On the Interaction between Asset Prices, Inflation and Interest Rates

A Thesis Submitted for the Degree of Doctor of Philosophy

by

Alexandros Kontonikas

Department of Economics and Finance, Brunel University

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Abstract

This thesis examines the interaction between monetary policy, inflation and asset prices. The role of asset prices in the transmission mechanism of monetary policy via consumption wealth effects and investment balance sheet effects is receiving a growing degree of attention nowadays. Financial asset prices respond quickly to new information about monetary policy shifts, while the transmission of policy actions to output and inflation exhibits significant lags. Therefore, it is important to examine the feedback between interest rates and asset prices, since it will provide important insights for central bankers and investors alike. This area of the literature draws from both the monetary economics and financial economics disciplines and has become quite important given the new challenges for monetary policymakers in the context of fundamental changes in the underlying financial and macroeconomic framework. In this respect, we are interested in three main issues: first, to investigate the impact of the, nowadays prevalent, inflation targeting monetary policy regime on average inflation and the related inflationary uncertainty (Chapter 2); second, to establish quantitatively the existence of a transmission link from changes in the monetary policy stance to the stock market (Chapter 1); third, to examine the monetary policy reaction to asset price fluctuations (Chapters 3-5).

Chapter 2 looks at the significant changes that occurred in the inflation process over the 1990s using British data. We show that post-targeting, inflation is lower, less persistent and less volatile. In chapter 3, we use data from the UK and the US and find that lower expected inflation allows monetary policy to relax by decreasing short-term interest rates. In chapter 1, international evidence suggests that decreases in interest rates exert a significantly positive impact on stock prices in the majority of the countries under investigation. Hence, the empirical evidence in chapters 1-3 is consistent with the scenario underlying the so-called 'new environment' hypothesis. Inflation targets were successful in anchoring inflation expectations and subsequently boosting stock prices due to lower interest rates. In chapters 3-5 we focus on the role of asset prices for monetary policy formulation. We present empirical (chapter 3), theoretical (chapter 4), and simulation (chapter 5) evidence indicating that monetary policy *has* responded and *should*, in principle, respond to asset price fluctuations. Particularly, in chapter 3 we augment the standard forward-looking Taylor rule with the change in asset prices (house prices, stock prices) and find that there is a positive and statistically significant weight attached to asset price fluctuations in both the UK and the US. The estimates suggest that policymakers in the US are more concerned about stock market developments, while in the UK about house market developments. In chapter 4, we utilise a structural backward-looking economic model, augmented for the effect of asset prices on aggregate demand, that allows us to derive the optimal interest rate rule via dynamic minimisation of the central bank's loss function. We show that under certain assumptions about the asset price evolution, monetary policy should react to asset price misalignments from their fundamental value. Finally, in chapter 5 we simulate a forward-looking model to examine the impact on macroeconomic volatility from reacting, or not, to asset price misalignments. We find that a policy reaction that is aggressive with respect to inflation, and mild (but not zero) with respect to asset price misalignments is able to promote overall macroeconomic stability.

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Introduction

The 1990s were characterised by significant shifts in monetary policy frameworks as well as investors' valuations in many advanced economies. In particular, following the failure to control inflation through money supply and exchange rate anchors during the 1970s and the 1980s, a growing number of central banks turned to inflation targeting regimes ever since the early 1990s. Central banks were endowed with clear mandates to maintain price stability and with the necessary autonomy to pursue them. These monetary policy regimes proved to be a success so far, since inflation rates became lower and less volatile implying that the significant economic costs associated with high and variable inflation have been largely subdued. During the same period, especially after the mid-1990s, both stock prices and house prices appreciated to record levels. The excessively exuberant stock market valuations, closely related with the claims about permanent profit increases due the 'new economy' and the 'dot com' boom of the 1990s, reversed sharply in early 2000. Since then, house prices have continued to appreciate, creating an extra source of uncertainty for policymakers regarding a possible correction in the property market, given the significance of property holdings for the average household's portfolio. The recent volatility in asset price markets has generated an intense debate in academic and policy circles regarding the appropriate monetary policy response to such dramatic shifts.

According to the 'new environment' hypothesis the two main macroeconomic and financial developments of the 1990s, low and stable inflation along with asset price boom and bust cycles, are inherently interrelated forming a new background for monetary policy to operate. Exponents of this hypothesis suggest that, contrary to the conventional wisdom, lower and less volatile inflation may be associated with higher financial instability. This is due to the fact that the decline in inflation leads to a similar decline in interest rates, thereby decreasing the cost of borrowing for consumers and firms. Such expansive monetary policies are typically associated with higher asset prices given the lower discount rate and the expectation of higher cash flows in the future. During the boom period, credit expands to accommodate the increasing levels of debt on the expectation of further increases in asset prices, whilst the assets themselves serve as a collateral. However, when asset prices eventually reverse, both consumers and firms cut back their spending in order to restore their balance sheets. In such an environment, the absence of obvious inflationary pressures adds to the sustainability of the boom and consequently magnifies the negative consequences of the bust. Hence achieving and maintaining price stability is not a sufficient condition for financial stability. In fact, the new environment hypothesis points out that low and stable rates of inflation may even foster asset price bubbles by generating excessively optimistic expectations about the future economic development.

There is a growing recognition that asset prices play an important role in the transmission mechanism of monetary policy via consumption wealth effects and investment balance sheet effects. It is also well known that significant lags do exist in the transmission of policy actions to output and inflation, while financial asset prices respond rather quickly to new information about monetary policy shifts. Therefore, it is important to examine the feedback between interest rates and asset prices, since it will provide important insights for central bankers and investors alike. This thesis is motivated by the aforementioned arguments and attempts to examine the interaction between monetary policy, inflation and asset prices. This area of the literature draws from both the monetary economics and financial economics disciplines and has become quite important given the new challenges for monetary policymakers in the context of fundamental changes in the underlying financial and macroeconomic framework.

In this respect, we are interested in three main issues: first, to investigate the impact of the, nowadays prevalent, inflation targeting monetary policy regime on average inflation and the related inflationary uncertainty (Chapter 2); second, to establish quantitatively the existence of a transmission link from changes in the monetary policy stance to the stock market (Chapter 1); third, to examine the monetary policy reaction to asset price fluctuations (Chapters 3-5). Chapter 2 looks at the significant changes that occurred in the inflation process over the 1990s using British data. We show that post-targeting, inflation is lower, less persistent and less volatile. In chapter 3, we use data from the UK and the US and find that lower expected inflation allows monetary policy to relax by decreasing short-term interest rates. In chapter 1, international evidence suggests that decreases in interest rates exert a significantly positive impact on stock prices in the majority of the countries under investigation. Hence, the empirical evidence in chapters 1-3 is consistent with the scenario underlying the new environment hypothesis. Inflation targets were successful in anchoring inflation expectations and subsequently boosting stock prices due to lower interest rates. In chapters 3-5 we focus on the role of asset prices for monetary policy formulation. We present empirical (chapter 3), theoretical (chapter 4), and simulation (chapter 5) evidence indicating that monetary policy *has* responded and *should*, in principle, respond to asset price fluctuations.

As we already argued, in chapter 2 we document the impact of inflation targeting on the distribution of price changes using UK data over the period 1972-2002. Friedman (1977) suggests a positive correlation between the level of inflation and inflation uncertainty, with higher inflation leading to greater uncertainty and lower output growth. Ball (1992) formalises Friedman's argument in the context of an asymmetric information game between the public and the policy maker. The empirical evidence on the relationship between average inflation and inflation uncertainty largely accepts the Friedman-Ball prediction. Thus, policies that lower average inflation, such as inflation targeting, lead to lower inflation uncertainty with apparent economic benefits. A key issue in this literature is whether explicit targeting leads to a greater decrease in inflation uncertainty, as compared to the case where formal targets are not announced and the central bank is not officially obliged to act so that to keep inflation at the target (or in the range) within some specified time horizon (implicit targeting). Targets have an independent role if they help to anchor inflation expectations and to produce an additional decline in inflation uncertainty. In chapter 2 we employ a variety of GARCH related models (symmetric, asymmetric, component-GARCH) to proxy inflation uncertainty with the estimated conditional volatility. Our main contribution to the existing literature is that even if we take into account the indirect effect of lower average inflation throughout the 1990s the adoption of a formal inflation target in the UK on October 1992 directly decreased long-run inflation uncertainty. In line with previous evidence by Siklos (1999), we also find that post-targeting inflation has been less persistent. Therefore, high inflation countries and implicitly targeting countries should consider the extra benefits associated with explicit targeting.

The increased aversion of monetary authorities to inflation and its variability over the 1990s eventually brought credibility gains, allowing interest rates to successfully control inflationary pressures even after climbing down the double-digit levels experienced during the 1970s and 1980s. This had important implications for the evolution of stock prices, since according to the discounted cash flow model stock prices are equal to the present value of expected future net cash flows. Expansive monetary environments are commonly viewed as good news for the stock market because such periods are associated with low interest rates, increases in economic activity and higher earnings for the firms in the economy. Hence, monetary policy plays an important role in determining equity returns either by altering the discount rate used by market participants or by influencing market participants' expectations of future economic activity. Chapter 1 investigates the impact of changes in monetary conditions on stock returns using international data from 13 OECD countries over the period 1972-2002. Given the disagreements on the use of money aggregates as indicators of monetary policy, we adopt the nowadays standard approach of measuring policy with interest rate variables. Our results indicate that shifts in monetary policy significantly affect stock returns, either concurrent returns, or expected returns. In particular, tighter monetary policy stance exerts a negative effect on the stock market, while expansive policies boost equity returns. Our contribution with respect to previous work is threefold. First, we show that our findings are robust to various alternative measures of stock returns, such as returns that include dividend payments in their calculation. Second, our empirical estimates are adjusted for the non-normality exhibited by stock returns data. Third, we also take into account the increasing co-movement among international stock markets. The sensitivity analysis indicates that the results remain largely unchanged in the majority of our sample countries.

Following the establishment of a link between monetary policy conditions and stock market valuations in chapter 1, in chapter 3 we focus on the determinants of policy decisions. The main objective of chapter 3 is to provide some further insight into the interest rate setting behaviour of central banks. We use data over the period 1992-2002 from the UK (explicit inflation targeting) and the US (implicit inflation targeting) and estimate forward-looking Taylor rule reaction functions. Our contribution to the empirical Taylor rules literature stems from the fact that we condition nominal short-term interest rates not only upon expected consumer price inflation and the output gap, but also upon stock price and house price inflation. Changes in asset prices are allowed to enter the monetary policy reaction function due to their effect on aggregate demand and inflation. The results crucially indicate that asset prices play an important role for monetary policy formulation above and beyond their information content as instruments in the GMM estimation. We find that monetary policy has reacted to asset price fluctuations with a higher weight being attached to house price inflation in the UK, and stock price inflation in the US. We also show that the Bank of England has become more averse to inflation deviations from the target after being awarded operational independence in setting interest rates on May 1997.

In chapter 4 we revisit the relationship between monetary policy and asset prices in the context of optimal policy rules. Feedback rules for interest rates of the type advocated by Taylor (1993) have been extensively analysed in the theoretical literature. Many studies show that such rules are optimal in that they derive from the first order condition for the optimisation of the central bank's objectives. Typically, such objectives are characterised by a quadratic loss function penalising deviations of inflation from its target value and output from its potential level. We also follow this approach and start from a backward-looking aggregate supply / aggregate demand model in the spirit of Ball (1997) and Svensson (1997). The backward-looking nature of the model allows for the derivation of analytical solutions and is largely consistent with the actual behaviour of inflation. The main difference between our framework and the aforementioned studies is that we model explicitly the wealth effect of asset prices on aggregate demand. The optimal rule for nominal interest rates is obtained by dynamic minimisation of the central bank's loss function. The results depend on the assumption underlying the dynamic evolution of asset prices. If asset prices are always equal to their fundamental value (no bubbles), the derived policy rule conditions the policy instrument upon concurrent inflation and the output gap, as standard in the literature. In the most realistic case where, in addition to the reversion towards fundamentals, asset prices are allowed to be positively affected by their past change the results change critically. We show that monetary policy should respond to asset price misalignments with the aggressiveness of the response being a positive function of the impact of asset prices on aggregate demand. This result constitutes the main contribution of chapter 4 to the existing literature and has important implications for the conduct of monetary policy given the recent, as well as historical, experience of sustained asset price deviations from their fundamental value.

Finally, in chapter 5 we take another look at the interaction between asset price misalignments and monetary policy using stochastic simulation techniques. The model employed in this chapter is forward-looking in order to be consistent with agent microfoundations. In particular, we augment the standard New Keynesian framework to allow for the impact of asset prices on aggregate demand and, using simulations, we examine how inflation, output, interest rates, and asset prices behave under alternative monetary policy rules. Previous evidence by Bernanke and Gertler (1999, 2001) and

Cecchetti et al. (2000) is inconclusive since the former argue that a central bank should pay no attention asset prices per se, except insofar as they signal changes to expected inflation, while the latter show that are gains from responding to asset price misalignments even when inflation appears to remain on track. Our results contribute to the existing literature in a dual manner. First, in addition to the forward-looking Taylor rule that is employed in the aforementioned studies, we also examine the case of the inflation-forecast targeting rule. Second, we incorporate a partial adjustment mechanism of asset prices towards their fundamental value that allows for both bubble build-up and reversion towards fundamentals, without making explicit assumptions about the probabilistic structure of the bubble. Our simulation evidence confirms pervious findings by Cecchetti et al. (2000) in that the central bank can reduce macroeconomic volatility with a mild adjustment of its interest rate instrument to asset price misalignments. This result does not depend on whether the Taylor rule or the inflation-forecast targeting rule is utilised. Hence, monetary authorities should take into account asset price misalignments when formulating policy despite the measurement errors that they might face.

Chapter 1

Monetary Policy and the Stock Market

1.1 Introduction

Monetary policy attempts to achieve a set of objectives that are expressed in terms of macroeconomic variables such as inflation, real output and employment. However, monetary policy actions such as changes in the central bank discount rate have at best an indirect effect on these variables and considerable lags are involved in the policy transmission mechanism. Broader financial markets though, for example the stock market, government and corporate bond markets, mortgage markets, foreign exchange markets, are quick to incorporate new information therefore a more direct and immediate effect of changes in the monetary policy instruments may be identified using financial data. Identifying the link between monetary policy and financial asset prices is highly important to gain a better insight in the transmission mechanism of monetary policy, since changes in asset prices play a key role in several channels.

This chapter will provide empirical evidence on the relationship between monetary policy and one of the most important financial markets, the stock market. Stock prices are among the most closely monitored asset prices in the economy and are regarded as being highly sensitive to economic conditions. In the context of the transmission mechanism through the stock market, monetary policy actions affect stock prices which themselves are linked to the real economy through their influence on consumption spending (wealth effect channel) and investment spending (balance sheet channel). As Bernanke and Kuttner (2003) point out, some observers view the stock market as an independent source of macroeconomic volatility to which policymakers may wish to respond. Stock prices often exhibit pronounced volatility and boom-bust cycles leading to concerns about sustained deviations from fundamental values that, once corrected, may have significant adverse consequences for the broader economy. Hence, establishing quantitatively the existence of a stock market response to monetary policy changes will not only be germane to the study of stock market determinants but will also contribute to a deeper understanding of the conduct of monetary policy and of the potential economic impact of policy actions or inactions.

According to the discounted cash flow model stock prices are equal to the present value of expected future net cash flows. Monetary policy should then play an important role in determining equity returns either by altering the discount rate used by market participants or by influencing market participants' expectations of future economic activity. As Crowder (2004) argues, these channels are generally reinforcing since a tighter monetary policy usually implies both higher discount rates and lower future cash flows. Thus, monetary policy tightening should be associated with lower stock prices given the higher discount rate for the expected stream of cash flows and/or lower future economic activity. In contrast, an expansive monetary environment is commonly viewed as good news as these periods are usually associated with low interest rates, increases in economic activity and higher earnings for the firms in the economy. Consequently, stock market participants pay close attention to strategies based on the stance of the monetary authority as inferred by changes in indicators of central bank policy. Also, the financial press often interprets asset price movements as reaction to monetary policy shifts, attributing for instance increases in stock markets to low interest rates (Economist, 24/04/2004).

Previous empirical evidence broadly supports the notion that restrictive (expansive) monetary policy decreases (increases) contemporaneous stock returns, as well as expected stock returns[1]. These studies typically relate stock returns to measures of monetary policy stringency in the context of single equation specifications and/or multivariate Vector Autoregressions (VARs). In this chapter we take a closer look at the impact of monetary policy on stock returns by utilising international data on thirteen OECD countries that covers the crucial period of the late 1990s stock market bubble and its subsequent collapse. Given the considerable debate on the relative merits of money aggregates during the late 1970s and early 1980s, we adopt the nowadays standard approach of measuring monetary policy using interest rate variables. We expand on previous work by examining the sensitivity of our findings in inclusion of dividend payments in the stock returns calculation, while considering both nominal and real returns. Our results indicate that for the majority of the countries under investigation the monetary environment is an important determinant of investors' required returns. This holds across a variety of returns specifications (nominal, real, dividend adjusted, non-adjusted). We also examine the contemporaneous effect of monetary policy on stock returns taking into account the non-normality typically inherent in such data as well as the significant comovement of international stock markets. The main result, that expansionary monetary policy boosts the stock market, remains largely robust in most sample countries.

The implications of such findings for monetary policy making and investor portfolio formation are quite important. Central bankers and stock market participants should be aware of the relationship between monetary policy and stock market performance in order to better understand the effects of policy shifts. Given the ability of monetary policy to affect stock prices, central bank policy makers face the choice of whether to respond to stock price movements, above and beyond the standard response to inflation and output developments. This important issue will be examined from various perspectives in the context of chapters 3 to 5.

The rest of the chapter is organised as follows. The next section surveys the vast theoretical and empirical literature that relates monetary conditions with real economic and stock market performance. Section 1.3 contains the econometric part of the chapter. Section 1.3.1 discusses the properties of the international data to be employed in testing the

[1] See among others, Conover, Jensen and Johnson (1999), Thorbecke (1997), Patelis (1997).

relationship between stock returns and monetary policy. Section 1.3.2 and 1.3.3 provide empirical estimates of the impact of monetary policy changes on contemporaneous and expected stock returns, respectively. Section 1.4 concludes.

1.2 Monetary policy, real economy and the stock market

1.2.1 Present value model and monetary policy effects

The present value or discounted cash flow model offers useful insights on the stock market effects of monetary policy changes. According to this widely used model the stock price (S_t) is the present value of the future expected dividends (D_{t+j}). Under the assumption of constant discount rate (R), it can be shown that[2]:

$$S_t = E_t\left[\sum_{j=1}^{K}\left(\frac{1}{1+R}\right)^j D_{t+j}\right] + E_t\left[\left(\frac{1}{1+R}\right)^K S_{t+K}\right] \quad (1.1.1)$$

where, E_t is the conditional expectations operator based on information available to market participants at time t, R is the rate of return used by market participants to discount future dividends, and K is the investor's time horizon (stock holding period). The standard transversality condition implies that as the horizon K increases the second term in the right-hand side of Eq. (1.1.1) vanishes to zero (no rational stock price bubbles):

$$\lim_{K\to\infty} E_t\left[\left(\frac{1}{1+R}\right)^K S_{t+K}\right] = 0 \quad (1.1.2)$$

Thus, we obtain the familiar version of the present value model[3]:

$$S_t = E_t\left[\sum_{j=1}^{K}\left(\frac{1}{1+R}\right)^j D_{t+j}\right] \quad (1.1.3)$$

[2] To derive Eq. (1.1.1) we may assume for simplicity that there is an investor with two alternative investment opportunities over a one-period horizon: either a stock with expected gross return $E_t[S_{t+1} + D_{t+1}] / S_t$, or a risk-free bond with constant nominal gross return $1+R$. Arbitrage opportunities imply that, for the investor to be indifferent between the two alternatives, they must yield the same expected return: $E_t[S_{t+1} + D_{t+1}] / S_t = 1+R$. We then solve forward the resulting expectational difference equation and obtain Eq. (1.1.1).

Campbell, Lo, and MacKinlay (1996) relax the assumption of constant discount rate. They show that when discount rates are time-varying (R_t), the log-linear approximation of Campbell and Shiller (1988a,b) yields the following expression for the log-stock price (s_t):

$$s_t = \frac{k}{1-\rho} + E_t\left[\sum_{j=0}^{\infty} \rho^j [(1-\rho)d_{t+j+1} - r_{t+j+1}]\right] \tag{1.1.4}$$

where, logs of variables are denoted by lowercase letters, and ρ and k are parameters of linearization defined by $\rho = 1/[1+e^{\overline{(d-p)}}]$, where $\overline{(d-p)}$ is the average log dividend-price ratio, and $k = -\ln(\rho) - (1-\rho)\ln(1/\rho - 1)$. In order to derive Eq. (1.1.4), the transversality condition has been imposed ($\lim_{j\to\infty} \rho^j s_{t+j} = 0$). As Campbell et al. (1996) point out, when the dividend-price ratio is constant, then $\rho = 1/(1+D/P)$. The average dividend yield in the US over the period 1871-2003 has been around 4.7%, implying that ρ should be about 0.954 in annual data[4]. This implies that the weight on log dividend ($1-\rho$) is close to zero reflecting the fact that on average the dividend is smaller than the stock price, hence a given proportional change in the dividend exerts a smaller effect on the stock return than the same proportional change in the stock price.

Eqs. (1.1.2) and (1.1.4) indicate that a change in monetary policy can affect stock returns in a dual manner. First, there is a direct effect on stock returns by altering the discount rate used by market participants (one-off shift in R in the case of constant discount rate). In particular, tighter monetary policy leads to an increase in the rate at which firms' future cash flows are capitalised causing stock prices to decline. The underlying assumptions are that, first, the discount factors used by market participants are generally linked to market rates of interest and second, the central bank is able to influence market interest rates[5]. Second, monetary policy changes exert an indirect effect on the firms' stock value by altering expected future cash flows. Monetary policy easing is expected to increase the overall level of economic activity and the stock price responds in a positive

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[3] Campbell, Lo, and MacKinlay (1996, p.258) discuss models of rational bubbles that relax the transversality condition.

[4] The calculations were made using the annual US data available online at Robert J. Shiller's website (http://aida.econ.yale.edu/~shiller/data.htm).

manner (expecting higher cash flows in the future). Hence, this channel generally assumes the existence of a link between monetary policy and the aggregate real economy. As Patelis (1997) argues, stocks are claims on future economic output, so if monetary policy has real economic effects then stock markets should be influenced by monetary conditions. In the next section we review the empirical evidence and theoretical arguments put forth by various schools of thought considering the impact of monetary policy on the real economy.

1.2.2 Money, interest rates and real economic conditions

Standard Keynesian theory predicts that variations in the money stock may affect the real economy by changing the level of interest rates (liquidity effect) and consequently the cost of capital for firms. If changes in the money supply have no effect on the real system then money is said to be neutral or money does not matter. Walsh (1998) provides a summary of the empirical evidence regarding the effect of money on real output. He points out (p.39) that, "the consensus...on the long-run relationship between money, prices, and output is clear. Money growth and inflation essentially display a correlation of 1; the correlation between money growth or inflation and real output growth is probably close to zero". The consensus on the short-run effects of monetary policy is quite different though. Empirical evidence from VARs and large scale structural econometric models suggest that monetary policy tightening shocks decrease real economic activity with the peak effects occurring after several quarters, as much as one to three years (see e.g. Sims, 1992; Brayton and Tinsley, 1996; Angeloni et al. 2002). The empirical estimates, however, depend significantly on how monetary policy is measured.

VAR studies typically use a short-term interest rate as a proxy for monetary policy (e.g. Sims, 1992). Eichenbaum (1992) shows that when M1 is used to measure policy, positive money supply innovations (expansionary monetary policy shocks) lead to higher interest rates and lower output (output puzzle). The failure of the liquidity effect prediction (faster money growth should be associated with lower nominal interest rates) has led to its subsequent examination in many studies with mixed results, see e.g. Christiano and Eichenbaum (1992), Strongin (1995) for evidence in favour of the liquidity effect, and Thornton (1996) for evidence against it. Eichenbaum (1992) finds that when monetary

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[5] Fuhrer (1995) shows that the US monetary policy instrument (federal funds rate) constitutes a source of change for many longer term interest rates.

policy is measured by the federal funds rate, as opposed to M1, contractionary shocks lead to lower output and to a positive price level response. Hence, while the output puzzle disappears, a price puzzle emerges instead. Sims (1992) shows that the price puzzle is present not only in the US but also in France, Germany, Japan and the UK. The price puzzle becomes smaller but not in all cases disappears, when inflation-sensitive variables such as a commodity price index and nominal exchange rate are included in the system. VAR studies have been generally criticised in that they focus on the effect of monetary policy shocks that are by construction unrelated to the endogenous policy responses to the state of the economy. They also fail to incorporate forward-looking behaviour in the policy feedback rule (Walsh, 1998).

From a theoretical perspective the issue of whether monetary conditions matter for real economic prospects is one of the oldest in economics. Its origins lay in the quantity theory of money, an identity developed to illustrate the classical dichotomy - the idea that real variables in the economy, such as real interest rates, real wages, employment, and real output, are determined by real forces and that monetary forces only affect nominal quantities. Thus, in the classical model money is said to be neutral (money is a 'veil over barter')[6]. Money neutrality is dependent on a number of conditions, such as price and wage flexibility, an absence of money illusion and an absence of distribution effects. These assumptions are most likely to be violated in the short-run, thus money does not exhibit short-run neutrality. This was acknowledged by the quantity theorists. As Patinkin (1987) argues, Hume recognised that prices do not rise proportionately to the increased quantity of money and that in the intervening period this stimulates production.

While classical analysis had shown that money supply fluctuations may have real effects in the short run, in the 1960s and early 1970s the Keynesian/Monetarist debate was in full swing. On the one hand, according to the Keynesian view in some circumstances an increase in the nominal money stock will lead to increased money-hoarding reducing the velocity of money and the real impact of monetary policy shifts[7]. In particular, when

[6] David Hume (1752), one of the best known exponents of the quantity theory and the (long-run) neutrality of money, argued that wealth should be measured by the stock of commodities of a nation, not its stock of money: "...We may conclude that it is of no manner of consequence, with regard to the domestic happiness of a state, whether money be in greater or less quantity".

[7] In the Keynesian speculative version of liquidity preference the portfolio holdings of agents include either money or bonds (and not a combination of both assets) based upon their individual assessment of the 'normal' long-run interest rate. If they think that the present rate of interest is smaller than the normal rate, they will expect an interest rate increase which will decrease bond prices, and hence move out of bonds and into money.

nominal interest rates are close to zero, absolute liquidity preference may exist. In this case, there is a loss of monetary policy control because an increase in money supply will have only a very small negative effect or no effect at all on interest rates, due to consensus among bondholders that interest rates will rise in the future (liquidity trap). Hence, at very low interest rates monetary policy may be not effective in altering the cost of capital for firms and thereby the level of investment. However, this is the extreme position and in general most moderate Keynesians, while subordinating the role of monetary policy to maintaining low interest rates, would acknowledge some effect of a change in money on real output (although changes in the velocity will reduce the impact of such effects).

On the other hand, Monetarists adopt a similar line to the classical economists and see increases in the money supply impinging mainly on output in the short-run and on prices in the long-run. In this sense, money stability via a rule for the growth rate of money supply[8] is important for long-run price stability but not for long-run real growth. Long-run output is determined by real factors such as the state of the technology, the stock of capital goods, and the size and quality of the labour force. The monetarist position is based on Friedman's (1956) restatement of the quantity theory of money as a theory of money demand. Friedman introduced the expected income stream or Permanent Income as a determinant of money demand. This generates a crucial difference with the Keynesian approach (where current income was the relevant variable) in that money demand will be less volatile because it will respond less to changes in transitory income.

Friedman's version of money demand is quite similar to the quantity theory of money, the difference being that the velocity of money in the monetarist model is a stable function whereas in the classical model it is simply a numerical constant. Variations in money supply will have important short-run real effects since, following a monetary expansion, agents have money balances in surplus to their requirements. These excess money balances will be spent and hence aggregate demand will rise. According to the Pigou effect there is a direct wealth effect linking changes in real money balances to consumption spending (Patinkin, 1965). As Walsh (1998) argues, wealth effects can be

[8] As Friedman (1968, p.16) argues, "My own prescription is still that the monetary authority go all way in avoiding such swings by adopting publicly the policy of achieving a specified rate of growth in a specified monetary total. The precise rate of growth, like the precise monetary total, is less important than the adoption of some stated and known rate".

incorporated by including real money balances or a broader measure of wealth (e.g. asset prices) in the aggregate demand[9].

The issue of whether money exhibits cyclicality with respect to output is crucial for the Monetarists and has been extensively investigated in numerous empirical studies. The evidence of Friedman and Schwartz (1963), Romer and Romer (1989), and Stock and Watson (1999) suggests that money supply is procyclical and leads the business cycle in the US. However, Fiorito and Kolintzas (1994) use G7 data and find that money does not have a clear-cut cyclical pattern. Also, as Benati (2001) demonstrates, band-passed filtered money may appear procyclical even when the money stock follows a random walk by construction. As Walsh (1998) argues, short-run dynamic correlations between money, inflation and output reflect both the private agents and the monetary authority's reaction to the same economic disturbances. Hence, these relationships are likely to vary both across time in a single country and across countries, due to variation in the sources of economic disturbances, and due to differences in policy implementation, respectively. The money-output correlation also depends on the measure that is employed for money supply. Walsh (1998) shows that the while for narrow money (M0) the correlation is positive at both leads and lags, a broader measure (M2) is positively correlated with real output at lags but negatively correlated at leads.

In the end of the 1970s and early 1980s, the UK and US experimented with the monetarist idea of targeting monetary aggregates in order to control accelerating inflation. However, the instability of money demand and the unpredictability of the velocity of money in the 1980s, due e.g. to increased deregulation and advances in financial innovation that blurred the lines between what is money and what is not, led to the abandonment of the monetarist experiment in the UK and US[10]. Following the rational expectations revolution of the 1970s, the New Classical school of thought focused in the distinction between expected and unexpected variations in money. In the flexible price model of Lucas (1972) if there is imperfect information about the current money supply (agents face a signalling extraction problem) unexpected changes in the stock of money can generate short-run transitory movements in real output. In the context of the New Classical specification money neutrality holds only if there is no imperfectness on information. Luca's model heavily influenced the analysis of Sargent and Wallace (1975) which led to the 'policy

[9] We adopt this approach in the models of chapters 3-5

[10] See chapter 2, section 2.5 for a description of the evolution of UK monetary policy operating procedures.

irrelevance hypothesis'. According to it, any policy that creates predictable variations in the money supply will have no impact on the real economy.

During the 1980s and early 1990s, the development of real business cycle (RBC) analysis, as an outgrowth of the New Classical theory, focused explicitly on non-monetary factors as the driving forces behind business cycles (Kydland and Prescott, 1982). In the RBC framework, it is argued that shocks that affect technology, capital formation and labour productivity, as well as shocks that influence the availability and prices of natural resources can explain both short-run fluctuations in output and its long-run growth path. As King and Plosser (1984, p. 363) argue, fluctuations in real output and employment arise "from variations in the real opportunities of the private economy". Hence, contrary to the New Classical prediction, RBC theorists expect no impact from monetary surprises on the real economy.

Another important strand of the literature, the New Keynesian school of thought, started to emerge over the last several years incorporating the techniques of dynamic general equilibrium theory and the focus in microeconomic foundations which were key aspects of the RBC analysis. Thus, in these models agents optimize (acting in their own self-interest) and markets clear. A key difference between RBC and New Keynesian models involves the explicit incorporation of nominal price rigidities in the latter, providing the key friction that gives rise to the non-neutral short-run effects of monetary policy. The assumption of staggered nominal price setting in the spirit of Taylor (1980) and Calvo (1983) allows nominal product prices to adjust incompletely to changes in the nominal quantity of money, increasing the impact of monetary disturbances on real output. As Clarida, Gali and Gertler (1999, p.8) point out, "within the model, monetary policy affects the real economy in the short-run, much as in the traditional Keynesian IS-LM framework. A key difference however, is that the aggregate behavioural relationships evolve explicitly from optimization by households and firms". Other differences with earlier Keynesian models include the New Keynesian assumption of imperfect competition (as opposed to perfect competition) and the focus on nominal product price rigidity (as opposed to money wage rigidity)[11].

[11] Apart from the standard New Keynesian nominal price rigidities, other types of rigidities that received attention in recent literature include restrictions to financial transactions in the context of 'limited participation' models (see e.g. Lucas, 1990; Christiano and Eichenbaum, 1992). These models, in order to generate effects from monetary injections on employment and real output, assume that there are limits in the ability of households to participate in financial markets.

The New Keynesian model, in its most basic form, consists of three equations. The demand side of the economy is represented by a forward looking IS curve, which is the linear approximation to the representative household's Euler condition for optimal consumption. The supply side of the economy is represented by a forward looking Phillips curve derived under the assumption of monopolistically competitive firms setting prices in a staggered, overlapping fashion. Monetary policy operates through a rule for setting the nominal interest rate according to deviations of inflation (or expected inflation) from the central bank's target, and deviations of output from its natural-rate (Taylor rule form). The rule is either exogenously specified or derived under certain assumptions for the central bank's preferences. Monetary policy actions attempt to ensure that the nominal anchor, usually specified in terms of inflation, is achieved with interest rate changes that affect inflation through their impact on aggregate demand. The focus on interest rate rules is prevalent nowadays given the demise of monetarism and difficulties faced by central banks that attempted to target money growth during the 1980s. Some of the issues have been raised about the use of interest rate rules in the New Keynesian model include the following (Arestis and Sawyer, 2003, p.9): "the consensus neglects the possibility that interest rates are a cost to business that may be passed along to their customers. This simple model refers to a single interest rate, and the interdependence of the central bank interest rate and long term interest rates is an issue". In their view, the theory is relevant only for demand-driven inflationary pressures and does not offer guidance in the case of supply-side disturbances, such as oil shocks.

One of its most important characteristics of the New Keynesian model is the absence of money from the system, reflecting the endogenous nature of money. In contrast to the standard textbook IS-LM analysis the New Keynesian money supply is not exogenously determined by the central bank but endogenously generated within the model. McCallum (2001a) demonstrates that it is possible to add to the new Keynesian model a (base) money demand relationship relating the stock of money to variables such as income and the rate of interest. However, such an equation would be redundant, since money would not affect the behaviour of inflation, real output and nominal interest rates. The only function of a money demand equation in such a framework would be to specify the amount of base money necessary for the implementation of the interest rate rule. Hence, as McCallum (2001a, p. 145) argues, "it has recently become common practise...for monetary policy analysis to be conducted in models that include no reference to any monetary aggregate...this general tendency is true of research conducted by both central bank and academic economists." Money endogeneity is also central feature in the analysis of the Post Keynesian school of thought. The Post Keynesian endogenous (bank) money approach has a special interest in the process by which loans and deposits are created and destroyed, generating causal links between loan creation and investment spending[12].

The review of the literature suggests that both empirical evidence and state-of-the-art models for policy analysis are largely consistent with the existence of a transmission mechanism of monetary policy actions to the real economy. Hence, referring back to Patelis's (1997) statement, since monetary policy has real economic effects, the value of claims to future real output (stock price) should be influenced by monetary conditions. In the next section we present theoretical models that investigate the relationship between stock returns and monetary conditions.

1.2.3 Theoretical models of money and stock prices

In addition to the simple present value model reviewed in section 1.2.1, a variety of more elaborate models have been employed in the financial and monetary economics literature. These models fall into two general categories: utility maximising representative agent models, and structural macroeconomic models where the underlying relationships among variables are postulated rather than derived from microfoundations. We will focus on the first category, given the prevalence of the microfoundations-consistent models in the modern literature[13].

A number of different approaches have been suggested in order to introduce money into a dynamic general equilibrium asset pricing framework. It is necessary to specify a role for money so that agents have positive money demand, and money is, in equilibrium,

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[12] As Tcherneva (2001, p.113) points out, in Post Keynesian analysis "money emerges not spontaneously in order to lubricate markets, but rather because of the government's conscious efforts to generate a demand for its currency". The money supply depends on private sector activity; therefore is endogenously determined and cannot be controlled by the central bank. The central bank can only control short-term interest rates (e.g. federal funds rate). Post Keynesian accept that interest rates are determined not in the loanable funds market but by the demand for liquidity, adopting Keyne's (1936) liquidity preference theory.

[13] Sellin (2001) reviews various structural macroeconomic models that analyse the interaction between inflation and the stock market. For example, Lachler (1983) employs a neoclassical framework and shows that if the inflation tax is offset by a lower income tax, higher inflation increases real stock prices.

positively valued[14]. As Sellin (2001) argues, if money is not to be dominated by assets that pay interest, such as bonds, it must offer a non-pecuniary return greater than zero. The money-in-the-utility function (MIU) model assumes that real money balances enter (along with consumption) in the utility function of the representative agent (see e.g. Sidrauski, 1967; Brock, 1974). Suitable restrictions on the utility function can then guarantee that, in equilibrium, there a positive demand for money so that money has a positive value[15]. Feenstra (1986) shows that this way of incorporating money balances in general equilibrium is equivalent to assuming that money facilitates consumption transactions.

Bakshi and Chen (1996) adopt the MIU approach model in their theoretical asset pricing model (see also, LeRoy 1984; Danthine and Donaldson, 1986; Boyle, 1990 Stultz 1986). They show that in an economy driven by random processes for output and money, where monetary policy has no impact of output and neither is policy accommodating to economic growth, the growth rate of real stock prices is equal to the growth rate of output. Another important result considers the correlation between real stock returns and money growth; it is positive (negative) if the correlation between money growth and output growth is positive (negative). Thus, the money growth-stock returns relationship depends on whether monetary policy is procyclical or countercyclical. If money supply is procyclical (countercyclical), it will be positively (negatively) correlated with stock returns.

The MIU approach has been criticized on the grounds that it solves the problem of creating a positive value for money in general equilibrium, simply by assuming away the problem. An alternative approach in monetary economics employs transaction costs to produce positive demand for money. This happens due to asset exchanges being costly (Baumol, 1952; Tobin, 1956), or commodities barter being costly (Kiyotaki and Wright, 1989), or due to the role of money in facilitating transactions (Clower, 1967). In Marshall's (1992) model agents hold money to reduce the cost of consumption transactions. In particular, Marshall assumes that the agent maximises the utility derived from consumption, subject to a budget constraint that is affected by the real cost of transactions. These transactions costs are negatively related to real money balances, and positively to

[14] As Walsh (1998, p.41) argues, "this is just another way of saying that we would like the money price of goods to be bounded". Given a money price of goods equal to P, one unit of money will buy $1/P$ units of goods. If money has positive value, $1/P > 0$, and P is bounded ($0 < P < \infty$).

[15] In the MIU approach the utility function of the representative agent takes the form: $U_t = u(c_t, z_t)$, where, c_t, z_t denote per-capita consumption and real money balances. Utility is increasing in both c, z, strictly concave and continuously differentiable. There is positive demand for money if $\lim_{z\to 0} \partial u / \partial z = \infty$, for all c.

consumption. Marshall shows that in the presence of transaction costs, the Fisher hypothesis as applied to stocks does not hold since real returns and inflation are not independently determined[16]. His simulation results indicate that the transaction costs model can generate negative correlations between real stock returns and inflation, of the type observed using actual data (see e.g. Fama and Schwert, 1977; Fama, 1981).

Lucas (1982) suggests an alternative way to introduce money in a general equilibrium framework. In his model agents have to meet a cash in advance (CIA) constraint in order to purchase goods. In essence, the CIA approach reflects the role of money as a medium of exchange by requiring that agents use money (that has been obtained before the goods market opens) to buy consumption or investment goods (see also Clower, 1967). Boyle and Peterson (1995) extend the framework of Lucas to answer the question whether monetary policy, as opposed to money itself, matters for real output and asset pricing. They focus on this distinction by arguing that money growth variation may be due to the monetary authority following or changing a particular monetary policy, or it may be due to changes in the precision with which a given policy is implemented. In their model the monetary authority follows a policy of altering the growth rate of money in response to the realisation of the real state of the economy. The monetary policy reaction function targets money growth rates, as opposed to levels, to allow for serial correlation in the money supply. Also, following Walsh (1984) they allow for imperfect monetary policy implementation via adding exogenous disturbances to the money stock. A central result in Boyle and Peterson (1995) is that the stock returns-inflation correlation depends on monetary policy. If policy is strongly procyclical, equity returns and inflation are positively correlated. But if policy is weakly procyclical or countercyclical the stock returns-inflation correlation will be negative, thereby providing a formalisation of the explanation for the empirical findings in Geske and Roll (1983) and Kaul (1987).

