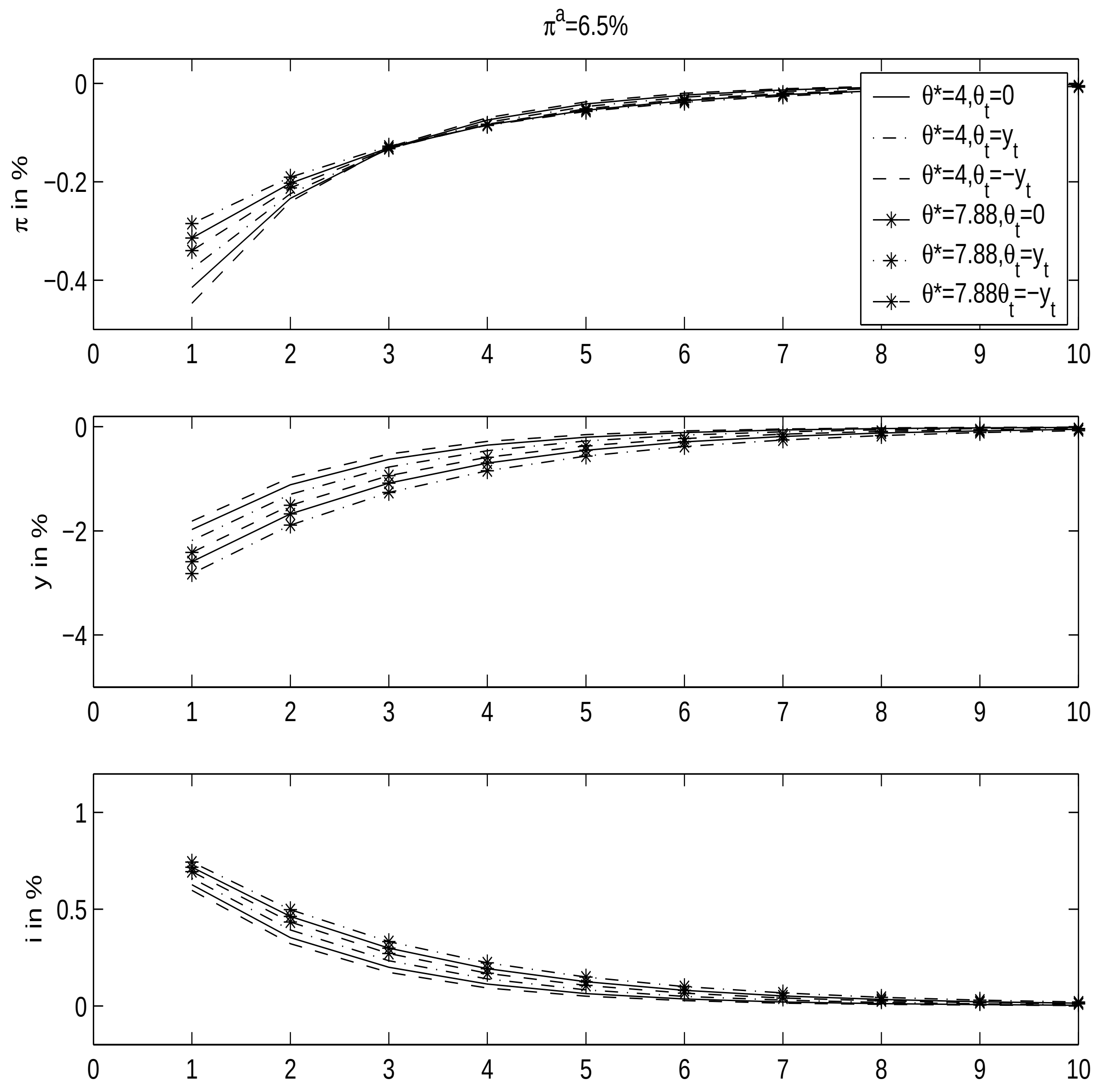


Chart 2 shows the results for impulse responses to a 1% monetary policy shock for constant, procyclical and countercyclical competitiveness.[18] We consider these cyclical variations relative to both θ_H and θ_L within the low inflation environment. We can see that, for a given level of trend inflation, procyclical competitiveness dampens the inflation response compared with the case of constant competitiveness. As output falls in response to the monetary policy shock, competitiveness decreases, and firms therefore have a higher desired mark-up, putting upward pressure on inflation. By contrast, countercyclical competitiveness amplifies the inflation response. For an elasticity of $b_\theta^y = 1$ in **(21)** shown in Chart 2, the dampening effect is not large. The dampening due to procyclical competitiveness is also reflected in the slope of the NKPC, given in **(17)** in the absence of cyclical variations in competitiveness. In the case of competitiveness varying procyclically with output according to **(21)**, the slope of the NKPC decreases as the elasticity b_θ^y increases, for our calibration. Therefore, inflation responds by less relative to output in response to nominal shocks if competitiveness is more procyclical. Chart 3 presents similar results in the high inflation environment.[19]

