2 Labour market and monetary policy reforms in the UK: a structural interpretation of the implications

Francesco Zanetti
University of Oxford

2.1 Introduction

Two key changes can arguably be said to have characterised the economic landscape in recent UK history: first, labour market reforms enforced by the Thatcher government in the late 1980s and, second, the introduction of an explicit inflation target in 1992, which entrusted the monetary authority with the mandate of stabilising inflation around a numerical target. Subsequently, the UK economy experienced a step change in macroeconomic performance. Figure 2.1 shows the growth rate of real Gross Domestic Product (GDP) and the growth rate of the GDP deflator, an inflation indicator, in the UK from 1970 to the present: it suggests that both real output growth and inflation have been more stable than they were in the 1970s and the 1980s. Moreover, the level of inflation has decreased remarkably since the early 1990s. Would the introduction of these policy changes have produced a different economic outlook if they had been accomplished in the earlier decades? And, if so, to what extent, if at all, might each of these two changes have played a role?

To answer these questions, this chapter uses a model that details the functioning of the UK economy during the 1970s and 1980s which is able to incorporate the policy reforms described. It then uses the model to draw inferences about how these policy changes might have altered the economic outlook had they been introduced in the early 1970s.

I am very grateful for insightful discussions with John Fender and the extremely useful comments and suggestions of Richard Barwell, Arnab Bhattacharjee, Jagjit Chadha, Gulcin Ozkan, Joe Pearlman, Peter Sinclair, Martin Weale and seminar participants at the conference on 'The Causes and Consequences of the Long UK Expansion: 1992 to 2007' at the University of Cambridge. Correspondence: Francesco Zanetti, University of Oxford, Department of Economics, Manor Road, Oxford, OX1 3UQ, United Kingdom. Email: francesco.zanetti@economics.ox.ac.uk.

349-CUP_Chadha-3490022_c02 19 January 2016; 20:23:35

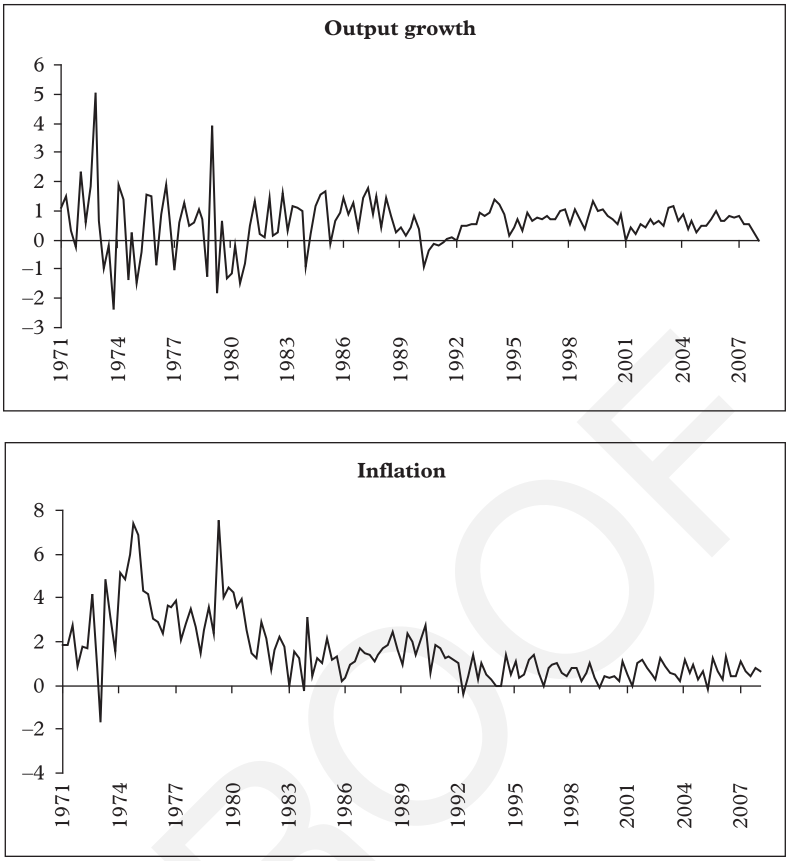

Figure 2.1. Real output growth and inflation in the UK
Notes: Output growth is measured by the growth rate of the real GDP (upper figure) and inflation is measured by the growth rate of GDP deflator (lower figure).

The analysis is conducted using a microfounded New Keynesian model where firms face a cost to adjusting nominal prices and the labour market is characterised by search frictions. The theoretical framework also incorporates a monetary authority that conducts monetary policy by setting the nominal interest rate in reaction to deviations of inflation from its target and output from its long-run equilibrium. Unlike the explicit inflation-targeting framework introduced in 1992, where the target of inflation is constant, during the 1970s and 1980s, the monetary authority could be perceived as having an implicit time-varying inflation target, where the target was allowed to change in reaction to exogenous disturbances. Although the monetary authority never explicitly announced an inflation target before 1992, to the extent that 'inflation is always and everywhere a monetary phenomenon', as suggested by Friedman (1968), changes in actual inflation should not have taken place without changes in at least the monetary authority's implicit inflation target. Hence, this modelling strategy seems an appropriate representation of the conduct of monetary policy before the introduction of an explicit and constant inflation target in 1992. The outcome is a setting similar to those of Blanchard and Galì (2010), Zanetti (2011) and Ireland (2007), which offers a detailed description of the optimising behaviour of households, firms and the monetary authority, and their interactions in the determination of macroeconomic outcomes. The model is then taken to the data and estimated on the UK 1971–91 period to provide a detailed characterisation of the UK economy prior to these policy changes. The econometric estimation separates out the policy parameters, such as those representing monetary policy and the structure of the labour market, which may vary due to changes in policy, from those which represent the household's preference and firm's technology, which ought to be policy-invariant. Hence, the model is immune to Lucas's (1976) critique and can be used to draw inferences about how the introduction of these policy changes may alter the economic outlook. For this reason, counterfactual scenarios, described below, are used to determine to what extent either labour market reforms or changes in the monetary policy framework, or both, could explain the changed economic outlook.

The counterfactual scenarios presented in this chapter aim to establish whether the labour market reforms designed to reduce the unions' power and the replacement ratio of unemployment benefits, and the changes to the monetary policy framework, such as the constant inflation target and the consequent increased weight assigned to inflation as an objective of monetary policy, would have changed the economic outlook if they had been introduced in the earlier decades. The exercise therefore consists of imposing these policy changes on the estimated model for the period 1971–91 to establish to what extent, if at all, each of them would have altered the economic outlook. The findings of this exercise suggest that labour market reforms are unlikely to have produced a considerably different economic outlook. Although a decrease in either unemployment benefits or the power of unions generates a lower level of inflation, the volatility of inflation and output growth significantly increases. The effects of changes in the monetary policy framework are mixed. The degree of reaction to deviations of inflation from the target is important for explaining the lower variance of inflation, output growth and the reduced inflation level. On the other hand, the introduction of a constant inflation target, or a monetary policy that responds more forcefully to output fluctuations, actually increases the volatility of inflation and output growth.

The remainder of the chapter is organised as follows: Section 2.2 relates this chapter to the literature, Section 2.3 provides an overview of the economic context, Section 2.4 sets up the model, Section 2.5 derives the equilibrium and the model's solution, Section 2.6 presents the results and Section 2.7 concludes.