As Boyle and Young (1999) point out, there is a link between monetary policy and stock prices since by altering the supply of money in response to real conditions the monetary authority affects both the average level and the volatility of future real equity dividends. Hence, changes in macroeconomic uncertainty affect the stock market not only by changing the required rate of return on stock, but also through their effect on expected

[16] Marshall finds that the expected excess stock return is more likely to covary negatively with expected inflation, if inflation innovations are due to output shocks rather than money shocks. This mechanism works

future dividends. Boyle and Young (1999) compare the effects of two alternative monetary policy rules, inflation target as opposed to money growth target, on aggregate wealth. They employ a general equilibrium framework augmented by CIA constraint and show that the real stock price is higher under the inflation rule if and only if the agents' intertemporal elasticity of substitution is sufficiently low. This is due to the fact that the lower the elasticity of substitution, the investors are more averse to volatility in expected dividends. The inflation target rule by neutralising the effect of real disturbances in expected dividends generates lower fluctuations in the future real dividend stream than does the money rule; hence, it is preferred by risk-averse investors.

Summarising the theoretical studies, it appears that the empirical finding of a negative relationship between money growth/inflation and real stock returns can be explained in the context of microfoundations-consistent models. This result is robust to the manner via which money is introduced in general equilibrium. Several of the theoretical models also indicate that the sign of the correlation between monetary conditions, inflation and stock returns depends on whether monetary policy is procyclical or countercyclical. We continue by discussing existing econometric evidence on the effect of monetary policy on stock market returns.

1.2.4 Stock return predictability and monetary policy

Early empirical evidence from the 1960's and 1970s suggests that past money supply data has important information for the predictability of stock returns (see e.g. Sprinkel, 1964; Homa and Jaffee, 1971; Hamburger and Kochin, 1972). Such findings were against the efficient markets hypothesis, which states that current stock prices should reflect all available information, including past money supply data. Research that followed, however, seemed to contradict the previous evidence since it showed that past changes in money supply have no predictive ability for stock returns, but there could be a reverse causality -in Granger sense- from stock returns to changes in money (see e.g. Cooper, 1974; Pesando 1974). Rozeff (1974) stressed the importance of allowing for a publication lag of money supply data and ascertaining precisely when the information becomes publicly

through the effect of output shocks on the intertemporal marginal rate of substitution, inflation, and the real return to money.

available, in order to provide an explanation for the contradictions with previous findings[17]. Rogalski and Vinso (1977) extended Rozeff's approach by organising the data so that the money supply data were generated at intervals that were the same as those for the stock return data and also by taking into account the data autocorrelation. In agreement with Rozeff, Rogalski and Vinso (1977, p.1029) find that "causality does not appear to go from money supply to stock prices but rather from stock prices to money supply".

As Sellin (2001) argues, in the aforementioned studies, it is not clear whether the money stocks data reflect exogenous money supply, as suggested by the authors, or demand for money. The results of the early empirical studies may be difficult to interpret, if velocity varies over time and is related to changes in stock prices. Indeed, Friedman (1988) shows that while real demand for money relative to income is negatively related to concurrent stock prices (both nominal and real), it is positively related to the 3-quarters lagged stock prices. According to Friedman, the negative contemporaneous relationship between stock prices and monetary velocity may be explained by three factors: a wealth effect, a risk-spreading effect, and a transactions effect. According to the first explanation, an increase in stock prices leads to higher nominal wealth increasing the wealth to income ratio, which should be reflected in higher money to income ratio and hence lower velocity (wealth effect). The second explanation notes that higher stock prices and excess returns on stocks may be associated with higher risk, inducing investors to shift to lower risk assets, like money, and thereby increasing the money to income ratio (risk-spreading effect). The third explanation states that higher stock prices should imply a higher money volume of transactions, which would require increased money balances (transactions effect). Friedman also argues that these three effects may be partially offsetted by a contemporaneous substitution effect: if real stock prices increase, stocks will be more attractive in a portfolio and should be substituted for money, decreasing the money to income ratio.

Due to problems with money endogeneity, a number of empirical studies has focused on the 'announcement effect' using an event-study approach, which looks at the stock market effects immediately after a monetary policy announcement using high

[17] Rozeff (1974) tested the efficient markets hypothesis against the monetary portfolio model, which was developed by Brunner (1961) and Friedman and Schwartz (1963) among others. According to the monetary portfolio model, asset holders view money as another asset in their portfolios. If the monetary authority follows expansionary policy and increases the money supply, investors will be wiling to exchange money for a variety of other assets, e.g. stocks, in order to restore their desired money holdings. This increases the demand for stocks and thus stock prices. If investors respond with a lag, this implies that money can predict future stock returns.

frequency (daily and/or weekly) survey data. In these studies, changes in monetary conditions are decomposed into expected and unexpected components using survey data as a measure of the market's expectations. According to the efficient markets hypothesis, stock prices should react only to the unexpected component of any announcement, since the expected part should already be embedded in the stock price. The studies of Cornell (1983), Pearce and Rolley (1983, 1985), Hardouvelis (1987), and McQueen and Rolley (1993) use US data and all report that unanticipated increases in money supply announcements exert a significant negative impact on stock prices. They also find that the estimated effect does not differ across monetary policy regimes.

Cornell (1983) discusses several different hypotheses that attempt to explain how unexpected money supply expansion may negatively affect stock prices. The expected inflation hypothesis suggests that an unexpected rise in money supply increases market participants' expectations of future inflation leading to higher short-term interest rate[18]. As a result, expected cash flows decrease and the rate at which these cash flows are discounted increases, leading to lower stock prices. The policy anticipation hypothesis argues that since the price level doesn't respond to a monetary shock in the short-run, higher than expected money stock leads agents to anticipate higher interest rates to equilibrate the money market. Hence, stock prices will decline. Another hypothesis related to monetary policy changes is the risk premium hypothesis. An unanticipated increase in the money stock adds pressure on the central bank to 'do something'. This generates higher uncertainty about future policy, increasing risk premiums and decreasing stock prices. Cornell (1983) also pointed out that there may be a positive stock market effect from unexpected increases in money supply. According to real activity hypothesis, higher than expected money supply signals information about higher future money demand (accommodated by the central bank) caused by higher expected output. Higher expected output implies higher expected cash flows, which cause stock prices to increase.

The aforementioned event studies that use the money supply (M1) as a measure of monetary policy find a negative effect from unexpected monetary easing on stock returns. Completely opposite conclusions, though, are reached when monetary policy is measured by the change in an instrument interest rate. In particular, unexpected increases in the discount rate (monetary policy tightening) lead to lower stock prices (see e.g. Hardouvelis,

[18] A positive response of the short term interest rate to higher expected inflation is consistent with the Fisher hypothesis, as well as a forward-looking Taylor rule reaction function.

1987; Sellin, 1997). Guo (2002), and Bernanke and Kuttner (2003) use data from the federal funds futures market to infer investor's expectations about the target to be set for the federal funds rate. Bernanke and Kuttner (2003) find that unexpected funds rate increases lead to a decline in stock prices. They argue that the impact of monetary surprises on stock prices seems to derive mainly from their effect on expected future dividends and excess returns. Tight money may increase the equity risk premium, either directly (by increasing interest costs and weakening balance sheets of publicly owned firms), or indirectly by increasing investors' risk aversion (e.g. by reducing expected income or increasing the probability of unemployment). Their evidence indicates a stronger stock market response to policy changes that are perceived as relatively more permanent, and to reversals in the direction of federal funds rate movements. They find that the reactions differ considerably across industries, with high-tech and telecommunication sectors being strongly affected by monetary policy, while energy and utilities seem not to be affected.

Guo's (2002) evidence suggests that unanticipated target rate increases have significant effect on the price of size-sorted portfolios. He finds that while small stocks in the 1970s were more sensitive to monetary innovations (as compared to large stocks) this pattern does not persist in the 1990s. Given that the 1970s were a period of global economic downturn and the 1990s were marked by a large economic expansion, Guo (2002, p.16) notes that "our results provide support to a credit channel of monetary transmission – small firms are more likely to be credit constrained than large firms in economic downturns, but not in economic expansions". Thorbecke (1997) extends the daily dataset of Cook and Hahn (1989) and finds that including utilities and transportation stocks in the calculation of the broad stock market index reduces the magnitude of the coefficient relating monetary policy to stock returns. This reflects the fact that the impact of discount rate changes on such stocks in the US market is rather small.

In addition to the event-study, Thorbecke (1997) employed a number of alternative methodologies to examine the relationship between monetary policy and stock prices. Using a VAR system, he finds that monetary policy shocks, measured by orthogonalized innovations in the federal funds rate, have a greater impact on smaller stocks, which is in line with the hypothesis that monetary policy affects firms' access to credit[19] (Gertler and

[19] The variables in the VAR are the growth rate of industrial production, the inflation rate, the log of a commodity price index, the federal funds rate, the log of non-borrowed reserves, the log of total reserves, and stock returns.

Gilchrist, 1993). VARs have been frequently applied in empirical literature to test for Granger causality between monetary policy and stock prices and to examine the dynamic response of the stock market to a monetary policy shock using impulse response functions and variance decompositions. In order to identify the structural parameters from the VAR estimates, Thorecke (1997) uses the Choleski identification scheme placing equity returns at the last position of the chain order. This is consistent with the efficient market hypothesis since it assumes that the stock market reacts sensitively to shocks in macroeconomic variables (see e.g. Chen, Roll and Ross, 1986). Alternative identification schemes include Rigobon and Sacks' (2003) approach. They argue that their identification method, which relies on the heteroskedasticity of stock returns and interest rates over time, avoids the simultaneity problem of stock market returns and interest rates responding contemporaneously to each other[20] (see also Bohl, Siklos and Werner, 2004).

Thorbecke (1997) adopts the Boschen and Mills' (1995) index as an alternative measure of monetary policy conditions. This index uses a five category classification of the monetary policy stance (from strongly anti-inflationary to strongly pro-growth) and is based on the Federal Open Market Committee records and other relevant information. In line with his VAR estimates, Thorbecke finds that expansionary monetary policy exerts a large and statistically significant positive effect on monthly stock. He concludes that (p. 61): "...evidence that positive monetary shocks increase stock returns indicates that expansionary monetary policy exerts real effects by increasing future cash flows or by decreasing the discount factors at which those cash flows are capitalised...these findings are consistent with the hypothesis that monetary policy, at least in the short-run, has real and quantitatively important effects on real variables".

Patelis (1997) examined whether some portion of the observed predictability in excess stock returns can be attributed to shifts in the monetary policy stance. Following Fama and French[21] (1989), he employed the long-horizon regression methodology, using two sets of explanatory variables: monetary policy variables and financial variables. The monetary policy variables are the federal funds rate, the spread between the federal funds rate and the 10-year Treasury bond, the (default) spread between the return on 6-month commercial paper and 6-month Treasury Bills, the quantity of non-borrowed reserves, and

[20] A crucial assumption in this approach is that the central bank raises interest rates in response to higher stock market returns. As we will see in chapters 4 and 5, the theoretical literature has mixed views on this subject.

the portion of non-borrowed reserve growth orthogonal to total reserve growth. The financial variables are the dividend yield, the (term) spread between the 10-year Treasury bond and the 1-month Treasury bill, and the 1-month real interest rate. He finds that monetary policy variables are significant predictors of future returns, although they cannot account fully for the observed stock return predictability. As he points out (p.11), "there is predictive power in the financial variables that is independent of the predictive power of the monetary variables, and vice versa". His results are also consistent with Fama and French (1989), in that there is increased predictability at longer horizons.

Patelis' explanation for the finding that monetary policy indicators are significant predictors of excess stock returns relates to the financial propagation mechanism (Bernanke and Gertler, 1989) and to the credit channel of monetary policy transmission (Bernanke and Gertler, 1995). Both theories assume that monetary policy shocks are propagated depending on the financial health of the firms in the economy. Shocks to firms' balance sheets are amplified by the financial propagation mechanism through endogenous changes in the agency costs of lending, and the spread between external and internal finance. The credit channel incorporates both the balance sheet channel mentioned above (broad credit channel), and the bank lending channel (narrow credit channel), whereby a monetary policy shock leads to a reduced and costlier bank-loan supply. Hence, firms' responses to macroeconomic shocks will be state-dependent. A monetary policy shock during a easy money period has smaller effects than one during tight money periods, since the financial health of firms has already improved due to higher balance-sheet income (and thus smaller dependence on costlier external finance), and increased bank loan supply.

Jensen and Johnson (1995) also find that monetary policy developments are associated with stock returns patterns. In particular, they show that long-term stock returns following discount rate decreases are higher and less volatile than returns following rate increases. Their motivation for the employment of the discount rate as a proxy for the stance of monetary policy follows from the view that the discount is typically regarded as a signal of monetary and possibly economic developments. This argument is based on Waud's (1970) suggestion that discount rate changes affect market participants' expectations about monetary policy because rate changes are made only at substantial intervals, they represent a somewhat discontinuous instrument of monetary policy, and they

[21] Fama and French (1989) regress stock returns at increasing time horizons on the dividend yield, the default spread and the term spread. They find that predictability increases with the time horizon.

are established by a public body perceived as being competent in judging the economy's cash and credit needs. Financial economists discuss various reasons why changes in the discount rate may affect stock returns. For example, discrete policy rate changes influence forecasts of market determined interest rates and the equity cost of capital. Also, changes in the discount rate possibly affect expectations of corporate profitability (Waud, 1970).

In a subsequent study, Jensen, Mercer and Johnson (1996) extend Fama and French's (1989) analysis by suggesting that the monetary environment affects investors' required returns. Monetary policy stance is proxied by a binary dummy variable indicating discount rate changes. Jensen et al. (1996) find that predictable variation in stock returns depends on monetary as well as business conditions, with expected stock returns being higher in tight money periods than in easy money periods. The results also indicate an asymmetry in the relation between business conditions and stock returns: business conditions could predict future stock returns only in periods of expansive monetary policy. During restrictive periods, the three business proxies (term spread, dividend yield, default spread) possess little explanatory power for expected stock returns.

Booth and Booth (1997) adopt the Jensen et al. (1996) methodology including an additional proxy for the stance of the monetary authority, the federal funds rate, and examining portfolios of small and large US stocks to determine whether the results are size-dependent. Their findings indicate that monetary policy indicators contain significant information that can be used to forecast expected stock (both small and large) portfolio returns. However, the result of Jensen et al. that only during restrictive monetary environments do the business conditions proxies have explanatory power for stocks is not confirmed by Booth and Booth. This is attributed to differences in the definitions of business conditions proxies and to differences in the stock and bond portfolios employed.

Conover, Jensen and Johnson (1999) argue that not only US stock returns, but also returns on foreign markets are related with US monetary environments (as well as their local monetary environment). They find that stock returns in twelve OECD countries over the period 1956-1995 are generally higher in expansive US and local monetary environments than they are in restrictive environments. As in Jensen and Johnson (1995) and Jensen et al. (1996), the monetary policy proxy used by Conover et al. (1999) is a dummy variable based on discount rate changes. Jensen et al. (1996) show that this categorisation of monetary regimes differentiates effectively US monetary conditions. They employ parametric and non-parametric tests and demonstrate that there are significant differences, in magnitude and frequency, between the levels as well as changes of several macroeconomic variables (monetary aggregates, credit, excess reserves, federal funds premium) across the defined environments[22].

Thus to summarize, while early evidence is ambiguous as to the role of monetary policy for stock return predictability, more recent studies provide strong evidence suggesting that monetary easing (tightening) increases (decreases) stock returns. As Sellin points out, the problem inherent in early analyses is that no distinction is made between shocks to the supply and demand for money. Following the recent literature, in the next section we examine empirically the effect of changes in monetary stringency on international stock returns using interest rate policy indicators.

1.3 Empirical evidence on monetary policy and stock returns

1.3.1 Data description, monetary policy proxies & unit root tests

We employ monthly stock prices and interest rates data from thirteen countries over the period January 1972 to July 2002. The data are obtained from OECD's *Main Economic Indicators: Historical Statistics.* Our sample of advanced economies, includes the G7 (United States, United Kingdom, Japan, Germany, France, Italy and Canada), and other European economies: Sweden, Finland, Switzerland, Belgium, Netherlands, Spain. Out of the nine European Union sample countries: Germany, France, Italy, Finland, Belgium, Netherlands, Spain, UK, Sweden, the first seven have adopted the single European currency (Euro) in the context of the European Monetary Union (EMU).

Table 1.1.a presents summary statistics for monthly nominal stock returns over the thirty year sample period. The mean monthly stock return for Sweden, Finland, and France is the highest while it is the lowest for Japan, Belgium, Germany, and Canada. The standard deviation of returns is the highest for Italy, Finland, and UK while it is the lowest for the US, Belgium, and Canada. The Jarque-Bera test for normality indicates that stock returns are non-normally distributed. Non-normality is a typical feature of stock returns data, especially in higher frequencies, potentially leading to problems with hypothesis testing

[22] Note that as Conover et al. (1999) argue, while this method for monetary regime classification effectively differentiates monetary conditions, the procedure is not advocated as the best technique of identifying minor

based on reported probability statistics from regression analysis. The non-normality of stock returns will be accounted for, through bootstrap analysis.

Table 1.1a: Descriptive statistics for nominal stock returns, 1972.02 - 2002.07.

	US	UK	Japan	France	Germany	Canada	Italy
Mean	0.62	0.63	0.41	0.69	0.48	0.48	0.67
Maximum	13.46	42.31	16.68	24.44	16.70	13.33	26.25
Minimum	-26.41	-30.92	-22.83	-28.07	-25.21	-25.65	-22.39
Std. Dev.	4.57	6.04	5.16	6.03	5.33	4.92	7.17
Normality (JB)	239.01 [0.000]	1061.84 [0.000]	42.79 [0.000]	171.09 [0.000]	110.16 [0.000]	257.68 [0.000]	8.87 [0.01]
Correlation with US return	1	0.61	0.36	0.44	0.50	0.74	0.31

	Belgium	Netherlands	Finland	Sweden	Spain	Switzerland
Mean	0.42	0.62	0.92	0.98	0.53	0.50
Maximum	14.84	18.09	26.16	24.24	22.82	16.88
Minimum	-28.05	-26.58	-31.84	-24.28	-26.74	-26.30
Std. Dev.	4.64	4.99	6.76	5.94	5.68	4.94
Normality (JB)	375.11 [0.000]	192.02 [0.000]	80.87 [0.000]	49.16 [0.000]	41.71 [0.000]	407.91 [0.000]
Correlation with US return	0.35	0.64	0.09	0.48	0.31	0.61

Note:

(a) Monthly nominal stock returns measured in local currency terms as the first difference of the logarithm of the local stock price index.
(b) JB denotes the value of the Jarque-Bera normality test (probability shown in bracket below).

We also calculate the correlation coefficient of local stock returns with US stock returns. The correlation is positive for all countries and exceeds 40% for Canada, Netherlands, UK, Switzerland, Germany, Sweden, and France. The correlation is less than 40% for Japan, Belgium, Italy, Spain, and Finland. The emerging high degree of correlation between international equity markets is a relatively recent phenomenon. As Brooks and Del Negro (2002) argue, the monthly correlation coefficient of US stock returns with stock returns in other developed economies has risen from a relatively stable level of around 0.4 from the mid-1980s through the mid-1990s to close to 0.9 more recently. Several explanations have been suggested, including the increasing level of diversification of firms' sales and financing across countries that exposes firms, more than before, to the

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changes in the stringency of monetary policy.

global business cycle, causing national stock markets to move together more. Another explanation for the rise in comovement since the mid-1990s is that it simply a temporary phenomenon associated with the recent stock market bubble. Finally, additional reasons include the convergence in industrial composition and greater policy coordination across countries, or simply that country specific shocks have declined in importance (Brooks and Del Negro, 2002). The high degree of international correlation is another feature of stock returns data that will be taken into account in the empirical estimations.

Table 1.1b: Descriptive statistics for short-term interest rates, 1972.01 - 2002.07.

	US	UK	Japan	France	Germany	Canada	Italy
Mean	6.65	9.23	2.64	8.46	5.95	8.31	11.62
Maximum	15.92	16.27	6.00	18.92	13.60	20.82	22.08
Minimum	1.67	3.78	0.01	2.46	2.58	1.97	2.45
Std. Dev.	2.76	3.20	1.69	3.52	2.52	3.58	4.65
Normality (JB)	90.61 [0.000]	17.59 [0.000]	16.74 [0.000]	6.74 [0.033]	59.44 [0.000]	37.58 [0.000]	6.65 [0.035]
Correlation with US rate	1	0.72	0.50	0.69	0.51	0.86	0.6

	Belgium	Netherlands	Finland	Sweden	Spain	Switzerland
Mean	8.38	6.01	7.73	7.50	11.06	9.01
Maximum	17.60	14.00	9.50	12.00	32.17	20.13
Minimum	3.03	0.70	3.50	2.00	3.00	2.00
Std. Dev.	3.42	2.49	1.74	2.43	5.15	3.51
Normality (JB)	18.43 [0.000]	19.31 [0.000]	42.25 [0.000]	8.18 [0.016]	98.33 [0.000]	13.21 [0.001]
Correlation with US rate	0.71	0.57	0.51	0.56	0.44	0.46

Note:

(a) Descriptive statistics for local 3 month Treasury Bill Rates.
(b) JB denotes the value of the Jarque-Bera normality test (probability shown in the bracket below).

Table 1.1.b presents summary statistics for short-term interest rates. From the early 1990's researchers and policy makers focused mainly on interest rate variables and spreads as indicators of monetary policy. The change in the short-term interest rate is one of our measures for the stance of the monetary authority. Short-term interest rates are proxied by the three month Treasury Bill (TB) rate (see also, Nelson, 2000; Martin and Milas, 2002).

TB rates are highly correlated with the central bank interest rate instruments[23]. In Euro-members, national monetary policies were abolished on December 1998. Thereafter, common monetary policy is implemented by the European Central Bank (ECB) through changes in the ECB refinancing rate. Local TB rates reflect the single ECB interest rate plus local market risk. Over the period 1999.01-2002.07, the correlation between the local three month TB rate and the ECB refinancing rate is equal to 0.84, 0.89, 0.97, 0.97, 0.98, 0.97, 0.99 in Finland, France, Germany, Italy, Belgium, Netherlands and Spain, respectively.

The average short tem interest rate is the highest for Italy, Spain, and UK while it is the lowest for Japan, Germany, and Netherlands. The volatility of short-term rates is substantially lower than the equity return volatility. Interest rate standard deviations obtain values in the neighbourhood of 2% to 5%, while the equity return standard deviations range from 4% to 7%. The standard deviation of short-term rates is the highest for Spain, Italy, and Canada while it is the lowest for Japan, Finland, and Sweden. The average standard deviation of sample short-term interest rates is almost two times smaller than the average standard deviation of stock returns (2.85% as opposed to 5.55%), reflecting the higher risk associated with stock market investment. The Jarque-Bera test shows that, similarly to stock returns, interest rates are non-normal variables. The correlation between local short-term rates and US rates is the highest for Canada, UK and Belgium (see also Conover et al., 1999). In contrast, the correlation coefficient with the US rate is the lowest for Spain and Switzerland. The results in Tables 1.1a and 1.1b suggest that our sample exhibits a high degree of diversity with respect to average stock market performance and monetary policy, and their unconditional volatilities. Foreign stock market returns and short term interest rates are positively correlated with their US counterparts, but their correlations range substantially across the sample.

We also employ an alternative proxy for the stance of the monetary authority, that is, a binary dummy variable based upon changes in the discount rate constructed according to Jensen et al. (1996) approach. Unlike the TB rate, the discount rate is not market determined but administered by the central bank[24]. The discount rate dummy variable is

[23] Table A1.1 in Appendix I shows that the correlation coefficient between three month TB rates and central bank discount rates over the period 1972-2002 is close to one (except from Switzerland where it is 0.58).

[24] As Arestis and Sawyer (2003) argue, the discount rate is the rate of interest at which the central bank is willing to supply reserves to the financial system and is used to cover rates such as the federal funds rate in the US, the repo rate (ECB) etc.

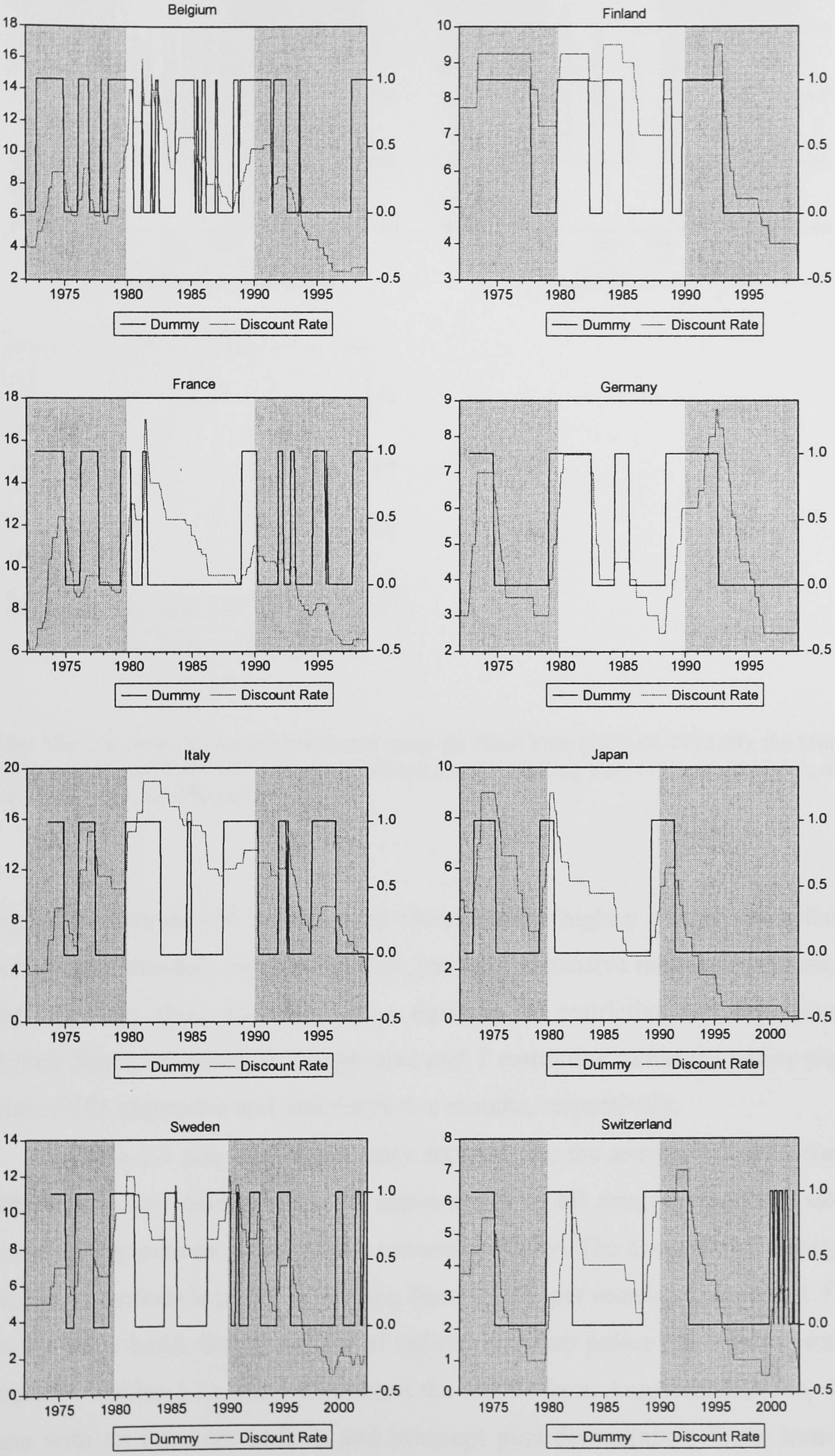
equal to one if the previous discount rate change was an increase (restrictive monetary policy) and zero (expansive monetary policy) if the previous change was a decrease. The dummy variable relies on discount rate changes, which, as Conover et al. (1999, p.1360) argue "are likely to correspond with changes in the monetary environment as well as changes in business and economic conditions". The monetary environment classification remains the same until the discount rate is changed in the opposite direction, since the central bank is assumed to be operating under the same fundamental monetary policy until the discount rate is changed in the opposite direction from the prevailing trend. For example, the period following a discount rate decrease is classified as expansive. Further discount rate decreases do not alter the classification of the monetary environment. Likewise, restrictive monetary environments begin when the discount rate first increases and end when the discount rate is decreased. The initial categorisation of monetary environments cannot begin until there is a change in the discount rate[25].

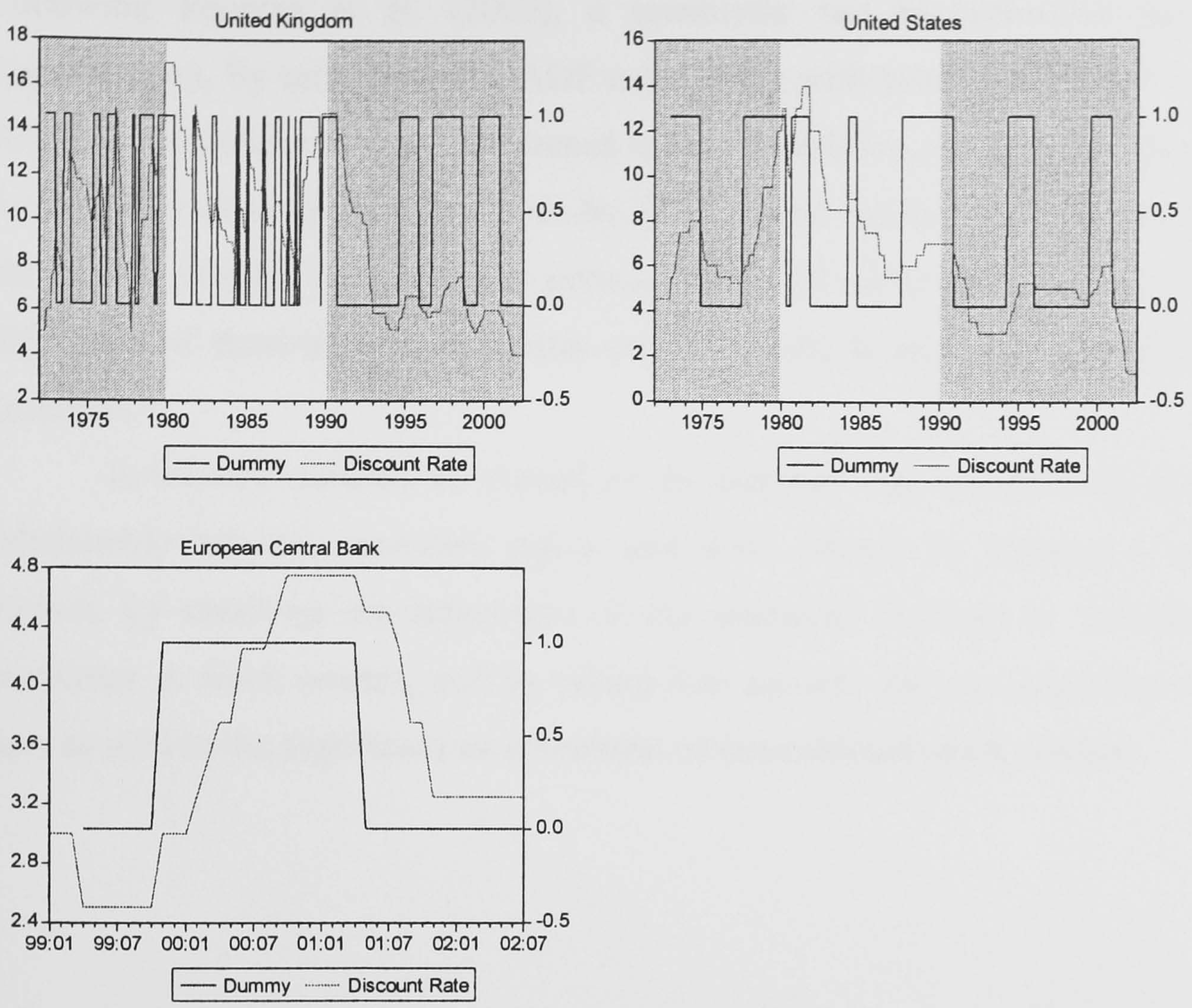
Following the Jensen et al. (1996) approach, we exclude months when the discount rate was pegged to a market rate than being set by the central bank itself. This results in elimination of data for Canada from March 1980 to December 1993[26]. Local discount rate data for Belgium, France, Finland, Germany, Italy (Euro members) is available up till December 1998; over the rest of the sample period (1999.01-2002.07), we use the ECB refinancing rate as a proxy for the Euro-members discount rate. Figure 1.1 shows graphs of the local discount rate, and the local discount rate dummy variable. The graphs indicate that interest rates have been declining over the 1990s, reflecting the lower average inflation rates experienced over that period.

Table 1.2 presents descriptive statistics for monetary environments, defined using the discount rate dummy variable. The number of expansive and restrictive periods varies substantially from country to country implying a disparity in how actively discount rates were used by the sample central banks. In the United Kingdom there were 19 expansive and 14 restrictive periods, while in Japan we document only 4 periods of expansive and 3 periods of restrictive monetary policy[27]. The average duration of the monetary environments varies significantly, with Japan reporting the highest average duration of

[25] For example, the first change in the discount rate for Sweden, and hence the first characterisation of the monetary environment, occurs in April 1974.
[26] Spain and Netherlands are also excluded from the empirical analysis using the discount rate dummy variable, due to the lack of adequate number of discount rate observations in the Datastream series.
[27] See Table A1.2 in Appendix I for more details on the chronology of discount rate changes.

Figure 1.1: Graphs of discount rates and discount rate dummy variables.





Note: The UK series has been constructed using the Bank Rate (1972.01-1972.09), the Minimum Lending Rate (1972.10-1981.07), the Minimum Band 1 Dealing Rate (1981.08-1997.04), and the Repo Rate (1997.05-2002.07).

expansive periods (74 months) and Germany the highest average duration of restrictive periods (32 months). Switzerland also has long expansive monetary periods, while Finland and UK have about the same mean duration for restrictive and expansive periods. The United States experienced 7 expansive and 7 restrictive monetary policy periods, giving a total of 195 expansive and 146 restrictive months, respectively.

Table 1.2 also shows summary statistics for the average monthly real stock returns across monetary environments. It appears that in all sample countries, stock returns are lower during periods of restrictive monetary policy. The average real equity return during expansive periods is positive, ranging from 0.39% per month in Japan to 1.77% in Finland. On the other hand, during periods of tighter monetary policy the average return on stocks is negative. Tables 1.3a and 1.3b present the results from Augmented Dickey Fuller unit root tests with an intercept (ADF), and intercept plus deterministic linear trend (ADF trend).

Following Fountas et al. (2000), a sensitivity test is performed for the order of augmentation, by estimating the ADF regressions with both a small (LB = 4) and a large (UB = 24) number of lagged difference terms. In addition, we calculate the ADF *t*-statistic for the order of augmentation chosen by the Schwartz Information Criterion (SIC). Overall, the results suggest that, over the period 1972-2002, nominal stock returns and the first difference of short-term interest rates can be treated as stationary variables in all sample countries[28].

In the next section, we expand on the literature that examines the contemporaneous relationship between monetary policy and stock returns by utilising a more up-to-date dataset, by checking the robustness of the empirical findings to inclusion of dividend payments in stock returns, and by taking into account the non-normality inherent in our data as well as the significant co movement of international stock markets.

[28] Tables A1.3a, A1.3b and A1.3c in Appendix I show ADF unit root test results for real stock returns and dividend adjusted (nominal and real) stock returns. The results broadly support the notion that stock returns are stationary in real and dividend adjusted terms.

Table 1.2: Descriptive statistics for local monetary environments and real stock returns, 1972.02 -2002.07.

Country	Number of expansive periods	Total number of expansive months	Average duration of expansive periods	Average real stock return in expansive periods	Number of restrictive periods	Total number of restrictive months	Average duration of restrictive periods	Average real stock return in restrictive periods
Belgium	15	176	13	0.57	11	164	15	-0.35
Canada	8	74	10	0.64	8	96	13	-0.31
Finland	7	177	32	1.77	6	160	30	-1.02
France	10	205	26	0.85	10	95	12	-0.89
Germany	6	211	39	0.75	5	143	32	-0.32
Italy	10	244	23	0.78	8	145	19	-1.10
Japan	4	292	74	0.39	3	64	22	-1.33
Sweden	10	182	20	0.89	11	138	14	-0.03
Switzerland	5	230	46	0.90	7	114	17	-1.06
UK	19	186	11	1.31	14	145	10	-0.32
US	7	195	29	0.91	7	146	22	-0.77

Note:

(a) The monetary environment is classified as expansive (restrictive) if the most recent change in the discount rate was a decrease (increase).
(b)The data excludes months when the central bank discount rate was pegged to a market rate than being set by the central bank. This results in elimination of data for Canada from March 1980 to December 1993. The discount rate data for Belgium, Finland, Germany, Italy (Euro-members) ends on December 1998. Thereafter, their monetary environments classification was based upon changes in the ECB refinancing rate.

Table 1.3a: Unit root tests for nominal stock returns, 1972.02 - 2002.07.

		Belgium	Canada	Finland	France	Germany	Italy	Japan
ADF	UB	-3.69 ***	-4.04 ***	-2.93 **	-3.86 ***	-3.55 ***	-3.39 ***	-3.14 **
	LB	-8.21 ***	-7.86 ***	-7.29 ***	-7.12 ***	-8.43 ***	-7.63 ***	-7.61 ***
	SIC	-7.77 ***	-10.42 ***	-14.10 ***	-10.19 ***	-12.88 ***	-5.31 ***	-10.16 ***
ADF Trend	UB	-3.71 **	-4.01 ***	-2.37	-3.78 **	-3.39 *	-3.37 *	-3.51 **
	LB	-8.21 ***	-7.85 ***	-7.28 ***	-7.11 ***	-8.38 ***	-7.62 ***	-7.80 ***
	SIC	-13.26 ***	-10.41 ***	-3.71 **	-5.85 ***	-6.37 ***	-12.78 ***	-10.38 ***

		Netherlands	Spain	Sweden	Switzerland	UK	US
ADF	UB	-3.24 **	-2.86 *	-2.58 *	-3.60 ***	-3.54 ***	-3.98 ***
	LB	-8.01 ***	-7.60 ***	-7.72 ***	-8.14 ***	-8.79 ***	-8.34 ***
	SIC	-7.38 ***	-5.07 ***	-6.21 ***	-6.99 ***	-5.96 ***	-6.32 ***
ADF Trend	UB	-2.96	-2.62	-3.26 *	-3.63 ***	-3.46 **	-4.11 ***
	LB	-8.01 ***	-7.66 ***	-7.72 ***	-8.18 ***	-8.77 ***	-8.41 ***
	SIC	-9.69 ***	-9.16 ***	-6.55 ***	-10.81 ***	-6.98 ***	-10.91 ***

Note:

(a) The reported *t*-statistics test the null hypothesis of unit root in monthly nominal stock returns.
(b) In order to correct for serial correlation, the Augmented Dickey Fuller test (ADF) uses lagged differences of the variable into question. UB = 24, is the upper bound of lagged difference terms; LB = 4, is the lower bound of lagged difference terms. SIC is the order of augmentation of the ADF that minimises the Schwartz information criterion starting from upper bound UB.
(c) *, **, *** indicate rejection of the null-unit root hypothesis at 10, 5, 1 % level of significance respectively.

Table 1.3b: Unit root tests for the change of the short-term interest rate, 1972.02 - 2002.07.

		Belgium	Canada	Finland	France	Germany	Italy	Japan
ADF	UB	-4.03 ***	-4.55 ***	-4.21 ***	-4.22 ***	-4.11 ***	-3.98 ***	-4.64 ***
	LB	-7.86 ***	-8.49 ***	-7.24 ***	-7.86 ***	-5.87 ***	-7.15 ***	-7.28 ***
	SIC	-9.25 ***	-10.37 ***	-5.78 ***	-11.24 ***	-7.67 ***	--11.56 ***	-5.71 ***
ADF Trend	UB	-4.11 ***	-4.74 ***	-4.25 ***	-4.18 ***	-4.08 ***	-4.71 ***	-4.60 ***
	LB	-7.93 ***	-8.58 ***	-7.27 ***	-7.92 ***	-5.88 ***	-7.16 ***	-7.28 ***
	SIC	-6.92 ***	-5.59 ***	-9.53 ***	-6.42 ***	-5.62 ***	-9.55 ***	-12.51 ***

		Netherlands	Spain	Sweden	Switzerland	UK	US
ADF	UB	-3.53 ***	-4.45 ***	-3.83 ***	-5.23 ***	-3.99 ***	-4.64 ***
	LB	-10.79 ***	-11.03 ***	-6.42 ***	-9.44 ***	-7.91 ***	-8.91 ***
	SIC	-9.58 ***	-10.31 ***	-5.17 ***	-6.06 ***	-6.72 ***	-8.83 ***
ADF Trend	UB	-3.54 ***	-4.67 ***	-4.51 ***	-5.74 ***	-4.01 ***	-4.71 ***
	LB	-10.83 ***	-11.04 ***	-6.59 ***	-9.49 ***	-7.95 ***	-9.01 ***
	SIC	-6.67 ***	-11.51 ***	-5.22 ***	-6.19 ***	-10.94 ***	-10.42 ***

Note:

(a) The reported *t*-statistics test the null hypothesis of unit root in monthly short-term interest rates.
(b) In order to correct for serial correlation, the Augmented Dickey Fuller test (ADF) uses lagged differences of the variable into question. UB = 24, is the upper bound of lagged difference terms; LB = 4, is the lower bound of lagged difference terms. SIC is the order of augmentation of the ADF that minimises the Schwartz information criterion starting from upper bound UB.
(c) *, **, *** indicate rejection of the null-unit root hypothesis at 10, 5, 1 % level of significance respectively.