Next, we examine how different forms for the cyclical variation in competitiveness affect impulse responses to monetary policy shocks, for different levels of trend inflation, but for a given level of steady-state competitiveness.

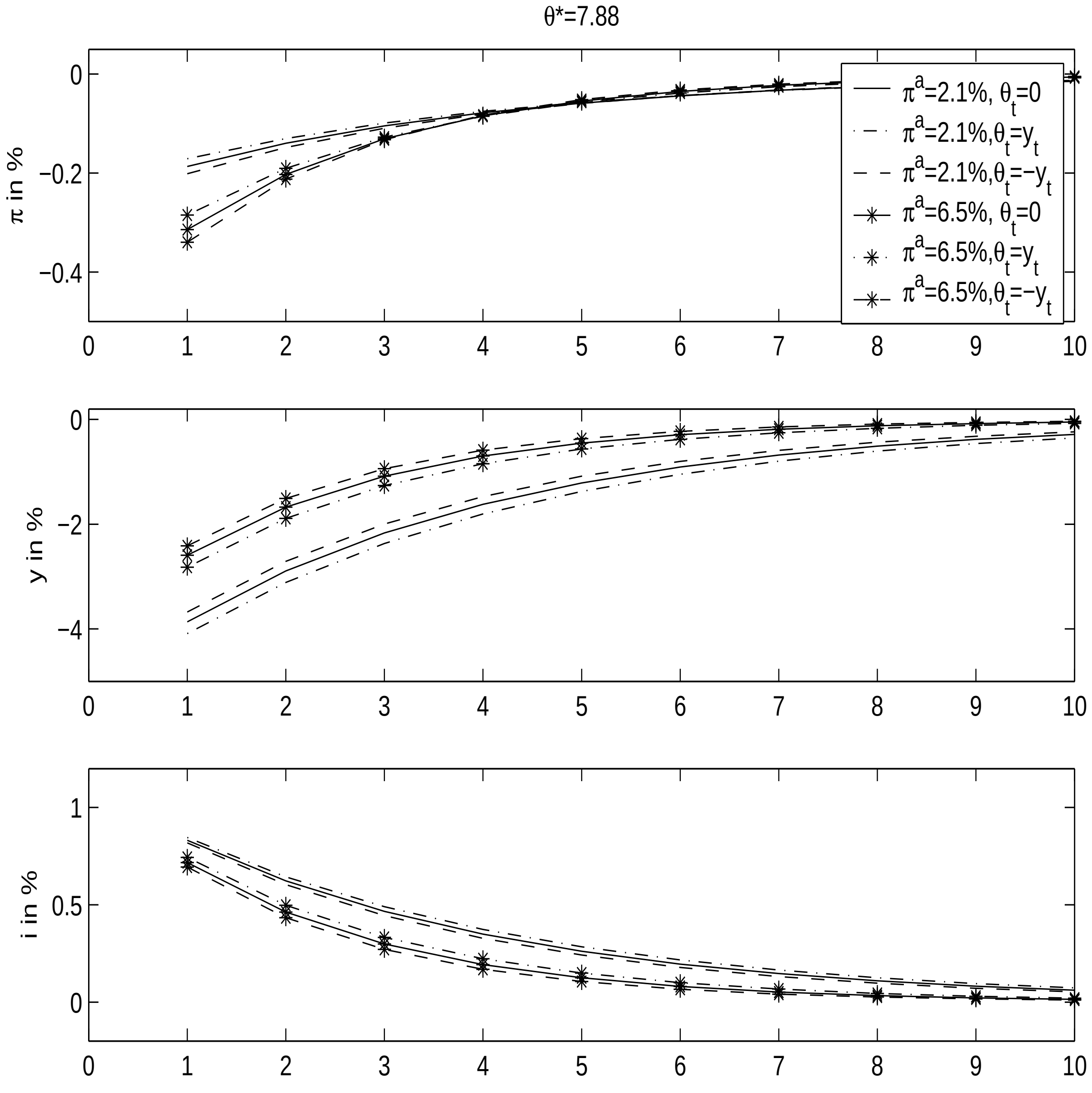
Chart 4 shows the results for impulse responses to a 1% monetary policy shock for constant, procyclical and countercyclical competitiveness, for the high and low inflation environments, and a level of steady-state competitiveness of $\theta = 7.88$. For a given level of trend inflation, procyclical competitiveness dampens the inflation response compared with the case of constant competitiveness. However, our calibration implies that the dampening and amplification effects are again not large. In the low inflation environment, the initial impulse response to the monetary policy shock is around 8% smaller (larger) for procyclical (countercyclical) competitiveness, compared with the case of constant competitiveness. The dampening and amplification effects are similar in the high inflation environment, leading to a change of approximately $8\% - 9\%$ in the initial impulse response of inflation to the monetary policy shock.