2.2 Related literature

This chapter relates closely to two branches of the literature. First, a number of works have investigated the causes of the reduced macroeconomic volatility in the UK from the early 1990s onward, the period often referred to as an era of 'Great Moderation'. Benati (2008) uses econometric techniques to find that smaller shocks might have caused the muted economic outlook. Canova et al. (2007) use a time-varying VAR to show that changes in the transmission of demand shocks and the reduced volatility of supply and monetary policy shocks account for the improved macroeconomic stability. On the other hand, Batini and Nelson (2009) document that the change in view of policymakers about the importance of monetary policy that culminated with the introduction of inflation targeting, is likely responsible for the post-1990 UK macroeconomic stability. Bianchi et al. (2009) use a FAVAR model to show that the slope of the yield curve is related to a lower and stable inflation in the UK. Unlike these works, this chapter is the first to investigate the importance of labour market reforms and the introduction of a constant inflation target using an estimated, dynamic, stochastic, general equilibrium model. It therefore provides an empirically grounded assessment of the effect of these reforms and enables the model to quantify the structural shocks, which are used to derive the counterfactual scenarios. A closely related study is Blanchard and Galì (2007), which investigates the effect of oil shocks on the US economy. Like this chapter, they find that changes in the labour market, by decreasing real wage rigidities, and a more credible monetary policy, which reacted more aggressively to inflation, played a role in the more muted effect of oil shocks and therefore the different economic outlook in the post-1980 period compared to the 1970s. However, both their approach and focus are different. In Blanchard and Galì (2007) the labour market rigidities are not microfounded, since they assume that wages are exogenously prevented from adjusting, whereas here they are derived from first principles. While they interpret the degree of wage rigidities as a measure of changes in the labour market, this chapter investigates the effect of two well-defined labour market reforms. Moreover, they calibrate the model's parameters, while here the estimation uses the data to determine the parameters' values. Furthermore, the analysis here also focuses on the introduction of a constant inflation target, which is uncovered in Blanchard and Galì (2007).

Second, this chapter also contributes to the estimation of structural models for the UK economy, which is an understudied area of research, as emphasised by DiCecio and Nelson (2007). Unlike DiCecio and Nelson (2007), who estimate the model using a vector autoregression to match the responses of variables to a monetary policy shock, this chapter uses maximum likelihood estimation to fully exploit the ability of the structural model to match the data. In addition, this chapter also incorporates labour market frictions, which, as advocated by Nickell (1997), are an important feature of the UK labour market, and therefore provide a more accurate description of the economy. This chapter also relates to recent works by Kamber and Millard (2008) and Harrison and Oomen (2010), who estimate an array of New Keynesian models to investigate the monetary transmission mechanism in the UK. Finally, the chapter is also related to Faccini et al. (2013), who estimate a general equilibrium model with labour market frictions on UK data. While these works focus on the period from the 1980s onward, this chapter is the first study to provide a detailed description of the economy during the 1970s and 1980s. Moreover, the focus here is broader, as it uses the model to perform normative analysis to determine the relevance of labour market reforms and the introduction of inflation targeting.

2.3 The economic context

To place the analysis in context, before proceeding with the analysis it is worth describing the economic situation and the actual policy changes that took place. In the late 1970s UK economic performance had been subdued: Bean and Crafts (1996, Table 6.1) document that the UK had the lowest growth rate of GDP per capita among a sample of 12 OECD countries and that output dropped more sharply during the 1980s recession than in other developed counties. The top panel of Figure 2.1 shows that output growth was low during the 1970s, and that the second half of the 1980s was characterised by a high level of growth. Interestingly, the strong economic performance of the UK economy coincided with far-reaching labour market and monetary policy reforms.

In the late 1980s the Thatcher government introduced a series of labour market reforms aimed at reducing the distortions in the labour market considered responsible for the poor performance of the UK economy. In particular, as pointed out by Minford (1983), the unemployment benefit system and the power of the unions were regarded as particularly damaging. Consequently, legislation such as the Trade Union Act of 1984 and the Employment Act of 1988 led, as documented by Blanchflower and Freeman (1993), to a steady decline in union density and to a reduction of the replacement ratio of unemployment benefits. In particular, Gregory (1998) documents that union membership declined from 11.7 million in 1979 to 7.2 million in 1996 and union density of employment also declined from 50 per cent in 1979 to 31.3 per cent in 1996. Moreover, Millward, Stevens et al. (1992) reports that the decline of the unions' role was concentrated in the late 1980s.

In the late 1980s the UK government started to reconsider the monetary policy framework. Following Britain's departure from the Exchange Rate Mechanism in September 1992, the Chancellor of the Exchequer, Norman Lamont, established an explicit numerical target for the rate of inflation and gave the legal mandate to the monetary authority to maintain inflation around the target in the medium term. The 1998 Bank of England Act made the Bank independent to set interest rates. The Bank of England became accountable to parliament and started to implement the annual explicit target for the rate of inflation set by the Government. The bottom panel of Figure 2.1 shows that inflation became remarkably low and stable from the early 1990s.

2.4 The economic environment

The theoretical model resembles those used by Blanchard and Galì (2010) and Zanetti (2009, 2011), which combine a standard New Keynesian model with labour market search. In addition, monetary policy accounts for a time-varying inflation target as in Ireland (2007). The model economy consists of a representative household, a representative finished-goods-producing firm, a continuum of intermediate-goods-producing firms, indexed by $i \in [0, 1]$, and a monetary authority.

The labour market is similar to that in Blanchard and Galì (2010), which is based on the Diamond–Mortensen–Pissarides model of search and matching. This framework relies on the assumption that the processes of job search and recruitment are costly for both the firm and the worker. Job creation takes place when a firm and a searching worker meet and agree to form a match at a negotiated wage, which depends on the parties' bargaining power. The match continues until the parties exogenously terminate the relationship. When this occurs, job destruction takes place and the worker moves from employment to unemployment, and the firm can either withdraw from the market or hire a new worker.

The goods market is comprised of a representative finished-goods-producing firm, and a continuum of intermediate-goods-producing firms indexed by $i \in [0, 1]$.[1] During each period $t = 0, 1, 2, \ldots$, each intermediate-goods-producing firm hires workers and produces a distinct, perishable good. During each period $t = 0, 1, 2, \ldots$, the finished-goods-producing firm purchases intermediate goods from the intermediate-goods-producing firms and sells them at an established price on the market. Each intermediate-goods-producing firm sets the price as a markup over its marginal cost, and it faces a cost to adjusting its nominal price, as in Rotemberg (1982). This cost to price adjustment allows the monetary authority to influence the behavior of real variables in the short-run.

The monetary authority is modelled with a modified Taylor (1993) rule as in Clarida et al. (1998): it adjusts the nominal interest rate in response to deviations of output from its steady state and inflation from its target. Similarly to Ireland (2007), monetary policy also allows the inflation target to adjust in response to exogenous shocks.

The next section describes the agents' tastes, technologies, the policy rule and the structure of the goods and labour market in detail.

2.4.1 The representative household

During each period $t = 0, 1, 2, \ldots$, the representative household maximises the expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t a_t (\ln C_t), \tag{2.1}$$

where the variable C_t is consumption, β is the discount factor $0 < \beta < 1$, and a_t is the aggregate preference shock that follows the autoregressive process

$$\ln(a_t) = \rho_a \ln(a_{t-1}) + \varepsilon_{at}, \tag{2.2}$$

1 Note that the model abstracts from issues of heterogeneity and distribution among economic agents, since it is based on the representative agent framework.

where $\rho_a < 1$. The zero-mean, serially uncorrelated innovation ε_{at} is normally distributed with standard deviation σ_a. The representative household enters period t with bonds B_{t-1}. At the beginning of the period, the household receives a lump-sum nominal transfer T_t from the central bank and nominal profits D_t from the intermediate-goods-producing firms. The household supplies N_t units of labour at the wage rate W_t to each intermediate-goods-producing firm $i \in [0, 1]$ and receives unemployment benefits b_t during period t. Then, the household's bonds mature, providing B_{t-1} additional units of currency. The household uses part of this additional currency to purchase B_t new bonds at nominal cost B_t/R_t, where R_t represents the gross nominal interest rate between t and $t+1$. The household uses its income for consumption, C_t, and carries B_t bonds into period $t+1$, subject to the budget constraint

$$C_t + B_t/P_tR_t = [B_{t-1} + W_tN_t + D_t + T_t + (1 - N_t)b_t]/P_t, \tag{2.3}$$

where N_t lies between 0 and 1 for all $t = 0, 1, 2, \ldots$. Thus the household chooses $\{C_t, B_t\}_{t=0}^{\infty}$ to maximise its utility (Eq. (2.1)) subject to the budget constraint (Eq. (2.3)) for all $t = 0, 1, 2, \ldots$. Letting $\pi_t = P_t/P_{t-1}$ denote the gross inflation rate, and Λ_t the non-negative Lagrange multiplier on the budget constraint (Eq. (2.3)), the first-order conditions for this problem are

$$\Lambda_t = a_t/C_t, \tag{2.4}$$

and

$$\Lambda_t = \beta R_t E_t(\Lambda_{t+1}/\pi_{t+1}). \tag{2.5}$$

According to Eq. (2.4), the Lagrange multiplier must equal the household's marginal utility of consumption. Equation (2.5), once Eq. (2.4) is substituted in, is the representative household's Euler equation that describes the consumption decision.