1.3.2 Monetary conditions and stock returns

(a) Nominal stock returns

The contemporaneous relationship between monetary conditions and stock returns is examined using the following regression model:

$$\Delta S_t = a + \beta \Delta i_t + u_t \tag{1.2}$$

where, ΔS_t is the local monthly nominal stock return, S_t is the local share price index measured in local currency terms, and Δi_t is the change of the local short-term interest rate. It is assumed that positive (negative) values of the change of the short-term rate are associated with a restrictive (expansive) monetary environment. If the β coefficient is negative and statistically significant, then it is implied that monetary tightening depresses the stock market within the same month that the interest rates increase(s) occurred.

Eq. (1.2) has been frequently used in the financial economics literature with previous international evidence broadly supporting a negative relationship between stock returns between (the level and/or the first difference of) interest rates[29]. Eq. (1.2) is estimated with Ordinary Least Squares (OLS) using the Newey-West heteroskedasticity and autocorrelation consistent covariance matrix estimator. In Table 1.4, the estimated intercepts are all positive and the majority of them statistically significant at the conventional significance levels, reflecting the generally positive average returns associated with stock market investment. The F statistic indicates acceptance of the null of joint (explanatory variable) insignificance only in the cases of Finland, Japan, Spain and Switzerland. Ten of the thirteen coefficient estimates for local monetary conditions are negative and statistically different from zero at conventional significance levels, indicating that higher interest rates are associated with lower stock returns than the returns experienced during periods of lower interest rates.

[29] In the literature that examines the effect of inflation on stock prices, using a generalised Fisher effect framework (which relates nominal stock returns with expected inflation), expected inflation is often proxied by the nominal Treasury Bill rate at the beginning of the period, see e.g. Fama and Schwert (1977), Gultekin (1983). Fama and Schwert justify this approach by observing that almost all of the variability in the nominal TB rate is due to revisions of inflation expectations. This approach is extensively justified in Fama (1975).

Table 1.4: Regressions of nominal stock returns against the change in the short-term interest rate, 1972.02 - 2002.07.

Country	α	β	F	JB	R^2
Belgium	0.423 * (1.764)	-1.212 *** (3.642)	8.93 [0.038]	483.02 [0.000]	0.031
Canada	0.483 * (1.919)	-1.654 *** (2.923)	15.55 [0.000]	440.62 [0.000]	0.04
Finland	0.915 *** (2.59)	-0.768 (0.509)	0.27 [0.601]	81.74 [0.000]	0.001
France	0.689 ** (2.226)	-2.338 *** (3.032)	15.42 [0.000]	157.06 [0.000]	0.04
Germany	0.474 * (1.709)	-1.471 * (1.928)	4.71 [0.03]	109.86 [0.000]	0.01
Italy	0.574 (1.502)	-1.363 ** (2.283)	6.52 [0.011]	14.12 [0.000]	0.01
Japan	0.396 (1.328)	-1.781 (1.327)	2.16 [0.14]	38.36 [0.000]	0.006
Netherlands	0.626 ** (2.411)	-0.855 ** (2.251)	4.07 [0.04]	207.68 [0.000]	0.011
Spain	0.534 * (1.799)	0.114 (0.99)	1.00 [0.316]	43.02 [0.000]	0.002
Sweden	0.967 *** (3.125)	-1.63 ** (2.286)	4.34 [0.037]	81.46 [0.000]	0.011
Switzerland	0.501 * (1.94)	-0.432 * (1.95)	2.38 [0.123]	409.61 [0.000]	0.006
United Kingdom	0.631 ** (2.087)	-2.581 *** (5.406)	34.88 [0.000]	1347.43 [0.000]	0.08
United States	0.616 *** (2.599)	-0.859 ** (2.302)	4.51 [0.034]	352.96 [0.000]	0.01

Note:

(a) OLS estimates, with Newey-West heteroskedasticity and serial correlation consistent covariance matrix estimator, of the regression equation $\Delta S_t = \alpha + \beta \Delta i_t + u_t$ where ΔS_t is the monthly nominal stock return and Δi_t is the change of the short-term interest rate.
(b) Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) JB denotes the value of the Jarque-Bera normality test. The associated probability is shown in the bracket below.
(d) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Some of the largest return differences are observed in the UK, France, Canada, and Italy. On an annualized basis, the returns in expansive monetary environments exceeded the returns in restrictive environments for these countries by approximately 31%, 28%, 20%, and 16%, respectively. These differences exceed the difference of approximately 10% exhibited by the US market. Especially strong statistical relationships are observed for four of the thirteen sample countries. Specifically, the monetary conditions coefficient is

More recent literature on monetary policy rules also suggests a positive correlation between the level of short-significant at the 1% level in Belgium, Canada, France and UK. The regression R-squares suggest that, for these four countries, the monetary policy variable explains approximately 3% to 8% of the variation in stock returns. Given the monthly horizon of our data, the proportion of stock variation that is explained is relatively high. The results indicate that only in Finland, Japan and Spain stock returns are unrelated to the change in short-term interest rate.

The fifth column of Table 1.4 shows the Jarque-Bera test for normality of the residuals from regression Eq. (1.2). The Jarque-Bera test rejects residual normality in all sample countries. In order to calculate the non-normality-adjusted critical values, we undertook bootstrap analysis. In particular, we created 1000 bootstrapped versions of the original dependent variable (nominal stock returns) using the reshuffled (random draw with replacement) scaled residuals from Eq. (1.2). The generated dependent variable is then regressed on the original explanatory variable (lagged change in short-term rate). This process is repeated 1000 times for each country in the sample, generating 1000 t-ratios. These 1000 t-ratios are then sorted, so that the 5% critical values can be selected as the 25^{th} (lower bound) and 975^{th} (upper bound) values of the series. Finally, average critical values are computed from 100 repetitions of 1000 iterations producing a distribution of critical values. Comparing the bootstrap results (Table A1.4 in Appendix I) with the OLS results, we see that when residual non-normality is taken into account, Germany and Switzerland are added to the list of countries where the effect of interest rate changes on equity returns is significant at the 5% level.

Another sensitivity test for the validity of the results involves taking into account the contemporaneous correlation in the error terms across equations of the local country model 1.2. As we showed in Tables 1.1a, 1.1b, US stock returns are strongly correlated with stock returns in the other sample countries. We suspect that this correlation may be present in the residuals of Eq. (1.2) across different countries, and therefore, we form the following system of equations, to be estimated with the seemingly unrelated regression method (SUR):

$$\Delta S_{j,t} = a_j + \beta_j \Delta i_{j,t} + u_{j,t} \qquad (1.2)'$$

term interest rates and inflation, (Taylor, 1993).

where, j = Belgium, Canada, Finland, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, UK, US. The SUR method, also known as the multivariate regression (or Zellner's method) estimates the parameters of the system, accounting for heteroskedasticity, and contemporaneous correlation in the errors across equations. The estimation results are presented in Table 1.4.1 below:

Table 1.4.1 : Seemingly Unrelated Regressions of nominal stock returns against the change in the short-term interest rate, 1972.02 - 2002.07

Country	α	β	Cor	R^2
Belgium	0.402 * (1.699)	-0.742 ** (2.306)	0.350 ***	0.02
Canada	0.456 * (1.844)	-1.292 *** (4.853)	0.741 ***	0.04
Finland	0.889 *** (2.542)	-0.046 (0.037)	0.102 *	0.0001
France	0.667 ** (2.185)	-1.069 *** (2.378)	0.440 ***	0.03
Germany	0.443 (1.636)	-0.407 (0.951)	0.503 ***	0.006
Italy	0.554 (1.485)	-0.925 ** (2.119)	0.326 ***	0.02
Japan	0.376 (1.417)	-1.039 (0.986)	0.366 ***	0.004
Netherlands	0.589 *** (2.335)	-0.547 ** (2.317)	0.650 ***	0.01
Spain	0.501 * (1.718)	0.095 (1.027)	0.325 ***	0.002
Sweden	1.038 *** (3.371)	-0.904 (1.41)	0.410 ***	0.01
Switzerland	0.46 * (1.836)	-0.06 (0.35)	0.620 ***	0.001
United Kingdom	0.593 ** (2.003)	-2.009 *** (6.524)	0.624 ***	0.08
United States	0.583 *** (2.507)	-0.69 *** (2.923)	1	0.01

Note:

(a) SUR estimates of the system $\Delta S_{j,t} = \alpha_j + \beta_j \Delta i_{j,t} + u_{j,t}$ where ΔS_t is the monthly nominal stock return and Δi_t is the change in the short-term interest rate. The estimates of the cross-equation covariance matrix are based upon parameter estimates of the unweighted system.
(b)Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) Cor denotes the correlation coefficient of local country residuals with US residuals.
(d) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

The fourth column in Table 1.4.1 shows the contemporaneous correlation coefficient of the local country residuals with US residuals. As expected, the correlation coefficient is positive and statistically significant in all cases. The SUR estimates indicate a negative effect from monetary policy tightening on stock returns in 7 out of the 13 sample countries. Comparing the SUR results with the OLS results, we see that Sweden drops from the list of countries with a significant stock returns-monetary policy relationship at the 5% level.

(b) Real stock returns

The previous section results indicate that nominal stock returns are related to changes in the level of interest rates, however, it is unclear whether this is the case for real stock returns. Stock returns usually respond negatively to increased inflation (see e.g. Fama, 1981) and at the same time central banks typically respond with interest rate increases to increases in inflation. In this scenario, stock returns will decrease when monetary policy is contractionary, but this decrease will be related with changes in inflationary expectations. To determine whether the patterns identified in nominal returns are also present in real returns, Table 1.5 presents the estimation results (OLS, robust errors) of Equation 1.3, which relates local stock returns net of inflation to the change in the local monetary short-term interest rate.

$$\Delta s_t = a + \beta \Delta i_t + u_t \qquad (1.3)$$

where, $\Delta s_t = \Delta S_t - \pi_t$ is the monthly real stock return, π_t is the monthly inflation rate. We use monthly consumer price indices from the OECD's *Main Economic Indicators: Historical Statistics* in order to calculate π_t as the first difference of the natural log of consumer prices.

The results in Table 1.5 are qualitatively the same with those in Table 1.4, where nominal equity returns were used in the estimation. For all countries but Finland and Spain, the coefficient of the change of the short-term interest rate is negative and statistically different from zero at the usual levels of significance. For seven countries (Belgium, Canada, France, Italy, Netherlands, Sweden, UK) the relationship is significant at the 1% level. Large real return differences, associated with higher interest rates, are observed in UK and France. One striking difference between the results of Tables 1.4 and 1.5 is the statistical insignificance of the intercept for all the sample countries (except Sweden) when real returns are employed.

Table 1.5: Regressions of real stock returns against the change in the short-term interest rate, 1972.02 - 2002.07

Country	α	β	F	JB	R^2
Belgium	0.06 (0.24)	-1.254 *** (3.77)	9.49 [0.002]	446.58 [0.000]	0.025
Canada	0.063 (0.25)	-1.698 *** (2.972)	16.14 [0.000]	419.65 [0.000]	0.042
Finland	0.41 (1.159)	-1.033 (0.689)	0.48 [0.485]	76.27 [0.000]	0.001
France	0.237 (0.763)	-2.42 *** (3.161)	16.41 [0.000]	154.99 [0.000]	0.043
Germany	0.213 (0.764)	-1.524 * (1.941)	5 [0.025]	105.13 [0.000]	0.013
Italy	-0.12 (0.315)	-1.485 *** (2.476)	7.69 [0.005]	14.04 [0.000]	0.022
Japan	0.094 (0.392)	-2.118 * (1.806)	3.01 [0.083]	33.90 [0.000]	0.008
Netherlands	0.311 (1.19)	-0.843 *** (2.563)	3.90 [0.048]	186.22 [0.000]	0.01
Spain	-0.182 (0.604)	0.107 (0.896)	0.856 [0.355]	32.31 [0.000]	0.002
Sweden	0.62 * (1.929)	-1.824 *** (2.627)	5.48 [0.019]	79.74 [0.000]	0.016
Switzerland	0.247 (0.946)	-0.419 * (1.915)	2.18 [0.14]	385.82 [0.000]	0.005
United Kingdom	0.052 (0.173)	-2.592 *** (5.416)	35.15 [0.000]	1027.84 [0.000]	0.088
United States	0.213 (0.883)	-0.901 ** (2.194)	4.817 [0.028]	312.38 [0.000]	0.013

Note:

(a) OLS estimates, with Newey-West heteroskedasticity and serial correlation consistent covariance matrix estimator, of the regression equation $\Delta s_t = \alpha + \beta \Delta i_t + u_t$ where Δs_t is the monthly ex post real stock return and Δi_t is the change in the short-term interest rate.
(b) Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) JB denotes the value of the Jarque-Bera normality test. The associated probability is shown in the bracket below.
(d) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Overall, we find that contractionary monetary environments depress not only nominal but also inflation adjusted stock returns. Bootstrap analysis (see Table A1.5 in Appendix I) reveals that after non-normality in the residuals (as suggested by the Jarque-Bera test in Table 1.5) is taken into account, the relationship between changes in interest rates and stock returns is statistically different from zero at the 5% level in 10 out of the 13 countries. Simultaneous estimation of Eq. (1.3) for the 13 sample countries using the SUR method, indicates that the findings are identical to those obtained using nominal stock returns. Table 1.5.1, shows the SUR estimation results of the system (1.3)′. The estimated slope is negative and significant at the 5% level in Belgium, Canada, France, Italy, Netherlands, UK, US.

$$\Delta s_{j,t} = a_j + \beta_j \Delta i_{j,t} + u_{j,t} \qquad (1.3)'$$

Table 1.5.1 : Seemingly Unrelated Regressions of real stock returns against the change in the short-term interest rate, 1972.02 - 2002.07

Country	α	β	Cor	R^2
Belgium	0.04 (0.17)	-0.753 *** (2.338)	0.362 ***	0.02
Canada	0.038 (0.153)	-1.266 *** (4.705)	0.740 ***	0.04
Finland	0.39 (1.108)	-0.312 (0.248)	0.113 *	0.0006
France	0.214 (0.700)	-1.145 *** (2.541)	0.442 ***	0.03
Germany	0.185 (0.681)	-0.431 (0.997)	0.505 ***	0.006
Italy	-0.156 (0.417)	-1.01 ** (2.310)	0.336 ***	0.02
Japan	0.09 (0.336)	-1.359 (1.276)	0.367 ***	0.007
Netherlands	0.277 (1.092)	-0.541 ** (2.274)	0.652 ***	0.01
Spain	-0.212 (0.717)	0.085 (0.906)	0.337 ***	0.002
Sweden	0.537 * (1.73)	-0.989 (1.533)	0.413 ***	0.013
Switzerland	0.212 (0.834)	-0.02 (0.115)	0.625 ***	0.005
United Kingdom	0.018 (0.062)	-2.00 *** (6.565)	0.634 ***	0.08
United States	0.186 (0.787)	-0.724 *** (3.022)	1	0.01

Note:

(a) SUR estimates of system $\Delta s_{j,t} = \alpha_j + \beta_j \Delta i_{j,t} + u_{j,t}$ where Δs_t is the monthly ex post real stock return and Δi_t is the change in the short-term interest rate. The estimates of the cross-equation covariance matrix are based upon parameter estimates of the unweighted system.
(b) Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) Cor denotes the correlation coefficient of local country residuals with US residuals.
(d) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

(c) Dividend adjusted stock returns

The national stock price indices employed for the construction of the nominal and real return series are not adjusted for dividend payments. In order to perform an additional examination of the results' robustness, return series which include dividends were obtained from the Datastream Total Markets series[30]. Tables 1.6 and 1.7 present the results from the estimation of Eqs. (1.2) and (1.3) using dividend adjusted nominal stock returns (ΔS_t^D), and dividend adjusted real stock returns (Δs_t^D). It is evident that inclusion (or exclusion) of dividends in the calculation of the returns doesn't affect the strongly negative relationship between changes in the short-term interest rate and stock returns in Belgium, Canada, France, Italy, Netherlands, UK, US. Using nominal dividend adjusted returns, the coefficient of the proxy for monetary tightening is negative and statistically significant at the 10% level of significance in 11 of the 13 sample countries. Especially strong patterns are observed in France and the UK, where return differences of more than 2% (on a monthly basis) are observed. The majority of the estimated intercepts are positive and significant and higher in value, as compared to the case when we exclude dividends from the returns calculation. Using real dividend adjusted returns, changes in interest rates appear statistically insignificant in explaining local returns in Spain and Switzerland.

The Jarque-Bera tests in Tables 1.6, 1.7 indicate the presence of non-normality in the residuals of our estimated models. Bootstrapped confidence intervals (see Tables A1.6, A1.7 in Appendix I) show that the impact of interest rate changes on equity returns remains statistically significant in the majority of our sample countries, even when error non-normality is accounted for. SUR results in Tables 1.6.1, 1.7.1 indicate that, in line with the findings for non-dividend adjusted returns, when we employ dividend adjusted returns to estimate system (1.3)′, the relationship between interest rate changes and stock returns isn't statistically significant at the 5% level in Spain, Finland, Germany, Japan, Sweden and Switzerland.

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[30] The series commence on February 1973 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US while for Sweden, Spain, and Finland on 1982.02, 1987.04 and 1988.05, respectively.

Table 1.6: Regressions of dividend adjusted nominal stock returns against the change in the short-term interest rate.

Country	α	β	F	JB	R^2
Belgium	0.835 *** (3.279)	-1.574 *** (4.505)	13.83 [0.000]	235.86 [0.000]	0.037
Canada	0.824 *** (3.345)	-1.62 *** (3.956)	16.07 [0.000]	421.91 [0.000]	0.043
Finland	0.925 (1.305)	-4.07 * (1.836)	2.23 [0.136]	8.01 [0.018]	0.007
France	1.034 *** (3.204)	-2.458 *** (2.98)	15.59 [0.000]	15.41 [0.000]	0.042
Germany	0.637 *** (2.365)	-1.474 * (1.898)	4.75 [0.02]	121.19 [0.000]	0.013
Italy	0.941 *** (2.434)	-1.5 *** (2.478)	7.77 [0.005]	36.08 [0.000]	0.022
Japan	0.388 (1.409)	-1.889 (1.573)	2.40 [0.121]	33.86 [0.000]	0.006
Netherlands	0.976 *** (3.866)	-0.705 ** (2.249)	2.94 [0.087]	198.99 [0.000]	0.008
Spain	0.87 ** (2.019)	-0.078 (-0.035)	0.006 [0.936]	219.67 [0.000]	0.000
Sweden	1.501 *** (3.171)	-1.87 ** (2.221)	2.89 [0.09]	44.87 [0.000]	0.014
Switzerland	0.69 *** (2.768)	-0.343 * (1.658)	1.65 [0.198]	392.83 [0.000]	0.004
United Kingdom	1.075 *** (3.54)	-2.29 *** (4.702)	27.49 [0.000]	1364.29 [0.000]	0.072
United States	0.869 *** (3.572)	-0.844 ** (2.064)	4.261 [0.003]	171.41 [0.000]	0.011

Note:

(a) OLS estimates, with Newey-West heteroskedasticity and serial correlation consistent covariance matrix estimator, of the regression equation $\Delta S_t^D = \alpha + \beta \Delta i_t + u_t$ where ΔS_t^D is the monthly dividend adjusted nominal stock return and Δi_t is the change in the short-term interest rate. The Datastream return series are available from 1973.02 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US, and 1982.02, 1987.04 and 1988.05 for Sweden, Spain, and Finland, respectively.

(b)Absolute t-statistics are presented in parentheses beneath the coefficient estimates.

(c) JB denotes the value of the Jarque-Bera normality test. The associated probability is shown in the bracket below.

(d) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Table 1.6.1: Seemingly Unrelated Regressions of dividend adjusted nominal stock returns against the change in the short-term interest rate.

Country	α	β	Cor	R^2
Belgium	0.818 *** (3.407)	-0.758 *** (2.595)	0.514 ***	0.027
Canada	0.815 *** (3.469)	-1.177 *** (4.703)	0.768 ***	0.04
Finland	1.032 (1.558)	-3.262 (1.377)	0.223 ***	0.01
France	1.029 *** (3.345)	-0.873 ** (2.052)	0.550 ***	0.02
Germany	0.634 *** (2.523)	-0.573 (1.351)	0.517 ***	0.008
Italy	0.902 *** (2.44)	-1.007 ** (2.301)	0.339 ***	0.02
Japan	0.378 (1.427)	-1.316 (1.252)	0.379 ***	0.006
Netherlands	0.958 *** (4.069)	-0.397 ** (1.998)	0.671 ***	0.007
Spain	0.881 ** (2.162)	-0.96 (1.295)	0.358 ***	0.004
Sweden	1.29 *** (3.044)	-1.12 (1.247)	0.269 ***	0.01
Switzerland	0.67 *** (2.89)	-0.004 (0.003)	0.632 ***	0.00003
United Kingdom	1.063 *** (3.643)	-1.706 *** (5.798)	0.636 ***	0.07
United States	0.862 *** (3.726)	-0.781 *** (3.259)	1	0.015

Note:

(a) SUR estimates of system $\Delta S_{j,t}{}^{D} = \alpha_j + \beta_j \Delta i_{j,t} + u_{j,t}$ where ΔS_t^D is the monthly dividend adjusted nominal stock return and Δi_t is the change in the short-term interest rate. The estimates of the cross-equation covariance matrix are based upon parameter estimates of the unweighted system. The Datastream dividend adjusted return series are available from 1973.02 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US, and 1982.02, 1987.04 and 1988.05 for Sweden, Spain, and Finland, respectively.
(b)Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) Cor denotes the correlation coefficient of local country residuals with US residuals.
(d) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Table 1.7: Regressions of dividend adjusted real stock returns against the change in the short-term interest rate.

Country	α	β	F	JB	R^2
Belgium	0.473 * (1.865)	-1.614 *** (4.536)	14.38 [0.000]	203.33 [0.000]	0.039
Canada	0.404 (1.625)	-1.663 *** (2.99)	16.64 [0.000]	391.32 [0.000]	0.045
Finland	0.713 (1.00)	-4.404 * (1.874)	2.18 [0.14]	7.65 [0.02]	0.012
France	0.584 * (1.805)	-2.531 *** (3.107)	16.44 [0.000]	15.52 [0.000]	0.044
Germany	0.384 (1.418)	-1.514 ** (2.22)	4.95 [0.026]	112.77 [0.000]	0.013
Italy	0.245 (0.634)	-1.622 *** (2.67)	9.09 [0.002]	33.98 [0.000]	0.026
Japan	0.106 (0.384)	-2.227 * (1.896)	3.28 [0.07]	29.16 [0.000]	0.009
Netherlands	0.671 *** (2.642)	-0.687 ** (2.155)	2.75 [0.097]	178.25 [0.000]	0.007
Spain	0.527 (1.219)	-0.092 (0.041)	0.008 [0.926]	232.07 [0.000]	0.000
Sweden	1.117 ** (2.327)	-1.976 ** (2.267)	3.19 [0.075]	44.47 [0.000]	0.015
Switzerland	0.449 * (1.777)	-0.333 (1.609)	1.51 [0.218]	379.62 [0.000]	0.004
United Kingdom	0.498 * (1.653)	-2.303 *** (4.709)	27.71 [0.000]	1037.99 [0.000]	0.072
United States	0.463 * (1.877)	-0.889 ** (2.146)	4.60 [0.032]	152.89 [0.000]	0.012

Note:

(a) OLS estimates, with Newey-West heteroskedasticity and serial correlation consistent covariance matrix estimator, of the regression equation $\Delta s_t^D = \alpha + \beta \Delta i_t + u_t$ where Δs_t^D is the monthly dividend adjusted ex post real stock return and Δi_t is the change in the short-term interest rate. The Datastream dividend adjusted return series are available from 1973.02 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US, and 1982.02, 1987.04 and 1988.05 for Sweden, Spain, and Finland, respectively.
(b)Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) JB denotes the value of the Jarque-Bera normality test. The associated probability is shown in the bracket below.
(d) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Table 1.7.1: Seemingly Unrelated Regressions of dividend adjusted real stock returns against against the change in the short-term interest rate.

Country	α	β	Cor	R^2
Belgium	0.439 * (1.817)	-0.768 *** (2.618)	0.522 ***	0.03
Canada	0.374 (1.576)	-1.164 *** (4.595)	0.766 ***	0.04
Finland	0.707 (1.062)	-3.267 (1.378)	0.224 ***	0.01
France	0.55 * (1.78)	-0.945 ** (2.215)	0.551 ***	0.03
Germany	0.354 (1.398)	-0.604 (1.409)	0.518 ***	0.01
Italy	0.162 (0.438)	-1.108 *** (2.543)	0.348 ***	0.02
Japan	0.075 (0.283)	-1.571 (1.481)	0.381 ***	0.008
Netherlands	0.627 *** (2.645)	-0.379 ** (2.001)	0.675 ***	0.006
Spain	0.415 (1.013)	-0.933 (1.254)	0.356 ***	0.00003
Sweden	0.823 * (1.932)	-1.236 (1.373)	0.271 ***	0.01
Switzerland	0.402* (1.712)	0.039 (0.248)	0.639 ***	0.001
United Kingdom	0.461 (1.586)	-1.697 *** (5.819)	0.645 ***	0.067
United States	0.434* (1.851)	-0.824 *** (3.398)	1.000	0.011

Note:

(a) SUR estimates of system $\Delta s_{j,t}^D = \alpha_j + \beta_j \Delta i_{j,t} + u_{j,t}$ where Δs_t^D is the dividend adjusted monthly ex post real stock return and Δi_t is the change in the short-term interest rate. The estimates of the cross-equation covariance matrix are based upon parameter estimates of the unweighted system.The Datastream dividend adjusted return series are available from 1973.02 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US, and 1982.02, 1987.04 and 1988.05 for Sweden, Spain, and Finland, respectively.
(b)Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) Cor denotes the correlation coefficient of local country residuals with US residuals.
(d) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Summarising the findings of this section, we obtain a consistent strong negative contemporaneous impact of monetary policy on stock returns in seven sample countries: Belgium, Netherlands, Italy, France, UK, US and Canada. In contrast, the results do not suggest any contemporaneous relationship at the 5% level in Finland, Spain and Japan[31].

[31] See Table A1.8 in Appendix I for a summary of the Tables 1.4-1.7.1 (and Appendix I Tables A1.4-A1.7) related to the statistical significance of the change in the short term interest rate in Eqs. (1.2) -(1.3)'.

Japan is a particularly interesting case given the size of its economy and the huge boom and bust cycle that it experienced in land and stock prices over the end of the 1980s and the beginning of the 1990s. As Okina, Shirakawa and Shiratsuka (2001) point out, from the start of 1989 the Bank of Japan began seriously addressing the question of raising the discount rate, but faced difficulties in persuading the government or the general public on the need to tighten monetary policy. Eventually, Japanese monetary policy start tightening on May 1989, while the bubble was in full swing, but "the economy expanded rigorously even after the official discount rate was raised" and "it took a considerable time for these hikes to have visible effects on money supply and asset prices... Stock prices continued to rise until end-1989, and in 1990 plummeted with a few rebounds on the way" (Okina, Shirakawa and Shiratsuka, 2001, p. 425). Hence, historical experience alone suggests that the effect of policy changes may not be contemporaneous, and lags may be involved in the transmission of monetary policy to asset prices. Taking this into consideration, in the next section we will look at the lagged effect of monetary policy on stock returns, or in other words, the effect of discount rate changes on expected stock returns.

Finally, sensitivity analysis indicates that accounting for non-normality in equity returns generally increases the number of countries with a significant contemporaneous relationship between monetary policy and stock returns. Bootstrap results show that Germany should be included in the list of countries with significant monetary policy betas (and Switzerland in the case of non-dividend adjusted stock returns). Also, comparing single equation OLS estimates, with system SUR estimates, we see that controlling for international stock market correlation affects the monetary policy-stock returns relationship only in Sweden, rendering it insignificant.

1.3.3 Monetary conditions and expected stock returns

The previous section verified a strong negative contemporaneous response of stock markets to increases in the level of interest rates. In the majority of our sample countries, the empirical results suggest that stock returns are generally higher in expansive monetary environments than they are in restrictive environments. In this section we use the Jensen et al. (1996) dummy variable measure of monetary policy and examine whether the monetary environment is an important consideration for investor required returns. We expand on previous work by Jensen et al. (1996), Conover et al. (1999) and Durham (2001) by utilising a more up-to-date dataset and by looking at the robustness of the findings to inclusion of dividend payments in the calculation of stock returns. We estimate Eq. (1.4) using nominal (ΔS_t), real (Δs_t), nominal dividend-adjusted (ΔS_t^D) and real dividend-adjusted stock returns (Δs_t^D):

$$\Delta Q_t = a + \beta D_t + u_t \tag{1.4}$$

where, ΔQ_t is the monthly equity return (ΔS_t, Δs_t, ΔS_t^D, Δs_t^D), and D_t is the directional discount-rate change dummy variable, which takes a value of 1 if the most recent change in the central bank discount rate was an increase and zero if it was a decrease.

Following Jensen et al. (1996), months that include the first rate change in a series are eliminated from the sample. This is done to filter out announcement effects and focus on the relationship between longer-term stock returns and the monetary environment. In essence, we examine whether expected stock returns are time-varying and to some extent predictable, using as an information variable a dummy that represents monetary conditions[32]. The monetary policy variable is an ex-ante measure of monetary conditions, since it is known in advance of the stock returns measurement interval, hence investors could conceivably replicate the results. As Conover et al. (1999) argue, if the observed stock return patterns do not correspond with similar patterns in investor required returns, investors could predict periods of abnormal return performance.

(a) Nominal stock returns

Table 1.8 presents the results from the estimation of Eq.(1.4) using nominal stock returns. The estimated intercepts are all positive and statistically significant, indicating the generally positive return that is expected from stock market investment. The estimated β coefficients associated with the local monetary environment variable are negative and statistically significant in six countries (Finland, France, Italy, Switzerland, UK, US). Hence, for those countries our measure of the stance of monetary policy contains significant information, which can be used to forecast expected stock returns.

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[32] As Patelis (1997) argues, in order to disprove the constant expected returns hypothesis, one has to show that a variable contained in time *t* information set can help predict asset returns at time *t+k*. By deleting the months that include the first discount rate change we filter out the contemporaneous effect of monetary policy on stock returns and focus on whether expected stock returns are time varying and whether the monetary policy variable is a significant predictor of future returns.

Table 1.8: Regressions of nominal stock returns against monetary policy dummy variable.

Country	α	β	F	R^2
Belgium	0.915 *** (2.671)	-0.841 (1.37)	2.29 [0.131]	0.007
Canada	0.989 ** (2.03)	-0.808 (1.065)	1.05 [0.306]	0.006
Finland	2.014 *** (4.16)	-2.266 *** (3.414)	11.55 [0.000]	0.037
France	1.31 *** (3.014)	-1.644 ** (2.157)	5.21 [0.023]	0.016
Germany	0.956 *** (2.456)	-0.896 (1.521)	2.27 [0.132]	0.007
Italy	1.292 *** (2.982)	-1.449 * (1.871)	3.72 [0.044]	0.01
Japan	0.567 * (1.749)	-1.141 (1.478)	2.58 [0.108]	0.007
Sweden	1.232 *** (2.604)	-0.553 (0.811)	0.64 [0.424]	0.002
Switzerland	1.066 *** (3.241)	-1.704 *** (3.013)	9.00 [0.002]	0.025
United Kingdom	1.732 *** (3.966)	-1.431 ** (2.297)	5.14 [0.024]	0.016
United States	1.195 *** (3.853)	-1.401 *** (2.702)	7.61 [0.006]	0.021

Note:

(a) OLS estimates, with Newey-West heteroskedasticity and serial correlation consistent covariance matrix estimator, of the regression equation $\Delta S_t = \alpha + \beta D_t + u_t$ where ΔS_t is the monthly nominal stock return and D_t is a dummy variable equal to 1 if the most recent change in the central bank discount rate was an increase and 0 if it was a decrease. The data excludes months when changes occurred in local monetary policy. Also excluded are months when the central bank discount rate was pegged to a market rate than being set by the central bank itself. This results in elimination of data for Canada from March 1980 to December 1993. The discount rate data for Belgium, France, Finland, Germany, Italy (Euro members) ends on December 1998. Thereafter, the dummy variable for these countries was calculated using the ECB refinancing rate.
(b) Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Particularly, we find that restrictive (expansive) monetary policy stance decreases (increases) expected stock returns. The largest expected return differences are observed in Finland and Switzerland. On an annualized basis, the expected returns in expansive monetary environments exceeded the expected returns in restrictive environments for these countries by approximately 27% and 20%, respectively. These differences exceed the difference of approximately 17% exhibited by the UK, US stock markets. Especially strong statistical relationships are observed for three of the eleven countries under investigation[33]. Specifically, the discount rate dummy coefficient is significant at the 1% level in Finland, Switzerland and the US. In Belgium, Canada, Germany, Japan and Sweden expected stock returns appear to be unrelated to local monetary conditions[34].

(b) Real stock returns

In order to examine whether expected returns net of inflation differ significantly across monetary environments, we estimate Eq. (1.4) using real stock returns. The results in Table 1.9 indicate that the negative relationship between monetary tightening and expected stock returns is significant at the 10% level in Belgium and Germany; 5% level in France, Italy and Japan; and 1% level in Finland, Switzerland, UK and US. In the UK and US stock markets the annualised difference in real stock returns across expansive and restrictive environments is approximately 20%. Comparing the results in Tables 1.8-1.9 we see that the number of countries with a statistically significant β increases from six to nine. A notable addition to the list of countries with significant β's is Japan, where real expected returns differ by about 21% across periods of expansive and restrictive monetary policy. Our results agree with previous evidence by Conover et al. (1999) in that, in those countries where there is a significant relationship between local monetary conditions and expected nominal stock returns, there is also a significant relationship between local monetary policy and expected real stock returns.

(c) Dividend adjusted stock returns

Tables 1.10 and 1.11 present the results from the estimation of Eq. (1.4) using dividend adjusted nominal and real stock returns, respectively. In the case of nominal returns all intercepts are significantly positive and higher in value (compared to when dividend payments are excluded). The slope coefficient is negative and statistically significant in seven of the eleven sample countries.

[33] Recall that Spain and Netherlands are excluded from the empirical analysis in this section, due to the lack of adequate number of discount rate observations in the Datastream series.
[34] We should mention, though, that as Conover et al. (1999) point out, tests of significance of the monetary environment variable are actually joint tests of the hypotheses that the monetary policy variable effectively differentiates monetary conditions, and that the monetary environment is related to stock returns. Thus, an

Table 1.9: Regressions of real stock returns against monetary policy dummy variable.

Country	α	β	F	R^2
Belgium	0.57 (1.519)	-0.923 * (1.442)	2.73 [0.099]	0.009
Canada	0.646 (1.317)	-0.948 (1.244)	1.43 [0.232]	0.008
Finland	1.722 *** (3.528)	-2.752 *** (4.13)	16.88 [0.000]	0.054
France	0.852 * (1.982)	-1.751 ** (2.199)	5.837 [0.016]	0.018
Germany	0.751 * (1.926)	-1.074 * (1.828)	3.22 [0.073]	0.01
Italy	0.783 * (1.736)	-1.889 ** (2.074)	6.34 [0.012]	0.017
Japan	0.394 (1.381)	-1.731 ** (2.049)	5.88 [0.015]	0.016
Sweden	0.893 * (1.88)	-0.858 (1.244)	1.51 [0.21]	0.004
Switzerland	0.911 *** (2.758)	-1.976 *** (3.437)	11.83 [0.000]	0.037
United Kingdom	1.206 *** (3.075)	-1.631 *** (2.618)	6.76 [0.009]	0.022
United States	0.918 *** (2.939)	-1.695 *** (3.227)	10.89 [0.001]	0.031

Note:

(a) OLS estimates, with Newey-West heteroskedasticity and serial correlation consistent covariance matrix estimator, of the regression equation $\Delta s_t = \alpha + \beta D_t + u_t$ where Δs_t is the monthly ex post real stock return and D_t is a dummy variable equal to 1 if the most recent change in the central bank discount rate was an increase and 0 if it was a decrease. The data excludes months when changes occurred in local monetary policy. Also excluded are months when the central bank discount rate was pegged to a market rate than being set by the central bank itself. This results in elimination of data for Canada from March 1980 to December 1993. The discount rate data for Belgium, France, Finland, Germany, Italy (Euro members) ends on December 1998. Thereafter, the dummy variable for these countries was calculated using the ECB refinancing rate.
(b) Absolute t-statistics are presented in parentheses beneath the coefficient estimates.
(c) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Comparing Tables 1.8 and 1.10, it is evident that inclusion (or exclusion) of dividend payments in the returns calculation doesn't affect the negative relationship between monetary policy tightening and expected stock returns in Finland, France, Italy, Switzerland, UK and US. The strongest statistical relationship is observed in Finland, where β is equal to -3.784 and significant at the 1% level. The regression R^2 for Finland

insignificant dummy coefficient may reflect either a flow in the monetary variable, or that stock returns are genuinely unrelated to monetary conditions.

indicates that the local monetary policy variable explains approximately 5% of the variation in expected stock returns.

Table 1.10: Regressions of dividend adjusted nominal stock returns against monetary policy dummy variable.

Country	α	β	F	R^2
Belgium	1.177 *** (3.007)	-0.492 (0.848)	0.72 [0.396]	0.002
Canada	1.352 *** (2.856)	-0.802 (1.116)	1.16 [0.281]	0.006
Finland	2.634 *** (3.281)	-3.784 *** (2.456)	6.73 [0.01]	0.051
France	1.671 *** (3.781)	-1.389 * (1.863)	3.47 [0.063]	0.011
Germany	1.212 *** (3.191)	-0.994 * (1.777)	3.013 [0.083]	0.009
Italy	1.613 *** (3.64)	-1.331 * (1.658)	2.97 [0.085]	0.008
Japan	0.618 * (1.872)	-1.086 (1.423)	2.29 [0.13]	0.006
Sweden	1.346 *** (2.33)	-0.285 (0.294)	0.08 [0.771]	0.0003
Switzerland	1.131 *** (3.733)	-1.257 ** (2.319)	5.542 [0.019]	0.015
United Kingdom	2.066 *** (4.73)	-1.275 ** (2.064)	4.13 [0.042]	0.013
United States	1.353 *** (4.354)	-1.133 ** (2.186)	4.981 [0.034]	0.014

Note:

(a) OLS estimates, with Newey-West heteroskedasticity and serial correlation consistent covariance matrix estimator, of the regression equation $\Delta S_t^D = \alpha + \beta D_t + u_t$ where ΔS_t^D is the monthly dividend adjusted nominal stock return and D_t is a dummy variable equal to 1 if the most recent change in the central bank discount rate was an increase and 0 if it was a decrease.The data excludes months when changes occurred in local monetary policy. Also excluded are months when the central bank discount rate was pegged to a market rate than being set by the central bank itself. This results in elimination of data for Canada from March 1980 to December 1993. The discount rate data for Belgium, France, Finland, Germany, Italy (Euro members) ends on December 1998. Thereafter, the dummy variable for these countries was calculated using the ECB refinancing rate. The Datastream return series are available from 1973.02 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US, and 1982.02, 1987.04 and 1988.05 for Sweden, Spain, and Finland, respectively.

(b) Absolute t-statistics are presented in parentheses beneath the coefficient estimates.

(c) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

Finally, Table 1.11 shows that tighter monetary policy is associated with lower expected real returns, even after we adjust them for dividend payments. The slope coefficient is negative and statistically significant at the 5% level in eight of the eleven sample countries. The results are broadly consistent with the argument that monetary conditions are related to investor required returns. If monetary authorities tend to follow expansive policies when the economy is weak, then investors may require higher rates of return to invest in the stock market.

Table 1.11: Regressions of dividend adjusted real stock returns against monetary policy dummy variable.