---

(18) Impulse responses of inflation, output and the nominal interest rate are to a 1% monetary policy shock, for different levels of competitiveness and cyclical variations in competitiveness, within the low inflation environment, $\pi^a = 2.1\%$. Percentage deviations from steady state for the quarterly variables are shown.

(19) Note that for the high inflation environment, we consider a higher level of steady-state competitiveness of 7.88 rather than 10 in Chart 3, in order to obtain a determinate solution for impulse responses in the presence of procyclical competitiveness, for $b_\theta^y = 1$. For a given θ, the solutions for impulse responses become indeterminate for sufficiently large values of b_θ^y.

Chart 4: Responses to a 1% monetary policy shock with cyclical variations in competitiveness



6 Conclusions

In this paper we examine how differences in the level of steady-state competitiveness and trend inflation might affect inflation responses to monetary policy shocks, using a model based on Woodford (2003). We extend the model to allow for positive trend inflation and cyclical variations in competitiveness. This allows us to quantify separately the impact of differences in steady-state levels of and cyclical changes in competitiveness on inflation dynamics, in high and low inflation environments. We apply this model to scenarios chosen to broadly capture conditions in the UK economy in the early 1990s and recently. This is of interest to monetary policy makers, since it is not clear empirically whether changes in competitiveness have been structural or cyclical in nature. The model is kept tractable, and thereby applicable to policy analysis, by assuming that firms take these cyclical variations in competitiveness as given in their profit maximisation problem. We quantify the extent to which a higher level of steady-state competitiveness dampens the response of inflation to a given monetary policy shock, for a given level of trend inflation. We show that in a low inflation/high competitiveness environment, the higher degree of price stickiness implied by the low inflation environment, and the higher degree of steady-state competitiveness both have the effect of dampening the inflation response to monetary policy shocks, compared to the high inflation/low competitiveness scenario. By contrast, in the low inflation/low competitiveness environment, we find that the effect of lower steady-state competitiveness partially offsets the effect of the higher degree of price stickiness in the low inflation environment, so that the inflation responses in the high and low inflation environments are similar to each other. Moreover, we quantify the extent to which procyclical changes in competitiveness dampen the impulse response of inflation to a given monetary policy shock, and the extent to which countercyclical changes amplify it. If competitiveness varies proportionally to output over the cycle (with unit elasticity), we find that the dampening effect is not large.

Appendix A: Details of model solution

Closed-form NKPC under positive trend inflation for constant competitiveness

We obtain a closed-form NKPC under positive trend inflation (NKPC-PI) for constant competitiveness after setting the terms $\hat{\theta}_{t+j} = 0$ in **(11)** and using the following relations, where L^{-1} is the lead-operator,

$$\sum_{j=0}^{\infty} \gamma_1^j y_{t+j} = \sum_{j=0}^{\infty} (\gamma_1 L^{-1})^j y_t = \frac{1}{1-\gamma_1 L^{-1}} y_t \qquad \textbf{(A-1)}$$

$$\sum_{j=1}^{\infty} \gamma_1^j \sum_{k=1}^{j} \hat{\pi}_{t+k} = \frac{\gamma_1}{1-\gamma_1} \frac{1}{1-\gamma_1 L^{-1}} \hat{\pi}_{t+1} \qquad \textbf{(A-2)}$$