2.4.2 The labour market

During each period $t = 0, 1, 2, \ldots$, the flow into employment results from the number of workers who survive from the exogenous separation and the number of new hires, H_t. Hence, total employment evolves according to

$$N_t(i) = (1 - \delta)N_{t-1}(i) + H_t(i), \tag{2.6}$$

where $N_t(i)$ and $H_t(i)$ represent the number of workers employed and hired by firm i in period t, and δ is the exogenous separation rate and $0 < \delta < 1$. For all $t = 0, 1, 2, \ldots$, the fraction of aggregate employment and hires supplied by the representative household must satisfy $N_t = \int_0^1 N_t(i)di$, and $H_t = \int_0^1 H_t(i)di$ respectively. It is convenient to introduce the variable x_t, labour market tightness:

$$x_t = H_t / U_t, \tag{2.7}$$

and assume, as in Blanchard and Galì (2010), full participation in the labour market such that

$$U_t = 1 - (1 - \delta)N_{t-1} \tag{2.8}$$

is the beginning of the period unemployment. Finally, it is useful to define

$$u_t = 1 - N_t \tag{2.9}$$

the fraction of the population left without a job after recruitment. Since all new hires are from the part of unemployed workers, $0 < x_t < 1$. Hence, x_t also represents the probability that an unemployed worker finds a job.

Let $\mathcal{W}_t^N$, and $\mathcal{W}_t^U$, denote the marginal value of the expected income of an employed, and unemployed worker respectively. The employed worker earns a wage, suffers disutility from work and might lose her job with probability δ. Hence, the marginal value of a new match is:

$$\mathcal{W}_t^N = \frac{W_t}{P_t} + \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} \{[1 - \delta(1 - x_{t+1})]\mathcal{W}_{t+1}^N + \delta(1 - x_{t+1})\mathcal{W}_{t+1}^U\}. \tag{2.10}$$

This equation states that the marginal value of a job for a worker is given by the real wage and the expected-discounted net gain from being either employed or unemployed.

The unemployed worker expects to move into employment with probability x_t. Hence, the marginal value of unemployment is:

$$\mathcal{W}_t^U = \frac{b_t}{P_t} + \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t} \left[x_{t+1}\mathcal{W}_{t+1}^N + (1 - x_{t+1})\mathcal{W}_{t+1}^U\right]. \tag{2.11}$$

This equation states that the marginal value of unemployment is made up of unemployment benefits together with the expected-discounted capital gain from being either employed or unemployed. Similarly to Zanetti (2011), unemployment benefits are set as a proportion, ρ_b, of the established wage, such that $b_t = \rho_b w_t$, where ρ_b represents the replacement ratio.

The structure of the model guarantees that a realised job match yields some pure economic surplus. The share of this surplus between the worker and the firm is determined by the wage level, in addition to compensating each side for its costs from forming the match. As in Pissarides (2000), the wage is set according to the Nash bargaining solution. The worker and the firm split the surplus of their matches with the absolute share η, and $0 < \eta < 1$. The difference between Eqs. (2.10) and (2.11) determines the worker's surplus. The firm's surplus is simply given by the foregone cost of hiring, G_t, which, as in Blanchard and Galì (2010), is an increasing function of aggregate technology, z_t, and labour market tightness:

$$G_t = z_t B x_t^{\alpha}, \tag{2.12}$$

where $\alpha \geq 0$, and $B \geq 0$.[2] The aggregate technology, z_t, follows the auto-regressive process

$$\ln(z_t) = \rho_z \ln(z_{t-1}) + \varepsilon_{zt}, \tag{2.13}$$

where $\rho_z < 1$. The zero-mean, serially uncorrelated innovation ε_{zt} is normally distributed with standard deviation σ_z. Hence, the total surplus from a match is the sum of the worker's and the firm's surpluses, given by $\mathcal{W}_t^N - \mathcal{W}_t^U + G_t$. Nash bargaining sets the worker's surplus as a fraction η of the total surplus, $\mathcal{W}_t^N - \mathcal{W}_t^U = \eta(\mathcal{W}_t^N - \mathcal{W}_t^U + G_t)$, and therefore the wage bargaining rule for a match is:

$$\eta G_t = (1 - \eta)(\mathcal{W}_t^N - \mathcal{W}_t^U).$$

Substituting Eqs. (2.10) and (2.11) in this last equation produces the agreed wage:

$$W_t = b_t / P_t + [\eta/(1-\eta)]\{G_t - \beta(1-\delta)E_t(\Lambda_{t+1}/\Lambda_t)[(1-x_{t+1})G_{t+1}]\}, \tag{2.14}$$

where η is the bargaining power of the worker. Equation (2.14) shows that the wage equals the unemployment benefits together with current hiring costs, and the expected savings in terms of the future hiring costs if the match continues.[3] The influence of these last two terms on the wage depends on the relative power of the worker in the wage bargain.

2.4.3 The goods market

As described above, the production sector is comprised of a representative finished-goods-producing firm and a continuum of intermediate-goods-producing firms, indexed by $i \in [0, 1]$, characterised by staggered price-setting as in Rotemberg (1982).

2 Note that the cost and benefit of posting a job are the same in equilibrium.
3 Note that the wage of newly hired workers is applied to existing workers.

2.4.3.1 The representative finished-goods-producing firm During each period $t = 0, 1, 2, \ldots$, the representative finished-goods-producing firm uses $Y_t(i)$ units of each intermediate good $i \in [0, 1]$, purchased at nominal price $P_t(i)$, to produce Y_t units of the finished product at constant returns to scale technology

$$\left[\int_0^1 Y_t(i)^{\frac{\theta_t-1}{\theta_t}} di\right]^{\frac{\theta_t}{\theta_t-1}} \geq Y_t,$$

where θ_t is the time-varying elasticity of substitution among intermediate goods, as first introduced by Smets and Wouters (2007), Steinsson (2003) and Ireland (2004, 2007). This parameter follows the autoregressive process

$$\ln(\theta_t) = (1 - \rho_\theta)\ln(\theta) + \rho_\theta \ln(\theta_{t-1}) + \varepsilon_{\theta^t}, \tag{2.15}$$

where $\rho_\theta < 1$. The zero-mean, serially uncorrelated innovation ε_{θ^t} is normally distributed with standard deviation σ_θ.

Hence, the finished-goods-producing firm chooses $Y_t(i)$ for all $i \in [0, 1]$ to maximise its profits

$$P_t\left[\int_0^1 Y_t(i)^{\frac{\theta_t-1}{\theta_t}} di\right]^{\frac{\theta_t}{\theta_t-1}} - \int_0^1 P_t(i) Y_t(i) di,$$

for all $t = 0, 1, 2, \ldots$ The first-order conditions for this problem are

$$Y_t(i) = [P_t(i)/P_t]^{-\theta_t} Y_t \tag{2.16}$$

for all $i \in [0, 1]$ and $t = 0, 1, 2, \ldots$ The aggregate shocks θ_t can be interpreted as intermediate-goods-producing firm markup over marginal cost.