Country	α	β	F	R^2
Belgium	0.841 ** (2.155)	-0.579 (0.988)	0.98 [0.322]	0.003
Canada	1.01 ** (2.109)	-0.942 (1.302)	1.59 [0.20]	0.009
Finland	2.492 *** (3.067)	-3.998 *** (2.581)	7.39 [0.007]	0.056
France	1.213 *** (2.789)	-1.496 ** (1.998)	3.993 [0.046]	0.012
Germany	1.019 *** (2.678)	-1.18 ** (2.091)	4.19 [0.041]	0.013
Italy	1.112 *** (2.525)	-1.779 ** (2.223)	5.34 [0.021]	0.015
Japan	0.453 (1.558)	-1.685 ** (1.99)	5.46 [0.019]	0.016
Sweden	1.055 (1.542)	-0.411 (0.42)	0.17 [0.677]	0.0007
Switzerland	0.978 *** (3.215)	-1.529 *** (2.774)	8.02 [0.004]	0.002
United Kingdom	1.64 *** (3.857)	-1.475 *** (2.39)	5.61 [0.017]	0.018
United States	1.076 *** (3.439)	-1.427 *** (2.724)	7.748 [0.005]	0.022

Note:

(a) OLS estimates, with Newey-West heteroskedasticity and serial correlation consistent covariance matrix estimator, of the regression equation $\Delta s_t^D = \alpha + \beta D_t + u_t$ where Δs_t^D is the monthly dividend adjusted ex post real stock return and D_t is a dummy variable equal to 1 if the most recent change in the central bank discount rate was an increase and 0 if it was a decrease. The data excludes months when changes occurred in local monetary policy. Also excluded are months when the central bank discount rate was pegged to a market rate than being set by the central bank itself. This results in elimination of data for Canada from March 1980 to December 1993. The discount rate data for Belgium, France, Finland, Germany, Italy (Euro members) ends on December 1998. Thereafter, the dummy variable for these countries was calculated using the ECB refinancing rate. The Datastream return series are available from 1973.02 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US, and 1982.02, 1987.04 and 1988.05 for Sweden, Spain, and Finland, respectively.

(b) Absolute t-statistics are presented in parentheses beneath the coefficient estimates.

(c) ***, **, * denote the 1, 5, and 10 percent level of significance respectively.

1.4 Conclusions

This chapter examined the relationship between stock returns and monetary conditions providing a link between the macroeconomics literature, that views interest rates as indicators of the monetary policy stance, and the finance literature that uses interest rates to interpret stock market movements. The existence of such a relationship has important implications for both stock market participants and central bankers since, with respect to the former this issue relates to the broader topic of stock price determination and portfolio formation, while the latter are interested in whether monetary policy actions are transmitted through financial markets. Our proxies for shifts in monetary policy are based on interest rate variables including the change in the short-term Treasury Bill rate and a dummy variable reflecting discount rate changes. Our main contribution to the existing literature is that when we examine the impact of interest rate changes on stock price changes, we take into account the non-normal distribution of stock returns as well as the co-movement in international stock markets. The results suggest that in the majority of the countries under investigation, periods of tight money are associated with contemporaneous declines in stock market value. These findings can be understood in the context of the present value model, whereas interest rate increases are associated with lower stock prices via higher discount rates and lower future cash flows.

Another important result is that following monetary policy changes, not only contemporaneous but also future stock returns, across a variety of returns specifications, are affected. Hence, our interest rate measure of monetary policy contains significant information that can be used to forecast expected stock returns. Specifically, we find that in most sample countries a restrictive (expansive) monetary policy stance decreases (increases) expected stock returns. Such shifts in required returns do not necessarily contradict market efficiency since central banks often adopt expansive monetary policy when there is increased concern of an economic downturn. Hence, the finding that during these periods investors require higher returns to invest in the stock market may be a reasonable expectation after all. The practical implication of our results is that investors should be aware of the international diversification opportunities across countries with different monetary environments, while central bankers should keep in mind that interest rate decisions have important effects on stock market wealth.

Chapter 2

Modelling Inflation, Uncertainty and the Impact of Inflation Targeting

2.1 Introduction

In the 1990's a number of countries adopted explicit inflation targeting (IT) monetary policy frameworks. Over the same period, their inflation rates became lower and less variable. The reduction in inflation and inflation variance seems to be more generalised since it is observed both in countries where formal targets are in use and in non-targeting countries. Cecchetti and Ehrmann (2000) argue that over the last decade, aversion to inflation variability increased in all major economies irrespective of whether they were operating under explicit IT or not. Higher non-forecastable inflation variability increases inflationary uncertainty and induces significant economic costs by distorting the intertemporal and intratemporal allocation decisions of individuals and firms, by re-distributing wealth between debtors and creditors, and by reducing the effectiveness of relative prices in co-ordinating economic actions.

Friedman (1977) suggests a positive correlation between the level of inflation and inflation uncertainty, with higher inflation leading to greater uncertainty and lower output growth. Ball (1992) formalises Friedman's argument in the context of an asymmetric information game between the public and the policy maker. The empirical relationship between average inflation and inflation uncertainty has been studied extensively throughout the last three decades, with the results largely accepting the Friedman-Ball prediction. Thus, policies that lower average inflation lead to lower inflation uncertainty with apparent economic benefits. A key question that arises is whether explicit IT leads to a greater decrease in inflation uncertainty, as compared to the case where formal targets are not announced. Targets have an independent role if they help to anchor inflation expectations and to produce an additional decline in inflation uncertainty. Johnson (2002) finds that formal targets reduce expected inflation but bring no additional benefits in the form of lower uncertainty.

In this chapter we take a closer look at the effect of IT on average inflation and inflation uncertainty using British data over the period 1972-2002. The United Kingdom (UK) was among the first major economies to adopt explicit targeting in October 1992. We employ a variety of GARCH related models to account for time-varying inflation volatility. GARCH techniques are popular in empirical investigations of the inflation-uncertainty relationship, since the estimated conditional volatility can serve as a proxy for uncertainty. Furthermore, GARCH-in-mean (GARCH-M) specifications augmented by lagged inflation allow for the possibility of a simultaneous feedback relationship between inflation and uncertainty. In addition, given the importance of long-run price stability, we use Component GARCH models to decompose inflation uncertainty into a temporary a permanent component and examine whether past inflation and IT affect long-run uncertainty. The results have important implications for the design of monetary policy given the decade-long targeting experience. This chapter's major contribution to the existing literature is the finding that, even if we take into account the indirect effect of lower average inflation, the adoption of formal targeting exerts a direct negative impact on long-run uncertainty, thereby promoting macroeconomic stability.

The rest of the chapter is organised as follows. The next section discusses the serious economic consequences of inflation uncertainty. Sections 2.3 and 2.4 provide an overview of the various sources of inflation uncertainty, and its empirical measures, respectively. Section 2.5 describes the UK inflation data to be employed, and section 2.6 contains the empirical models and results. Section 2.7 provides conclusions and policy implications.

2.2 Consequences of Inflation Uncertainty

Economists often argue that uncertainty about the future rates of inflation is a major source of the welfare costs associated with inflation. Even perfectly foresighted inflation induces a welfare loss via the cost of economising on real money balances ('shoe leather' costs), the cost of operating in a less-than-perfectly indexed tax system and the cost of constantly revising price lists (menu costs) along with the increased variability in relative prices, among others[1]. Feldstein (1996) quantifies the first two costs of fully anticipated inflation for the U.S. economy, and concludes that the annual welfare cost of an inflation rate of 2 percent, rather than zero, is a surprisingly large 1 percent of GDP[2]. Bakshi et al. (1997) replicate Feldstein's analysis for the U.K. and conclude that the above effects are indeed significant, but smaller in magnitude due to differences in the tax system between the two countries.

Up till recently however, these costs of fully anticipated inflation were thought to be less important than the costs of unanticipated inflation. It is generally accepted that when contracts are written in nominal terms unexpected inflation enhances the relative position of debtors, while worsening the relative position of creditors. Another line of reasoning stresses the effects of unexpected inflation on the intra-generational distribution of wealth, with the re-distribution effect running from older people (which are more likely to be net-creditors) to younger people (net-debtors). When inflation is unexpected, risk-averse economic agents will incur a loss, even if prices and quantities are fully flexible in all

[1] For a further discussion of the costs of inflation see Driffill, Mizon, and Ulph (1990).
[2] Most of this cost derives from the distortion of the intertemporal allocation of consumption caused by the inflation-induced reduction in the real rate of saving.

markets, because the efficiency of the resources allocation system will deteriorate. In addition, unexpected inflation reduces the real value of government liabilities held by the public (wealth effect). Stultz (1986) argues that investors whose real wealth depreciates unexpectedly rebalance their portfolios and reduce the real value of their equity investment. Modigliani and Cohn (1979) suggest that "money illusion" effects, working via unexpected inflation, affect negatively the stock market. In particular, unexpected inflation is likely to increase nominal interest rates and if investors discount expected future earnings at these higher rates, ignoring the positive effect of inflation on nominal earnings, stocks will be under-valued. Increased inflation uncertainty implies higher unexpected inflation realisations, thus the costs associated with unexpected inflation will be more pronounced. Hu and Willett (2000) find that real stock returns in the US are negatively affected by inflation uncertainty.

Following Golob (1993), the effects of inflation uncertainty can be categorised into ex post and ex ante effects. Ex ante, inflation uncertainty is thought to affect financial markets by raising required rates of return on debt. Higher expected returns imply higher long-term interest rates, which in turn decrease consumption and investment spending. Another related argument stresses the spillover of uncertainty in inflation to interest rates and other economic variables. Inflation uncertainty might (and probably will) be incorporated into interest rates uncertainty, thus affecting the intertemporal allocate decisions made in the economy. Berument (1999) shows that in the UK both expected inflation and inflation risk positively affect the 3 month Treasury Bill rate.

Increased short-term interest rate uncertainty might encourage firms and consumers to finance their investment and saving decisions with long-term fixed rate debt, in order to avoid the risk of increases in short-term rates. Since long-term rates are typically higher than short-term rates, employment of long-term debt causes financing costs to increase, and therefore lowers investment. Also, in the absence of tax indexation, inflation uncertainty implies tax rates uncertainty. Generally, the saving and investment decisions of individuals and firms will be distorted by inflation uncertainty, since it causes the real value of future nominal payments to be unknown.

As Huizinga (1993) argues, in a world of nominal rigidities, inflation may affect intratemporal allocation decisions via its effects on: uncertainty about the real cost of various production factors, and uncertainty about the relative price of various final goods. In Huizinga's model, the transmission mechanism for the link between inflation uncertainty and investment is uncertainty about the real net present value of capital expenditures[3]. Lucas (1973) assumed imperfect information and no nominal rigidities to argue that the sensitivity of economic agent's actions to price signals can be dependent on the amount of inflation uncertainty.

In an uncertain inflation environment, firms will be devoting part of their resources to forecast and/or hedge against inflation which results to substantial distortions in the efficiency of resource allocation. Additionally, ex post, unexpected inflation causes a redistribution of wealth from net creditors to net debtors if contracts are written in nominal terms (Kessel and Alchian, 1959). When inflation uncertainty is higher, risk averse individuals will attempt to shorten the duration of contracts, in order to reduce the risk of welfare loss cause by deviations of actual from expected inflation. Contracts will be more frequently negotiated, thus diverting economic resources from other more efficient uses, to the contracting process. In the context of the stock market, according to the nominal contracting hypothesis, unexpected inflation should be negatively related to the equity value of a firm with a positive level of nominal contracts. Empirical evidence, however, on this topic is rather mixed[4].

Milton Friedman (1977) in his Nobel lecture stressed that increased inflation uncertainty reduces the effectiveness of relative prices in co-ordinating economic actions, by making it more difficult to distinguish between nominal and relative price changes, and may adversely affect real economic activity. The more uncertain inflation is, "the harder it becomes to extract the signal about relative prices from the absolute prices... at the extreme, the system of absolute prices becomes nearly useless...agents resort either to an alternative currency or to barter, with disastrous effects to productivity"[5] (Friedman , 1977, p. 467). The distortions in the economic system, that inflation uncertainty produces, affect negatively the efficiency of resource allocation and the level of real activity. Friedman argued that stagflation scenario of the 1970's reflected "temporary" deviations from a vertical Phillips curve due to higher inflation uncertainty.

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[3] See also Abel (1983), Hartman (1972), Bernanke (1983) and Pindyck (1991) among others, for theoretical and empirical work on the investment - inflation uncertainty link.

[4] Pearce and Rolley (1988) and Bernard (1986) argued that the nominal contracting hypothesis is empirically significant in explaining stock price behaviour. French, Ruback and Schwert (1983), on the other hand, find little evidence corroborating a positive effect of unexpected inflation on the stock returns of firms with relatively large net monetary liabilities (net debtors).

[5] Similar arguments are presented in Lucas (1973). It should be also emphasised that, in his analysis, Friedman refers to the terms "inflation variability" and "inflation uncertainty" interchangeably, while as we see in the next part of the paper these two terms are not necessarily identical.

Friedman's insight of how unexpected changes in wages-prices affect the economy's real equilibrium was given an explicit theoretical foundation by Lucas (1972). In Lucas's model economic agents face a signal extraction problem due to imperfect information about the current money supply. Unpredictable short-run fluctuations in money may cause output and employment movements (see also Barro, 1978). However, empirical evidence by Mishkin (1982) and others showed that, contrary to Lucas's prediction of "policy irrelevance", both anticipated and unanticipated money appear to influence real economic activity in the short-run. Nowadays, the general consensus on the effect of inflation on the real economy, can be well summarised by Taylor's (1996) first proposition, "about which there is now little disagreement ... is that there is no long-run trade off between the rate of inflation and the rate of unemployment" (Taylor, 1996, p. 186). Taylor's second proposition is that there is a short-run trade off between the variability of inflation and the variability of unemployment. There is vast empirical evidence concerning the effects of inflation uncertainty on real activity, measured either by employment or by output. U.S. studies with no assumption of fixed parameters for the inflation process tend to find a negative relationship between inflation uncertainty and real activity[6]. Closing the discussion of the consequences of inflation uncertainty, we should also point out the important social costs of inflation. As Fischer (1996) argues, the social costs have been less comprehensively catalogued and established, but these too contribute importantly to the public's dislike of high inflation. Evidence from opinion polls suggests that high inflation is politically unpopular, and history confirms that high inflation rates are disruptive to the society, since they are associated with political and social disorder.

2.3 Sources of Inflation Uncertainty

2.3.1 Friedman-Ball link

Inflation uncertainty is related to various monetary and non-monetary factors, such as uncertainty about price shocks and real shocks, uncertainty about money supply growth and its inflationary effects, the credibility of inflation targeting and other anti-inflationary policies, and relative-general price variability. Friedman (1977) claimed that there is a

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[6] See among others, Zarnowitz and Lambros (1987), Holland (1986), (1988), Evans and Wachtel (1993).

positive correlation between inflation rates and inflation uncertainty with the causation running from inflation to uncertainty about future inflation: "A burst of inflation produces strong pressure to counter it. Policy goes from one direction to the other, encouraging wide variation in the actual and anticipated rate of inflation ... Everyone recognizes that here is greater uncertainty about what actual inflation will turn out to be over any specific future interval ..." (p. 466). Friedman's hypothesis implies a positive relation between inflation and inflation uncertainty, which eventually depresses real activity, leading to a positively sloped Phillips curve. The idea that a rise in the level of inflation raises uncertainty about future inflation is also central in Okun's (1971) work. Employing a rather simple statistical analysis, Okun found that countries with high inflation generally had more variable inflation. Okun interpreted the higher variability as an indication of higher uncertainty.

Ball (1992) formalised Friedman's arguments in the context of an asymmetric information game between the public and the policy maker. Ball, following Alesina (1987), captures policy uncertainty by assuming that there are two types of policy-makers who alternate in power stochastically. The public knows that one type of policy-maker is willing to bear the cost of disinflation policies (Conservative–C), while the other is not (Liberal – L). Hence, L's loss function includes both unemployment and inflation, while C's includes only inflation:

$$Z_t^L = (U_t - U_0)^2 + \alpha\pi_t^2 \tag{2.1}$$

$$Z_t^C = \pi_t^2 \tag{2.2}$$

where, U is actual unemployment, U^0 is socially optimal unemployment, π is the inflation rate and α is a taste parameter.

A short-run Phillips curve determines the time series evolution of unemployment:

$$U_t = U^N - (\pi_t - \pi_t^e), \quad U^N = U^0 + 1 \tag{2.3}$$

where, U^N denotes the natural rate of unemployment, and π_t^e is expected inflation at t conditioned on the information at t-1 [7].

[7] Since $U^N > U^0$ there is a time-consistency problem that leads to inflation.

Ball (1992) assumes the following time-sequence of events: at the start of each period the public forms rational expectations of inflation, then the policy maker is determined and sets the target for inflation by minimising the expected present value of the loss function, putting equal weights on all periods when is in power and not. Thus, the central bank doesn't have perfect control over inflation (see also Canzoneri, 1985) and actual inflation (π) is determined only after the inflation shock (e) materialises:

$$\pi_t = \pi_t^* + e_t \qquad (2.4)$$

where, π^* is target inflation, and e is a white noise monetary control error, unobservable by the public.

The policy makers switch to power by a Markov process: if L is at power at t-1 then the probability that L remains in power at t is (1-c), while the probability of replacement by C is c. If at time t-1 the inflation rate remains bellow a positive bound π^b, then at t π^* is zero irrespective of which policy maker prevails. Hence, there is no uncertainty about π^* because both C and L target zero inflation. In this case, the conditional variance of inflation, $E_{t-1}[(\pi_t - \pi_t^e)^2]$, is equal to the constant variance of the monetary control error term: $E_{t-1}[e_t^2] = \sigma^2$. If, however, at time t-1 the policy maker is L with inflation above π^b, then at t the inflation target is equal to: $\pi^+ > \pi^b$, if L remains in power, and zero, if C comes to power. Compared to the previous case, expected inflation at t increases (from zero) to: $\pi^+ (1-c)$, while the variance of inflation increases (from σ^2) to : $c(1-c)\ (\pi^+)^2 + \sigma^2$. Consequently, higher inflation rates imply higher inflation uncertainty via the uncertainty concerning the future monetary stance.

Ball essentially shows that there is a positive relationship between the conditional mean and the conditional variance of inflation, with the causality running from the mean to the variance of inflation. A shortcoming of the Ball's model is that high inflation creates uncertainty only about disinflation, while in actual economies it appears that high inflation creates uncertainty about whether it will keep rising. The models of Evans and Wachtel (1993), and Holland (1993) also suggest that higher inflation uncertainty is part of the inflation welfare costs, since inflation precedes (Granger causes) inflation uncertainty. While Ball examined the effect of regime uncertainty, Holland's alternative explanation for the positive effect of inflation on inflation uncertainty considered the case in which agents are unsure about the price-level effects of a given change in the quantity of money. This type of uncertainty arises because the length of nominal contracts and the degree of indexation change over time. In Holland's model unexpected inflation is positively related to the squared root of expected inflation. During the post war period, inflation rates have been almost always positive, thus the correlation between inflation rates and the level of uncertainty has been positive[8].

Empirical evidence by Holland (1995) for the U.S., and Grier and Perry (1998) for the all the G7 countries during the post war period, suggests that, in agreement with the Friedman-Ball hypothesis, inflation Granger causes inflation uncertainty. Additional evidence supporting the Friedman-Ball hypothesis in the context of the U.S. economy has been provided by Bruner and Hess (1993) and Golob (1993) among others. Contrary to these studies, Fischer (1981), Cosimano and Jansen (1988), Baillie et al. (1996), find that the relationship between inflation and inflation uncertainty in the U.S. is insignificant. Finally, evidence by Joyce (1995), and Crawford and Kasumovich (1996) for the U.K. and Canada, respectively, yielded mixed results.

2.3.2 Cukierman - Meltzer link

Theoretical work by Cukierman and Meltzer (1986) and Cukierman (1992) suggests that the causality runs from inflation uncertainty to inflation. Reversing the causality link of the Friedman-Ball argument, they show that higher inflation uncertainty will raise the optimal inflation rate. Both studies build upon the traditional Barro-Gordon framework: the policymaker maximises his own (politically motivated) objective function that is positively related to economic stimulation through monetary surprises and negatively related to monetary growth. The relative weights assigned to each target evolve stochastically over time. The money supply process is also random, due to imprecise monetary control procedures. Thus, the public faces an inference problem when trying to distinguish between persistent changes in the objectives, and transitory monetary control errors. An increase in uncertainty about money growth and inflation provides the policymaker with an incentive to create an inflation surprise to stimulate real activity leading to a positive correlation between uncertainty and optimal average inflation.

[8] Holland's model allows for a "stabilisation motive", i.e. an increased incentive to lower the inflation rate in order to lower also the resulting uncertainty and the real economic costs that accompany it.

Empirical evidence in favour of the Cukierman and Meltzer causality link is rather scarce. Fountas et al. (2000) employing monthly U.S. data provide strong evidence supporting a positive effect of changes in inflation uncertainty on inflation. Grier and Perry (1998) obtain similar results only for a sub-sample of their G7 countries sample (namely Japan and France).

2.3.3. Dereveux link

Dereveux (1989) also starts with the Barro-Gordon model to argue that a link between the inflation rate and the inflation uncertainty arises because of real disturbances. In order to show it, a stochastic element is added to money growth, and workers are assumed to endogenously choose the degree of wage indexation. Larger real shocks reduce the optimal degree of wage indexation. Thus, since less indexing renders surprise inflation more effective, the incentives of monetary policy to create surprise inflation increase. Unlike the Friedman-Ball and the Cukierman and Meltzer explanations, in Dereveux's model the link between inflation rates and inflation uncertainty is not causal but depends mainly on real shocks (output uncertainty).

2.4 Measuring Inflation Uncertainty

Unlike the inflation rate, inflation uncertainty is a non-directly observable variable, therefore in empirical investigations of the inflation-uncertainty relationship, a measure for uncertainty needs to be constructed.

2.4.1. Unconditional volatility measures of uncertainty

A usual practise in the early studies of the 1970's and 1980's was to proxy inflation uncertainty by the unconditional variance of (observed) inflation. In the first empirical study on this topic, Okun (1971), using a sample of seventeen industrial countries for the period 1951-1968, found a high positive correlation between the average rate of inflation and its variability. Additional cross-country evidence supporting Okun's findings was provided by Logue and Willett (1976), Logue and Sweeney (1981), and Taylor (1981) among others. This evidence however, concerns the relationship between the cross-sectional mean and variance of inflation and how it varies over time, thus it is of little relevance in supporting the theories that relate the time-series variance of inflation and its mean.

Furthermore, cross-sectional analysis implicitly assumes homogeneity over time both across countries and within countries. According to Gale (1981), this assumption is rather questionable. Fischer (1981) and Katsimbris (1985) used a moving average inflation rate (either overlapping or non-overlapping) and the corresponding moving standard deviation, in to provide time series evidence for the inflation-uncertainty relation on a country-by-country basis. Fischer's results indicate a positive link between inflation and his proxy for uncertainty, while Katsimbris found no significant relation for the majority of the countries into consideration.

The employment of inflation variability as a proxy for inflation uncertainty has been widely criticised. As Driffill et al. (1990) point out, " ... the fact that inflation is variable does not mean that it is unpredictable: variability and uncertainty are distinct properties". Higher inflation variability implies higher uncertainty if and only if agents do not possess the relevant information to predict part of the increased variability. For instance, if agents possess enough information to predict a change in monetary policy, then, even though the unconditional variance of inflation increases, the uncertainty accompanying it is indeed very small. It is the unpredictable part of inflation volatility that seriously affects the efficiency of the economic system. Studies of the type cited above don't distinguish between predictable and unpredictable volatility, thus their results should be interpreted with extra cautiousness.

2.4.2 Survey-based measures of uncertainty

Apart from volatility measures, survey based measures have often been used to proxy inflation uncertainty. When using survey data, there are two major techniques to proxy inflation uncertainty. One approach proxies uncertainty by the variance of inflation forecasts across individual respondents to surveys on expected inflation. Uncertainty will be low when the survey participants' expectations on future inflation are similar, and vice versa. In the context of this approach, the surveys that have typically been used in the U.S., are the Livingston survey of professional economic forecasters and the Michigan University's SRC (Survey Research Center) survey of households. Studies based on these surveys tend to find a positive relationship between inflation and inflation uncertainty (see for instance, Cukierman and Wachtel, 1979, Fischer, 1981, Holland, 1995). More recently, Johnson (2002) measured uncertainty as the standard deviation of individual forecasts within a calendar year, and as the average next-year forecast error and finds a strong positive link between past inflation and current uncertainty in line with the Friedman-Ball view. Johnson (2002) analysed five inflation-targeting, and six non-targeting countries using data from the *Consensus Forecasts*, and its predecessor, *Economic Forecasts: a monthly worldwide survey.*

An alternative approach in measuring uncertainty from survey data is advocated by Zarnowitz and Lambros (1987). They pointed out that a proxy for inflation uncertainty should not be based on the standard deviation of forecasts, since it provides only a measure of the heterogeneity of expectations across individual forecasters. Their preferred measure of uncertainty the average size of the confidence interval for individual inflation forecasts. The respondent with a wider confidence interval is presumed to be more uncertain, and vice versa. Zarnowitz and Lambros employed data from the ASA-NBER Survey of Professional Forecasters (SPF), which, in addition to point forecasts, asks each participant to assign a probability to his/her forecast. Their evidence suggests a positive relation between inflation and inflation uncertainty. More recently, Giordani and Soderlind (2000) re-examined the statistical properties of the SPF data over the period 1969-99, and certified Zarnowitz and Lambros' empirical finding.

2.4.3 Conditional volatility measures of uncertainty

(a) *Fixed Parameters in the Inflation Process*

Ever since Engle's (1982) seminal paper on ARCH modelling of U.K. inflation, and the subsequent GARCH extension by Bollerslev (1986), ARCH and GARCH, techniques have been very popular in proxying inflation uncertainty. In the context of these models, the estimated one-step-ahead conditional variance of inflation serves as a proxy for the unobservable inflation uncertainty. More specifically, the ARCH(q) model specifies the conditional mean of inflation, π_t / I_{t-1} , as a function of a vector of explanatory variables, X_{t-1}, while the conditional error variance, h_t, is a function of lagged values of the squared forecast errors:

$$\pi_t \mid I_{t-1} \sim N(\gamma X_{t-1}, h_t) \tag{2.5}$$

$$E(\varepsilon^2_t \mid I_{t-1}) = h_t = \alpha_0 + \Sigma_{i=1}^{q} \alpha_i \varepsilon^2_{t-i} \tag{2.6}$$

$$\varepsilon_t = \pi_t - \gamma X_{t-1} \tag{2.7}$$

where, I_{t-1} is the information set at time t-1, ε_t is the the one-period forecast error, and the elements of vector γ and the α's are parameters to be estimated by maximum likelihood. The parameters in the conditional variance Eq. (2.6) should satisfy the following restrictions in orders for the conditional variance to be positive and covariance-stationary:

$$\alpha_0 > 0 \ , \quad 0 \leq \Sigma_{i=1}^{q} \alpha_i < 1 \tag{2.8}$$

If $\alpha_i = 0$, for $i = 1..q$, then Eq. (2.6) collapses to the standard homoskedastic specification for the conditional error variance: $h_t = \alpha_0$ (constant). Eq. (2.6) implies that inflation uncertainty, proxied by the conditional variance of inflation, h_t, will increase if periods with large forecast errors are grouped together. Thus, if there a positive relationship between the absolute size of forecast errors and the level of inflation, there will also be a positive relationship between inflation uncertainty and the level of inflation.

It is often the case that long lag processes for the squared residual in (2.6) are needed to capture the inflation dynamics. The GARCH(p,q) model by Bollerslev (1986) extended Engle's original work by allowing the conditional variance to follow an ARMA(p,q) process:

$$h_t = \alpha_0 + \Sigma_{i=1}^{q} \alpha_i \varepsilon^2_{t-i} + \Sigma_{j=1}^{p} \beta_j h_{t-j} \tag{2.9}$$

In order to model the conditional variance of U.S. inflation, Bollerslev employed a GARCH(1,1) model, which corresponds to an ARCH(∞) with geometrically declining weight:

$$h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} \tag{2.10}$$

where, the conditional variance positivity and stationarity restrictions imply that:

$$\alpha_0 > 0 , \quad 0 \leq \alpha_1 + \beta_1 < 1 \tag{2.11}$$

The presence of the autoregressive term (h_{t-1}) in the conditional variance Eq. (2.10) implies that the impact of inflation shocks declines geometrically over time. The GARCH(1,1) model offers a reasonable approximation of a higher order ARCH, and, due to its implicit parsimony, it has been preferred to ARCH specifications in modelling the persistence in inflation uncertainty.

As Grier and Perry (1998) argue, the ARCH-GARCH time varying conditional variance estimates of inflation uncertainty correspond better (than survey or moving standard deviation measures) to the notion of inflation uncertainty as defined in theoretical models, such as the Cukierman and Meltzer (1986) model. In addition, contrary to other measures of inflation uncertainty, ARCH-GARCH specifications allow the researcher to formally test the null hypothesis of a constant uncertainty over the sample period. If the tests for ARCH-GARCH effects accept the null of homoskedasticity, then this is equivalent to accepting the null of constant inflation uncertainty. Finally, as Pagan (1984) showed, the simultaneous conditional mean and variance estimation, implicit in ARCH-GARCH, is more efficient than a two-step process, when working with generated regressors. Studies of the inflation-inflation uncertainty relationship, based on survey or unconditional volatility measures, are typically forced to a two-step estimation process.

As far as the inflation - inflation uncertainty causality puzzle is concerned though, the seminal studies by Engle (1982), (1983) and Bollerslev (1986) simply compared the estimated conditional variance series with the average inflation rate over various periods, rather than performing an formal statistical test of the Friedman hypothesis. The results are mixed. ARCH and/or GARCH effects are usually statistically significant, implying that inflation uncertainty is time varying but there appears to be no systematic relationship between the level of inflation and the measure of inflation uncertainty. For instance Engle (1982) found significant ARCH effects in U.K. inflation over the period 1958-77, and the estimated conditional variance increased substantially, along with the average inflation rate, during the 1970's.

Engle (1983) examined the U.S. inflation rate, and, surprisingly, the estimated conditional variance for the highly inflationary 1970's was not significantly greater than conditional variance of the low-inflation late 1950's and 1960's, and both were well bellow the variances in the late 1940's and early 1950's. Engle's explanation was that, "although the level of inflation in the seventies was high, it was predictable". Thus, contrary to the Friedman-Ball causality link, an increase in the level of inflation does not necessarily lead to an increase in uncertainty. Engle and Kraft (1983) and Bollerslev (1986) reached similar conclusions.

The symmetry restriction on the conditional variance of standard ARCH, GARCH models – implying that "good" and "bad" news have identical effects on volatility- has been criticised by Bruner and Hess (1993). In their view, the assumption that agents become more uncertain about future inflation, whether inflation unexpectedly rises or falls may lead to misleading estimates of inflation uncertainty. Bruner and Hess (1993) and Joyce (1995) pioneered the employment of asymmetric GARCH models in estimating inflation uncertainty. Engle (1990) developed an asymmetric GARCH (AGARCH) model which under certain conditions, allows a negative shock to increase uncertainty by less than positive shock of the same size. For instance, in the context of the AGARCH(1,1) conditional variance Eq. (2.12), the necessary condition for the negative shocks to have a less pronounced effect on uncertainty is that $c > 0$. For $c = 0$, the AGARCH model nests the symmetric GARCH.

$$h_t = \alpha_0 + \alpha_1(\varepsilon_{t-1} + c)^2 + \beta_1 h_{t-1} \tag{2.12}$$

Another asymmetric model tha has been used to model inflation uncertainty is the threshold GARCH (TGARCH) model by Zakoian (1994) and Glosten et al. (1993). The TGARCH model adds a dummy variable to the GARCH process. Consider the TGARCH(1,1) conditional variance equation given by (2.13):

$$h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + d\varepsilon^2_{t-1}D_{t-1} \tag{2.13}$$

where, $D_t = 0$ if $\varepsilon_{t-1} \geq 0$ (positive shock), and $D_t = 1$ if $\varepsilon_{t-1} < 0$ (negative shock) The necessary condition for negative inflation shocks to have a smaller effect on uncertainty is: $d < 0$. Finding $d \neq 0$ implies asymmetry in the conditional variance.

The AGARCH model captures the asymmetry in the inflation shocks by allowing its news impact curve to be centered at $\varepsilon_{t-1} = - c$, which is to the left of the origin when $c > 0$, while the TGARCH model is centered at $\varepsilon_{t-1} = 0$, but it has a steeper slope for positive forecast errors if $d < 0$. For a comparison of the symmetric GARCH specification and various asymmetric alternatives see Engle and Ng (1993).

Bruner and Hess (1993) and Joyce (1995) both reject the symmetry restriction in their GARCH models for U.S. and U.K. inflation. Joyce found that inflation uncertainty is more responsive to positive inflation shocks than to negative shocks. Crawford and Kasumovich (1996) using Canadian data fail to reject the symmetry restriction. These three studies examined the inflation level- inflation uncertainty link more explicitly, by including lagged inflation rates in the conditional variance equation. Their finding of a significantly positive coefficient for lagged inflation implies that, consistently with the Friedman Ball hypothesis, higher inflation causes higher inflation uncertainty. Grier and Perry (1998) estimated the conditional variance of inflation from GARCH and asymmetric GARCH models and then employed Granger-causality tests to test for the direction of causality between average inflation and inflation uncertainty. They found that in all G7 countries over the period 1948-93, inflation significantly Granger-caused inflation uncertainty.

Baillie et al. (1996) advocated the employment of GARCH-in-mean (GARCH-M) models in testing for interactions between inflation and inflation uncertainty. They estimated a fractionally integrated GARCH-M model of the inflation rate and then tested the hypotheses that lagged inflation is a significant regressor in the conditional variance equation (Friedman-Ball link), and that the conditional variance is a significant regressor in the conditional mean inflation equation (Cukierman and Meltzer link). Baillie et al. (1996) discovered strong feedback effects between post war inflation and uncertainty, only in U.K., and the three high-inflation countries of their sample, namely Argentina, Brazil, and Israel. Fountas et al. (2000) employed the following GARCH-M (1,1) specification in order to model monthly U.S. inflation over the period 1960-99:

$$\pi_t = \gamma_0 + \gamma_1 \pi_{t-1} + \gamma_2 \pi_{t-12} + \gamma_3 \pi_{t-24} + \delta_1 h_t \tag{2.14}$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \delta_2 \pi_{t-1} \tag{2.15}$$

The estimated parameters δ_1 and δ_2 were significantly positive indicating a strong positive bi-directional relationship between inflation and inflation uncertainty. However, including lagged inflation in the conditional variance equation may cause problems regarding the non-negativity of the variance. The possibility of a negative variance can be avoided by using the square or the absolute value of inflation. Crawford and Kassumovich (1996) employed three alternative inflation variables: the level of inflation, the absolute change in inflation and squared inflation[9]. All three variables were found to be positive and statistically significant in explaining next period's conditional variance.

(b) *Time-Varying Parameters in the Inflation Process*

Evans and Wachtel (1993) stress that the assumption of fixed parameters in the inflation process overestimates the degree to which agents can forecast inflation, and consequently underestimates inflation uncertainty. Evans and Wachtel (1993) decompose the sources of inflation uncertainty into two components: "regime uncertainty component" and "certainty equivalence component". The second component ignores uncertainty about future inflation regimes and reflects only the variance of future shocks to the inflation process. The first component reflects the agents' uncertainty about the characteristics of the current policy regime or even future regimes, if there is a possibility that the regime will change. Thus, cross-counties differences in the conduct of monetary policy may account for the differences in the average levels of uncertainty. The decomposition employed by Evans and Wachtel allows inflation uncertainty to change over time as agents keep updating their information on the current regime and their expectations about the future regime.

Evans (1991) assumes that the inflation process varies over time due to changes in the frequency of occurrence of structural disturbances affecting inflation, such as money supply, productivity, and price shocks. The GARCH specification that he employed allows the parameter vector γ in the conditional mean equation to be time varying in order to take into consideration new information as soon as it becomes available:

$$\pi_t \mid I_{t-1} \sim N(\gamma_t X_{t-1},\ h_t + X_{t-1}\Omega_t X_{t-1}') \tag{2.16}$$

$$h_t = \alpha_0 + \Sigma_{i=1}^{q}\ \alpha_i \varepsilon^2_{t-i} + \Sigma_{i=1}^{p}\ \beta_i h_{t-i} \tag{2.17}$$

$$\varepsilon_t = \pi_t - \gamma_t X_{t-1} \tag{2.18}$$

$$\gamma_t = \gamma_{t-1} + u_t \qquad u_t \sim N(0, Q) \tag{2.19}$$

[9] The absolute change in inflation was used by the authors to test whether inflation uncertainty is more closely related to changes in inflation, as opposed to the level of inflation, while squared inflation was used to test for a non-linear relationship. As Bruner and Hess (1993) argue though, such symmetric measures of inflation,

where, Ω_t is the conditional covariance matrix of γ_t given the information set at t-1.

If γ_t is known with certainty then Ω_t is equal to the null matrix and the conditional variance inflation collapses to h_t that is the standard GARCH conditional variance. Evans' results for the U.S. over the period 1960-1988, indicate that short-run uncertainty, measured by the conditional variance $h_t + X_{t-1}\Omega_t X_{t-1}'$ is not related to the level of inflation, while long-run uncertainty, measured by the conditional variance of steady-state inflation, is positively related to the level of inflation. Steady-state inflation is defined for $u_t = 0$ (no unexpected changes in the structure of inflation) and $\varepsilon_t = 0$ (no inflation shocks).

The underlying intuition for decomposing uncertainty into short-run and long-run components is that the effect of inflation uncertainty on economic decision-making differs over the time-horizon employed. Short-run uncertainty is most likely to affect temporal economic decisions. Lucas (1973) showed that changes in the next period's inflation variance affect the inferences that agents draw from aggregate price movements about shifts in current individual relative prices. If short-run uncertainty is higher, agents will attribute more of a particular change in the price of a product to the general price changes; thus, the output response will be lower. On the other hand, uncertainty about the long-term prospects of inflation affects more seriously intertemporal decisions, which require long-term commitments.

Ball and Cecchetti (1990) decomposed US inflation changes into shifts in trend inflation and temporary deviations from the trend. Short-run uncertainty depends mainly on the variance of temporary deviations, while long-run uncertainty depends mainly on the variance of the trend. Their findings indicate that a higher level of inflation makes the trend considerably less stable, while the effect on the variance of deviations from the trend is smaller. Thus, there is a positive effect of inflation rates to long-run uncertainty, implying substantial inflation costs of the type analysed by Friedman (1977), that is, higher level of risk for individuals engaging in nominal contracting, and therefore lower economic efficiency[10].

In Table A2.1 in Appendix II we summarise a number of papers presented in section 2.4.3. In the majority of these studies, the empirical investigations end by the mid-

with the same value for inflation and deflation shocks, are not consistent with a test of the Friedman hypothesis.

[10] See also Kim (1993) for additional US evidence.

1990's therefore not covering the crucial decade when inflation targeting (explicit or implicit) became the prevalent monetary policy framework.