For ease of notation, we define $\gamma_1 = \alpha\beta\pi^{\theta-1}$ and $\gamma_2 = \alpha\beta\pi^{\theta+\omega\theta}$. Using these definitions, **(11)** can be written as [20]

$$(1+\omega\theta)x_t = (1-\gamma_2)E_t\left[(\theta+\omega\theta)\sum_{j=1}^{\infty}\gamma_2^j\sum_{k=1}^{j}\hat{\pi}_{t+k} + (1+\omega+\sigma^{-1})\sum_{j=0}^{j}\gamma_2^j y_{t+j}\right]$$
$$- (1-\gamma_1)E_t\left[(\theta-1)\sum_{j=1}^{\infty}\gamma_1^j\sum_{k=1}^{j}\hat{\pi}_{t+k} + \sum_{j=0}^{j}\gamma_1^j y_{t+j}\right] \qquad \textbf{(A-3)}$$

Using the relations **(A-1)** and **(A-2)** in **(A-3)**, we obtain

$$(1+\omega\theta)x_t = \frac{1}{1-\gamma_2 L^{-1}}E_t\left[\gamma_2(\theta+\omega\theta)\hat{\pi}_{t+1} + (1-\gamma_2)(1+\omega+\sigma^{-1})y_t\right]$$
$$- \frac{1}{1-\gamma_1 L^{-1}}E_t\left[\gamma_1(\theta-1)\hat{\pi}_{t+1} + (1-\gamma_1)y_t\right] \qquad \textbf{(A-4)}$$

Using **(A-4)** and **(15)** (with $\hat{\theta}_t = 0$), and multiplying through by the terms involving the lead operator, we obtain the expression for the NKPC-PI under constant competitiveness as

$$\hat{\pi}_t = a_1^\pi E_t\hat{\pi}_{t+1} + a_2^\pi E_t\hat{\pi}_{t+2} + S_{PI}y_t + a_1^y E_t y_{t+1} \qquad \textbf{(A-5)}$$

with the following expressions for the coefficients:
$a_1^\pi = \gamma_1 + \gamma_2 + \frac{1-\gamma}{\gamma}\frac{1}{1+\omega\theta}\left[(\theta+\omega\theta)\gamma_2 - (\theta-1)\gamma_1\right]$;
$a_2^\pi = -\frac{\gamma_1\gamma_2}{\gamma}$;
$S_{PI} = \frac{1-\gamma}{\gamma}\frac{1}{1+\omega\theta}\left[(\omega+\sigma^{-1}+1)(1-\gamma_2) - (1-\gamma_1)\right]$;
$a_1^y = -\frac{1-\gamma}{\gamma}\frac{1}{1+\omega\theta}\left[(\omega+\sigma^{-1}+1)\gamma_1(1-\gamma_2) - \gamma_2(1-\gamma_1)\right]$
Inserting the definitions for γ, γ_1 and γ_2, the slope of the NKPC can be written as

[20] Note that we ignore variations in the real stochastic discount factor for simplicity.

$S_{PI}=\left[\frac{(1-\alpha\pi^{\theta-1})(1-\alpha\beta\pi^{\theta+\omega\theta})}{\alpha\pi^{\theta-1}}\left(\frac{\omega+\sigma^{-1}}{1+\omega\theta}\right)+\frac{\beta(1-\alpha\pi^{\theta-1})(1-\pi^{1+\omega\theta})}{1+\omega\theta}\right]$

The optimal relative price for variable competitiveness

We transform equation **(11)** for a firm's optimal price from one with an infinite number of forward-looking terms into one with a finite number, by using the relations **(A-1)** and **(A-2)**, as well as

$$\sum_{j=0}^{\infty}\gamma_1^j j\hat{\theta}_{t+j}=\sum_{j=0}^{\infty}(\gamma_1 L^{-1})^j j\hat{\theta}_t=\frac{\gamma_1}{(1-\gamma_1 L^{-1})^2}\hat{\theta}_{t+1} \qquad \textbf{(A-6)}$$

in **(11)**, and multiplying through by the resulting factors in the denominators involving the lead operator. The resulting equation is

$$(1+\omega\theta)x_t=\sum_{j=1}^{4}\left(-c_j^x E_t x_{t+j}+c_j^\pi E_t\hat{\pi}_{t+j}\right)+\sum_{j=0}^{3}\left(c_j^y E_t y_{t+j}+c_j^\theta E_t\hat{\theta}_{t+j}\right) \qquad \textbf{(A-7)}$$

where the coefficients c_j^x, c_j^π (for $j=1,2,3,4$) and c_j^y, c_j^θ (for $j=0,1,2,3$) are given below.