Competition drives the finished-goods-producing firm's profit to zero at equilibrium. This zero profit condition implies that

$$P_t = \left[\int_0^1 P_t(i)^{1-\theta_t} di\right]^{\frac{1}{1-\theta_t}}$$

for all $t = 0, 1, 2, \ldots$

2.4.3.2 The representative intermediate-goods-producing firm During each period $t = 0, 1, 2, \ldots$, the representative intermediate-goods-producing firm hires $N_t(i)$ units of labour from the representative household in order to produce $Y_t(i)$ units of intermediate good i according to the constant returns to scale technology

$$Y_t(i) = z_t N_t(i). \tag{2.17}$$

Since the intermediate goods are not perfect substitutes in the production of the final goods, the intermediate-goods-producing firm faces an imperfectly competitive market. During each period $t = 0, 1, 2, \ldots$ it sets the nominal price $P_t(i)$ for its output, subject to satisfying the representative finished-goods-producing firm's demand. The intermediate-goods-producing firm faces a quadratic cost to adjusting nominal prices, measured in terms of the finished goods and given by

$$\frac{\phi_p}{2}\left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right]^2 Y_t,$$

where $\phi_p > 0$ is the degree of adjustment cost and π is the steady state gross inflation rate. This relationship, as stressed in Rotemberg (1982), accounts for the negative effects of price changes on customer–firm relationships. These negative effects increase in magnitude with the size of the price change and with the overall scale of economic activity, Y_t.

The problem for the firm is to choose $\{P_t(i),\ N_t(i),\ H_t(i)\}_{t=0}^{\infty}$ to maximise its total market value given by

$$E_0 \sum_{t=0}^{\infty} (\beta^t \Lambda_t / P_t) D_t(i), \tag{2.18}$$

where the variable $D_t(i)$ is profits, subject to the constraints imposed by Eqs. (2.6)–(2.8), (2.12) and (2.17). In Eq. (2.18), $\beta^t \Lambda_t / P_t$ measures the marginal utility value to the representative household of an additional dollar in profits received during period t and

$$D_t(i) = P_t(i) Y_t(i) - N_t(i) W_t - H_t(i) G_t - \frac{\phi_p}{2}\left[\frac{P_t(i)}{\pi P_{t-1}(i)} - 1\right]^2 Y_t \tag{2.19}$$

for all $t = 0, 1, 2, \ldots$ Thus the firm chooses $\{N_t(i), P_t(i)\}_{t=0}^{\infty}$ to maximise the profit (Eq. (2.19)) subject to the demand function (Eq. (2.16)), the production technology (Eq. (2.17)), and law of employment accumulation (Eq. (2.6)). Solving Eq. (2.6) for $H_t(i)$ and substituting the outcome, together with Eq. (2.16), into Eq. (2.19), and letting Ξ_t denote the non-negative Lagrange multiplier on Eq. (2.17), permits us to write the first-order conditions for this problem as

$$\frac{W_t}{P_t} = \frac{\Xi_t}{\Lambda_t} z_t - \frac{G_t}{P_t} + \beta(1-\delta)\frac{\Lambda_{t+1}}{\Lambda_t}\frac{G_{t+1}}{P_t}, \tag{2.20}$$

and

$$\phi_p\left[\frac{P_t(i)}{\pi P_{t-1}(i)}-1\right]\frac{P_t}{\pi P_{t-1}(i)}=(1-\theta_t)\left[\frac{P_t(i)}{P_t}\right]^{-\theta_t}+\theta_t\frac{\Xi_t}{\Lambda_t}\left[\frac{P_t(i)}{P_t}\right]^{-(1+\theta)}$$
$$+\beta\phi_p E_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\left[\frac{P_{t+1}(i)}{\pi P_t(i)}-1\right]\frac{P_{t+1}(i)P_t}{\pi P_t^2(i)}\frac{Y_{t+1}}{Y_t}\right\}. \tag{2.21}$$

Equation (2.20) is the firm's labour supply condition, which equates the real wage with the marginal product of labour minus the hiring costs to pay in period t, plus the expected saving on the hiring costs forgone in period $t+1$, if the job is not dismissed. Equation (2.21) is the New Keynesian Phillips curve in its non-linearised form and it states that the firm sets prices as a markup over marginal cost, accounting for price adjustment costs. As Ravenna and Walsh (2008) and Chadha and Sun (2008) point out, the presence of labour market search frictions enables the New Keynesian Phillips curve to track inflation fluctuations more precisely.

2.4.4 The monetary authority

During each period $t=0,1,2,\ldots$, the monetary authority conducts monetary policy using a modified Taylor (1993) rule,

$$\ln(R_t/R)=\rho_y\ln(Y_t/Y)+\rho_\pi\ln(\pi_t/\pi_t^\star)+\ln(v_t), \tag{2.22}$$

where R and Y are the steady state values of the nominal interest rate and output, and $\pi_t^\star$ is the monetary authority time-varying inflation target for the period t. According to Eq. (2.22), the monetary authority adjusts the nominal interest rate in response to movements in output from its steady state and inflation from the target. As pointed out in Clarida et al. (1998) and Nelson (2003), this modelling strategy for the central bank consistently describes the conduct of monetary policy in the UK since the early 1970s. The monetary policy shock v_t follows the autoregressive process

$$\ln(v_t)=\rho_v\ln(v_{t-1})+\varepsilon_{vt}, \tag{2.23}$$

where $\rho_v<1$. The zero-mean, serially uncorrelated policy shock ε_{vt} is normally distributed, with a standard deviation σ_v. Similarly to Ireland (2007), the time-varying inflation target $\pi_t^\star$ evolves according to

$$\ln(\pi_t^\star)=\ln(\pi^\star)+\delta_a\varepsilon_{at}-\delta_\theta\varepsilon_{\theta t}-\delta_z\varepsilon_{zt}+\sigma_\pi\varepsilon_{\pi t}, \tag{2.24}$$

such that it may vary exogenously, when $\sigma_\pi > 0$, and may adjust to preference, cost-push and technology shocks, when $[\delta_a, \delta_\theta, \delta_z] > 0$. Note that, as in Ireland (2007), since negative realisation of $\varepsilon_{\theta t}$ and ε_{zt} and positive realisation of ε_{at} increase prices, positive values for δ_θ, δ_z and δ_a generate more persistent movements in the inflation target. The presumption here, as detailed at the outset, is that changes in inflation should not have happened without changes in at least the implicit inflation target, and that the implicit inflation target reacts to shocks similarly to the underlying inflation.

2.5 Equilibrium and solution

In a symmetric, dynamic, equilibrium, all intermediate-goods-producing firms make identical decisions, so that $Y_t(i) = Y_t$, $N_t(i) = N_t$, $H_t(i) = H_t$, $D_t(i) = D_t$ and $P_t(i) = P_t$, for all $i \in [0, 1]$ and $t = 0, 1, 2,$. In addition, the market clearing conditions $T_t = M_t - M_{t-1}$ and $B_t = B_{t-1} = 0$ must hold for all $t = 0, 1, 2, \ldots$ These conditions, together with the firm's profit conditions (Eq. (2.19)) and the household's budget constraint (Eq. (2.3)), produce the aggregate resource constraint

$$Y_t = C_t + (\phi_p/2)(\pi_t/\pi - 1)^2 Y_t + G_t H_t, \tag{2.25}$$

where the term $G_t H_t$ expresses the resources spent in hiring. Substituting the Lagrange multiplier, Λ_t, from Eq. (2.4) into Eqs. (2.5), (2.14) and (2.20)–(2.21), and deriving the labour market equilibrium condition by combining the agreed wage (Eq. (2.14)) with the labour demand (Eq. (2.20)), the model describes the behavior of 14 endogenous variables $\{b_t, C_t, G_t, H_t, \Lambda_t, \Xi_t, N_t, \pi_t, \pi_t^\star, R_t, U_t, W_t, x_t, Y_t\}$ and four exogenous shocks $\{a_t, \theta_t, v_t, z_t\}$. The equilibrium is then described by the representative household's first-order conditions (Eqs. (2.4) and (2.5)), the law of employment (Eq. (2.6)), the definition of labour market tightness (Eq. (2.7)), the definition of unemployment accumulation (Eq. (2.8)), the definition of cost per hire (Eq. (2.12)), the agreed wage (Eq. (2.14)), the production function (Eq. (2.17)), the labour market equilibrium condition (Eq. (2.20)), the New Keynesian Phillips curve (Eq. (2.21)), the monetary authority policy rule (Eq. (2.22)), the time-varying inflation target (Eq. (2.24)), the aggregate resource constraint (Eq. (2.25)), the definition of unemployment benefits and the specification of the exogenous shocks as in Eqs. (2.2), (2.13), (2.15) and (2.23).