2.5 An overview of UK inflation data

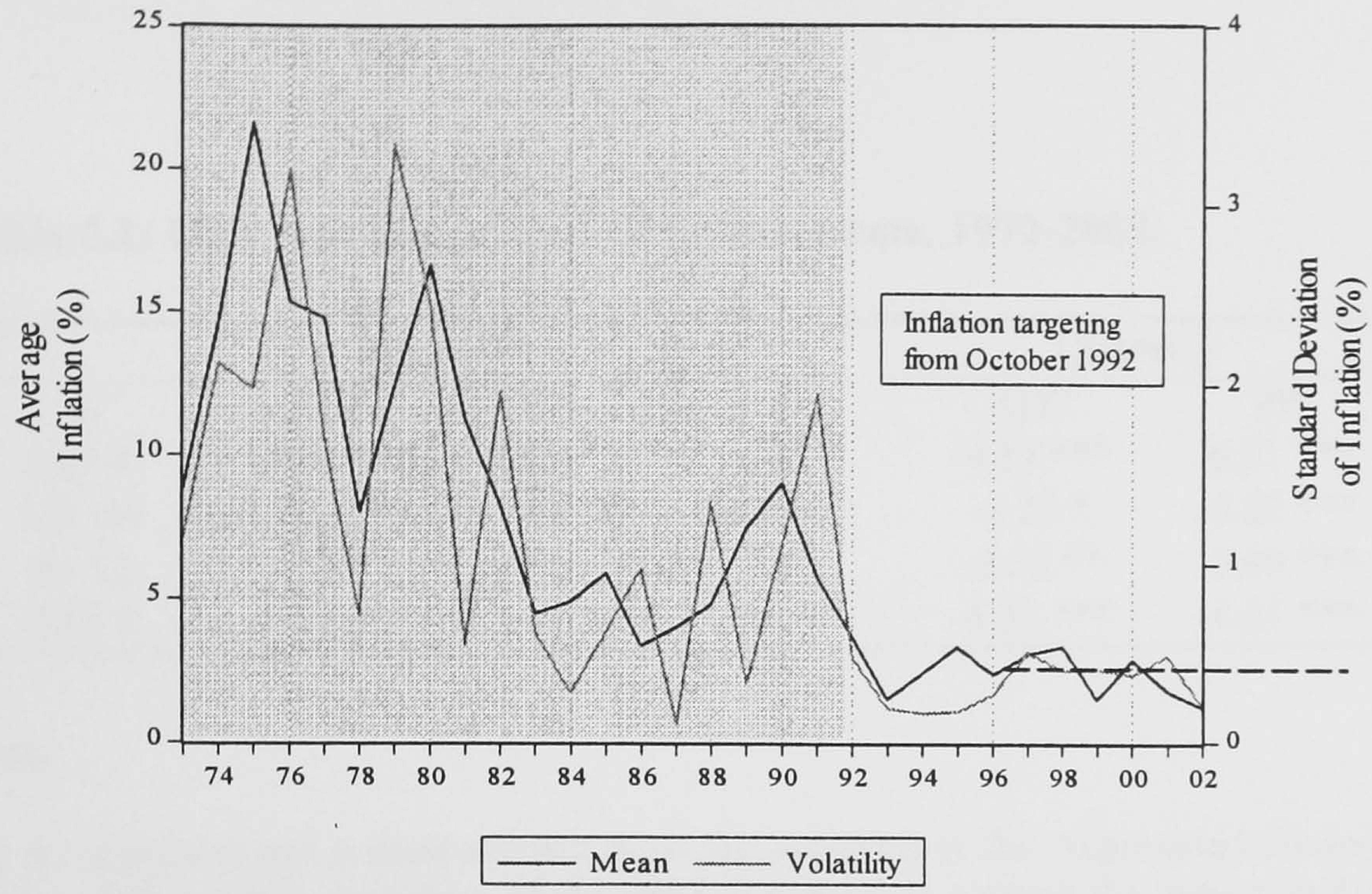
Inflation is measured as the first difference of the seasonally adjusted log consumer price index (CPI), $\pi_t = 100*(\ln CPI_t - \ln CPI_{t-1})$, using monthly and quarterly data in order to examine the relationship between inflation- uncertainty and IT over alternative time horizons[11]. This study utilises 370 monthly and 122 quarterly UK observations over the period 1972-2002. A decade of targeting experience is covered allowing us to study the effects of IT on inflation dynamics and uncertainty over a long horizon. The data are obtained from OECD's *Main Economic Indicators: Historical Statistics* series.

UK monetary policy has undergone important changes throughout the period under investigation. While from the late-1970's till the mid-1980's formal broad monetary targets were in use, these targets were abandoned in the 1987 Medium Term Financial Strategy[12]. A target for narrow money continue to exist but more emphasis was placed on a range of other indicators, including the exchange rate and the growth rate of nominal GDP. The pound was anchored to the Deutsche Mark in order to bring down inflation through imported credibility, first informally, and then formally by entering the ERM. in October 1990. On the 16th of September 1992, U.K. abandoned the ERM after strong downward pressures on the exchange rate and large official intervention to support it. In October 1992 the UK government adopted IT. By May 1997, the UK central bank was awarded operational independence in setting short-term interest rates to meet the government's stated target-currently 2.5%.

Figure 2.1 plots the year-to-year mean and standard deviation of annual inflation. It appears that periods of higher average inflation correspond to periods of more volatile inflation. During the 10 years of targeting regime, both the level of inflation and its unconditional volatility have been strikingly lower.

[11] Quarterly and even lower frequency data are more appropriate from the point of view of the monetary authority, due to the long lags in the implementation of monetary policy. Monthly sampling provides a robustness check for the quarterly results.
[12] More specifically, throughout the period July 1972 (1st full month of floating exchange rate) to June 1976, policy attempts to control inflation were largely non-monetary, i.e. they worked through prices and

Figure 2.1: Annual inflation rate, United Kingdom, 1973-2002.



2.5.1 Unit Root tests

Previous evidence considering the stationarity of UK inflation rate provides mixed results. For instance, Grier and Perry (1998) show that CPI inflation over the post WWII period (1948:10-1993:12) is non-stationary. Joyce (1995) uses quarterly data and contends that over the same period, inflation is stationary, but over a shorter sub-period (1976-1994), the Augmented Dickey Fuller (ADF) test cannot reject the unit root-null hypothesis. Table 2.1 reports the results from ADF and Phillips-Perron (PP) unit root tests with an intercept and a deterministic linear trend. Following Fountas et al. (2000), a sensitivity test is performed for the order of augmentation (*d*) by estimating the ADF regressions with a small and a large number of lagged difference terms. In addition, Table 2.1 presents the ADF *t*-statistic for orders of augmentation chosen by the reduction and the Schwartz information criteria (see Table 2.1 notes for more details). PP tests are also estimated for alternative Bartlett kernel truncation lags. Overall, the results suggest that UK CPI inflation over the period 1972-2002 can be treated as integrated of order zero, I(0), variable. Thus, the methods suggested by Ball and Cecchetti (1990) and Evans (1991) to decompose inflation uncertainty into long-run and short-run components, based upon the assumption of unit root in the level of inflation, are not applicable to our sample. Since the stationarity

wages controls. The period: July 1976 – October 1985 was characterised by £ M3 targeting.

criterion is satisfied, we proceed by estimating models from the autoregressive family to accommodate for the significant inertia inherent in inflation.

Table 2.1: Unit root Tests, UK CPI inflation rate, 1972-2002.

Monthly			Quarterly		
d	ADF	PP	*d*	ADF	PP
UB: 4	-5.82 ***	-11.59 ***	UB: 1	-4.39 ***	-6.21 ***
LB: 24	-3.21 *	-13.94 ***	LB: 8	-3.33 *	-6.52 ***
R: 11	-3.58 **	-14.21 ***	R: 7	-3.52 **	-6.49 ***
SIC: 5	-4.31 ***	-12.99 ***	SIC: 0	-6.31 ***	-6.31 ***

Note:

(a) An intercept and a deterministic trend are included in the Augmented Dickey Fuller (ADF) and Philips Perron (PP) models. Inclusion of the trend is needed to capture the reduction in average inflation that took place throughout the sample period. The reported *t*-statistics test the null hypothesis that inflation contains a unit root.
(b) In order to correct for serial correlation, ADF uses *d* lagged differences of inflation. PP tests employ a non-parametric estimator of the variance-covariance matrix with *d* truncation lags.
(c) UB: upper bound of lagged difference terms; LB: lower bound of lagged difference terms; R: number of lagged difference terms chosen by the reduction criterion. In the ADF regressions we set an upper bound of lagged differences, equal to UB, and test down by sequentially removing the last lag until a significant (at 5% level) lag is reached; SIC: order of augmentation for ADF that minimises the Schwartz information criterion starting from upper bound UB.
(d) *, **, *** indicate rejection of the null-unit root hypothesis at 10, 5, 1 % level of significance respectively.

2.6 Empirical models and results

2.6.1 Benchmark autoregressive conditional mean model

The first step in time varying volatility modelling is to specify a sufficient equation for the conditional mean of the series under investigation. Autoregressive specifications are popular in the empirical literature and are employed by Grier and Perry (1998), and Joyce (1995) among others to analyse the UK experience. Based on the Akaike - Schwartz information criteria and the whiteness of the residuals, general-to-specific approach led to the following models:

Monthly (M) $$\pi_t = \gamma_0 + \gamma_1 \pi_{t-1} + \gamma_2 \pi_{t-3} + \gamma_3 \pi_{t-6} + \gamma_4 \pi_{t-12} + u_{1t} \quad (2.20)$$

Quarterly (Q) $$\pi_t = \gamma_0 + \gamma_1 \pi_{t-1} + \gamma_2 \pi_{t-4} + u_{2t} \quad (2.21)$$

Allowing for maximum lag-length of one year, or more, is usual practise in time series studies of inflation in an effort to model the persistence of the data (see e.g. Bollerslev, 1986). Table 2.2 summarizes the ordinary least squares parameter estimates (robust estimates) and diagnostic statistics of Eqs. (2.20) and (2.21). At first glance, the benchmark autoregressive model performs adequately. All lagged inflation coefficients are significant at the 5% level and add up to around 0.8-0.9 in both monthly and quarterly regressions indicating high level of persistence. Batini and Haldane (1999) also specify a central value of 0.8 for the UK inflation persistence parameter. A battery of diagnostic tests indicates that the residuals are serially uncorrelated. Ljung-Box and Breusch-Godfrey serial correlation tests are insignificant at all lags.

2.6.2 Sensitivity analysis

The results are examined for robustness with respect to a temporal sample division of particular interest for the British economy. We would expect inflation to exhibit a structural break around October 1992 when IT commenced. Therefore, Eqs. (2.20) and (2.21) are re-estimated for both sub-periods, before and after IT. The results indicate crucial changes in the time-series behaviour of inflation. In monthly regressions, columns 4-5 of Table 2.2, the estimated coefficient of 1-month lagged inflation (γ_1) becomes insignificant during IT. On the other hand, the 12-month lag coefficient (γ_4) increases substantially in magnitude and significance: from 0.098 and significant at the 10% level, it becomes 0.413 and significant at the 1% level. Similar patterns are revealed using quarterly data (Table 2.2, columns 8-9). Inflation persistence, as proxied by the coefficient of 1-quarter lagged inflation (γ_1), turns out to be insignificant over the IT sub-period.

Parameter stability in Eqs. (2.20), (2.21) is formally tested with Chow breakpoint tests. With monthly data, the Chow F-statistic for breakpoint in October 1992 is significant at the 1% level, firmly rejecting the null of no-structural change in inflation dynamics. With quarterly data however, the Chow test fails to identify statistically significant

Table 2.2: OLS robust estimates of inflation conditional mean equations 2.20 to 2.23.

	Monthly Regressions				Quarterly Regressions			
	02/73 – 11/02 Full Sample		02/73-09/92 Pre-Target	10/92 – 11/02 After-Target	02/73 – 03/02 Full Sample		02/73 – 03/92 Pre-Target	04/92 – 03/02 After-Target
	Equation 2.20	Equation 2.22	Equation 2.20		Equation 2.21	Equation 2.23	Equation 2.21	
Coefficients								
γ_0	0.051 *	0.078 ***	0.108 *	0.041	0.231 **	0.446 ***	0.458 **	0.453 ***
γ_1	0.339 ***	0.408 ***	0.398 ***	0.008	0.659 ***	0.644 ***	0.639 ***	0.133
γ_2	0.176 ***	0.145 ***	0.132 *	0.197 **	0.196 **	0.151 *	0.152	0.101
γ_3	0.235 ***	0.215 ***	0.218 ***	0.168 **	-	-0.541 ***	-	-
γ_4	0.151 ***	0.11 ***	0.098 *	0.413 ***	-	-	-	-
γ_5	-	-0.445 ***	-	-	-	-	-	-
γ_6	-	0.253 ***	-	-	-	-	-	-
Diagnostic Statistics								
Adjusted R^2	0.49	0.52	0.41	0.33	0.62	0.64	0.50	0.02
Residual stand. dev.	0.432	0.423	0.491	0.244	0.923	0.907	1.08	0.38
Q(1)	0.129	0.007	0.045	1.596	1.508	1.096	0.852	0.094
Q(4)	2.098	1.434	1.244	2.167	4.564	4.805	3.521	0.470
Q(12)	3.272	9.045	7.631	4.199	13.445	13.014	9.856	10.081
T^*R^2 (4)	7.03	3.50	2.59	4.76	8.15	5.55	4.82	6.68
T^*R^2 (12)	16.34	10.61	9.67	11.66	14.80	13.41	9.73	11.66

Testing for break-point at 10/1992: Chow-break point- F-test : 3.27 ***
Wald X^2 –test for structural change: 30.48 ***

Testing for break-point at 04/1992 Chow-break point- F-test : 4.26
Wald X^2 –test for structural change: 12.76 ***

Note:

(a) Q, TR^2 denote the Ljung-Box, Breusch-Godfrey test statistics for serial correlation.
(b)*, **, *** indicate statistical significance at the 10, 5, 1 % level respectively.

structural change. Taking into account that the residual volatility of the estimated models is not equal over the two sub-samples but much higher during the pre-targeting period, we also calculate the Wald statistic for structural change that allows for unequal sub-sample variances. The null hypothesis of no structural change and independent samples is strongly rejected.

In general, temporal sample divisions and breakpoint tests suggest that the commonly employed benchmark autoregressive model is rather misspecified. In the following section we attempt a modification of the benchmark to avoid the instability arising from not modelling the effect of IT on inflation dynamics.

2.6.3 Dummy variable model and the dynamics of inflation

A multiplicative dummy variable is introduced in Eq. (2.20) via lags 1 and 12 and in Eq. (2.21) via the first lag, in order to allow for change in the slope of average inflation after targeting:

$$(M)\ \ \pi_t = \gamma_0 + (\gamma_1 + \gamma_5 D_t)\pi_{t-1} + \gamma_2\pi_{t-3} + \gamma_3\pi_{t-6} + (\gamma_4 + \gamma_6 D_t)\pi_{t-12} + e_{1t} \qquad (2.22)$$

$$(Q)\ \ \pi_t = \gamma_0 + (\gamma_1 + \gamma_3 D_t)\pi_{t-1} + \gamma_2\pi_{t-4} + e_{2t} \qquad (2.23)$$

where, D_t is a dummy variable equal to zero during the pre-targeting period and one during IT[13]. Variants of the above equations, with lagged inflation augmented by indicators of policy regimes or economic events, are often employed in the inflation persistence literature (see e.g. Alogoskoufis, 1992). The results in Table 2.2 reveal an improvement in statistical performance associated with the dummy augmented models. The adjusted R^2 increases while residual volatility declines.

In monthly regressions, all inflation lags as well as the dummy coefficients γ_5 and γ_6 are significant at the 1% level -their negative sum ($\gamma_5 + \gamma_6$ = -0.192) indicates that inflation

[13] We experimented by allowing the IT dummy to interact with all lagged inflation variables but the results were similar to those from Eqs. (2.22) and (2.23) in terms of parameter significance and worse in diagnostics. We also allowed for intercept change but the dummy coefficient was insignificant and the results are not presented to save space. In monthly regressions D_t is zero before October 1992 and one onwards. In quarterly regressions D_t is zero before 1992 Q4 and one onwards.

persistence declined under IT. The Wald test-statistic, X^2 version, for the joint significance of γ_5 and γ_6 is equal to 15.59, rejecting the null ($\gamma_5 = \gamma_6 = 0$) at the 1% level. In accordance with monthly results, estimates of the quarterly model in Table 2.2 suggest that IT has eliminated inflation inertia. Using a Wald test, the hypothesis $\gamma_1 + \gamma_3 = 0$ cannot be rejected at the usual levels of significance. Siklos (1999) agrees that inflation persistence has been significantly reduced in a number of explicit IT countries such as UK, New Zealand, and Canada among others. The dummy-augmented equations offer two main advantages: first, improved fit and second, they allow verifying the negative effect from a decade of targeting on UK inflation persistence.

2.6.4 Time-varying inflation volatility and pre-tests of the inflation-uncertainty link

Before estimating the conditional variance of inflation, it is necessary to examine the residuals of the mean equation for time-varying volatility. The standard test is a Lagrange multiplier test developed by Engle (1982) and involves regressing the squared OLS residuals from the conditional mean against a constant and their lagged values:

$$e_t^2 = \delta_0 + \sum_{i=1}^{q} \delta_i e_{t-i}^2 + \theta_t \tag{2.24}$$

where, the null hypothesis of constant variance (homoskedasticity) implies that:

$$\delta_1 = \delta_2 = \ldots = \delta_q = 0 \tag{2.25}$$

Bollerslev (1986) shows that the LM test for a q^{th} order ARCH is equivalent to a test for GARCH (i,j) where $i+j = q$. The results from the tests are reported in Table 2.3. There is overwhelming evidence that the residuals of the AR-dummy variable models (2.22) and (2.23) exhibit time-varying variance. The F and TR^2 test statistics indicate that the null hypothesis of homoskedasticity is rejected. In addition, Ljung-Box statistics of the squared residuals (Q^2) are all significant at the 1 % level signifying the typical volatility clustering of an ARCH process. A key pattern emerging from Table 2.3 is that the IT period

Table 2.3: Testing for time-varying residual variance in the conditional mean.

	Monthly Data			Quarterly Data		
	Equation 2.22	02/73 – 11/02	Full Sample	Equation 2.23	02/73 – 03/02	Full Sample
Q	F-statistic	TR^2	Q^2	F-statistic	TR^2	Q^2
1	16.58 ***	15.93 ***	16.113 ***	6.46 **	6.23 **	6.435 ***
4	4.26 ***	16.48 ***	16.571 ***	3.45 **	12.83 **	16.232 ***
8	2.25 ***	17.58 ***	17.778 ***	1.51	11.77	16.529 ***
	Equation 2.20	02/73 – 09/92	Pre-Target	Equation 2.21	02/73– 03/92	Pre-Target
Q	F-statistic	TR^2	Q^2	F-statistic	TR^2	Q^2
1	9.24 ***	8.96 ***	9.11 ***	2.96 **	2.92 **	3.07 **
4	2.36 **	9.26 **	9.17 **	1.67	6.56	7.52
8	1.24	9.89	9.78	0.75	6.34	8.02
	Equation 2.20	10/92 – 11/02	After-Target	Equation 2.21	04/92 – 03/02	After-Target
Q	F-statistic	TR^2	Q^2	F-statistic	TR^2	Q^2
1	0.68	0.69	0.717	0.44	0.46	0.51
4	0.59	2.43	2.719	1.09	4.47	2.42
8	0.79	6.49	3.561	0.68	6.15	3.43

Note:

(a) q indicates the order of augmentation of the test.
(b) *, **, *** indicate statistical significance at the 10, 5, 1 % level respectively.

coincides with a significant reduction in the variability of inflation. While at the pre-targeting period there is strong evidence of time varying residual variance, the period after October 1992 is clearly more stable as none of the diagnostic statistics suggests ARCH effects.

A pre-test of the inflation-inflation uncertainty link can be performed by regressing the squared OLS residuals from the conditional mean (proxy for inflation uncertainty) on a constant and a variable representing the effect of past inflation. Following Crawford and Kasumovich (1996), three alternative lagged inflation variables were considered: the level of inflation (asymmetric measure), the absolute change in inflation, and squared inflation (symmetric measures). The results are presented in Table 2.4. In full sample and pre-targeting regressions uncertainty is significantly and positively related to symmetric and asymmetric measures of past inflation. The relationship appears to break down during IT since none of the lagged inflation variables is different from zero at the usual levels of significance.

Table 2.4: Inflation uncertainty and lagged inflation variables.

Monthly Regressions			
	Equation 2.22	Equation 2.20	
Lagged Inflation Variable	02/73 – 11/02 Full Sample	02/73 – 09/92 Pre-Target	10/92 – 11/02 After-Target
π_{t-1}	0.392 ***	0.457 ***	-0.033
$\|\Delta\pi_{t-1}\|$	0.293 ***	0.349 ***	-0.06
π_{t-1}^2	0.121 ***	0.115 ***	-0.062

Quarterly Regressions			
	Equation 2.21	Equation 2.21	
Lagged Inflation Variable	02/73 – 03/02 Full Sample	02/73 – 03/02 Full Sample	02/73 – 03/02 Full Sample
π_{t-1}	0.518 ***	0.518 ***	0.518 ***
$\|\Delta\pi_{t-1}\|$	0.692 ***	0.692 ***	0.692 ***
π_{t-1}^2	0.072 ***	0.072 ***	0.072 ***

Note:

(a) The table presents the estimated coefficient of the lagged inflation variable obtained by regressing the squared OLS residuals from Equations 2.20 to 2.23 on a constant and the lagged inflation variable.
(b) *, **, *** indicate statistical significance at the 10, 5, 1 % level respectively.

As we have already point out, GARCH estimation has several advantages as compared to the current two-step process. Hence, the next section examines the interaction between inflation, uncertainty and IT in the context of GARCH-related frameworks.

2.6.5 GARCH models of inflation uncertainty

A model that tests simultaneously the Friedman-Ball and Cukierman-Meltzer links is the GARCH-in-mean (GARCH-M) with the conditional variance augmented by lagged inflation (see for instance Fountas et al., 2000, Kontonikas, 2004). We too allow for feedback effects between the conditional mean and the conditional variance by modifying mean Eqs. (2.22) and (2.23) as follows:

$$(M)\quad \pi_t = \gamma_0 + (\gamma_1 + \gamma_5 D_t)\pi_{t-1} + \gamma_2\pi_{t-3} + \gamma_3\pi_{t-6} + (\gamma_4 + \gamma_6 D_t)\pi_{t-12} + \delta\sqrt{h_t} + v_{1t} \qquad (2.26)$$

$$(Q)\quad \pi_t = \gamma_0 + (\gamma_1 + \gamma_3 D_t)\pi_{t-1} + \gamma_2\pi_{t-4} + \delta\sqrt{h_t} + v_{2t} \qquad (2.27)$$

where, h_t denotes the conditional variance of inflation[14]. Coefficient δ represents the effect of inflation uncertainty on average inflation. An estimated positive and significant δ is interpreted as evidence in favour of the Cukierman-Meltzer argument. The augmented GARCH(p,q) conditional variance models that we employ, utilise the following generic form:

$$h_t = \varphi + \sum_{i=1}^{q} a_i e_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} + \lambda' z_t \qquad (2.28)$$

where, $z_t = [z_{1t} \;\ldots\; z_{nt}]'$, and $\lambda = [\lambda_1 \;\ldots\; \lambda_n]'$ denote the vector of n-exogenous variance regressors and their coefficient vector respectively. The standard approach is to restrict z_t to contain only past levels of inflation. In this case, estimated positive and significant λ-coefficients are consistent with the Friedman-Ball link. Brunner and Hess

[14] The volatility measure used in the conditional mean Eqs. (2.26), (2.27) is standard deviation rather than variance. This approach to the in-mean modelling of inflation was introduced by Baillie et al. (1996).

(1993) point out that, tests of the Friedman hypothesis (higher inflation leads to more variable inflation) are consistent only with z_t including asymmetric measures of past inflation[15]. Nevertheless, in order to examine whether inflation variability is affected by the direction and/or the magnitude of price level changes we employ both asymmetric, $z_t = \pi_{t-1}$, and symmetric, $z_t = |\pi_{t-1}|$, measures of lagged inflation.

As indicated in Table 2.5 by quasi-maximum likelihood[16] estimates of the symmetric GARCH-M model formed by Eqs. (2.26), (2.27) and (2.28), there is a strong positive relationship between past inflation and the current conditional volatility of inflation. In most cases a GARCH(1,1) version of Eq. (2.28) is utilised. Ljung-Box statistics of the standarised and the squared standarised residuals are all insignificant implying proper model specification. In agreement with the Friedman-Ball link, the estimate of the 1-period lagged inflation coefficient, λ, is positive and statistically significant. Contrary to the Cukierman-Meltzer prediction, inflation uncertainty has no impact on average inflation as δ is insignificant in all cases. The finding of a positive link between past inflation and current variability does not depend on the data frequency and on whether symmetric or assymetric inflation measures are in use.

Figure 2.2 scatter-plots estimates of the conditional variance from GARCH-M models versus the corresponding lagged inflation variable. The upward slopping fitted linear regression lines (top 2 diagrams) depict a positive relationship using both lagged and absolute lagged inflation. Kernel regression fitted lines (bottom 2 diagrams) reveal similar patterns.

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[15] On the other hand, asymmetric measures of lagged inflation imply that the monetary authority can reduce uncertainty by pursuing deflation Furthermore, improper negative estimates of the conditional variance may be obtained since sample monthly and quarterly inflation rates take both positive and negative values.

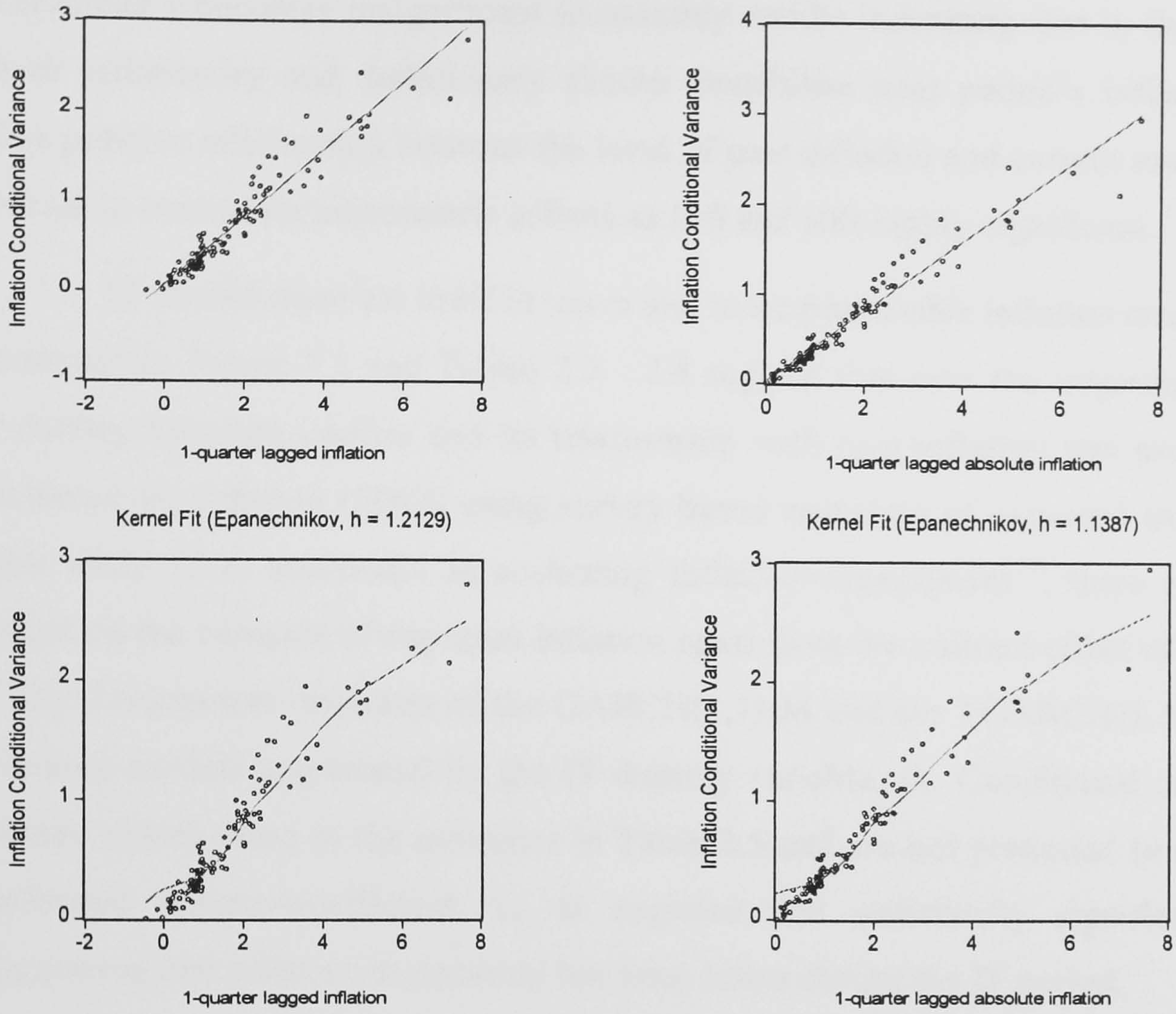
[16] Due to the departure of residuals from normality, as indicated by the Jarque-Berra test, we employ the quasi-maximum likelihood estimation which returns consistent estimates and compute standard errors using the method of Bollerslev and Wooldridge (1992).

Table 2.5: Symmetric and Threshold GARCH (p,q) -M models augmented by lagged inflation variables.

	Monthly Regressions: 02/73 – 11/02			Quarterly Regressions: 02/73 – 03/02		
	Symmetric GARCH-M		Threshold GARCH-M	Symmetric GARCH-M		Threshold GARCH-M
Conditional Mean	2.26 & 2.28		2.26 & 2.29	2.27 & 2.28		2.27 & 2.29
γ_0	0.086	0.125 ***	0.057	0.511 ***	0.451 ***	0.223
γ_1	0.519 ***	0.532 ***	0.513 ***	0.755 ***	0.585 ***	0.521 ***
γ_2	0.153 ***	0.143 ***	0.155 ***	0.147 **	0.099 *	0.125 *
γ_3	0.119 **	0.116 **	0.116 ***	-0.471 ***	-0.521 ***	-0.65 ***
γ_4	0.052 *	0.036	0.055 *	-		-
γ_5	-0.479 ***	-0.574 ***	-0.538 ***	-		-
γ_6	0.391 ***	0.392 ***	0.425 ***	-		-
δ	-0.006	-0.053	0.089	-0.338	0.268	-0.003
Conditional Variance	(p,q)=(1,1) $z_t = \pi_{t-1}$	(p,q)=(0,1) $z_t = \lvert \pi_{t-1} \rvert$	(p,q)=(1,1) $z_t = \pi_{t-1}$	(p,q)=(1,1) $z_t = \pi_{t-1}$	(p,q)=(1,1) $z_t = \lvert \pi_{t-1} \rvert$	(p,q)=(1,1) $z_t = \pi_{t-1}$
φ	0.007	0.005	0.012	-0.020	-0.021	0.101 **
α_1	0.247 *	0.369 **	0.421	0.007	0.003	0.225 *
β_1	0.410 **	-	0.426 **	0.474 ***	0.380 **	0.495 ***
λ	0.085 **	0.167 ***	0.064 *	0.229 ***	0.252 ***	0.112 **
γ	-	-	-0.277	-	-	-0.403 ***
Diagnostic Statistics	LL = -119.54 Q(1) = 0.536 Q(4) = 3.867 Q(12) = 5.593 $Q^2(4) = 3.466$ $TR^2(8) = 12.32$	LL = -112.96 Q(1) = 0.761 Q(4) = 1.418 Q(12) = 5.582 $Q^2(4) = 4.098$ $TR^2(8) = 12.24$	LL = -117.70 Q(1) = 0.825 Q(4) = 1.702 Q(12) = 4.116 $Q^2(4) = 3.974$ $TR^2(8) = 12.85$	LL = -122.32 Q(1) = 1.116 Q(4) = 3.838 Q(12) = 8.485 $Q^2(4) = 2.372$ $TR^2(8) = 3.39$	LL = -124.82 Q(1) = 0.200 Q(4) = 3.469 Q(12)= 14.671 $Q^2(4) = 1.614$ $TR^2(8) = 2.35$	LL = -125.82 Q(1) = 0.018 Q(4) = 3.098 Q(12) = 9.801 $Q^2(4) = 1.672$ $TR^2(8) = 1.74$

Note: (a) *p*, *q* represent the order of the GARCH, ARCH term respectively. (b) Diagnostic statistics are based upon the standardised residuals. LL denotes the maximised log-likelihood value; Q, Q^2 denote the Ljung-Box test statistic for residual serial correlation and ARCH; TR^2 denotes the test statistic for ARCH (c) *, **, *** indicate statistical significance at the 10, 5, 1 % level respectively.

Figure 2.2: Scatter plots and linear - kernel fit regressions lines of symmetric quarterly GARCH-M conditional variance versus past inflation.



Note:

Local polynomial kernel regressions fit Y, at each value x, by choosing the parameters β to minimise the weighted sum-of-squared residuals: $m(x) = \Sigma_{i=1}^{N}[(Y_i - \beta_0 - \beta_1(x-X_i) - \ldots - \beta_k(x-X_i)^k]^2 K(x-X_i)/h$ where N is the number of observations, h is the smoothing parameter (bandwidth) and K is a Kernel function that integrates to one. In specifying the order of the polynomial to be fitted at each data point, the local linear option, that sets k=1 at each x, was selected. The Kernel weighting function employed is the Epanechnicov function.

The Threshold GARCH (TGARCH) model of Zakoian (1994) and Glosten et al. (1993), as given by Eq. (2.29), allows for asymmetric news impact on inflation uncertainty:

$$h_t = \varphi + \sum_{i=1}^{q} a_i e_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} + \gamma w_{t-1} e_{t-1}^2 + \lambda' z_t \qquad (2.29)$$

where, $w_t = 1$ if $e_t < 0$, and 0 otherwise. With quartely data, estimates of the TGARCH(1,1) model in Table 2.5 suggest that the asymmetry parameter γ is negative and statistically significant: 'good news' on inflation result in a smaller increase in inflation uncertainty than 'bad news'. Joyce (1995) presents collaborating evidence using quarterly UK data. Parameter γ becomes insignificant in monthly results indicating that in the very short-run, both inflationary and deflationary shocks destabilise next period's inflation uncertainty. The positive relationship between the level of past inflation and current uncertainty appears robust to control for asymmetric effects as $\lambda>0$ and still highly significant.

IT should manifest itself in lower and more predictable inflation rates. Pre-eliminary evidence in Figure 2.1 and Tables 2.2 - 2.4 suggest that over the targeting years inflation volatility becomes smaller and its relationship with past inflation less pronounced. Panel evidence by Johnson (2002) using survey based measures of expected inflation indicates that while IT is successful in anchoring inflation expectations[17], there is no significant effect on the variance of expected inflation apart from the indirect effect of lower inflation. Table 2.6 presents estimates of the GARCH(1,1)-M and the TGARCH(1,1)-M conditional variance models augmented by the IT dummy variable, D_t. Conditional mean parameters obtain values close to the estimates in Table 2.5 and are not presented to save space. The estimated dummy-coefficient, λ_1, is negative and statistically significant at the 5% suggesting that inflation uncertainty has been lower during the IT period.

In order to examine whether lower uncertainty simply reflects lower average inflation as opposed to IT having an extra negative effect on uncertainty, we need to control for past inflation. Consequently, we report symmetric and asymmetric GARCH(1,1) models using both 1-period lagged inflation and the IT dummy and as conditional variance regressors: $z_t = \left[D_t \quad \pi_{t-1}\right]'$. The quarterly results in Table 2.6 indicate that the impact of IT, as given by λ_1, remains negative and significant even after controlling for the standard relationship between average inflation and uncertainty. Some puzzle remains though, since the aforementioned finding is not verified for higher frequency uncertainty. In monthly results the dummy coefficient becomes indistinguishable from zero when past inflation is taken into account.

[17] Two alternative approaches are employed in the literature to examine the effect of IT on expected inflation, a direct approach and an indirect approach. The indirect approach investigates whether the cost of disinflation (sacrifice ratio) declines after targeting. For instance, Clifton, Leon and Wong (2001) find that the adoption of IT reduces both trend inflation and the sacrifice ratio in a number of OECD countries. They also find that the improvement in the inflation-unemployment trade-off does not occur immediately after the announcement of IT but rather improves over time as the credibility of the new regime is established. The direct approach measures expected inflation using survey responses of professional forecasters (see among others Bernanke et al., 1999).

It appears that the time-horizon employed matters, and that in the very short-run IT has no additional impact on inflation variability. Given however, that most of the inflation uncertainty costs involves long-run uncertainty and that inflation shocks cannot be reversed in the short-run, monetary authorities are more interested in how IT and average inflation affect a longer-run measure of uncertainty.

The Component GARCH (CGARCH) model by Engle and Lee (1993) decomposes inflation uncertainty into a short-run and a long-run component by permitting transitory deviations of the conditional volatility around a time-varying trend, φ_t.

$$h_t = \varphi_t + a_1(e_{t-1}^2 - \varphi_{t-1}) + \beta_1(h_{t-1} - \varphi_{t-1}) \tag{2.30}$$

$$\varphi_t = \varphi + \rho\varphi_{t-1} + \mu(e_{t-1}^2 - h_{t-1}) + \lambda' z_t \tag{2.31}$$

If $1 > \rho > (\alpha_1+\beta_1)$, the transitory component in Eq. (2.30) will decay faster than the trend in Eq. (2.31), so that the trend will dominate the forecast of the conditional variance as the forecasting horizon increases[18]. Estimates of the CGARCH-M model in Table 2.6 support the view that IT reduces long-run inflation uncertainty as the dummy-coefficient in the permanent component, λ_1, is negative and significant. In an uncertain inflation environment, firms will be devoting part of their resources to forecast and/or hedge against inflation which results to substantial distortions in the efficiency of resource allocation.

The negative relationship between inflation targeting and uncertainty implies that successful targeters enjoy economic benefits far beyond the ones associated with lower level of nominal interest rates (as a result of lower average inflation). Finding a positive link between past inflation and long-run uncertainty, $\lambda_2>0$, reinforces the argument for lower inflation. Ljung-Box statistics show no remaining serial correlation and ARCH effects in the standarised and the squared standarised residuals. The estimate of persistence in the permanent CGARCH component, ρ, is less than one (0.691, 0.536 with monthly, quarterly data respectively) implying that long-run mean reversion of inflation's conditional variance does not occur very slowly.

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[18] The Component GARCH model simplifies to the GARCH(1,1) model if $\rho = 0$, or $\alpha_1 + \beta_1 = 0$. See Engle and Lee (1993) for further discussion of stationarity and non-negativity restrictions.

Table 2.6: Threshold and Component GARCH (p,q) -M models augmented by past inflation and targeting dummy.

	Monthly Regressions: 02/73 – 11/02			Quarterly Regressions: 02/73 – 03/02		
	Symmetric GARCH-M	Symmetric GARCH-M	Component GARCH-M	Threshold GARCH-M	Threshold GARCH-M	Component GARCH-M
Conditional Variance	(p,q)=(1,1) $z_t = D_t$	(p,q)=(1,1) $z_t = [D_t \ \ \pi_{t-1}]'$	(p,q)=(1,1) $z_t = [D_t \ \ \pi_{t-1}]'$	(p,q)=(1,1) $z_t = D_t$	(p,q)=(1,1) $z_t = [D_t \ \ \pi_{t-1}]'$	(p,q)=(1,1) $z_t = [D_t \ \ \pi_{t-1}]'$
φ	0.044 **	0.002 *	0.161 **	0.191 ***	0.339 **	0.382 *
α_1	0.455 **	0.239 *	0.423 *	0.185 ***	0.126 **	0.395 *
β_1	0.421 **	0.281 ***	0.010	0.747 ***	0.589 ***	-0.087
λ_1	-0.031 **	0.004	-0.037 *	-0.144 ***	-0.276 **	-0.215 *
λ_2	-	0.115 ***	0.061 ***	-	0.135 *	0.141 **
γ	-	-	-	-0.537 ***	-0.359 ***	-
ρ	-	-	0.691 ***	-	-	0.536 ***
μ		-	0.199	-	-	-0.248
Diagnostic Statistics	LL = -127.67 Q(1) =2.913 Q(4) = 3.705 Q(12) = 10.08 $Q^2(4)$ = 3.705 $TR^2(8)$ = 8.95	LL=-105.88 Q(1) =1.342 Q(4) = 2.529 Q(12) = 6.727 $Q^2(4)$ = 3.879 $TR^2(8)$ = 11.57	LL=-103.21 Q(1) =1.678 Q(4) = 2.021 Q(12) = 8.803 $Q^2(4)$ = 5.607 $TR^2(8)$ = 10.23	LL = -120.09 Q(1) = 0.198 Q(4) = 2.974 Q(12) = 9.546 $Q^2(4)$ = 2.152 $TR^2(8)$ = 2.59	LL = -119.24 Q(1) = 0.254 Q(4) = 2.521 Q(12) = 8.791 $Q^2(4)$ = 1.722 $TR^2(8)$ = 2.06	LL = -120.41 Q(1) = 0.731 Q(4) = 3.771 Q(12) = 10.204 $Q^2(4)$ = 2.398 $TR^2(8)$ = 2.321

Note:

(a) Parameters from the conditional mean Eqs. 2.26 (monthly), 2.27 (quarterly) are not reported.
(b) *p*, *q q* represent the order of the GARCH, ARCH term respectively.
(c) Diagnostic statistics are based upon the standardised residuals. LL denotes the maximised log-likelihood value.
(d) Q, Q^2 denote the Ljung-Box test statistic for residual serial correlation and ARCH; TR^2 denotes the test statistic for ARCH
(e) *, **, *** indicate statistical significance at the 10, 5, 1 % level respectively.