Coefficients in equation (A-7)

Defining $\gamma_1=\alpha\beta\pi^{\theta-1}$ and $\gamma_2=\alpha\beta\pi^{\theta+\omega\theta}$, the coefficients in **(A-7)** are as follows:
$c_1^x=-2(1+\omega\theta)(\gamma_2+\gamma_1)$;
$c_2^x=(1+\omega\theta)(\gamma_2^2+4\gamma_2\gamma_1+\gamma_1^2)$;
$c_3^x=-2(1+\omega\theta)\gamma_2\gamma_1(\gamma_2+\gamma_1)$;
$c_4^x=(1+\omega\theta)\gamma_2^2\gamma_1^2$;
$c_1^\pi=\gamma_2(\theta+\omega\theta)-\gamma_1(\theta-1)$;
$c_2^\pi=-(\gamma_2+2\gamma_1)\gamma_2(\theta+\omega\theta)+(\gamma_1+2\gamma_2)\gamma_1(\theta-1)$;
$c_3^\pi=\gamma_2\gamma_1((2\gamma_2+\gamma_1)(\theta+\omega\theta)-(2\gamma_1+\gamma_2)(\theta-1))$;
$c_4^\pi=-(1+\omega\theta)\gamma_2^2\gamma_1^2$;
$c_0^y=(1-\gamma_2)(\omega+\sigma^{-1}+1)-(1-\gamma_1)$;
$c_1^y=-(\gamma_2+2\gamma_1)(1-\gamma_2)(\omega+\sigma^{-1}+1)+(\gamma_1+2\gamma_2)(1-\gamma_1)$;
$c_2^y=\gamma_1(2\gamma_2+\gamma_1)(1-\gamma_2)(\omega+\sigma^{-1}+1)-\gamma_2(2\gamma_1+\gamma_2)(1-\gamma_1)$;
$c_3^y=\gamma_2\gamma_1(-\gamma_1(1-\gamma_2)(\omega+\sigma^{-1}+1)+\gamma_2(1-\gamma_1))$;
$c_0^\theta=(1-\gamma_2)[1-(1+\omega)\theta\ln(X)]-(1-\gamma_1)[\theta/(\theta-1)-\theta\ln(X)]$;
$c_1^\theta=-(\gamma_2+2\gamma_1)(1-\gamma_2)[1-(1+\omega)\theta\ln(X)]+(\gamma_1+2\gamma_2)(1-\gamma_1)[\theta/(\theta-1)-\theta\ln(X)]+$
$\theta\ln(\pi)(\gamma_2(1-\gamma_2)(1+\omega)-\gamma_1(1-\gamma_1))$;

$c_2^\theta = \gamma_1(2\gamma_2 + \gamma_1)(1 - \gamma_2)[1 - (1 + \omega)\theta \ln(X)] - \gamma_2(2\gamma_1 + \gamma_2)(1 - \gamma_1)[\theta/(\theta - 1) - \theta \ln(X)] - 2\gamma_2\gamma_1\theta \ln(\pi)((1 - \gamma_2)(1 + \omega) - (1 - \gamma_1))$;
$c_3^\theta = \gamma_2\gamma_1(-\gamma_1(1 - \gamma_2)[1 - (1 + \omega)\theta \ln(X)] + \gamma_2(1 - \gamma_1)[\theta/(\theta - 1) - \theta \ln(X)] + \theta \ln(\pi)(\gamma_1(1 - \gamma_2)(1 + \omega) - \gamma_2(1 - \gamma_1)))$.

References

Ascari, G (2004), 'Staggered price and trend inflation: some nuisances', *Review of Economic Dynamics*, Vol. 7, pages 642–67.

Bakhshi, H , Burriel-Llombart, P , Khan, H and Rudolf, B (2003), 'Endogenous price stickiness, trend inflation, and the New Keynesian Phillips curve', *Bank of England Working Paper no. 191*.

Bakhshi, H , Khan, H and Rudolf, B (2004), 'The Phillips curve under state-dependent pricing', *Bank of England Working Paper no. 227*.