The equilibrium conditions do not have an analytical solution. Instead, the model's dynamics are characterised by log-linearising them around the steady state. The log-linearised equilibrium conditions are

$$\hat{\Lambda}_t = \hat{a}_t - \hat{C}_t,$$
$$\hat{\Lambda}_t = \hat{R}_t + E_t\hat{\Lambda}_{t+1} - \hat{\pi}_t,$$
$$\hat{N}_t = (1-\delta)\hat{N}_{t-1} + \delta\hat{H}_t,$$
$$\hat{x}_t = \hat{H}_t - \hat{U}_t,$$
$$\hat{U}_t = -(1-\delta)\ (N/U)\hat{N}_{t-1},$$
$$\hat{G}_t = \psi\hat{z}_t + \alpha\hat{x}_t,$$
$$\hat{W}_t = (b/W)b_t + [\eta/(1-\eta)](G/b)\hat{G}_t + (1-\delta)\beta(x/b)[\eta/(1-\eta)]E\hat{x}_{t+1} - (\beta/b)(1-\delta)(1-x)[\eta/(1-\eta)](\hat{G}_{t+1} + \hat{\Lambda}_{t+1} - \hat{\Lambda}_t),$$
$$\hat{Y}_t = \hat{z}_t + \hat{N}_t,$$
$$\hat{b}_t = (\Xi z/\Lambda b)(\hat{\Xi}_t - \hat{\Lambda}_t + \hat{z}_t) - \{1 + [\eta/(1-\eta)]\}(G/b)\hat{G}_t + \beta(1-\delta)\{1 + (1-x)[\eta/(1-\eta)]\}(G/b)(\hat{\Lambda}_{t+1} + \hat{G}_t - \hat{\Lambda}_t) - \beta(1-\delta)(xG/b)[\eta/(1-\eta)]E\hat{x}_{t+1},$$
$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + (\theta\ \ \Xi/\phi\Lambda)(\hat{\Xi}_t - \hat{\Lambda}_t + \hat{\theta}_t) - (\theta/\phi)\hat{\theta}_t,$$
$$\hat{R}_t = \rho_y\hat{y}_t + \rho_\pi(\hat{\pi}_t - \hat{\pi}_t^\star) + v_t,$$
$$\hat{\pi}_t^\star = \delta_a\varepsilon_{at} - \delta_\theta\varepsilon_{\theta t} - \delta_z\varepsilon_{zt} + \sigma_\pi\varepsilon_{\pi t},$$
$$\hat{Y}_t = (C/Y)\hat{C}_t + (GH/Y)(\hat{G}_t + \hat{H}_t),$$
$$\hat{a}_t = \rho_a\hat{a}_{t-1} + \varepsilon_{at},$$
$$\hat{\theta}_t = \rho_\theta\hat{\theta}_{t-1} + \varepsilon_{\theta t},$$
$$\hat{v}_t = \rho_a\hat{v}_{t-1} + \varepsilon_{vt},$$

and

$$\hat{z}_t = \rho_z\hat{z}_{t-1} + \varepsilon_{zt},$$

where a hat on a variable denotes the logarithmic deviation from its steady state and a variable without the time index represents its value at the steady state. The solution to this system is derived using Klein (2000), which is a modification of Blanchard and Kahn (1980), and takes the form of a state space representation. This latter can be conveniently used to compute the likelihood function in the estimation procedure.

2.6 Estimation and findings

The econometric estimation uses UK quarterly data for output growth, consumption growth, the nominal interest rate, inflation and the growth rate of wages for the sample period 1971:1 through 1991:4. Output growth is defined as the quarterly growth rate of gross domestic product at basic prices; consumption growth is defined as the quarterly growth rate of final consumption expenditure; the nominal interest rate is defined as quarterly averages of daily readings on the three-month UK Treasury Bill rate; inflation is defined as the quarterly growth rate of the GDP deflator; and wages growth is defined as the quarterly growth rate of the Average Earnings Index. All the data are taken from the Office for National Statistics dataset, with the exception of the series of the three-month UK Treasury Bill rate, which is from the Statistical Interactive Database. The data are demeaned prior to the estimation.

As in other similar studies, such as Ireland (2004), a first attempt to estimate the model produced implausible values for the discount factor. Thus the real interest rate is set to 4 per cent annually, a number commonly used in the literature, which pins down the quarterly discount factor β to 0.99. Consistent with UK data, the steady state value of the job finding rate, x, and unemployment rate, u, are set equal to 0.4 and 0.3 respectively. This yields a value for the separation rate, $\delta = ux/((1-u)(1-x))$, equal to 0.29, which is in line with the UK estimate by Jolivet et al. (2006). Also the parameter B, which determines the steady state proportion of hiring costs of total output, is difficult to identify and is calibrated. Since there is no precise empirical evidence on this parameter, following Blanchard and Galí (2010) it is set approximately to 0.0438 so that hiring costs represent 1 per cent of total output, which seems a reasonable upper bound. Of special interest is the bargaining power parameter, η, which represents the fraction of the total surplus attributed to the worker. The estimation was unable to identify this parameter and therefore it is set equal to 0.5, as estimated by Petrongolo and Pissarides (2001), so that the household and the firm have the same bargaining power. Consequently, in order to satisfy the Hosios (1990) condition, which guarantees that allocations of the economy are Pareto optimal, the parameter of the elasticity of hiring costs with respect to labour market tightness, α, is set equal to one.[4] Another parameter that the estimation procedure was unable to identify is the replacement ratio, ρ_b, that represents the ratio of unemployment benefits to the past wage, which is set equal to 40 per cent, as estimated

4 A similar calibration strategy is used in Blanchard and Galì (2010) and Zanetti (2008).

by Bean (1994) and Nickell (1997). The steady state value of the elasticity of substitution between intermediate goods, θ, is set equal to six so that the equilibrium markup is equal to 20 per cent, as suggested in Britton et al. (2000). The gross steady state value of inflation, π, is set equal to 1.02, matching the average inflation rate in the data. Finally, Eqs. (2.14) and (2.20) pin down the parameter χ which is set equal to 0.9985.

Table 2.1 displays the maximum likelihood estimates of the model's parameters together with their standard errors. The estimate of the degree of nominal price rigidities, ϕ_p, is equal to 24.3425. As shown in Ireland (2000), given that θ is equal to six, it implies that approximately 20 per cent of the firms adjust their price each period, a value in line with Britton et al. (2000). It is worth noticing that, given the sizable standard error of this parameter, considerable uncertainty remains about the degree of nominal price rigidities in the economy.