2.7 Conclusions

This chapters looks at the relationship between average inflation - inflation uncertainty and the impact of explicit targeting in the context of the UK economy. The significant economic costs of inflation uncertainty are well established in the literature. Higher uncertainty implies more frequent negotiations of nominal contracts, undermines the economic agents' task to distinguish between nominal and relative price changes, and may adversely affect real activity. The results from symmetric, asymmetric and component GARCH inflation models indicate a positive relationship between past inflation and uncertainty about future inflation, in line with the Friedman-Ball causal link. The policy implication for high inflation countries is to aim at low average inflation rates in order to reduce the negative consequences of uncertainty.

The key contribution of this chapter is that the establishment of IT ever since October 1992 is explicitly modelled, allowing to examine its effect on inflation dynamics and uncertainty. The results show that in the post-targeting period UK inflation is substantially less persistent and less variable. Even after we control for the effect of lower average inflation throughout that period, we can still identify a direct negative impact from IT on long-run uncertainty, suggesting an independent role for formal targets. The monetary authorities of non-IT countries should acknowledge the long-run benefits associated with the adoption of explicit targeting. Further work should examine the inflation – uncertainty relationship with data from other IT countries and using alternative specifications for the conditional mean of inflation.

Chapter 3

Monetary Policy and Asset Prices in Empirical Reaction Functions

3.1 Introduction

This chapter provides an overview and empirical estimates of monetary policy rules that take into account the effects of fluctuations in asset prices. We focus on interest rate rules since nowadays most central banks implement policy through changes in the level of short-term interest rates. Although no CB admits adhering to a simple mechanical rule for setting interest rates, Taylor-rule type of reaction functions have been shown to provide a sufficient characterisation of developments in monetary policy in many major economies (see e.g. Clarida, Gali and Gertler, 1998). In the context of these models, there is an operating target for the nominal interest rate based upon the state of the economy, as characterised by inflation, and the output gap. Asset prices, in the form of the exchange rate, have already been included in the analysis in an effort to explain movements in interest rates. Recently however, the focus has moved away from the exchange rate and towards two other important asset prices, house prices and stock prices. The increased financial volatility throughout the 1990's and the first part of the new decade, along with the boom and bust cycle that most industrialized economies experienced, reminded to investors and central bankers that movements in asset prices are highly correlated with developments in output and inflation. In the last decade, it has been widely recognised that asset prices play an important role in determining business cycles conditions. As Bernanke and Gertler (2001) emphasise, asset market boom and busts have been important factors behind macroeconomic volatility in both industrial and developing countries.

Following the financial deregulation in the early 1980s and the increased capital market globalization, industrial economies have witnessed an upward trend in asset prices. Alongside this trend, stock land and property prices have undergone swings around typical business cycle frequencies ranging from three to ten years (IMF, 2000). For some countries such as Japan and the Scandinavian counties during the late 1980s and the early 1990s, these swings had disruptive effects on domestic financial systems and contributed to prolonged recessions. In the U.K. case of 1990-92, the financial system withstood the asset price collapse but the ensuing recession was anyway severe. Over the last years, the housing market has been exhibiting overvaluation patterns analogous to the 'internet bubble' stock market of the late 1990's. The Economist (2003) calculates that nominal house prices have been more than doubled in the UK, and Netherlands, and tripled in Ireland, over the period 1995-2003. Even after adjusting for inflation, house price gains have been substantial in the majority of developed economies.

Many recent theoretical and empirical contributions on the transmission mechanism of monetary policy imply that equity and property prices play an important role via wealth effects and balance sheet effects. Monetary policy affects asset prices via changes in expected future dividends and/or changes in the discount rate, which consequently affect aggregate demand and future inflation through balance sheet and wealth effects. Mishkin (2001) offers an excellent review of all the related arguments. For example, a rise in stock prices decreases the perceived level of financial distress by households which leads to increased consumption spending. The balance sheet channel implies a positive relationship between the firms' ability to borrow and their net worth which in turn depends on asset valuations. This extra credit can be used to purchase goods and services and thus stimulates economic activity (Kiyotaki and Moore, 1997). Goodhart and Hofmann (2001) find that stock price and house price inflation increases raise future aggregate demand in many major economies.

Since banks engage heavily in real estate lending, in which the value of the real estate acts as a collateral, swings in property prices lead to increased financial instability. The monetary and financial stability objectives are intertwined. Sinclair (2002) reminds us that the central bank by setting the interest rate controls an important link between the two forms of stability. Borio and Lowe (2002) point out that while a low and stable inflation environment promotes financial stability, it also raises the likelihood that excess demand pressures will first show up in credit aggregates and asset prices rather than in consumer prices.

Over the last decade the United Kingdom has followed explicit inflation targeting, while during the second half of the decade interest rates are set independently by the BoE in response to medium term RPIX inflation forecasts. Apart from inflation, the prospects for real activity also matter[1]. Thus, given the importance of asset price fluctuations for future demand and inflation, the main objective of this chapter is to provide some further insight into the interest rate setting behavior of the Bank of England, by estimating reaction functions that have been augmented to take into account the effect of asset price inflation. In addition, we extend previous work by Kontonikas and Montagnoli (2004) and estimate asset price augmented Taylor rules for the case of a non-explicit inflation targeting regime, namely the one followed in the US. We should point out that the results provide a genuine contribution to the literature, since, only recently, did other empirical studies emerge, that estimate Taylor rules incorporating house and stock market returns.

The remainder of the chapter is structured as follows. The next section discusses the properties of the data. In section 3.3 we provide some empirical evidence on the impact of asset price changes on aggregate demand using a small structural model of the UK

[1] Although the 1998 Bank of England Act places price stability, defined by the Chancellor's inflation target, as the overriding objective of monetary policy, the BoE is also required to support the Government's other

economy. Section 3.4 presents a brief overview of monetary policy reaction functions, while section 3.5 contains the empirical results for the UK. Section 3.5.1 provides the benchmark model results, Section 3.5.2 presents the asset price augmented results, and Section 3.5.3 accounts for the effect of BoE independence on the inflation-policy rule parameter. Section 3.5.4 compares the historical performance of the benchmark forward-looking rule versus the asset price augmented rule. Section 3.6 presents the US results and Section 3.7 concludes.

3.2 Data description

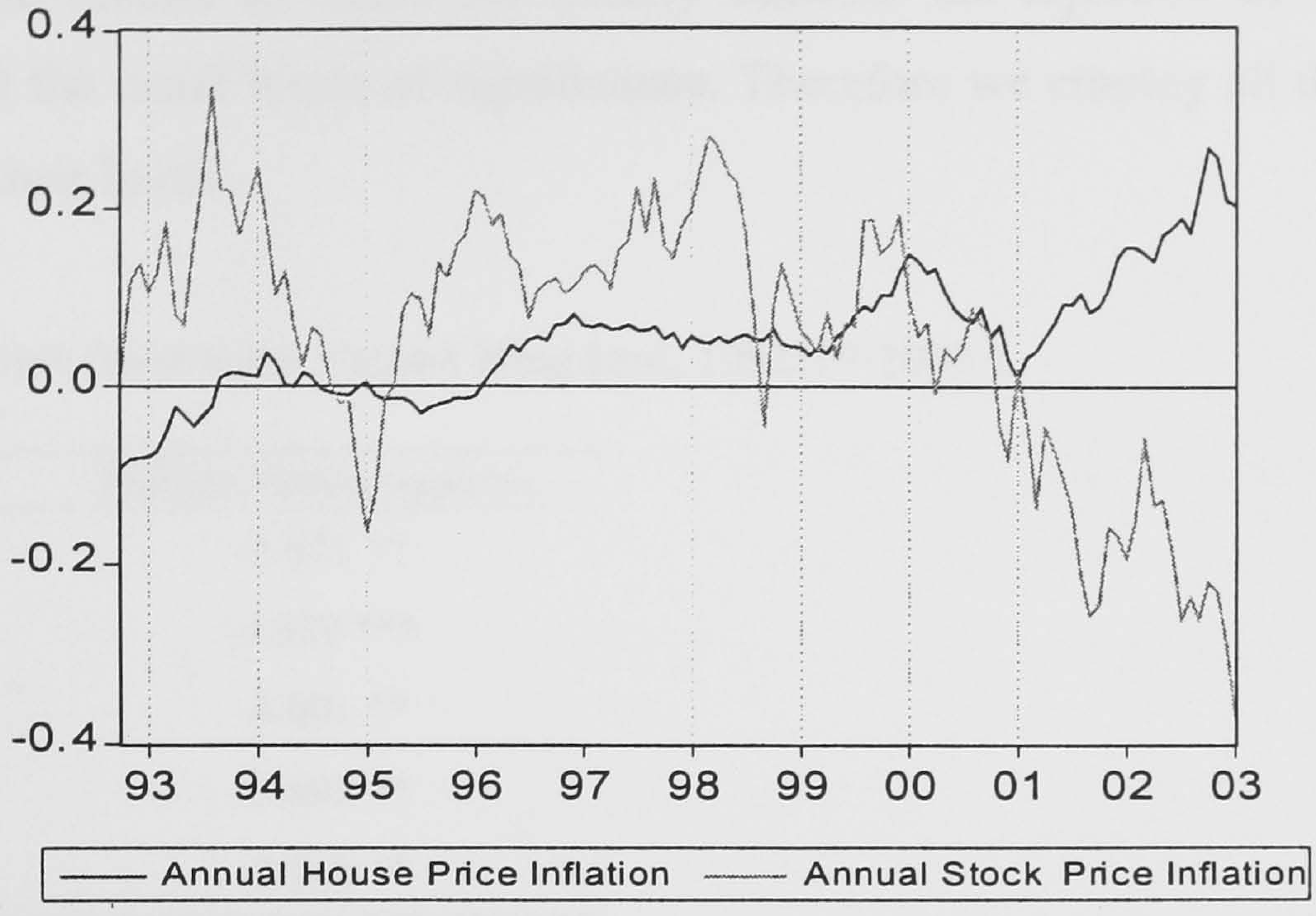
We employ monthly data on short-term interest rates, industrial production, Retail Price Index minus mortgage interest payments (RPIX), stock prices and house prices for the United Kingdom from October 1992 to January 2003. All data is obtained from Datastream, *OECD Historical Statistics* series. Our sample period commences with the establishment of an explicit inflation targeting regime on October 1992. An inflation target of 1-4 % was initially adopted and on June 1995 the target was reset at 2.5% or less.

The (annualised) output gap, y_t, the difference between actual and potential output, is calculated via quadratic detrending of the industrial production series, as in Clarida, Gali, and Gertler (1998), and Nelson (2000). The 3-month Treasury Bill rate, i_t, is employed as a measure of the stance of the monetary policy[2]. The annual change in stock prices, $\Delta_{12}S_t$, house prices, $\Delta_{12}H_t$, and retail prices, π_t, are proxied by the 12[th] difference of the natural logarithm of the monthly FTSE All Shares stock index, S_t, the Halifax house price index, H_t, and the (seasonally adjusted) RPIX respectively. We used annual, rather than monthly, changes for retail prices, stock prices and house prices since year on year changes on these variables are much more relevant for monetary policy decisions (Goodhart, 2001).

economic goals. As Nikolov (2002) points out, the practical implication is that the BoE has an obligation to consider the resulting volatility in real activity when setting interest rates.

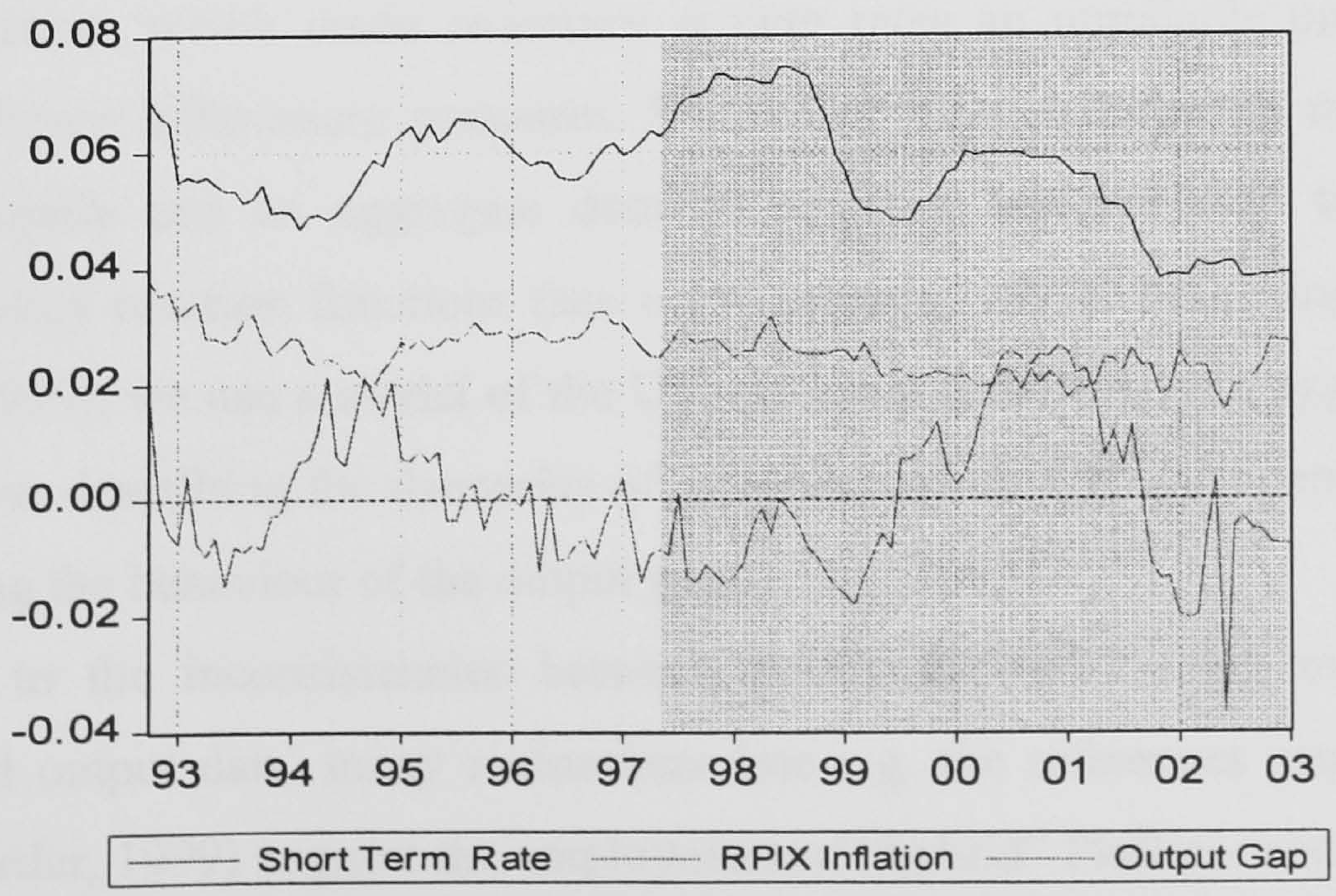
2 The actual interest rate used by the Bank of England as its instrument for money market intervention has varied over time, and has included Bank Rate (until 1972), Minimum Lending Rate (1972-1981), the Minimum Band One Dealing Rate (1981-1996), and the two-week Repo Rate (since 1997). The 3 month Treasury Bill rate has historically moved close with these instruments, and is available for the entire sample period. Following Nelson (2000) For August 1992, the only month for which no observation on the bill rate is available, a value of 9.7 is used. This figure was obtained by assuming a 20 basis point spread above the 91-day rate (the 91-day rate was 20 basis points below the bill rate in both July and Sept. 1992.

Figure 3.1: Annual UK House Price and Stock Price inflation, 1992:10-2003:01.



As we see in Figure 3.1 stock prices have been far more volatile as compared to house prices. In the aftermath of the burst of the stock market bubble in 2000, the two series start diverging significantly, with house price inflation accelerating, while the stock market collapsed. The output gap in Figure 3.2 indicates a post-bubble weaker UK economy since it is generally declining after peaking in early 2001. Finally, the nominal interest rate is consistently above the strikingly stable (as compared to its 1970's 'rollercoaster' behaviour) inflation rate.

Figure 3.2: UK Output Gap, Short-term interest rate, RPIX inflation, 1992:10-2003:01.



Standard Phillips-Perron (PP) tests are employed in order to test for unit roots in our data. The results in Table 3.1 clearly indicate the rejection of the unit root null hypothesis at the usual levels of significance. Therefore we employ all the aforementioned variables at their levels.

Table 3.1: Unit Root tests, United Kingdom, 1992:10-2003:1.

Variables	Phillips Perron t-statistic
i_t	-3.621 **
y_t	-4.529 ***
π_t	-4.001 **
$\Delta_{12}S_t$	-3.803 **
$\Delta_{12}H_t$	-3.748 **

Note:

(a) In order to correct for serial correlation the Phillips Perron (PP) test uses a non-parametric estimator of the variance-covariance matrix. The truncation lag employed is chosen by the Newey-West criterion using the Bartlett kernel. An intercept and a linear trend term were included in the PP regressions.
(b) *, **, *** indicate rejection of the null-unit root hypothesis at 10, 5, 1 % level of significance respectively.

3.3 Asset prices in an estimated AS/AD model

As Goodhart and Hofmann (2001) argue, from the early 1990's many countries adopted explicit inflation targeting regimes as a response to the instability of the money demand function, which made monetary growth rates an unreliable proxy of monetary policy and future inflationary pressures. Simplified inflation targeting models include an aggregate supply and an aggregate demand equation and are used to derive optimal monetary policy reaction functions (see e.g. Svensson, 1997). Following Rudebusch and Svensson (1999), we use a model of the UK economy consisting of a aggregate supply, or Phillips curve, describing the dynamics of inflation and an aggregate demand, or IS curve, characterising the behaviour of the output gap.

Due to the inconsistencies between purely forward-looking models and actual inflation and output data, many researchers (see e.g. the references provided in Clarida, Galí and Gertler, 1999) suggest the employment of "hybrid" Phillips- and IS-curves, which include both backward and forward-looking elements. We specify a hybrid empirical Phillips curve where current inflation depends upon past and expected future inflation and on past demand pressures:

$$\pi_t = \mu_0 + \mu_1 \pi_{t-i} + \mu_2 E_t[\pi_{t+n}] + \mu_3 y_{t-m} + \eta_t \tag{3.1}$$

The backward-looking element in Eq. (3.1) reflects inertia in inflation that is justified not only empirically, but also theoretically on the assumption that a fixed proportion of firms has backward-looking price setting behavior (see Galí and Gertler, 1999). The forward-looking element derives from the rational expectations staggered-contracting models of Taylor (1980), and Calvo (1983). The GMM estimates[3] of the hybrid Phillips curve over the period 1992:10-2003:01, as given in (3.2), imply that the backward-looking component is stronger in UK data, as $\mu_1 > \mu_2$. The estimated magnitude of μ_1 is close to the value of 0.8 which has been used as central value by Batini and Haldane (1999) in simulations for the UK. The output gap coefficient, μ_3, is positive and highly significant indicating that current demand pressures feed into higher future inflation.

$$\begin{aligned} \pi_t = &-0.001 + 0.81\pi_{t-3} + 0.15\pi_{t+3} + 0.09 y_{t-12} + \hat{\eta}_t \\ &(.001) \quad (.04) \qquad (.05) \qquad (.005) \\ &\qquad \text{SE} = 0.003, \quad \text{J-stat} = 14.25\ [0.38] \end{aligned} \tag{3.2}$$

The demand-side of the economy is modelled as a hybrid IS, that is consistent with dynamic optimising behaviour by the agents (micro-foundations) and also allows for some persistence in output. Thus, Eq. (3.3) allows the output gap to be a function of past and expected future output, lagged real interest rate, and lagged values of a vector, **X**, of additional explanatory variables.

$$y_t = \lambda_0 + \lambda_1 y_{t-i} + \lambda_2 E_t[y_{t+n}] + \lambda_3 \bar{r}_{t-s} + \mathbf{\Omega}' \mathbf{X}_{t-k} + v_t \tag{3.3}$$

[3] GMM estimation with MA(12) autocorrelation correction has been used. The instrument set includes six lags of inflation, agricultural commodity prices, and the output gap. The *J*-statistic indicates that the overidentifying restrictions are not rejected.

where, $\bar{r}_t = (\frac{1}{12})\sum_{i=0}^{11}(i_{t-i} - \pi_{t-i})$ is the twelve-month average *ex post* real interest rate.

As we already pointed out there are many channels via which, changes in equity prices and house prices affect consumer wealth. Direct effects include the change in consumption plans as a response to swings in asset prices (Modigliani, 1971), while indirect effects operate mainly via households and firms' balance sheets. There is a growing consensus that, apart from the conventional explanatory variables, output is also determined by changes in consumption and investment demand induced by changes in the level of asset prices. Therefore, the aggregate demand function given by Eq. (3.3) is estimated with GMM including house price inflation, Eq. (3.4), and stock price inflation, Eq. (3.5).

$$
\begin{aligned}
y_t &= \underset{(.002)}{0.01} + \underset{(.03)}{0.03}y_{t-3} + \underset{(.03)}{0.91}y_{t+3} - \underset{(.05)}{0.30}\bar{r}_{t-12} + \underset{(.01)}{0.08}\Delta_{12}H_{t-12} + \hat{v}_{1t} \\
&\text{SE} = 0.008, \quad \text{J-stat} = 18.91\ [0.48]
\end{aligned}
\tag{3.4}
$$

The results indicate that, in contrast to the aggregate supply, aggregate demand is more affected by its forward-looking component, since λ_2 is positive and significant while λ_1 turns out to be insignificant. The one-year lagged real interest rate is negative and strongly significant, as expected. Finally, the coefficient of lagged house price changes shows that a 10 % increase in house prices boosts current aggregate demand by a factor of 0.8 %, indicating significant wealth effects.

$$
\begin{aligned}
y_t &= \underset{(.002)}{0.01} + \underset{(.04)}{0.007}y_{t-3} + \underset{(.03)}{0.78}y_{t+3} - \underset{(.06)}{0.55}\bar{r}_{t-12} + \underset{(.01)}{0.04}\Delta_{12}S_{t-12} + \hat{v}_{2t} \\
&\text{SE} = 0.009, \quad \text{J-stat} = 16.12\ [0.64]
\end{aligned}
\tag{3.5}
$$

The estimated coefficients in (3.5) reveal similar patterns. Future output is strongly significant, real interest rate affects output negatively with a lag, and stock price inflation exerts a positive impact on aggregate demand. The magnitude of the wealth effect depends among other factors on the share of the respective asset in private sector wealth, with housing constituting the most significant asset in the households' portfolio in most countries. Indeed, we find that the magnitude of the wealth effect due to stock price increases is much smaller than the effect due to house price increases. The coefficient of stock price inflation is half the coefficient of stock price inflation (0.04 as compared to 0.08) a result that is in line with previous evidence by Goodhart and Hofmann (2001) for the UK. Using a panel of 14 developed economies Case, Quigley, and Shiller (2001) also find that the housing market appears to be more important than the stock market in affecting the real economy.

Having demonstrated that movements in asset prices affect future aggregate demand and consequently also future inflation, in the next section we shall focus on the key empirical question of this chapter, that is, what has been the response of the monetary policy instrument to asset price inflation.

3.4 Monetary policy reaction functions

It is generally assumed that the monetary policy interest rate instrument responds with fixed, positive weights to deviations of inflation from a pre-specified target, and deviations of output from its potential level. Taylor (1993) proposed a simple link between the interest rate, inflation, and the output gap which well reflected US monetary policy from 1987 to 1992. The Taylor rule reaction function suggests that the nominal interest rate is set as follows:

$$i_t = r + \pi^* + 1.5(\pi_t - \pi^*) + 0.5y_t \qquad (3.6)$$

where, r is the long-run equilibrium real interest rate, and π^* is the inflation target.

The past decade has seen a vast amount of empirical and theoretical work considering monetary policy reaction functions. Clarida, Gali and Gertler (1998) present econometric estimates of the Taylor rule coefficients for the United States. Nelson (2000) provides empirical evidence for the United Kingdom under alternative monetary policy regimes, over the period 1972-97, prior to the Bank of England (BoE) receiving operational independence. Focusing on the inflation-targeting period 1992-1997, Nelson's results suggest that a forward-looking looking Taylor rule outperforms a backward-looking specification. His results contradict those of Kuttner and Posen (1999).

In contrast with Nelson, who used quarterly data, Kuttner and Posen employed monthly data over the period October 1992-December 1997 and found a coefficient of zero on inflation. Other important differences with the Nelson study include the use of the unemployment rate, instead of the real GDP for the construction of the output gap proxy, and the employment of the annualised month-to-month rather than annual inflation rate. As Nelson argues though, the use of annual inflation in the estimated rule is crucial for the results since the BoE's inflation target has always been expressed in terms of the annual (year-ended), rather than the monthly inflation rate.

Following Clarida et al. (1998) we assume that the central bank has an operating target for the nominal short-term interest rate that is based upon the state of the economy. In the benchmark model the state of the economy is characterised by the evolution of the output gap and expected inflation. This forward-looking behaviour is consistent with a central bank that operates in the context of an inflation targeting regime (Kent and Lowe, 1997).

$$i_t^* = \bar{i} + \beta(E_t[\pi_{t+n}] - \pi^*) + \gamma y_t \tag{3.7}$$

where, i_t^* denotes the target nominal interest rate, π_{t+n} is the rate of inflation between periods t and $t+n$, $\bar{i}$ is the long-run equilibrium nominal rate. It is also intuitive to consider the implied target for the ex ante real interest rate, $r_t = i_t - E_t[\pi_{t+n}]$:

$$r_t^* = r + (\beta - 1)(E_t[\pi_{t+n}] - \pi^*) + \gamma y_t \tag{3.8}$$

where, r is the long-run equilibrium real rate of interest, determined purely by real factors.

Eq. (3.8) implies that the target real rate, r_t^*, adjusts relative to its natural rate responding to deviations of expected inflation from its target value and deviations of output from its potential level. Crucial for the ensuing analysis is the magnitude of the expected inflation coefficient, β. The estimated value of β serves as a yardstick for the evaluation of the stance of the monetary authority. If $\beta > 1$, the target real rate adjustment stabilises inflation and output (given that $\gamma > 0$). Larger values of β are associated with more inflation averse policy. If however, $\beta < 1$, monetary policy accommodates changes in inflation. That is, although nominal rates increase in response to an increase in expected inflation, the policy tightening is not sufficient to keep real interest rates from falling. As Bernanke and Woodford (1997) and Clarida et al. (1998) have emphasised, in such accommodative regime, self-fulfilling bursts of inflation and output may occur.

Policy rules of the type presented in Eq. (3.7) are chosen not only due to plausibility, but also due to theoretical arguments. Ball (1997) and Svensson (1997), among others, demonstrate how a policy rule of the type employed here is 'optimal' that is, derives from the first order optimisation condition for a central bank with quadratic preferences over inflation and output. In the next chapter we derive such an optimal rule that takes into account indirectly the effect of asset prices. In this chapter however, we focus on empirical estimates of monetary policy rules and therefore will not further discuss the optimality conditions and their relationship to the underlying structural macroeconomic parameters and the weights given to inflation and output volatility in the loss function.

We further assume that, in each period, the actual interest rate partially adjusts towards the target value. This assumption intends to capture the tendency of central banks to smooth changes in interest rates (see e.g. Goodfriend, 1991). Svensson (1997) justifies the partial adjustment mechanism by including the change in interest rates in the central bank's loss function. In the literature we identify four major reasons why the central bank might prefer small gradual movements in the interest rate instrument[4]. These reasons, presented in turn bellow, are uncertainty, policy effectiveness, financial stability, and the policymaker's reputation.

Uncertainty. Monetary policy makers face substantial uncertainty, since the data on which interest rate decisions are based upon, in particular the output gap, are available only with a lag and are often revised. Orphanides (1998), and Sack and Wieland (2000), among others, discuss the effects of data uncertainty on interest rate setting. In addition, considerable lags are required till the full impact of interest rate changes on inflation and the output gap is revealed, and the reaction may vary over time. Brainard (1967), and Rider and Haslem (2000) discuss the effects of this parameter uncertainty. Thus, in the context of

[4] Some economists (see e.g. Rudebusch, 2001) challenge the policy inertia hypothesis of interest rate smoothing. Rudebusch argues that smoothing could be present in the data due shocks which monetary policy reacts to, but which are not considered in the estimated reaction function. If these omitted variables are autocorrelated, interest rate smoothing seemingly arises. Such omitted variables may be financial crises, and a time varying equilibrium real rate.

data and parameter uncertainty, policy makers choose a cautious approach by moving interest rates gradually in order to assess the impact of policy changes on the target variables. Further interest rate changes may follow until the central bank is satisfied with the achieved effect.

Policy effectiveness. This arguments states that monetary policy inertia improve the effectiveness of any given policy change due to two reasons. First, as argued by Batini and Haldane (1999), and Goodhart (1999) among others, by changing the interest rate several times in the same direction (rate smoothing) the central bank generates an 'announcement' effect in the case of a policy reversal. For instance, if the (interest rate smoothing) central bank announces an increase in rates, following a series of decreases, further tightening is expected. Hence, short-term interest rates will also be affected via the expected future path of short-term rates (term structure) and since monetary policy impacts on the economy through short-term rates, interest rate smoothing should enhance policy effectiveness[5]. The second factor linking interest rate smoothing with policy effectiveness is based on the following argument. If interest rates are gradually altered, their variance will be lower and with it the probability that the zero interest rate bound (bellow which monetary policy becomes ineffective) will be hit[6].

Financial Stability. Some economists point out that interest rate smoothing promotes financial stability (see e.g. Goodfriend, 1987). Cukierman (1991) shows that if commercial banks pay flexible interest rates on deposits and receive fixed payments for loans, highly volatile interest rates may trigger bankruptcies, since the liabilities of commercial banks may exceed the available assets. By adjusting rates gradually, the central bank allows commercial banks to smoothly adjust their portfolios in response to interest rate changes. As Sinclair (2002) points out, a low degree of policy smoothness may cause an excess volatility in financial markets, especially when the policy is delayed.

Reputation. Interest rate smoothing is viewed sometimes as an attempt by policymakers to safeguard their reputation (see Eijffinger, Schaling, and Verhagen, 1999; Goodhart, 1999). Since outsiders sometimes cannot assess with certainty whether a change in policy reflects reaction to new developments or merely the correction of an earlier

---

[5] Lowe and Ellis (1997) show that in US, UK, and Australia 10-year bond yields react more strongly to interest rate reversals, and they attribute this to the announcement effect.

[6] See the discussion in Amato and Laubach (1999), and Rudebusch and Svensson (1999).

mistake, policymakers may choose to smooth interest rates in order to reduce the need for reversals and the subsequent exposure to criticism.

Combining the target rule (3.7) with the partial adjustment mechanism we obtain the following expression for the actual interest rate:

$$i_t = (1 - \sum_{i=1}^{l} \varphi_i) i_t^* + \sum_{i=1}^{l} \varphi_i i_{t-i} + \upsilon_t \tag{3.9}$$

where, $\sum_{i=1}^{l} \varphi_i \in [0,1]$ measuring the degree of interest rate smoothing and υ_t is an exogenous random *iid* shock to the interest rate.

As Clarida et al. (1998) emphasise, υ_t may indicate a purely random component to policymaking, or it could be the result of the central bank imperfectly forecasting idiosyncratic reserve demand and not immediately supplying reserves to offset the shock. In the second case, the interest rate changes responding to unexpected movements in reserve demand that are orthogonal to movements in inflation and output. Substituting (3.7) in (3.9) and defining $a = \bar{i} - \beta\pi^*$ we obtain[7]:

$$i_t = \left(1 - \sum_{i=1}^{l} \varphi_i\right) \left\{a + \beta(E_t[\pi_{t+n}] - \pi^*) + \gamma y_t\right\} + \sum_{i=1}^{l} \varphi_i i_{t-i} + \upsilon_t \tag{3.10}$$

Due to the fact that monetary policymakers cannot observe y_t when setting i_t, we replace the actual value of the output gap with its expected level, $E_{t-1}[y_t]$; see McCallum and Nelson, 1999, and Orphanides et al., 2000 for a further discussion of the uncertainties faced by the policymaker with respect to output. Thus, (3.10) becomes:

$$i_t = \left(1 - \sum_{i=1}^{l} \varphi_i\right) \left\{a + \beta(E_t[\pi_{t+n}] - \pi^*) + \gamma E_{t-1}[y_t]\right\} + \sum_{i=1}^{l} \varphi_i i_{t-i} + \upsilon_t \tag{3.11}$$

---

[7] Note that, since $a = \bar{i} - \beta\pi^*$ and $\bar{i} = r + \pi^*$, it is implied that $a = r + (1-\beta)\pi^*$. We can also get an expression for the target inflation: $\pi^* = (r - a)/(\beta - 1)$. As Clarida et al. (1998) point out, if the sample is sufficiently long, the sample average real rate can be used to provide an estimate of r. With this estimate, it is then possible to construct an estimate of π^*.

We consider an inflation forecast horizon of one year, therefore we set n equal to 12 in our monthly sample. In order to estimate the model, unknown expected variables are replaced with their ex post realised values. This leads us to Eq. (3.12) [8] :

$$i_t = \left(1 - \sum_{i=1}^{l} \varphi_i\right)\left\{a + \beta(\pi_{t+n} - \pi^*) + \gamma y_t\right\} + \sum_{i=1}^{l} \varphi_i i_{t-i} + \omega_t \tag{3.12}$$

The set of orthogonality conditions implied by Eq. (3.12) is:

$$E_t\left[i_t - \left(1 - \sum_{i=1}^{l} \varphi_i\right)\left\{a + \beta(\pi_{t+n} - \pi^*) + \gamma y_t\right\} + \sum_{i=1}^{l} \varphi_i i_{t-i} \middle| Z_t \right] = 0 \tag{3.13}$$

where, Z_t represents all the variables in the central bank's information set available at time t when the interest rate is chosen. Z_t is a vector of variables that are orthogonal to ω_t. These instruments are lagged variables that help forecasting inflation and output, and contemporaneous variables that are uncorrelated with the exogenous monetary policy shock, u_t. The benchmark reaction function given by Eq. (3.12) will be estimated using the Generalised Method of Moments (GMM). The instruments include a constant and six lags of the nominal short-term interest rate, inflation, output gap, and a world commodity price index (agricultural raw materials). Since the number of instruments is greater than the number of elements of the parameter vector [φ_i, α, β, γ], we test for the validity of the over-identifying restrictions using Hansen's J-statistic. Failure to reject orthogonality implies that the central bank considers lagged variables in its reaction function, only to the extent that they forecast future inflation or output.

As pointed out in section 3.3, asset prices contain important information about future aggregate demand and consequently inflation pressures. Also, there are theoretical arguments in favour of including asset price inflation in the reaction function of the central bank. Cecchetti, Genberg, Lipsky, and Wadhwani (2000) find that, on the basis of simulations, it would be desirable to include asset inflation in the policy rule. Therefore, we

[8] The disturbance term in Equation (3.12) is a linear combination of the inflation and output gap forecast errors and the exogenous monetary policy shock υ_t : $\omega_t = -(1-\sum_{i=1}^{l}\varphi_i)\{\beta(\pi_{t+n} - E_t[\pi_{t+n}]) + \gamma(y_t - E_{t-1}[y_t])\} + \upsilon_t$

will also consider alternatives to the benchmark specification, by allowing changes in asset prices to enter the reaction function. The augmented reaction functions we shall estimate are of the form:

$$i_t = \left(1 - \sum_{i=1}^{l} \varphi_i\right)\left\{a + \beta(E_t[\pi_{t+n}] - \pi^*) + \gamma E_{t-1}[y_t] + \Theta' \mathbf{X}_t\right\} + \sum_{i=1}^{l} \varphi_i i_{t-i} + \upsilon_t \qquad (3.14)$$

where, $\mathbf{X}_t = [x_{1t} \quad \ldots \quad x_{jt}]'$, and $\Theta = [\theta_1 \quad \ldots \quad \theta_j]'$ denote the vector of *j*-additional explanatory variables, and the relevant coefficient vector respectively. In the cases that we will examine, X_t contains contemporaneous house price and/or stock price inflation. We use contemporaneous, and not expected, asset price inflation due to the well known difficulties involved in forecasting asset price movements. Also, weak form efficiency implies that the current asset price reflects all past history, thus there is no need to incorporate lags.

3.5 Empirical results: United Kingdom

3.5.1 Benchmark model

The GMM estimation results in Table 3.2, column 2, indicate that the benchmark specification (3.12) satisfies the dynamic stability criterion since the estimated inflation coefficient, β, is greater than one (1.02). If β was smaller than the stability threshold of one, then this would imply a positively sloped aggregated demand, with output decreasing in response to an inflation shock (Taylor, 1999). The output gap coefficient, γ, is positive and statistically significant at the 1 % level, although quite modest in magnitude (0.03). Its estimate implies that, holding expected inflation constant, one-percent increase in the level of output gap induces the BoE to raise interest rates by 3 basis points. This result is consistent with those reported by Martin and Milas (2002) who employed quarterly UK data. Therefore, during the inflation-targeting period that we consider, U.K. monetary policy has put more weight on price stability than output stabilisation. The sum of the interest rate smoothing parameters is close to one (0.92) indicating a high level of persistence in short-term interest rates. This finding supports the view that the Bank of England smooth the adjustment of interest rates towards their target values. Finally, the *J*-

statistic indicates that the over-identifying restrictions of the benchmark model are not rejected.

Table 3.2: GMM Estimates of Forward Looking Taylor Rule, UK, 1992:10-2003:1.

	Benchmark Model	$X_t = [\Delta_{12}H_t]'$	$X_t = [\Delta_{12}S_t]'$	$X_t = [\Delta_{12}H_t, \Delta_{12}S_t]'$
α	2.59 *	4.00 ***	2.51 ***	4.56 ***
β	1.02 *	1.60 ***	1.01 ***	1.82 ***
γ	0.03 ***	0.04 ***	0.08 ***	0.02 ***
$\sum_{i=1}^{I}\varphi_i$	0.92 ***	0.91 ***	0.91 ***	0.83 ***
θ_1	-	0.15 ***	-	0.12 ***
θ_2	-	-	0.06 ***	0.07 ***
S.E. of Reg.	0.0023	0.0022	0.023	0.0030
J- Stat.	14.10	17.38	21.19	15.51

Note:

(a) Estimates are obtained by GMM estimation with correction for MA(12) autocorrelation. Two-stage least squares estimation is employed to obtain the initial estimates of the optimal weighting matrix.
(b) In the benchmark model the instruments used are a constant and lags 1 to 6 of the nominal short term interest rate, inflation, output gap, and the log difference of a world commodity price index (agricultural raw materials). In the models that include asset price inflation, lags 1 to 6 of the relevant asset price inflation variable are also included.
(c) *J*-stat denotes the test statistic for overidentifying restrictions.
(d) *, **, *** indicate level of significance of 10%, 5%, and 1% respectively.

3.5.2 Asset price augmented model

We now allow annual house price and stock price inflation to enter the reaction function. The results are presented in Table 3.2, columns 3-5. Following Bernanke and Gertler (1999), in order to help control for the simultaneity bias in the relationship between monetary policy and asset returns, we instrument for the contemporaneous value of the asset price inflation[9]. In particular, we add lags 1-6 of the relevant asset inflation variable in our instrument list. Hence, our estimates of the responses of policy to asset price changes

[9] Rigobon and Sack (2003) employ an alternative approach to identify the relationship between monetary policy and asset prices using a procedure that exploits the heteroskedasticity of shocks to high frequency financial series. Using daily and weekly US data over the period 1985-1999, Rigobon and Sack conclude that rising stock prices drive short-term interest rates in the same direction, suggestive of a systematic reaction by the Fed to stock price movements. Bohl, Siklos, and Werner (2004) modify the Rigobon and Sack identification procedure and apply it to German data over the period 1985-1998. Contrary to Rigobon and Sack, they fail to find a statistically significant relationship between stock returns and short-term interest rates.

arising from the predictive power of asset prices for output and inflation are fully accounted for. In other words, any estimated response of the policy instrument to asset price inflation must be above and beyond the part due to the predictive power of stock returns. This approach in augmenting the standard Taylor rule with additional variables has been suggested Clarida, Gali, and Gertler (1998, p1041), "...we then proceed to estimate the alternative model in the same fashion as the baseline, except that we expand the parameter vector to include the coefficient on the additional variable and expand the instrument set to include lagged values of that variable. It is then straightforward to evaluate whether the direct effect...on policy is quantitatively important".

The findings in column 3 indicate that the house price inflation coefficient, θ_1, is positive and highly significant. Monetary policy tightens in response to increases in house prices: a one percent rise in house prices increases interest rates by 15 basis points. The response to expected inflation is stronger than in the benchmark case, with a smaller standard error. The estimated inflation coefficient is 1.6 close to the theoretical value of 1.5, as suggested by Taylor (1993), thus ensuring that real rates increase in response to inflationary pressures. We then add stock price changes in the benchmark model. The estimated coefficient, θ_2, (Table 3.2, column 4) is still positive and statistically significant but its value (0.06) is much smaller as compared to house price coefficient. The results agree with the findings of Chadha, Sarno, and Valente (2003). Chadha et al. employ an augmented forward looking Taylor rule specification and find a positive and statistically significant coefficient on stock prices.