Ball, L , Mankiw, N and Romer, D (1988), 'The New Keynesian economics and the output-inflation trade-off', *Brookings Papers on Economic Activity*, Vol. 1, pages 1–65.

Ball, L and Romer, D (1990), 'Real rigidities and the non-neutrality of money', *Review of Economic Studies*, Vol. 57, pages 183–203.

Ball, L and Romer, D (2003), 'Inflation and the informativeness of prices', *Journal of Money, Credit, and Banking*, Vol. 35, pages 177–96.

Benabou, R (1992a), 'Inflation and efficiency in search markets', *Review of Economic Studies*, Vol. 59, pages 299–330.

Benabou, R (1992b), 'Inflation and markups: theories and evidence from the retail trade sector', *European Economic Review*, Vol. 36, pages 566–74.

Bils, M (1987), 'The cyclical behaviour of marginal cost and price', *American Economic Review*, Vol. 77, pages 838–57.

Blanchard, O and Giavazzi, F (2003), 'Macroeconomic effects of regulation and deregulation in goods and labour markets', *Quarterly Journal of Economics*, Vol. 118, pages 879–909.

Britton, E , Larsen, J and Small, I (2000), 'Imperfect competition and the dynamics of mark-ups', *Bank of England Working Paper no. 110*.

Calvo, G (1983), 'Staggered prices in a utility-maximizing framework', *Journal of Monetary Economics*, Vol. 12, pages 383–98.

Clarida, R , Galí, J and Gertler, M (1999), 'The science of monetary policy: a New Keynesian perspective', *Journal of Economic Literature*, Vol. 37, pages 1,661–707.

Ireland, P (2004), 'Technology shocks in the New Keynesian model', *NBER Working Paper no. 10309*.

Khan, H (2004), 'Price-setting behaviour, competition, and mark-up shocks in the New Keynesian model', *Bank of England Working Paper no. 240*.

Kimball, M (1995), 'The quantitative analytics of the basic neomonetarist model', *Journal of Money, Credit, and Banking*, Vol. 27, pages 1,241–77.

King, R and Wolman, A (1996), 'Inflation targeting in a St. Louis model of the 21st century', *Federal Reserve Bank of St Louis Review*, Vol. 78, pages 83–107.

Nickell, S (2001), 'Has UK labour market performance changed?', Bank of England, *Speech given at the Society of Business Economists*.

Romer, D (1990), 'Staggered price setting with endogenous frequency of adjustment', *Economics Letters*, Vol. 32, pages 205–10.

Rotemberg, J (1982), 'Sticky prices in the United States', *Journal of Political Economy*, Vol. 90, pages 1,187–211.

Rotemberg, J (2002), 'Customer anger at price increases, time variation in the frequency of price changes and monetary policy', *NBER Working Paper no. 9320*.

Rotemberg, J and Woodford, M (1991), 'Markups and the business cycle', *NBER Macroeconomics Annual*, pages 63–129.

Rotemberg, J and Woodford, M (1997), 'An optimization-based econometric framework for the evaluation of monetary policy', in Bernanke, B and Rotemberg, J (eds), *NBER Macroeconomics Annual*, MIT Press.

Rotemberg, J and Woodford, M (1999), 'The cyclical behaviour of prices and costs', in Taylor, J and Woodford, M (eds), *The handbook of macroeconomics*, pages 1,051–135.

Sbordone, A (2002), 'Prices and unit labor costs: a new test of price stickiness', *Journal of Monetary Economics*, Vol. 49, pages 265–92.

Sims, C (2002), 'Solving linear rational expectations models', *Computational Economics*, Vol. 20, pages 1–20.

Small, I (1997), 'The cyclicality of mark-ups and profit margins: some evidence for manufacturing services', *Bank of England Working Paper no. 72*.

Smets, F and Wouters, R (2003), 'An estimated stochastic dynamic general equilibrium model of the euro area', *Journal of European Economic Association*, Vol. 1(5), pages 1,123–75.

Steinsson, J (2003), 'Optimal monetary policy in an economy with inflation persistence', *Journal of Monetary Economics*, Vol. 50, pages 1,425–56.

Tirole, J (1988), *The theory of industrial organization*, MIT Press.

Wadhwani, S (2000), 'Monetary challenges in a 'New Economy'', *Bank of England Quarterly Bulletin*, November, pages 411–22.

Woodford, M (2003), *Interest and prices: foundations of a theory of monetary policy*, Princeton: Princeton University Press.