The parameter estimates of Eqs. (2.22) and (2.24) characterise the conduct of monetary policy. The estimate of the reaction coefficient to the fluctuations of output from its steady state, ρ_y, is 0.1229, and the estimate of the reaction coefficient to the fluctuations of inflation from the inflation target, ρ_π, is 1.1019. These estimates suggest that the monetary authority responded weakly to inflation and output. This is in line with the estimates in Nelson (2003) and the documentation in Batini and Nelson (2009). The estimates of Eq. (2.24), which describes the inflation target, point out that preference, cost-push and technology

Table 2.1. Maximum likelihood estimation and standard errors

Parameters	**Estimates**	**Standard errors**
ϕ_p	24.3425	29.3824
ρ_π	1.1019	0.0557
ρ_y	0.1229	0.0922
δ_a	0.2375	0.2779
δ_θ	0.1428	0.1824
δ_z	0.2612	0.8819
ρ_a	0.9938	0.0003
ρ_θ	0.8557	0.0148
ρ_v	0.4280	0.1954
ρ_z	0.6506	0.0307
σ_a	0.2920	0.5819
σ_θ	1.1144	0.6935
σ_π	0.1420	0.5678
σ_v	0.0008	0.0047
σ_z	0.6763	0.0723

shocks are all important components to determine the implicit inflation target. In fact, the estimates of δ_a, δ_θ and δ_z are equal to 0.2375, 0.1428 and 0.2612 respectively. Interestingly, the monetary authority leaves the target to react more aggressively to technology shocks while giving less weight to preference and cost-push shocks.

The estimates of the exogenous disturbances show that preference shocks are highly persistent, with ρ_a equal to 0.9938, while cost-push and technology shocks are less so, with ρ_θ and ρ_z equal to 0.8557 and 0.6506 respectively. The estimates of the volatility of the exogenous disturbances show that cost-push and technology shocks are highly volatile, with σ_θ and σ_z equal to 1.1144 and 0.6763 respectively, while shocks to the monetary policy rule, inflation target and households' preferences are of lower magnitude, with σ_v, σ_π and σ_a equal to 0.0008, 0.1420 and 0.2920 respectively. Clearly, these values suggest that cost-push and technology shocks are important components of economic fluctuations.

To investigate how the variables of the model react to each shock, Figures 2.2 and 2.3 plot the impulse responses of selected variables to one standard deviation of each of the exogenous shocks. The first column in Figure 2.2 shows that after a one standard deviation technology shock, output and unemployment both rise, while inflation falls. The fall in inflation allows for an easing in monetary policy such that the nominal interest rate falls. Finally, the one-period immediate increase in unemployment leads to a fall in labour market tightness, which then increases due to the subsequent fall in unemployment. The second column in Figure 2.2 shows that a one standard deviation cost-push shock causes a fall in inflation and the nominal interest rate, and a rise in output. The increase in output triggers a fall in unemployment that generates a rise in labour market tightness. Given the opposite reaction of output and inflation in the case of technology and cost-push shocks, these disturbances behave as supply-side shocks, as mentioned in the outset. The third column in Figure 2.2 shows that a one standard deviation monetary policy shock translates into an increase in the nominal interest rate and into a fall in output. The fall in output generates an increase in unemployment and a consequent fall in the number of hires. Opposite shifts in the number of hires and unemployment generate a fall in labour market tightness. Since the monetary policy disturbance is serially uncorrelated, the reaction of each variable dies off over a period of one year. The first column in Figure 2.3 shows that after a one standard deviation preference shock both output and inflation rise, leading the nominal interest rate, due to the modified Taylor rule, to increase. Unemployment falls, and therefore labour market tightness rises due to

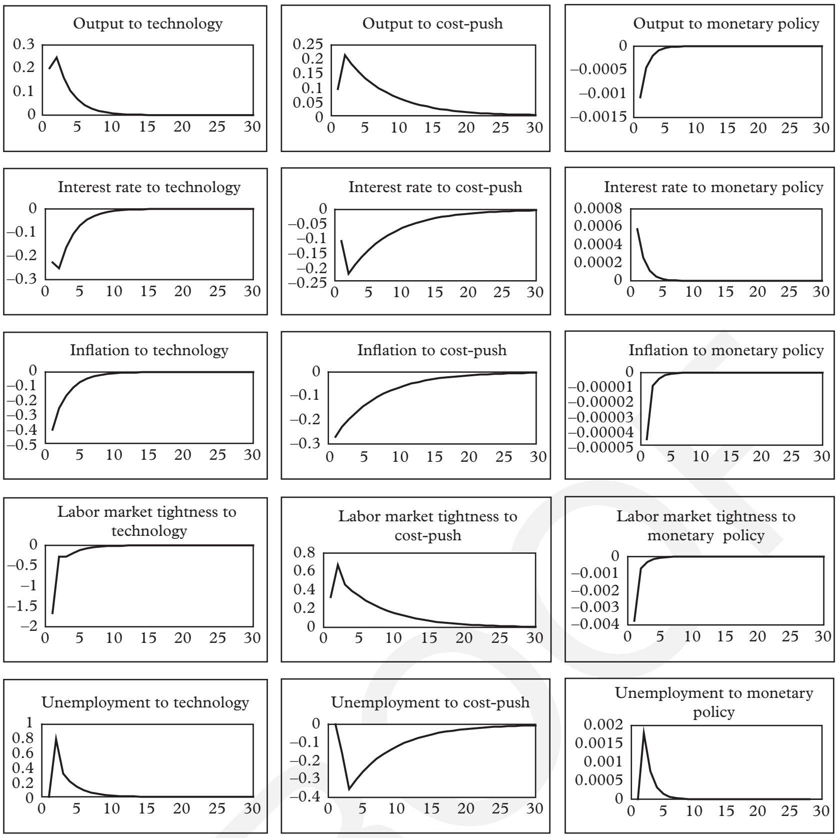

Figure 2.2. Impulse responses to technology, cost-push and monetary policy shocks

Notes: Each panel shows the percentage-point response of selected models' variables to a one standard deviation shock. The horizontal axis measures the time, expressed in quarters.

the lower response of vacancies. Finally, the second column in Figure 2.3 shows that a one standard deviation inflation target shock decreases the nominal interest rate and raises inflation, whose combined movements generate a decrease in the real interest rate and therefore a rise in output. Unemployment falls and so labour market tightness increases.

Looking across all these impulse responses also provides some insights into how the presence of labour market search and the introduction of a time-varying inflation target affect the transmission