Finally, when both asset returns are included (Table 3.2, column 5), the magnitude of the coefficients confirms that house prices enter more significantly the monetary policy reaction function, since $\theta_1 > \theta_2$. Further, the *J*-statistic for overidentifying restrictions suggests that the instrument set is valid.

3.5.3 Accounting for Bank of England independence

There is a wide consensus among academics and practitioners that central bank independence produces lower average inflation (Cukierman, 1992). Spiegel (1998) finds that the BoE independence on May 1997 had a significant negative impact on agents' inflationary expectations. In order to account for the change in the underlying regime and preferences we allow the expected inflation coefficient to be different post-independence.

We therefore introduce a multiplicative dummy variable, D_t, in the reaction function, where $D_t = 0$ prior to independence and 1 onwards:

$$i_t = \left(1-\sum_{i=1}^{I}\varphi_i\right)\{a+(\beta+\mu D_t)(E_t[\pi_{t+n}]-\pi^*)+\gamma E_{t-1}[y_t]+\Theta' \mathbf{X}_t\}+\sum_{i=1}^{I}\varphi_i i_{t-i}+\upsilon_t \qquad (3.15)$$

Table 3.3: GMM Estimates of Forward Looking Taylor Rule adjusted for the Effect of Bank of England Independence, 1992:10-2003:1.

	Benchmark Model	$X_t = [\Delta_{12}H_t]'$	$X_t = [\Delta_{12}S_t]'$	$X_t = [\Delta_{12}H_t, \Delta_{12}S_t]'$
a	4.53 **	5.85 ***	3.27 **	5.62 ***
β	1.81 **	2.35 ***	1.30 ***	2.25 ***
γ	0.03 ***	0.04 ***	0.02 ***	0.03 ***
μ	0.41 *	0.47 **	0.61 ***	0.40 *
$\sum_{i=1}^{I}\varphi_i$	0.92 ***	0.88 ***	0.89 ***	0.87 ***
θ_1	-	0.12 ***	-	0.13 ***
θ_2	-	-	0.04 ***	0.03*
S.E. of Reg.	0.0022	0.0024	0.0022	0.0025
J- Stat.	13.30	15.76	23.18	15.78

Note:

(a) Estimates are obtained by GMM estimation with correction for MA(12) autocorrelation. Two-stage least squares estimation is employed to obtain the initial estimates of the optimal weighting matrix.
(b) In the benchmark model the instruments used are a constant and lags 1 to 6 of the nominal short term interest rate, inflation, output gap, and the log difference of a world commodity price index (agricultural raw materials). In the models that include asset price inflation, lags 1 to 6 of the relevant asset price inflation variable are also included.
(c) *J*-stat denotes the test statistic for overidentifying restrictions.
(d) *, **, *** indicate level of significance of 10%, 5%, and 1% respectively.

We would expect the dummy coefficient, μ, to be positive and significant indicating that the BoE becomes more inflation-averse, which leads to lower inflation expectations. The results from the estimation of the empirical counterpart of Eq. (3.15) in Table 3.3 confirm our predictions. In the benchmark model, μ is equal to 0.41 suggesting that post-independence the BoE reacts to one percent increase in expected inflation by raising interest rates by an additional 41 basis points. Even when we control for the effect of asset prices, the dummy remains positive and significant, reaffirming a higher degree of inflation aversion as a result of independence. We notice that the magnitude of the estimated asset inflation coefficients does not change. The monetary policy response to house prices is always stronger than the one with respect to stock prices. For instance, in the case of both assets entering the reaction function, θ_1 is equal to 0.13 and significant at the 1% level, while θ_2 is equal to 0.03 and significant at the 10%. The coefficient of house price inflation in particular is almost double the coefficient of stock price inflation. This supports the findings in the previous section where we reported a strong link between house price inflation and aggregate demand which induces policy makers to track more closely developments in the housing market.

3.5.4 Historical Performance

In this section we examine the historical performance of our estimated reaction functions against the actual policy setting of the BoE. In Figures 3.3, 3.4, we plot the implied target rates from the dummy augmented model versus the actual short-term interest rate. As Clarida et al. (1998) point out, employment of the target rate as opposed to the fitted rate, that includes the lagged interest rate, allows for a better comparison of the alternative specifications. Figure 3.3 uses the target interest rate implied by the benchmark model, while Figure 3.4 uses the target rate implied by the asset price augmented policy rule (using both house price and stock price inflation).

It is clear that the benchmark target rate underperforms in capturing actual BoE behaviour. With the exception of two short periods at the beginning and the end of our sample, actual interest rates were consistently higher than the rule predicted value. Thus, the BoE was far tighter than the simple benchmark forward-looking model would predict. When asset prices are allowed to be one of the state variables monitored by the central bank, the picture becomes clearer. As we notice in Figure 3.4 the target rate tracks the general trend of the actual interest rate for most of the period under investigation.

Figure 3.3: Actual and Target interest rate (benchmark model), UK, 1992:10-2002:01.

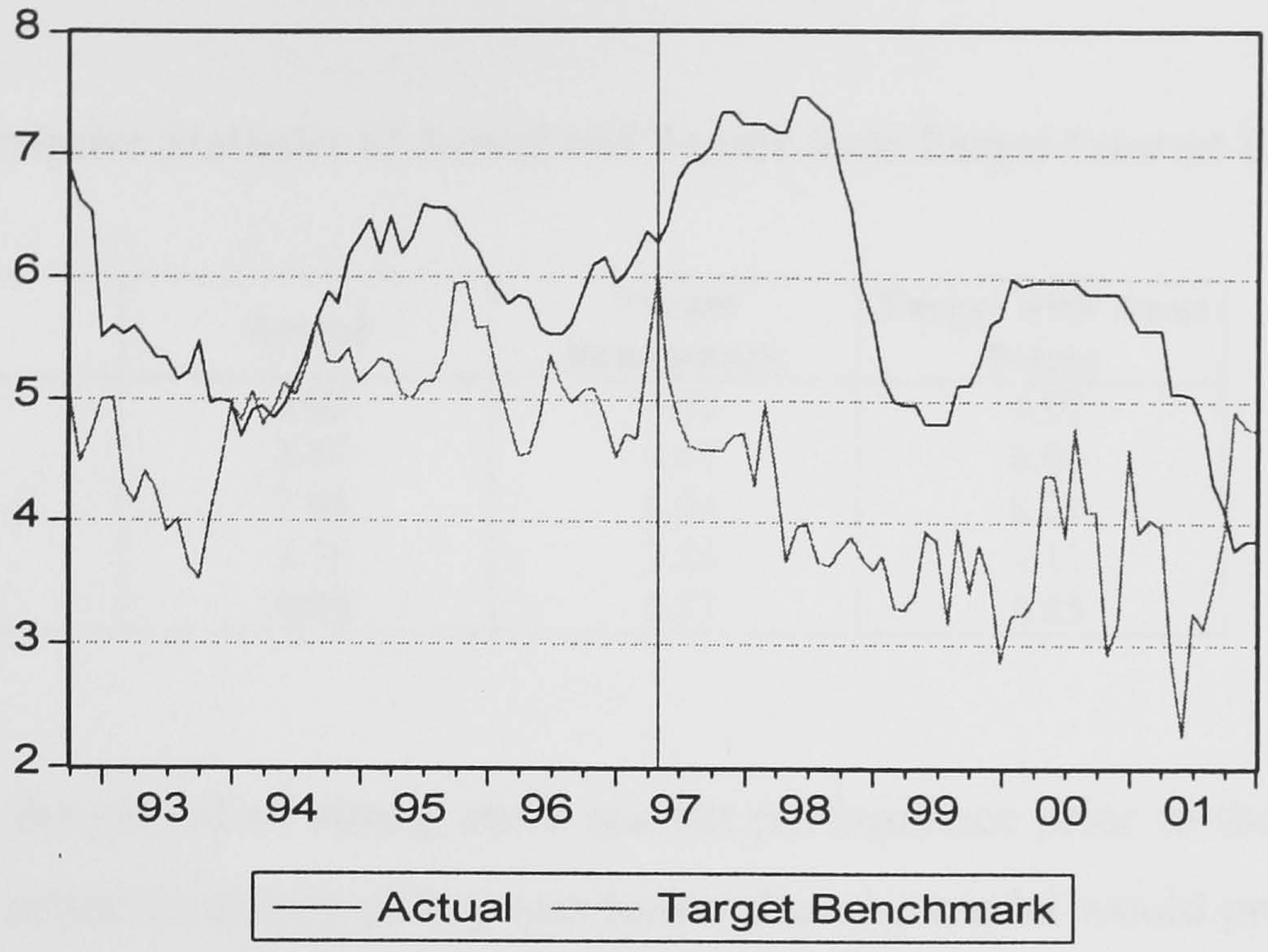
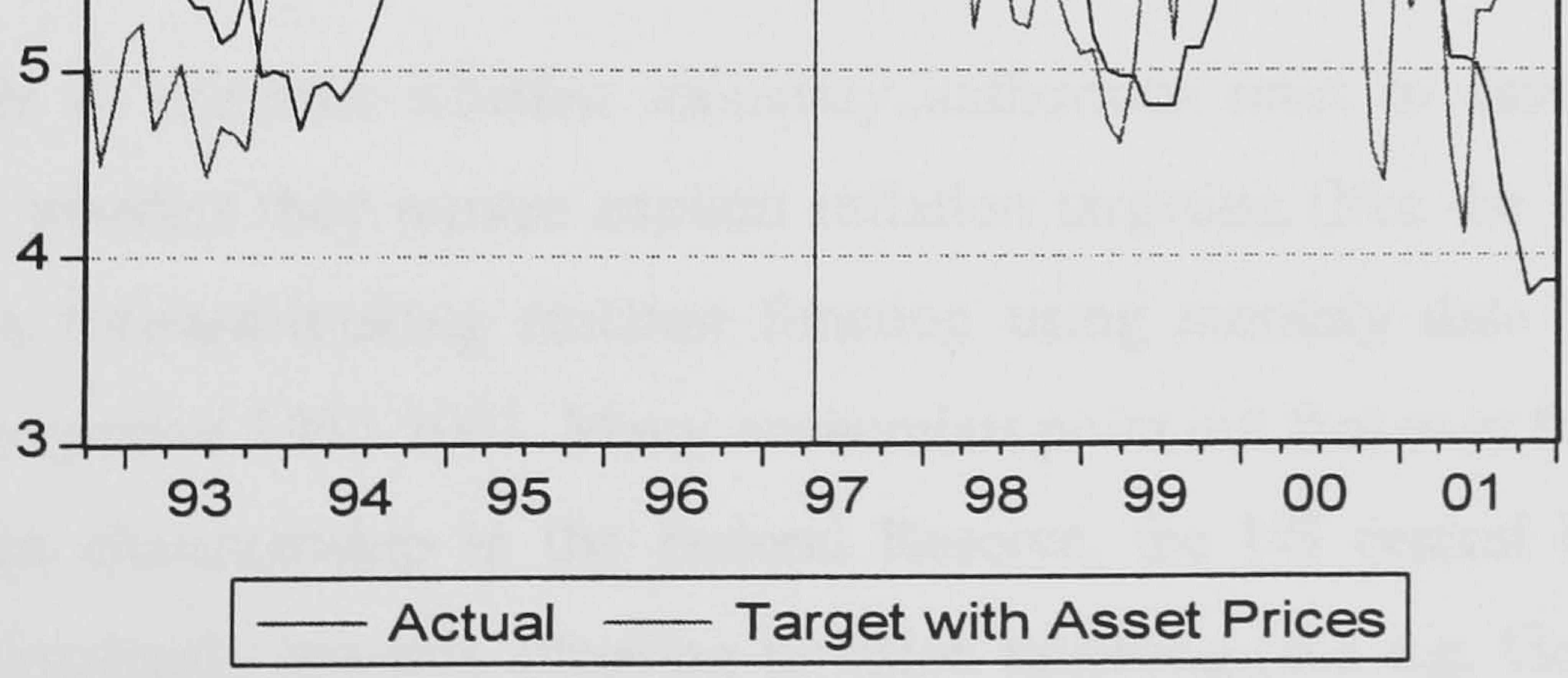


Figure 3.4: Actual and Target interest rate (asset price model), UK, 1992:10-2002:01.



Indeed, summary statistics presented in Table 3.4 indicate that when asset prices are not considered, the target interest rate is on average more than 1 % lower than the actual rate. Thus, the benchmark Taylor rule doesn't seem to explain well interest rate setting in the UK. The alternative specification produces a target rate which is much closer to the actual behaviour in terms of both mean and variability.

Table 3.4: Descriptive Statistics of Actual and Taylor Rule Target Interest Rate, UK, 1992:10-2002:1.

	Actual	Target Benchmark	Target with Asset Prices
Mean	5.83	4.42	5.92
Median	5.87	4.57	6.03
Maximum	7.46	6.04	8.24
Minimum	3.78	2.25	4.11
Std. Dev.	0.82	0.77	0.85

During the period of strong stock market performance prior to the Asian financial crisis of 1997, actual monetary policy was looser than the model would predict; and then it was somewhat tighter during the first years of independence. One possible interpretation of these findings is that the BoE was trying to signal its commitment to keep inflation on track, even though some would argue that the falling stock market required lower interest rates. A notable divergence of the target from the actual occurs after 2001, when the large increases in house prices call for much tighter policy than the one followed.

3.6 Empirical results: United States

In order to examine whether monetary authorities react to asset price inflation irrespective of whether they pursue explicit inflation targeting (like the BoE), or not, we will estimate a forward-looking reaction function using monthly data from the United States[10] over the period 1992-2003. Many economists point out that over the recent years of Alan Greenspan chairmanship in the Federal Reserve, the US central bank has moved gradually and implicitly towards adopting inflation targeting (see e.g. Goodfriend, 2003). Implicit targeting is differentiated from its explicit counterpart in that: first, there is no

[10] In the US regressions, we used the Federal funds rate as a measure of monetary policy, while inflation and the output gap have been calculated using the Consumer Price Index and the industrial production, respectively. The stock index employed is the Dow Jones, while Datastream provided the house price index. The transformation of the raw US data to growth rates and gaps was done using the same methodology as described in section 3.2. See Figures A3.1, A3.2 in Appendix III for plots of the US data employed in this section.

officially announced explicit numerical target, or target zone, for the inflation rate; and second the central bank is not officially obliged to act so that to keep inflation at the target (or in the range) within some specified time horizon. Other economists, however, strongly question the notion that the Fed has been practising implicit targeting (see for instance, Kohn, 2003; McCallum, 2003).

Table 3.5: GMM Estimates of Forward Looking Taylor Rule, US, 1992:10-2003:1

	Benchmark Model	$X_t = [\Delta_{12}H_t]'$	$X_t = [\Delta_{12}S_t]'$	$X_t = [\Delta_{12}H_t, \Delta_{12}S_t]'$
a	3.69 ***	3.58 ***	3.07 ***	2.82 ***
β	1.49 ***	1.47 ***	1.22 ***	1.12 ***
γ	0.12 ***	0.11 ***	0.21 ***	0.17 ***
$\sum_{i=1}^{l}\varphi_i$	0.95 ***	0.96 ***	0.93 ***	0.89 ***
θ_1	-	-0.06	-	-0.02
θ_2	-	-	0.09 ***	0.08 ***
S.E. of Reg.	0.002	0.003	0.001	0.001
J- Stat.	16.11	16.93	17.28	15.25

Note:

(a) Estimates are obtained by GMM estimation with correction for MA(12) autocorrelation. Two-stage least squares estimation is employed to obtain the initial estimates of the optimal weighting matrix.
(b) In the benchmark model the instruments used are a constant and lags 1 to 6 of the nominal short term interest rate, inflation, output gap, and the log difference of a world commodity price index (agricultural raw materials). In the models that include asset price inflation, lags 1 to 6 of the relevant asset price inflation variable are also included.
(c) *J*-stat denotes the test statistic for overidentifying restrictions.
(d) *, **, *** indicate level of significance of 10%, 5%, and 1% respectively.

The GMM estimation results of Eq. (3.12)[11] in Table 3.5, column 2, indicate a satisfactory benchmark specification. The estimated inflation coefficient, β, is about 1.5 indicating stabilising policy by the Fed with respect to inflation. The output coefficient, γ, is positive and quite larger in magnitude than the corresponding UK benchmark coefficient (0.12 as opposed to 0.03) indicating that the Fed has placed more weight on output stabilisation. In line with the previous UK findings, a high degree of interest rate persistence is also evident in the US data since the sum of the lagged interest rate

[11] For the US case, the inflation target, π^*, has been set to zero when estimating Eq. (3.12).

coefficients is 0.95. The *J*-statistic accepts the over-identifying restrictions of the benchmark specification.

When asset price inflation is added in the Fed reaction function (columns 3-5 of Table 3.5) it appears that only stock market fluctuations have been taken into account by the Fed, since θ_2 is positive and statistically significant, with a magnitude of around 0.1. Using a forward-looking Taylor rule model, similar time-period (1990-2003), and a different measure of stock market valuation Cecchetti (2003) agrees that there has been a significant reaction by the Fed to stock price movements[12]. On the other hand, Bernanke and Gertler (1999) fail to find a statistically significant coefficient for stock price inflation in an augmented Taylor rule, over the period 1979-1997. The difference between our results and Bernanke and Gertler's results may be attributed, among other factors, in the different sample periods.

The house price inflation coefficient, θ_1, is statistically insignificant in all cases, indicating that the Fed has not been as keen as the Bank of England in monitoring house market developments. This may reflect the fact that the US housing market has been substantially less volatile as compared to the UK market and its pronounced boom and bust cycles. As we see in Figure A3.1 in Appendix III, annual house price increases in the US have been quite modest, ranging between 1 to 8 %, while UK house price inflation has ranged substantially from -9 % to 26%. Finally, the *J*-statistic cannot reject the overidentifying restrictions.

3.7 Conclusions

This chapter examined the empirical reaction of monetary policy to asset prices using forward-looking Taylor rule models of interest rates. The intuition for monetary policy to consider asset prices lays on the fact that consumption wealth effects and

[12] Cechetti proxies stock price misalignments using the deviation of the implied equity premium from a 20-year lagged moving average. The equity risk premium is estimated as the dividend yield minus the risk free interest rate plus the growth rate of dividends (adjusted for stock repurchases). The equity premium variable in the augmented Taylor rule that Cecchetti estimates, has a negative and statistically significant coefficient. This is consistent with the view that stock market overvaluation, leads to lower equity premium, and the Fed reacts by tightening monetary policy. Chadha, Sarno and Valente (2003) also find a significant reaction by the Fed to stock price movements. Cecchetti (2003) provides similar results for Germany (1979-2003) and Japan (1979-2001).

investment balance sheet effects may destabilise aggregate demand and inflation, the two main variables of interest for the CB. Changes in real property prices and stock prices have significant impact on households' consumption and firms' investment. Using UK data over the period October 1992 to January 2003 we show that movements in asset prices, especially house prices, have a significant positive impact on aggregate demand. Demand pressures feed into higher future inflation, thus there is scope for an inflation targeting CB to consider asset inflation in its forward-looking reaction function.

The main contribution of this chapter is to find that policymakers in the explicitly inflation targeting UK appear to take into account both stock price inflation and house price inflation when setting interest rates, with the results suggesting that they are more concerned about developments in the property market. When the standard forward-looking Taylor rule is augmented by house prices and stock prices, the estimated coefficient of house price changes is always greater. The benchmark Taylor rule conditions short-term interest rates upon expected inflation and the output gap and fails to provide an accurate characterisation of actual policy. When asset prices are included in the reaction function, the implied target rate describes the general trends of the actual interest rate much better. In addition, we model the effect of central bank independence on the policy preferences towards expected inflation. We find that the relationship between asset price inflation and interest rates is robust, and that inflation aversion increased post-independence. The result that monetary policy reacts to asset price movements appears to be also robust to whether an explicit or implicit inflation targeting regime is at work, since the empirical findings for the US suggest that the Fed is also concerned about asset prices, in particular equity market fluctuations.

Chapter 4

Optimal Interest Rate Rule with Wealth Effects

4.1 Introduction

The role of asset prices in the monetary policy transmission mechanism has been the subject of a growing debate in recent literature. Asset prices could be part of the monetary policy objectives, and/or part of the information set that they employ in pursuing those objectives (Vickers, 2000). As Bernanke and Gertler (2001, p.253) point out, in an inflation targeting framework the answer to how central banks should respond to asset prices is clear: "changes in asset prices should affect monetary policy *only* to the extent that they affect the central bank's forecast of inflation". Some authors favor a *pro*-active monetary policy response to asset price bubbles. Cecchetti, Genberg, Lipsky, and Waldwani (2000) suggest that the central bank can reduce long-term inflation and output volatility by adjusting interest rates in response to asset price misalignments even when inflation remains on track. Other authors however take a contrarian view: asset prices are too volatile relatively to their information content and any attempt to include them in a feedback rule for interest rates would worsen economic outcomes. Bernanke and Gertler (1999, 2001) allow for non-deterministic bubble processes and suggest that a too aggressive interest rate response increases inflation volatility. Filardo (2000, 2001) also explores the role of asset prices for monetary policy and finds that if there is no uncertainty about their effect on inflation and output, then monetary policy should respond to asset prices.

It is often argued that the forward-looking nature of asset prices makes them good proxies for the information left out of conventional inflation measures. Goodhart (2001) stresses that asset price inflation developments are closely associated with general inflation trends. Goodhart and Hoffman (2000) derive financial conditions indices that employ assets such as stocks and property in their calculation, and show that they are a useful indicator for future consumer price inflation. In any case, as Bäckström (2000, p.1) argues, "in a regime that explicitly targets inflation, asset prices are taken into account via the effects on aggregate demand. Rising share prices increase household wealth and that would raise consumption for a given level of income if these increases in wealth are considered to be of a permanent nature". Thus, the link between asset prices and aggregate demand is crucial in the context of the transmission mechanism of monetary policy. Expansionary monetary policy boosts asset prices leading to an increase in aggregate demand which feeds into future inflationary pressures.

This chapter examines the relationship between asset prices and monetary policy in the context of optimal policy rules. In particular, following the seminal work by Taylor (1993), feedback rules conditioning the interest rate instrument on current or expected inflation and the output gap have been extensively analysed in both theoretical and empirical literature. Svensson (1997), Clark, Goodhart and Huang (1999), Ellingsen and Södeström (2001), and Clarida, Gali and Gertler (1999, 2001) among others, show that such a feedback rule is optimal in that it derives from the first order condition for the optimisation of the central bank's objectives. The standard approach in the literature to characterise these objectives by a loss function, which is quadratic in the deviation of inflation from target and in the output gap (see e.g. Woodford, 1999), is also taken here.

We start from a backward-looking structural macro model where asset prices affect future inflation indirectly, through direct wealth effects on aggregate demand. The model for asset price dynamics that we initially employ is consistent with reversion of asset prices to fundamentals, and no-bubble buildup. The optimal interest rate rule is obtained by optimising intertemporally the aforementioned central bank loss function. The derived policy rule conditions the current nominal interest rate instrument upon concurrent inflation and output gap, with the weight on inflation being lower than in the traditional case of no demand-wealth effects. We then relax the assumptions governing the asset price block of the model in order to allow for momentum trading situations, where the asset price is positively affected by its past rate of change. This is done in an effort to bring some realism to the model as, among other historical bubbles, the recent experience of the 1990s implies that in an 'irrationally exuberant' economic environment, asset prices can deviate significantly from their underlying fundamental value. We show that monetary policy should respond to asset price misalignments with the aggressiveness of the response being a positive function of the impact of asset prices on aggregate demand. This result has important implications for the conduct of monetary policy and contributes crucially to the existing literature, as existing work on optimal rules considering asset prices, either fails to find a role for asset prices (Bean, 2003), or obtains complex, non linear, and non-intuitive interest rate rules (Bordo and Jeanne, 2002; Durré, 2001).

The rest of the chapter is structured as follows. In the next section we provide the theoretical background relating asset prices and real economy. Sections 4.3 and 4.3.1 are devoted to the construction of the structural macro model and its solution. Section 4.3.2 derives the optimal monetary policy rule using stochastic control, while in section 4.3.3 we discuss the results. Section 4.3.4 calibrates the model and performs numerical simulations. In section 4.4 we relax the assumption that asset prices move on average along with their fundamental value, and derive and analyse an alternative optimal feedback rule. Section 4.5 concludes.

4.2 Asset prices and the transmission mechanism to the real economy

4.2.1 Historical perspective of theoretical developments

The majority of the theories on the monetary policy transmission mechanism have stressed the direct effects of interest rates of on output, and then, indirectly on inflation. However, there is also an old tradition in macroeconomics stressing the links between financial markets and real activity and the role of asset prices in the transmission mechanism. During the Great Depression, some economists, most notably Irving Fisher, pointed out that high levels of indebtedness and the resulting financial crisis were the main culprits for the sharp output contraction. As Fisher (1933) argued, over-indebtedness of firms, due to "new opportunities to invest at a big prospective profit" and "easy money", leading to liquidation, results in a contraction of firms' activity and deflation. Deflation leads to a higher real debt burden and bankruptcies, and as a result aggregate output decreases and the economy is trapped in recession with falling prices. More recently, Bernanke (1983b) focused on the importance of financial factors in the Great Depression, while Bernanke and Gertler (1999) argue that financial crises can be traced back to the origins of many other historical episodes, most notably the recessionary behaviour of the Japanese economy in the 1990's. Keynes has also stressed the importance of financial markets for real activity prospects, his followers, however, focused on the role of interest rates in the transmission mechanism of monetary policy to the investment and the real economy.

Up till quite recently, with a few exceptions[1], financial market conditions have been largely ignored in the standard macroeconomic literature. As Bernanke (1993) emphasizes, "in the standard model, factors such as financial conditions of banks and firms play no role in affecting investment or other types of spending". A potential explanation for the lack of attention to financial markets over the 1950's-1960's involves the prevalence, during that period, of the paradigm of perfect information and complete markets (see Alexandre and Bacao, 2002). Modigliani and Miller (1958) showed that under competitive markers and perfect information, the financial structure of the firm is irrelevant. In the 1970's, however, new theories in the economics of imperfect information challenged the results of the complete markets literature and pointed out the crucial role of banks and other financial

[1] See e.g. Gurley and Shaw (1955).

intermediaries in the functioning of credit markets. According to this literature, financial markets are characterized by imperfect and asymmetric information, which in turn determine the borrower-lender relationship and the financial structure of the firms. Jensen and Meckling (1976), for instance, argue that with imperfect information and incentive problems, external finance is more expensive than internal finance.

The role of asymmetric information in loans markets has been theoretically explored in a series of papers (see e.g. Bernanke and Gertler, 1989; Kiyotaki and Moore, 1997; Bernanke, Gertler and Gilchrist, 1998). In the context of these models, households and firms may face a borrowing constraint due asymmetric information in the market for bank loans, which produces moral hazard or adverse selection problems. Hence, households and firms can only borrow when they offer collateral in exchange. In such an environment, the Modigliani-Miller theorem does not hold, and investment demand depends positively on the firms' balance-sheet position. A higher net worth has a positive effect on investment both directly, by increasing the sources of internal finance, and indirectly, by offering more collateral. According to Bernanke and Gertler (1995), a new channel of transmission of monetary policy arises due to information imperfection in the financial and credit markets. This 'credit channel' constitutes a set of factors that amplify and propagate conventional interest rate effects, and can be decomposed into a balance sheet and a bank-lending channel. For example, an increase in interest rates, decreases asset prices and consequently the value of the firms' collateral leading to a reduction in investment spending as the firms' ability to borrow declines. Bernanke, Gertler and Gilchrist (1996) provide empirical evidence supporting the balance sheet channel. The bank-lending channel points out the effect of monetary policy on banks' ability to lend and thus on the amount of external funds available for firms' investment[2].

Goodhart and Hofmann (2003) examine empirically the relationship between credit and asset prices using data from ten industrialized economies over the 1972-1998 period. Using cointegration techniques they demonstrate a strong positive bi-directional relationship between house prices and the credit to GDP ratio. They argue that the relationship between credit and asset prices is multifaceted, since credit conditions may also affect asset valuations. The role of credit for asset valuations has already been emphasized by Kindleberger (1996) and Minsky (1982). This argument has also been

[2] See Kashyap and Stein (1994) for empirical evidence on the importance of the bank-lending channel.

restated in more policy orientated literature (see e.g. Schinasi and Halgraves, 1993). However, standard asset pricing models do not claim an explicit direct role for credit conditions since they argue that real asset prices depend on the discounted future stream of real dividend payments. In such framework, higher liquidity exerts an indirect effect by lowering interest rates (and thus decreasing discount factors), or by indicating stronger future growth (and thus higher expected dividends). On the other hand, as Goodhart and Hofmann (2003) point out, "whether asset prices always obey asset pricing formulae in reality is not to be taken for granted, and it may simply be that additional available liquidity increases the demand for a (temporarily) fixed supply of assets, which results in higher real asset prices.

4.2.2 Channels of asset price influence to consumption and investment

In the monetary policy transmission mechanism literature we usually identify three types of asset prices, besides those on debt instruments, that provide important channels through which monetary policy affects the real economy: stock prices, house prices, and exchange rates. Asset price changes affect aggregate spending via changes in consumption and investment spending. In light of their overwhelming role in the composition of the private sector portfolios the focus here will be on equity and property prices.

Stock prices

As Mishkin (2001) points out, transmission mechanisms of monetary policy via the stock market can be categorized in four types: stock market effects on investment, firm balance-sheet effects, household wealth effects, and household liquidity effects.

Stock market and investment

A theory that allows for a mechanism linking changes in stock prices to the aggregate economy is Tobin's q-model (Tobin, 1969). Tobin's q is defined as the market value of firms divided by the replacement cost of capital. Higher values of q imply that the market price of firms is high relative to the replacement cost of capital, and therefore new plant and equipment capital is cheap relative to the market value of firms. The companies then may issue equity capital and get a high price for it relative to the cost of the facilities and equipment they are buying. Consequently, investment spending increases because firms can now buy a lot of new investment goods with only a small issue of stock. Expansionary monetary policy which lowers interest rates makes bonds less attractive relative to stocks and results in increased demands for stocks that bids up their price. Chapter 1 offered empirical evidence indicating that stock returns and interest rate changes are inversely related. Combining the negative relationship between interest rates and stock prices and the positive relationship between stock prices and investment spending, leads to the following transmission mechanism of monetary policy:

Expansionary monetary policy → Higher Stock Prices → Higher q → increase in investment spending → increase in aggregate spending

In addition, when stock prices increase, it becomes cheaper for firms to finance their investment by issuing shares instead of bonds, since each new share that is issued produces more funds. Thus a rise in stock prices will lead to higher investment spending. Therefore the transmission mechanism can also take the following form:

Expansionary monetary policy → Higher Stock Prices → lower cost of capital → increase in investment spending → increase in aggregate spending

Morck, Shleifer and Vishny (1990) review five main theories concerning the causal direction of the underlying positive relationship between stock returns and the investment component of output growth. These theories are categorised into those according to which stock price movements not reflecting changes in future fundamentals (bubbles) cannot predict changes in investment - the 'passive informant' hypothesis and the 'accurate informant' hypothesis- and those according to which they can - the 'faulty active informant' hypothesis, the 'financing' hypothesis, and the 'stock market pressure on managers' hypothesis. Under the 'passive informant' hypothesis, the stock market simply captures information that people already know and doesn't play an important role in allocating investment funds. This hypothesis assumes that the fundamental share price reflects the present discounted value of all future dividends, and that dividend growth is positively related to GDP growth. Thus, if next year's growth is buoyant, news revealed this year will typically be positive, resulting in positive stock price movements throughout the year.

Under the 'accurate active informant' hypothesis, stock price movements convey to managers information about the future economic developments. This information is in turn employed by the managers to base their investment decisions, thereby justifying the market's expectations. In this case the stock market acts as a sunspot bringing about one of several possible self-fulfilling equilibria. Thus, under this hypothesis, the stock market cannot predict investment, after controlling for future fundamentals, because it is perfectly correlated with future fundamentals. From the viewpoint of the above two hypotheses, there is no behavioural causal relationship running from asset prices to investment and economic activity. The only causal relationship is between current and future output growth, with stock markets merely being a "side-show".

On the other hand lies the more traditional view that asset price changes affect investment and output via various channels. The "faulty active informant" hypothesis states that managers' investment decisions are influenced by stock price movements, but managers cannot distinguish between movements that reflect investor sentiments and movements that reflect changes in fundamentals. Under this hypothesis, investor optimism (pessimism) may mislead the managers to over-investment (under-investment). Under the 'financing' hypothesis, based upon Tobin's q theory of investment, the key channel of the stock market's influence on investment is through the issuance of new shares. It argues that when stock prices are high compared to the replacement cost of capital, managers are more likely to invest in new physical capital by issuing new shares of their company. Thus there is a direct positive causal link running from high stock returns to high investment and output growth. If stock prices are assumed to have an important influence on financing decisions then as Fischer and Merton (1984) argue, investor sentiment may affect real economic activity.

Changes in stock prices have been found to exert significant effects on investment in most industrialised countries. In the U.S. the impact of changes in stock prices on investment appears to have been particularly strong with the Tobin's q having risen by 75 percent between 1992 and 1998 to reach its highest level since World War II (Barro, 1990). Although the predictive performance of q-type investment models has been traditionally weak – an interesting exception is the paper by Erickson and Whited (2000) – there is little dispute that the market drop in the price of capital associated with the late 1990's US internet boom in equity markets has contributed importantly to rapid investment growth. Studies for other countries also yield a strong relationship between stock prices and investment[3]. In France, Germany, and the Netherlands however, the link between asset prices and investment is less pronounced (IMF, 2000).

One potential explanation for the historically smaller role for stock prices in continental Europe is the difference in corporate laws and traditions, as witnessed by less frequent takeovers, the great importance accorded to employees in decision making and the higher gearing ratios. These features imply that managers tend to be less responsive to the stock market relative to their counterparts in the Anglo-Saxon countries. On the other hand, there is evidence that property prices – rather than stock prices- have a more significant effect on investment in continental Europe and Japan, consistent with the more widespread use of property collateral against loans.

Firms balance sheet effects

As we already argued, the presence of asymmetric information problems in credit markets provides another stock market-related transmission mechanism of monetary policy. When stock prices decline, the net worth of firms decreases as well inducing more severe adverse selection and moral hazard problems associated with lending to these firms. Lower net worth is equivalent to lower value for the collateral to be employed for loans. Thus, potential losses from adverse selection are higher, leading to a decrease in available financing and consequently investment spending. The lower net worth of firms implies also more pronounced moral hazard since the owners of the firms have a lower equity stake, giving them greater incentives to engage in risky investment projects. Undertaking riskier investment projects makes it more likely that lenders will not be paid back, thus a decrease in net worth will lead to an decrease in lending and hence in investment spending. Hence, monetary policy can affect firms' balance sheets and aggregate spending via the following transmission channel:

Expansionary monetary policy → Higher Stock Prices → Increase in net worth of firms → smaller adverse selection and moral hazard → higher lending→ increase in investment spending → increase in aggregate spending

[3] See, among others, Andersen and Subbaraman (1996) and Bayoumi (1999) for Australia, the United Kingdom, and Japan .

Household liquidity effects

As Mishkin (2001) points out, an alternative way to consider balance-sheet channels of monetary policy is by examining household balance sheets, particularly liquidity effects on consumer durables and housing expenditures. According to the liquidity effects view, balance sheet effects work through their impact on consumer's desire to spend rather than on the lender's desire to lend (Mishkin, 1977). Due to asymmetric information about their quality, consumer durables and housing are very illiquid assets. Following a negative income shock, if consumers need to sell their consumer durables or housing to raise money, they would expect a loss because they could not get the full value of these assets in a distress sale. In contrast, if they held financial assets (bank deposits, stocks, bonds) they could sell them quickly for their full market value and raise the cash. When stock prices increase, consumer durable expenditure also increases since consumers have a more secure financial position and a lower estimate of the likelihood of financial distress. This leads to the following transmission mechanism:

Expansionary monetary policy → Higher Stock Prices → higher value of financial assets → decrease in perceived financial distress → higher durable consumption and housing spending → increase in aggregate spending

Household wealth effects

Consumption spending also plays an important role in another balance-sheet-related transmission mechanism that involves household wealth effects. According to the life cycle model of Modigliani (1971), consumption is determined by the lifetime resources of consumers. Financial wealth constitutes a major component of consumers' lifetime resources. Hence, expansionary monetary policy which raises stock prices, raises the value of household wealth, thereby increasing the lifetime resources of consumers which causes consumption to rise. Research has shown that this transmission mechanism is quite strong but the size of the wealth effect is still controversial (see e.g. Ludvingson, Steindel, and Lettau, 2002; Lettau and Ludvingson, 2001).

Expansionary monetary policy → Higher Stock Prices → higher household wealth → higher consumption spending → increase in aggregate spending

Property prices

Property prices are another important category of asset prices with active role in the monetary policy transmission mechanism. Property price movements have been closely related to the business cycle in the most of the industrialised world (IMF, 2000). For some countries like Japan the correlation is even stronger. Recessions in Japan since the early 1980s have been accompanied with falling property prices. Conversely, the strong upswings in economic activity in Australia and many EU countries since the mid-1990s have been associated with robust growth in property prices. As Mishkin (2001) argues, property prices can affect aggregate demand through three channels: direct effects on housing expenditure, household wealth, bank balance sheets.

Direct effects on housing expenditure

Monetary expansion lowers interest rates and thus decreases the cost of financing houses, which bids up their price. As the price of housing relative to its construction cost increases, construction firms try to increase the supply of housing and thus housing expenditure increases and aggregate spending also increases. This model of housing expenditure resembles the Tobin's q theory of investment[4].

Expansionary monetary policy → lower cost of financing housing → higher housing spending → increase in aggregate spending

Household wealth effects

Household wealth depends, among other factors, on the value of the property. Hence, expansionary monetary policy which raises property prices also raises household wealth and therefore consumption spending. The consumption wealth effect from higher property prices is expected to be stronger in countries where property ownership is more prevalent among households.

[4] See McCarthy and Peach (2002) for relevant empirical evidence.

Expansionary monetary policy → higher housing prices → higher household wealth → higher consumption spending → increase in aggregate spending

Bank balance sheets

Real estate lending constitute a major business for banks, in which the value of the property acts as a collateral. Higher real estate prices, due to monetary expansion, lead to lower bank loans losses, which increases the bank capital. Higher bank capital allows banks to engage in more lending, with the resulting credit expansion leading to higher investment and aggregate demand. When the process is inverted and property prices fall, leading to a decrease in credit availability and subsequently to smaller investment and output this transmission mechanism has often been described as a "capital crunch". Bernanke and Lown (1991) point out that a capital crunch was operational in the U.S. in the early 1990's, while Mishkin (2001) claims that it has been an important source of stagnation in Japan in recent years.

Expansionary monetary policy→ higher real estate prices → higher bank capital → higher bank lending → increase in investment → increase in aggregate spending

Following our discussion on the literature underlying the wealth effects and their impact on investment and consumption, we proceed to the theoretical model.

4.3 A structural backward-looking model

We use a structural backward-looking model of a (closed) economy that allows for the effect of asset prices on aggregate demand. As Svensson (1997) argues, the main simplification of the backward-looking model is that private-sector expectations are implicitly treated as adaptive expectations, thereby simplifying considerably the ensuing discussion. The model (Model I) is given by the following equations:

Model I

$$\pi_{t+1} = \pi_t + ay_{t+1} + \varepsilon_{t+1} \qquad (4.1)$$

$$y_{t+1} = \beta_1 y_t - \beta_2 (i_t - E_t[\pi_{t+1}]) + \beta_3 q_t + \eta_{t+1} \qquad (4.2)$$

$$q_{t+1} = -\gamma_1 (i_{t+1} - E_{t+1}[\pi_{t+2}]) + \gamma_2 y_{t+1} + u_{t+1} \qquad (4.3)$$

where, $\pi_t = p_t - p_{t-1}$ is the inflation rate at time t (strictly, the deviation from target), p_t is the natural logarithm of the price level, y_t is the deviation of log output from its steady-state level (output gap), i_t is the monetary policy instrument (a nominal short-term interest rate, e.g. repo rate), q_t is the log real asset price at t. Different interpretations of q_t are possible (e.g. house price, stock price), in what follows though we mainly treat it is a real stock price. ε_t, η_t, and u_t are i.i.d. shocks to inflation, aggregate demand and asset prices with zero means and constant variances: σ_ε^2 , σ_η^2 , σ_u^2. The coefficients can be interpreted as partial elasticities which have the following properties: $\alpha, \beta_2 , \gamma_1 , \gamma_2 > 0$; $0 < \beta_1 < 1$; $\beta_3 \geq 0$.