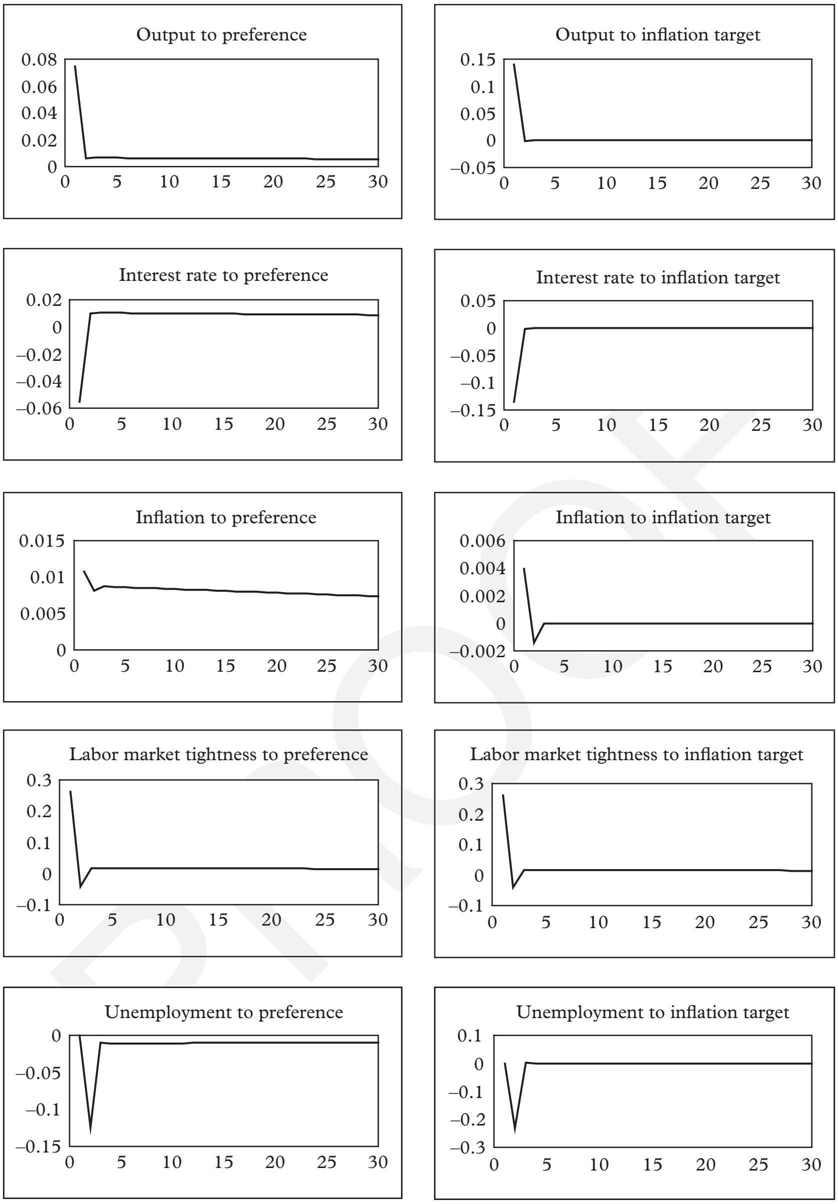

Figure 2.3. Impulse responses to preference and inflation target shocks
Notes: Each panel shows the percentage-point response of selected models' variables to a one standard deviation shock. The horizontal axis measures the time, expressed in quarters.

mechanism of a standard New Keynesian framework. For all shocks, the coexistence of these two features leaves the baseline transmission mechanism of a New Keynesian setting qualitatively unaffected: all the variables respond to shocks similarly to a standard New Keynesian model without labour market search and a time-varying inflation target, as in Woodford (2003). This corroborates the findings in Christoffel et al. (2006) and Ireland (2007), who show that each of these two features on its own leaves the qualitative response of the underlying New Keynesian model unchanged. Nonetheless, as detailed below, the joint presence of labour market search and the time-varying inflation target affects the model's quantitative response to disturbances.

To understand the extent to which the movements of each variable are explained by the shocks, Table 2.2 reports the asymptotic forecast error variance decompositions for the estimated model. The results show that cost-push shocks explain low-frequency movements in output and the nominal interest rate, while technology shocks play an important role in driving long-run fluctuations in inflation, labour market tightness and unemployment. On the other hand, preference and inflation target shocks explain a small fraction of aggregate fluctuations.

To detail how the exogenous shocks have evolved during the estimation period, Figure 2.4 plots the estimate of each shock using the Kalman smoothing algorithms from the state space representation of the estimated model. These estimates point out that monetary policy shocks, in the form of exogenous shocks to either the inflation target or the policy rule, were of smaller magnitude compared to technology or cost-push shocks, suggesting that, in line with the findings of the forecast error variance decomposition, the latter had a more relevant role in affecting aggregate fluctuations. These stochastic shocks, once fed into the state space representation of the model, generate time series for all the model's variables. This therefore allows the derivation of the unobserved time-varying inflation target, which is plotted in Figure 2.5

Table 2.2. Asymptotic forecast error variance decomposition

	Technology	**Cost-push**	**Monetary policy**	**Preference**	**Inflation target**
Output	41.17	50.69	0	2.59	5.54
Interest rate	40.84	51.51	0	3.03	4.63
Inflation	50.19	48.66	0	1.15	0
Labour market tightness	63.92	28.67	0	2.02	5.39
Unemployment	58.61	35.67	0	1.82	3.90

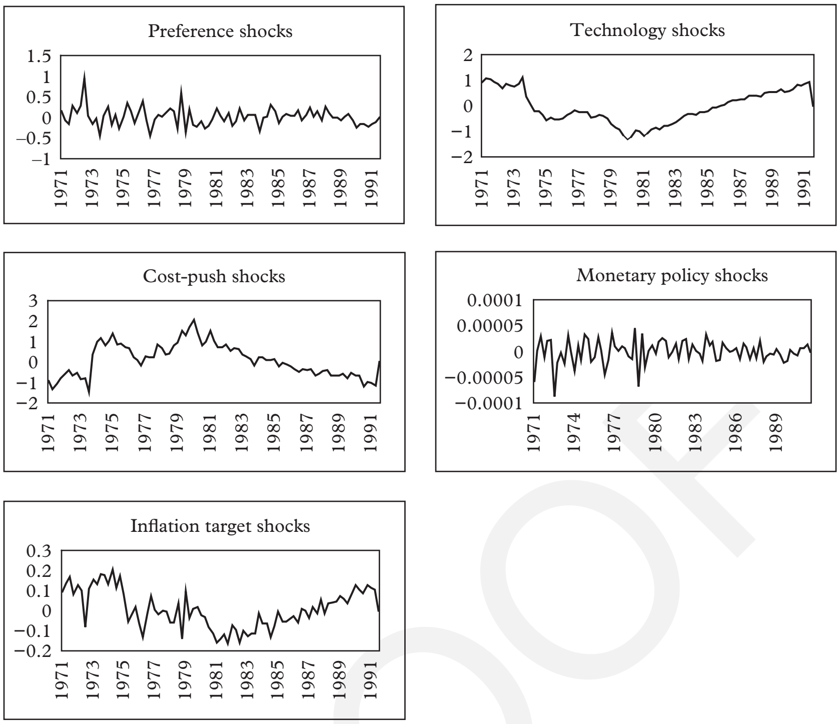

Figure 2.4. Smoothed estimates of preference, technology, cost-push, monetary policy and inflation target shocks
Notes: Each panel shows estimates of the exogenous shocks using the Kalman smoothing algorithm from the state space representation of the estimated model.

against the observed inflation. The figure shows that during the 1970s the monetary authority translated adverse technology shocks into higher inflation, by allowing the implicit inflation target to grow. In the early 1980s, it had taken advantage of the positive supply shocks to reduce inflation and it subsequently allowed the implicit inflation target to grow throughout the 1990s. This is in line with the narrative evidence in Batini and Nelson (2009).

As detailed at the outset, since this model is immune to Lucas' (1976) critique, counterfactual scenarios can disclose whether the introduction of labour market reforms or a monetary policy framework based on a constant inflation target might have altered the economic outlook if they had been introduced in the earlier decades. The exercise consists in superimposing these policy changes on the model, assuming

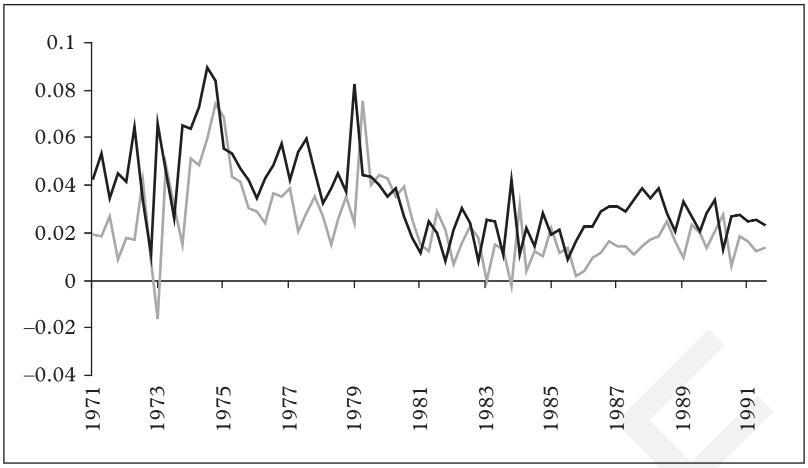

Figure 2.5. Estimate of the time-varying inflation target and inflation
Notes: Unobserved time-varying inflation target (black line) and observed inflation (grey line).

that all the other parameters and stochastic shocks remained unchanged, to generate time series for the alternative scenarios. To this end, Figures 2.6 and 2.7 compare the historical series of inflation and output growth against the series that would have been generated under counterfactual scenarios. Figure 2.6(a) shows the counterfactual case of a reduction of 10 per cent in the replacement ratio of unemployment benefits, ρ_b, such that it equals 0.36 instead of its estimated value. This policy change would have had a sizable effect on the level of inflation, which would have been on average lower compared to its realised counterpart: 2.1 per cent instead of 2.3 per cent. However, inflation volatility would have increased somewhat (0.0292 instead of 0.0273). Interestingly, output growth would have displayed a substantially unchanged level, but a slightly higher variance (0.0140 instead of 0.0138). Figure 2.6(b) shows the observed series against those generated under the counterfactual scenarios of a 10 per cent reduction in the household's bargaining power, η, such that it equals 0.45 instead of 0.5. The level of inflation would have been materially lower, 1.6 per cent instead of 2.3 per cent, while the variance of inflation would have doubled, 0.0560 instead of 0.0273. Similarly, both the level and variance of output growth would have remained substantially unchanged compared to their realised counterparts. This suggests that the implementation of these labour market reforms would have contributed to the reduction of the level of inflation, but would have been unable to

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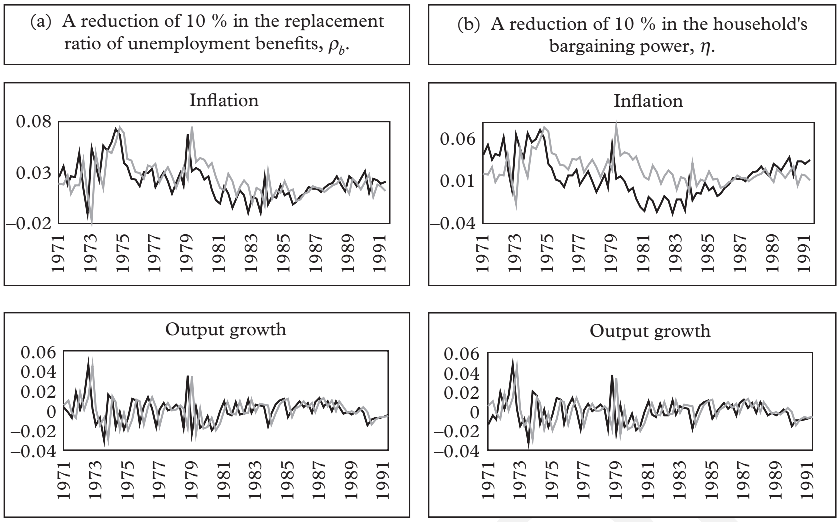

Figure 2.6. Labour market reforms counterfactual scenarios
Notes: Counterfactual experiments. Each panel shows the actual series (grey line) and the model estimates (black line) of how the actual series would have behaved under some alternative scenarios.

generate a lowering of inflation and output growth volatility. This echoes the results in Zanetti (2009, 2011) who finds that a decrease in labour market regulation, in the form of either lower workers' bargaining power or unemployment benefits, increases the volatility of inflation.

Figures 2.7(a)–(c) show counterfactual cases for changes in the monetary policy framework. Figure 2.7(a) shows time series generated by assuming that the monetary authority undertakes a constant inflation target instead of allowing the target to vary in reaction to shocks, by imposing the parameters δ_a, δ_θ, δ_z and σ_π equal to zero. Under this scenario the level of inflation would have lowered to 1.4 per cent instead of 2.3 per cent, while the variance of inflation would have approximately tripled to 0.0652 instead of 0.0273. By keeping a constant inflation target the monetary authority would have offset adverse technology shocks with more pronounced change in the nominal interest rate, which would have produced higher variance of inflation. Instead, output growth would have remained at the same level, but with higher volatility, 0.0327 instead of 0.0138. Figure 2.7(b) shows how the path would have changed for a 5 per cent increase in the monetary authority response to the deviation of inflation from its target, such that

Figure 2.7. Monetary policy reforms counterfactual scenarios
Notes: Counterfactual experiments. Each panel shows the actual series (grey line) and the model estimates (black line) of how the actual series would have behaved under some alternative scenarios.

ρ_π equals 1.1571. Differently from the case that superimposes a constant inflation target, if the monetary authority had increased the degree of reaction to the deviation of inflation from its time-varying target both the level and variance of inflation would have been lower, at 2.2 per cent instead of 2.3 per cent and 0.0260 instead of 0.0273 respectively,

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while output growth would have remained substantially unchanged. Finally, Figure 2.7(c) displays the counterfactual case where the monetary authority would have increased by 5 per cent its reaction to deviations of output from its steady state, such that ρ_y equals 0.1291. Under this scenario, inflation would have been substantially unchanged from its historical counterpart, while output growth would have displayed higher volatility, with its variance equal to 0.0418 instead of 0.0138. This analysis suggests that the degree to which the monetary authority reacted to inflation deviations from the inflation target would have contributed to a decrease in the variance of inflation and output growth and also to a lower level of inflation. On the other hand, the introduction of a constant inflation target or a monetary policy that would have reacted strongly to output would have been unlikely to produce a different economic outlook. These findings are in line with numerous related studies on other economies. For instance, Clarida et al. (2000), Boivin and Giannoni (2006), Lubik and Schorfheide (2004) and Castelnuovo (2007) find that by responding more strongly to inflation, monetary policy has stabilised the US economy more effectively in the post-1980 period. Gambetti and Pappa (2008), using sign restrictions on a VAR, find that the introduction of inflation targeting is unable to explain the reduced volatility of inflation in several economies.

2.7 Conclusion

This chapter has developed a general equilibrium model that details the functioning of the UK economy during the 1970s and 1980s to investigate to what extent labour market reforms enforced by the Thatcher government in the later 1980s, in the form of reduction of unemployment benefits and union power, and the introduction of a constant inflation target in 1992, might have changed the economic outlook if they had been introduced in the early 1970s. The econometric estimation of the model has permitted us to separate out the policy parameters, such as those representing monetary policy and the structure of the labour market, which may vary due to changes in policy, from those which represent the household's preference and firm's technology that ought to be policy-invariant. Hence, the model positively answers Lucas' (1976) critique and can be used to draw inferences about how these policy changes might have altered the economic outlook. The exercise shows that the decreases in unemployment benefits and union power are unlikely to have produced a different macroeconomic performance. The results on monetary policy reform are mixed. A stronger reaction to inflation deviations from target would have lowered the volatility of inflation and output growth. By contrast, the introduction of a constant inflation target or a monetary policy that had reacted strongly to output fluctuations are unlikely to have changed the economic outlook.

But while the results do support the importance of the way in which the monetary authority reacts to inflation, it should also be noted that the model abstracts from some relevant attributes of the economy. For instance, it ignores the oil sector, which, as Blanchard and Galì (2007) and Nakov and Pescatori (2010) point out, may alter the propagation of exogenous disturbances and therefore interact with the policy changes to reduce macroeconomic volatility. Similarly, the model also sets aside important developments of the period, such as improved inventory management, as emphasised in McConnell and Perez-Quiros (2000), or the development of financial innovations, as pointed out by Dynan et al. (2006), whose presence may also have a non-trivial effect on the way in which the economy reacts to policy changes and how these interact with aggregate disturbances. Furthermore, although the model developed here allows aggregate productivity, cost-push shocks and nominal disturbances to have effects on the economy, in practice a variety of other aggregate shocks may play a role. To establish to what extent the results hold for refinements of the theoretical framework remains an outstanding task for future research.

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