Eq. (4.1) is an accelerationist (or backward-looking NAIRU type) Phillips Curve where the change in inflation is a positive function of the current output gap and the inflation shock. The presence of inflation inertia in the inflation equation implies that disinflations will be costly in terms of output losses, thus there is a short-run trade-off between inflation and the output. However, since lagged inflation enters Eq. (4.1) with unity coefficient, this specification implies a vertical long-run Phillips Curve, i.e. there is no long-run relationship between the output and inflation[5]. Eq. (4.1) resembles the inflation equation employed by Svensson (1997) and Rudesbusch and Svensson (1999) in that the role of expected future inflation in the inflation adjustment equation is being ignored[6]. Fuhrer (1997) employed US data and argued that forward looking expectations are unimportant empirically in inflation adjustment equations. The parameter α is a positive constant which measures the sensitivity of inflation to excess demand[7].

[5] We should note, however, that as McCallum (1997) argues, the use of Eq. (4.1) in which lagged actual inflation obtains a unity coefficient, can lead to problems of instability that would not arise if expectations of current of future inflation were included.

[6] Svensson (1997) employs a variant of Eq. (1) in which inflation depends on the one-period lagged, rather than concurrent, output gap.

[7] As Clark, Goodhart, and Huang (1999) point out, there are good reasons to believe that α is not constant (see also Clark et al., 1996; Laxton et al. (1995). The assumption of linearity in the Phillips curve helps to obtain a closed-form solution for the optimal feedback rule. Bean (1996) discusses the implications of nonlinearity in the Phillips curve for optimal monetary policy in a model which does not utilize rational expectations.

The demand side, as given by Eq. (4.2), is based upon previous work by Walsh (1998), Ball (1997), and Svensson (1997), with one important difference: aggregate demand at time $t+1$ not only is serially correlated and negatively related to the lagged real interest rate, $i_t - E_t[\pi_{t+1}]$, but also depends upon past real asset prices (wealth effects), which themselves are a negative function of the real interest rate and a positive function of output. The presence of lagged variables in the aggregate demand equation intends to capture the dynamics in the data which call for a lagged response of output to policy changes.

Monetary policy will affect aggregated demand via changes in the real interest rate, therefore in a specification like the one given by Eqs. (4.1)-(4.3), current interest rate actions will affect next period output. This is consistent with the result of a number of VAR studies[8]. As indicated by Eq. (4.2) expected future output gap is not included in the aggregate demand equation. The presence of expected future output derives from models consistent with optimising agents (see e.g. McCallum and Nelson, 1999a). Unless, lagged output gap proxies expected future output gap, the interrelationship between current demand and expected future output, as predicted by optimal consumption choice models, is not reflected in Eq. (4.2). Parameter β_3 in the aggregate demand indicates wealth effects which have a positive impact on the aggregate demand. If there are no wealth effects and $\beta_3 = 0$ then Eq. (4.2) resembles a traditional dynamic AD. The value of β_3 depends, among other factors, upon the amount of wealth that is locked in the stock market. We would expect that in a market-based economy the value of β_3 is higher than a bank-based economy with a smaller portion of wealth invested in capital markets.

The third equation describes the behaviour of the stock market. In line with the present value model of equity valuation, the real asset price is negatively related to current real interest rate and positively to current output[9]. This is supported by the majority of empirical studies examining the effect of macroeconomic variables on the stock market[10]. Financial theory posits that stock prices equal the expected present value of future net cash

[8] See for example Leeper, Sims, Zha (1996).

[9] Note that Eq. (4.3) relates the real asset price, q_t, with the expected value of the output gap. Strictly speaking, the asset price should be a function of expected output. Since, however, output is the sum of the output gap plus the potential output, it is implied that higher output gap is associated with higher output and hence higher asset price.

[10] See among others Fama (1981), Conover Jensen and Johnson (1999).

flows[11]. Holding everything else equal, higher interest rates are associated with lower stock prices, given the higher discount rate for the expected stream of cash flows. The conventional view suggests that a restrictive monetary policy environment serves as bad news for the stock as it is generally associated with higher future interest rates and lower level of economic activity. In contrast, an expansive monetary environment signals higher average real equity returns, as these periods are usually associated with lower future interest rates and increases in economic activity. The empirical findings in chapter 1 verified the aforementioned conventional view since we showed that stock returns in a number of countries are significantly lower following a monetary policy tightening. The stochastic error term in Eq. (4.3), u_{t+1}, represents the non-fundamental component of the asset price. Here, for simplicity, it is assumed to have zero mean and constant variance, σ_u^2. Thus, for the moment we assume that, on average, asset prices move in line with their fundamentals and we don't allow for bubble-type events.

The structure of the model implies that the monetary policy instrument affects the stock market contemporaneously, and inflation and output with one period lag. In the context of an annual model, the monetary policy instrument could be interpreted as a one-year interest rate that is controlled by the central bank, or alternatively as a 2-week repo rate that must be held constant throughout each year. At time t the central bank chooses i_t which affects current period's real asset price and next period's inflation and output; however, contemporaneous inflation and output gap, π_t, y_t are predetermined by previous decisions and current exogenous shocks.

4.3.1 Solution of model I

Substituting for the lagged real asset price, q_t, in the aggregate demand Eq. (4.2) and using the expectational version of Eq. (4.1) to eliminate $E_t[\pi_{t+1}]$ we get:

$$y_{t+1} = (\beta_1 + \beta_3\gamma_2)y_t - (\beta_2 + \beta_3\gamma_1)(i_t - \pi_t - aE_t[y_{t+1}]) + v_{t+1} \tag{4.4}$$

where, $v_{t+1} = \beta_3 u_t + \eta_{t+1}$

[11] It is assumed that capital gains in the stock market are positively related to expected future dividends which are themselves proportional to current output.

Taking expectations on both sides of Eq. (4.4), conditional upon time t information, gives:

$$E_t[y_{t+1}] = \delta_1 y_t - \delta_2(i_t - \pi_t)$$

where, $\delta_1 = \dfrac{\beta_1 + \beta_3\gamma_2}{1-\alpha(\beta_2 + \beta_3\gamma_1)}$, $\delta_2 = \dfrac{\beta_2 + \beta_3\gamma_1}{1-\alpha(\beta_2 + \beta_3\gamma_1)}$

Using the above expression to eliminate $E_t[y_{t+1}]$ from (4.4) and rearranging, yields:

$$y_{t+1} = [(\beta_1 + \beta_3\gamma_2) + (\beta_2 + \beta_3\gamma_1)a\delta_1]y_t - (\beta_2 + \beta_3\gamma_1)(1 + a\delta_2)(i_t - \pi_t) + v_{t+1}$$

Following Walsh (1998), since π_t , y_t are predetermined when i_t is chosen we can define φ_t as the control variable of the central bank, where φ_t is given by:

$$\varphi_t = [(\beta_1 + \beta_3\gamma_2) + (\beta_2 + \beta_3\gamma_1)a\delta_1]y_t - (\beta_2 + \beta_3\gamma_1)(1 + a\delta_2)(i_t - \pi_t) \tag{4.5}$$

Using the definition of φ_t the Phillips Curve and the AD Eqs. (4.1) and (4.2) can be re-written as:

$$\pi_{t+1} = \pi_t + a\varphi_t + \omega_{t+1} \tag*{(4.1)$'$}$$

$$y_{t+1} = \varphi_t + v_{t+1} \tag*{(4.2)$'$}$$

where, $\omega_{t+1} = \varepsilon_{t+1} + av_{t+1}$

4.3.2 Optimal interest rate rule I

The central bank objective is to solve the following stochastic control problem: choose an infinite sequence of controls to minimise the expected discounted value of the intertemporal quadratic loss function that penalizes both inflation and output gap volatility:

$$\min_{\{\varphi_t\}_{t=0}^{\infty}} \tfrac{1}{2} E_t \sum_{i=1}^{\infty} \beta^i [\pi_{t+i}^2 + \mu y_{t+i}^2] \qquad (4.6)$$

subject to the transition Eqs. (4.1)′ and (4.2)′

where, $\mu \geq 0$ is the relative weight attached by the central bank on output gap stabilisation . β is the discount factor, $0 < \beta < 1$. In the absence of discounting, the postulated loss function is a weighted average of conditional volatility of inflation (deviations from target) and the output gap. It is evident from (4.2)′ that at time *t*, when the interest rate (and consequently φ_t) is chosen the only state variable is π_t. Therefore, the value function is defined in terms of π_t only, $V(\pi_t)$. Applying Bellman's dynamic programming principle, and substituting for the two constraints (4.1)′ and (4.2)′ in the value function, we obtain:

$$V(\pi_t) = \min_{\varphi_t} E_t \{\tfrac{1}{2}[(\pi_t + a\varphi_t + \omega_{t+1})^2 + \mu(\varphi_t + v_{t+1})^2] + \beta V(\pi_t + a\varphi_t + \omega_{t+1})\} \qquad (4.7)$$

The first order condition with respect to φ_t and the envelope theorem allow to derive an expression for the optimal path of the control variable [12]:

$$\varphi_t = -\left(\frac{a}{a^2 + \mu}\right)\pi_t + \left(\frac{\mu\beta}{a^2 + \mu}\right) E_t[\varphi_{t+1}] \qquad (4.8)$$

Since we have a linear-quadratic structure in the stochastic control problem the solution will be of the form

$$\varphi_t = c\pi_t \qquad (4.9)$$

Thus the optimal control will be linear function of the state variable. Updating one period ahead and taking expectations at time *t* of (4.9) yields:

$$E_t[\varphi_{t+1}] = cE_t[\pi_{t+1}] = cE_t[\pi_t + a\varphi_t + \omega_{t+1}] = c(\pi_t + a\varphi_t) = \varphi_t + ca\varphi_t \Leftrightarrow$$

$$E_t[\varphi_{t+1}] = (1 + ca)\varphi_t \qquad (4.10)$$

Substitution of (4.9) and (4.10) in (4.8) yields the following quadratic whose solution gives the optimal c value:

$$(\mu\beta a)c^2 + (\mu\beta - a^2 - \mu)c - a = 0 \tag{4.11}$$

The solution we accept has to fulfil the inflation process stability criterion. This condition implies that only the negative c-root is accepted[13]. Hence, c is a negative parameter depending on the model's structural parameters and on the central bank's preferences. Finally, we obtain the optimal interest rate, i_t, by using Eq. (4.5) and Eq. (4.9), and substituting for δ_1 and δ_2 :

$$i_t = f_\pi \pi_t + f_y y_t \tag{4.12}$$

where, $f_\pi = 1 - \frac{c}{\beta_2 + \beta_3\gamma_1} + ca$, $f_y = \frac{\beta_1 + \beta_3\gamma_2}{\beta_2 + \beta_3\gamma_1}$, are the respective interest rate weights on inflation, and the output gap.

Eq. (4.12) resembles a Taylor rule where the nominal interest rate is a linear function of inflation and the output gap. The inflation coefficient, f_π, should exceed the value of one, to ensure a real interest rate response that will lead to lower inflation (Taylor principle). This, in turn, imposes the condition that the slope of the Phillips curve, a, should satisfy[14]: $a < \frac{1}{\beta_2 + \beta_3\gamma_1}$. In Giannoni and Woodford's (2002) terminology, the policy rule in Eq. (4.12) is an *direct explicit instrument rule* since it provides a formula for the setting of policy instrument that specifies feedback only from predetermined target variables (π_t, y_t), without involving any 'intermediate target' variables.

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[12] See A4.1 in Appendix IV for more details.
[13] See A4.2 in Appendix IV for more details.
[14] $f_\pi > 1 \Leftrightarrow -\frac{c}{\beta_2 + \beta_3\gamma_1} + ca > 0 \Leftrightarrow c\left[-\frac{1}{\beta_2 + \beta_3\gamma_1} + a\right] > 0$. Taking also into account that only negative c-values are accepted we obtain the Phillips curve slope restriction.

4.3.3 Analysis of the results I

In the standard case of the no wealth effects, β_3 is equal to zero in Eq. (4.2) and the system would be formed by a typical AS/AD model. In this benchmark specification the optimal weights on inflation and output would be:

$$f_\pi^* = 1 - \frac{c}{\beta_2} + ca \quad \text{and} \quad f_y^* = \frac{\beta_1}{\beta_2}$$

Comparing the standard case ($\beta_3 = 0$) with the wealth effects case ($\beta_3 > 0$), we notice that the optimal response of monetary policy to inflation when aggregate demand is affected by wealth, should be smaller ($f_\pi < f^*_\pi$ since $c < 0$). The intuition behind this finding, is that the negative impact on inflation from a monetary tightening would be amplified when there are significant wealth effects on aggregate demand and consequently on inflation. With respect to the output gap coefficient we notice that the final result depends upon the relative effects of interest rates and output on the real asset price, (γ_1 and γ_2, respectively). If $\gamma_1 > \gamma_2$ and $\beta_1 > \beta_2$ then $f_y < f_y^*$; This implies a weight on output lower than the benchmark case. On the other hand, if $\gamma_1 < \gamma_2$ and $\beta_1 < \beta_2$ then $f_y > f_y^*$; When asset prices are more sensitive to output rather than interest rates, the model suggests that, in the presence of wealth effects, the central bank should adopt more aggressive interest policy with respect to output.

We now examine the effect of the underlying structure of the model on the policy parameters, by calculating the partial derivatives of f_π and f_y with respect to $\gamma_1, \gamma_2, \beta_3$.

Table 4.1: Partial Derivatives, Model I.

f	$\partial f / \partial \gamma_1$	$\partial f / \partial \gamma_2$	$\partial f / \partial \beta_3$
f_π	$\frac{c\beta_3}{(\beta_2 + \beta_3\gamma_1)^2} \leq 0$	0	$\frac{c\gamma_1}{(\beta_2 + \beta_3\gamma_1)^2} < 0$
f_y	$-\frac{(\beta_1 + \beta_3\gamma_2)\beta_3}{(\beta_2 + \beta_3\gamma_1)^2} \leq 0$	$\frac{\beta_3}{\beta_2 + \beta_3\gamma_1} \geq 0$	$\frac{\gamma_2}{(\beta_2 + \beta_3\gamma_1)} - \frac{(\beta_1 + \beta_3\gamma_2)\gamma_1}{(\beta_2 + \beta_3\gamma_1)^2}$

The results in Table 4.1 lead to the following propositions:

Proposition 1: *In the presence of wealth effects ($\beta_3 > 0$), the higher the elasticity of asset prices to the real interest rate, γ_1, the smaller is the optimal interest rate weight on inflation and the output gap.*

Proof: **(i)** Since $c < 0$, $\beta_3 \geq 0$, $(\beta_2 + \beta_3\gamma_1)^2 > 0$, it is implied that $\partial f_\pi / \partial \gamma_1 \leq 0$

(ii) Since $\beta_3 \geq 0$, $(\beta_1 + \beta_3\gamma_2) > 0$, $(\beta_2 + \beta_3\gamma_1)^2 > 0$, it is implied that $\partial f_y / \partial \gamma_1 \leq 0$

This result can be interpreted on the basis that central bank actions exert a double effect on real economy. This happens because an increase in interest rates not only exerts a direct negative impact on the firms' level of investment but will also depress consumption *via* a reduction in realised capital gains, leading to a greater-than-before decrease in aggregate demand and inflation. Thus, an increased sensitivity of asset prices to interest rates allows the monetary transmission mechanism to work through the financial market, but on the same time puts some downward constraints on the central bank's responses to inflation and the output gap.

Proposition 2: *In the presence of wealth effects ($\beta_3 > 0$), the more procyclical asset price are (i.e. higher γ_2), the higher is the optimal interest rate weight on the output gap.*

Proof: Since $\beta_3 \geq 0$, $(\beta_2 + \beta_3\gamma_1) > 0$, it is implied that $\partial f_y / \partial \gamma_2 \geq 0$

The intuition behind proposition 2 is that, according to Model I, output expansion is associated with asset price increases that feed into even higher output. Therefore, in order to achieve output stabilisation in the presence of a strong link between output and asset prices, a stronger response is required from the central bank.

Proposition 3: *The stronger the wealth effect, β_3, the smaller is the optimal interest rate weight on inflation.*

Proof: Since $c < 0$, $\gamma_1 > 0$, $(\beta_2 + \beta_3\gamma_1)^2 > 0$, it is implied that $\partial f_\pi / \partial \beta_3 < 0$

When the role of capital markets as creator of wealth and collateral is taken into account, the magnitude of the inflation related-interest rate adjustment should be smaller. This does not imply that the central bank intervenes less frequently. In fact, if the true data generation process for aggregate demand is given by the augmented IS, Eq.(4.2), then monetary policy may have to be more frequently adjusted. Proposition 4.3 suggests that as wealth effects build up, a too aggressive interest rate response to inflation will lead to recession and will threaten the price stability objective[15].

4.3.4. Calibrating model I

In order to examine the properties of the model we conduct simulation analysis. To do so, we need to calibrate the behavioural parameters in Eqs. (4.1)-(4.3). For the benchmark model coefficients (α, β_1, β_2) we employ the values from Ball's (1997) model. The lag structure of the model is more appropriate for annual data[16] therefore we used a discount factor $\beta = 0.96$. We assign a value of 0.1 for the elasticity of aggregate demand with respect to wealth effects (β_3). According to the Bank of England's model for consumption expenditure, a one percent rise in real net financial wealth and real gross housing wealth boosts aggregate spending by 0.12 percent in the long-run (Gramlich, 2002).

For the parameter values given in Table 4.2 and equal weight on inflation and output in the loss function ($\mu = 1$) we obtain the following benchmark optimal policy rule:

$$i_t = 1.4\pi_t + 0.8y_t \qquad (4.12)$$

[15] On the other hand no clear result emerges with respect to the weight attached on output since $\frac{\partial f_y}{\partial \beta_3} > 0$ if $\beta_2\gamma_2 > \beta_1\gamma_1$, and $\frac{\partial f_y}{\partial \beta_3} < 0$ if $\beta_2\gamma_2 < \beta_1\gamma_1$.

[16] The evidence in Batini and Nelson (2001) suggests that it takes a year before monetary policy actions have their peak effect on inflation.

Table 4.2: Baseline parameter values, Model I.

Coefficient	Benchmark Model	Wealth effect Model
α	0.4	0.4
β_1	0.8	0.8
β_2	1	1
β_3	-	0.1
γ_1	-	1
γ_2	-	0.7

The coefficients in Eq. (4.12) have magnitudes similar to those reported by Taylor (1993) and Ball (1997). The nominal interest rate is increased more than proportionally with respect to inflation, ensuring a real interest rate adjustment that will lead to lower inflation, while the output gap coefficient is higher than the standard Taylor rule response of 0.5. Inclusion of the wealth effect in the AD results into the following rule:

$$i_t = 1.1\pi_t + 0.76 y_t \tag{4.13}$$

The inflation coefficient is sensibly smaller while the output gap coefficient is not substantially altered. This type of response by the central bank ensures that output gap and inflation are stabilised at a lower interest rate as compared to the standard case of no wealth effects. Figure 4.1 shows the inflation coefficient as a function of the relative weight on output gap fluctuations (μ). We plot both f_π^* (*fpb*) and f_π (*fpw*) and notice that the optimal inflation coefficient is decreasing in μ and that when wealth effects are taken into consideration, the optimal weight on inflation is lower in general. This result certifies the predictions in Table 4.1. Since monetary policy can act not only directly on the level of inflation but also indirectly through the wealth channel, the interest rate response does not have to be as large as in the traditional case.

Taylor (1996) has argued that there is a trade-off between the variability, rather than the average levels, of inflation and output. Figure 4.2 plots the output gap-inflation volatility frontier deriving from the minimisation of the objective function of the model; it is negatively sloped indicating the presence of trade-offs in optimal policy choice. We present two alternative volatility frontiers; *spb* corresponds to the benchmark case, while

Figure 4.1: Optimal inflation coefficient as a function of the weight on output gap variance.

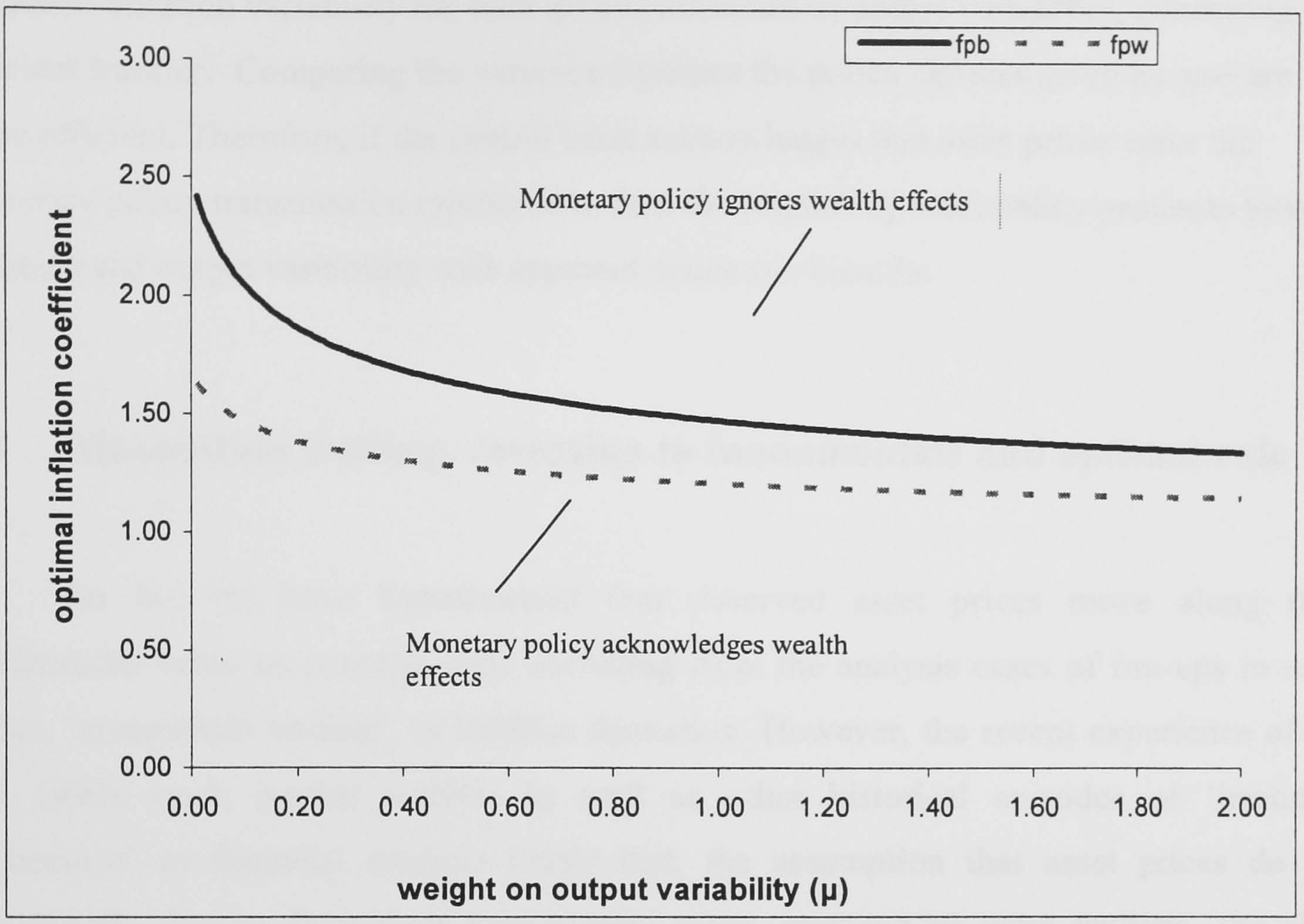
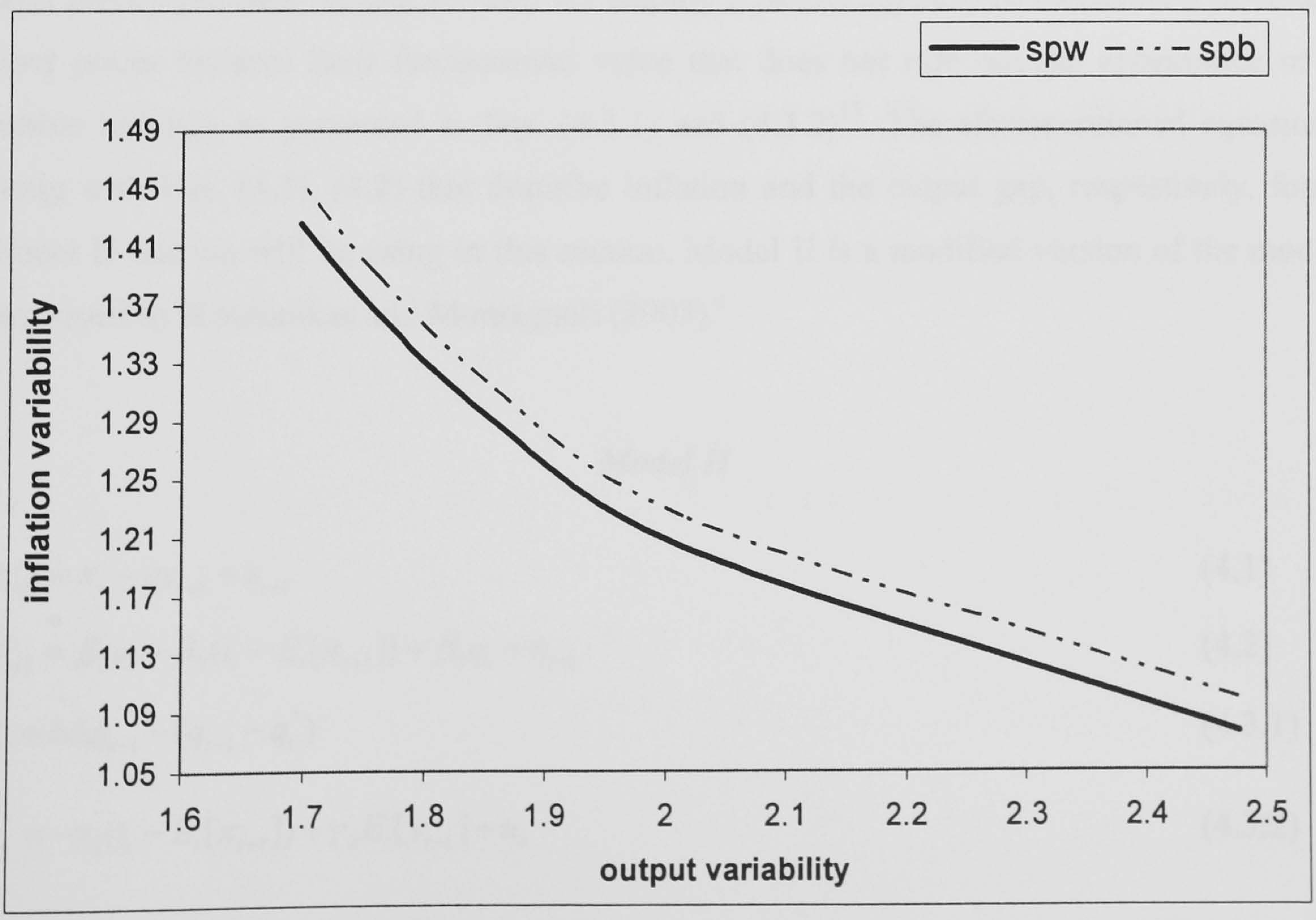


Figure 4.2: Volatility frontier for the wealth effects and benchmark case.



spw derives from the model taking into account asset prices. An efficient policy should minimise inflation variability for each given realisation of output variability, generating an efficient frontier. Comparing the variance frontiers the policy choices given by *spw* are more efficient. Therefore, if the central bank acknowledges that asset prices enter the monetary policy transmission mechanism, then the implied optimal policy produces lower inflation and output variability with apparent economic benefits.

4.4 Momentum trading, reversion to fundamentals and optimal rule

So far, we have hypothesised that observed asset prices move along their fundamental value on average, thus excluding from the analysis cases of run-ups to asset prices, 'momentum trading', or bubbles formation. However, the recent experience of the late 1990s stock market bubble, as well as other historical episodes of 'irrational exuberance' in financial markets imply that, the assumption that asset prices do not significantly deviate from their fundamental value, may not be quite realistic. We shall therefore relax the above assumption by postulating two alternative equations to describe asset price dynamics. In this section, we employ a partial adjustment mechanism of actual asset prices towards their fundamental value that does not rule out the appearance of a bubble buildup, as presented in Eqs. (4.3.1) and (4.3.2)[17]. The aforementioned equations along with Eqs. (4.1), (4.2) that describe inflation and the output gap, respectively, form Model II that we will be using in this section. Model II is a modified version of the model employed by Kontonikas and Montagnoli (2003).

Model II

$$\pi_{t+1} = \pi_t + a y_{t+1} + \varepsilon_{t+1} \tag{4.1}$$

$$y_{t+1} = \beta_1 y_t - \beta_2 (i_t - E_t[\pi_{t+1}]) + \beta_3 q_t + \eta_{t+1} \tag{4.2}$$

$$q_t = b\Delta q_{t-1} - (q_{t-1} - q_t^*) \tag{4.3.1}$$

$$q_t^* = -\gamma_1 (i_t - E_t[\pi_{t+1}]) + \gamma_2 E_t[y_{t+1}] + u_t \tag{4.3.2}$$

As Eq. (4.3.1) indicates, investors may feel that positive realised returns ($\Delta q_{t-1} > 0$) may continue in the future therefore inducing a positive 'momentum' effect on the current level of the real asset price ($b > 0$). In essence, investors bid up the demand for asset holdings in expectation that past capital gains will persist in the future. The higher the value of b the stronger the effect from past asset price changes and therefore q_t can diverge significantly from its fundamental value, q_t^*, albeit not permanently[18]. In addition, the asset price specification that we employ allows for reversion to fundamentals since following a decrease in fundamentals ($q_t^* < q_{t-1}$) there is a negative pressure on q_t. Eq. (4.3.2) describes fundamental asset prices in line with the standard dividend model of asset pricing. There is a positive effect from expected future dividends (assumed to depend on expected output) and a negative effect from real interest rates. We also allow for uncertainty in the fundamentals' process by including the random disturbance term, u_t.

4.4.1 Solution of model II

As we shall show the model's solution in terms of inflation and the output gap exhibits a form similar to Eqs. (4.1)′, (4.2)′. We begin by substituting for fundamentals, q_t^*, in Eq. (4.3.1) in order to get an alternative expression for real asset prices:

$$q_t = b\Delta q_{t-1} - \{q_{t-1} + \gamma_1(i_t - E_t[\pi_{t+1}]) - \gamma_2 E_t[y_{t+1}] - u_t\} \tag{4.14}$$

We then use Eq. (4.14) and the expectational version of Eq. (4.1) to eliminate q_t, $E_t[\pi_{t+1}]$ from the aggregate demand Eq. (4.2):

$$y_{t+1} = \beta_1 y_t - (\beta_3\gamma_1 + \beta_2)(i_t - \pi_t) + [a(\beta_3\gamma_1 + \beta_2) + \beta_3\gamma_2]E_t[y_{t+1}] + \beta_3(b\Delta q_{t-1} - q_{t-1}) + v_{t+1} \tag{4.15}$$

where, the composite error term, v_t, is again defined as: $v_{t+1} = \beta_3 u_t + \eta_{t+1}$

[17] We would like to thank Charles Goodhart for his useful suggestions regarding Model II.
[18] We do not regard the divergence of q_t from q_t^* as an explicit bubble because we do not assign any probabilistic structure to its evolution.

Taking expectations on both sides of the above expression, conditional upon time t information, yields the following expression for $E_t[y_{t+1}]$:

$$E_t[y_{t+1}] = \lambda_1 y_t - \lambda_2(i_t - \pi_t) + \lambda_3(b\Delta q_{t-1} - q_{t-1}) \tag{4.16}$$

where,

$$\lambda_1 = \frac{\beta_1}{1-[a(\beta_3\gamma_1+\beta_2)+\beta_3\gamma_2]},\ \lambda_2 = \frac{\beta_3\gamma_1+\beta_2}{1-[a(\beta_3\gamma_1+\beta_2)+\beta_3\gamma_2]},\ \lambda_3 = \frac{\beta_3}{1-[a(\beta_3\gamma_1+\beta_2)+\beta_3\gamma_2]}$$

Using Eq. (4.16) to eliminate $E_t[y_{t+1}]$ from Eq. (4.15) and rearranging, yields:

$$y_{t+1} = \lambda_1 y_t - \lambda_2(i_t - \pi_t) + \lambda_3(b\Delta q_{t-1} - q_{t-1}) + v_{t+1} \tag{4.17}$$

We define φ_t as the control variable of the central bank since π_t, y_t are predetermined when i_t is chosen (see also Walsh, 1998).

$$\varphi_t = \lambda_1 y_t - \lambda_2(i_t - \pi_t) + \lambda_3(b\Delta q_{t-1} - q_{t-1}) \tag{4.18}$$

Thus, the system of Eqs (4.1), (4.2), (4.3.1), (4.3.2) can be expressed in terms of φ_t:

$$\pi_{t+1} = \pi_t + a\varphi_t + \omega_{t+1} \tag{4.1'}$$

$$y_{t+1} = \varphi_t + v_{t+1} \tag{4.2'}$$

where, $\omega_{t+1} = \varepsilon_{t+1} + av_{t+1}$

4.4.2 Optimal interest rate rule II

As in the previous section, and as standard in the literature, the monetary authorities are assumed to have an objective function, like Eq. (4.6), that is quadratic in the deviation of inflation from the target and in the output gap. The technical procedure to derive the optimal interest rate feedback rule, as given by Eqs. (4.7) to (4.11) of the previous section, remains the same. Also, we utilise again the results in Appendix A4.1, and A4.2.

The optimal path for the interest rate is obtained using Eqs. (4.18) and (4.9), substituting for λ_1, λ_2, λ_3, and re-arranging.

$$i_t = \left(1 - \frac{c[1-A]}{\beta_3\gamma_1 + \beta_2}\right)\pi_t + \left(\frac{\beta_1}{\beta_3\gamma_1 + \beta_2}\right)y_t + \left(\frac{\beta_3}{\beta_3\gamma_1 + \beta_2}\right)(b\Delta q_{t-1} - q_{t-1}) \tag{4.19}$$

where, $A = a(\beta_3\gamma_1 + \beta_2) + \beta_3\gamma_2$, is a positive constant.

Eq. (4.19) can be transformed into a more intuitive expression by recalling that according to the asset price Eq. (4.3.1):

$$q_t = b\Delta q_{t-1} - q_{t-1} + q_t^* \Leftrightarrow b\Delta q_{t-1} - q_{t-1} = q_t - q_t^* \tag{4.20}$$

Hence, via Eq. (4.20), the final expression for the optimal interest rate rule is:

$$i_t = f_\pi \pi_t + f_y y_t + f_{q-q^*}\left[q_t - q_t^*\right] \tag{4.21}$$

where, $f_\pi = 1 - \frac{c[1-A]}{\beta_3\gamma_1 + \beta_2}$, $f_y = \frac{\beta_1}{\beta_3\gamma_1 + \beta_2} > 0$, $f_{q-q^*} = \frac{\beta_3}{\beta_3\gamma_1 + \beta_2} \geq 0$, are the respective interest rate weights on inflation, output gap, and asset price misalignments from fundamentals. The inflation coefficient, f_π, should exceed the value of one, to ensure a real interest rate response that will lead to lower inflation[19].

4.4.3 Analysis of the results II

The rule for adjusting nominal interest rates shown in Eq. (4.21), signifies a genuine result in the interest rates rules literature, since we show that the central bank should not only take into consideration inflation and output when setting interest rates, but should also

[19] As we show in A4.3 in Appendix IV, this condition is consistent with $A < 1$.

react to asset price misalignments. Durré (2001) and Bean (2003) also assume wealth effects augmented demand curves in their analyses, but the results that they obtain for optimal policy differ significantly from the ones presented in this section. In particular, Durré derives an interest rate rule conditioned upon the shocks to, and not the levels of, aggregate demand, aggregate supply and asset prices, while Bean finds no role for asset prices in the commitment and discretionary equilibrium. Bean's optimality conditions contain neither the policy instrument, nor anything to do with the demand side of the economy.

In our results, the aggressiveness of the reaction to asset price misalignments depends upon the impact of wealth effects in aggregate demand. If there are significant wealth effects, $\beta_3 > 0$, then the central bank should raise interest rates in response to increasing asset price misalignments ($f_{q-q^*} > 0$). In the next chapter we simulate a forward-looking variant of the macroeconomic model presented here, and find that a mild response to misalignments ($f_{q-q^*} = 0.1$) promotes overall macroeconomic stability. Such a pro-active response has also been advocated by Cecchetti et al. (2000) using the Bernake and Gertler (1999) new keynesian sticky wages – financial accelerator model[20]. A common feature in the aforementioned studies is that they assume, rather than derive, a rule for interest rate setting and then examine the effect on macroeconomic volatility from reacting or not reacting to asset prices. Our main focus however, was to show that in the context of optimal central bank behavior, asset price misalignments should be an element in the monetary authority's feedback rule. Hence, this chapter extends the literature that obtains analytical expressions for interest rates based upon optimization of the central banks' objectives. The augmented Taylor rule depicted in Eq. (4.21) points out explicitly that the financial and real instability associated with growing financial imbalances should not be tolerated by the central bank.

In the absence of a link between aggregate demand and asset prices, i.e. $\beta_3 = 0$, there is no scope for monetary policy to react to asset prices ($f_{q-q^*} = 0$), and the feedback rule which implements the optimal policy takes the form of a standard Taylor rule (see

[20] We should point out that as Cecchetti et al. (2000) emphasize, policy makers should *react to* and *not target* asset prices. Quoting from Cecchetti et al. (2003, p.428): "It is our view that central banks can improve macroeconomic performance by reacting to asset price misalignments. We are not now saying, nor have we ever said, that policymakers should target asset prices".

Taylor, 1993) with interest rates being an increasing function of inflation and the output gap. This rule is presented bellow:

$$i_t = f_\pi^* \pi_t + f_y^* y_t \qquad (4.22)$$

where, the inflation and output gap weights are given by the same expressions as in section 4.3.3, that is: $f_\pi^* = 1 - \frac{c}{\beta_2} + ca$, $f_y^* = \frac{\beta_1}{\beta_2}$.

In order to examine the impact of asset prices on the behaviour of the central bank, we calculate the partial derivative of the interest rate reaction coefficients with respect to the magnitude of wealth effects, β_3. The results, presented in Table 4.3, lead to Propositions 4 to 6.

Table 4.3: Partial Derivatives, Model II.

f	$\partial f / \partial \beta_3$
f_π	$\frac{c(1-A)\gamma_1}{(\beta_2 + \beta_3\gamma_1)^2} < 0$
f_y	$-\frac{\beta_1\gamma_1}{(\beta_2 + \beta_3\gamma_1)^2} < 0$
f_{q-q^*}	$\frac{\beta_2}{(\beta_2 + \beta_3\gamma_1)^2} > 0$

Proposition 4: *The stronger the wealth effect,* β_3, *the smaller is the optimal interest rate weight on inflation.*

Proof: Since γ_1, $(\beta_3\gamma_1 + \beta_2)^2 > 0$, $c < 0$, $A<1$, it is implied that: $\partial f_\pi / \partial \beta_3 < 0$.

Proposition 5: *The stronger the wealth effect,* β_3, *the smaller is the optimal interest rate weight on output gap.*

Proof: Since β_1, γ_1, $(\beta_3\gamma_1 + \beta_2)^2 > 0$, it is implied that: $\partial f_y / \partial \beta_3 < 0$.

Thus, as Proposition 4 indicates, the result obtained in the previous section (Proposition 3) that the monetary policy response to inflation should be less aggressive when there are significant wealth effects, is robust to the alternative specification that we used to model asset price dynamics. In addition, Proposition 5 calls for a less pronounced response to the output gap in the presence of significant correlation between asset prices and aggregate demand..

Proposition 4.6: *The stronger the wealth effect,* β_3, *the larger is the optimal interest rate weight on asset price misalignments from fundamentals.*

Proof: Since β_2, $(\beta_3\gamma_1 + \beta_2)^2 > 0$, it is implied that: $\partial f_{q-q^*} / \partial \beta_3 > 0$.

The intuition and policy implications of Propositions 4 and 5 become clearer when considered in combination with Proposition 6. In essence, Model II implies that if aggregate demand is affected by the evolution of asset prices then monetary authorities should include asset price misalignments in their optimal feedback rule and there should be a change in the distribution of the relevant interest rate weights. Particularly, the interest rate weight on inflation and output decreases while the weight attached to asset price misalignments increases. This allows asset prices to be considered as an element of the authorities' reaction function without necessarily implying overall tighter, than before, policy since the response to inflation and output will be less aggressive. In other words, our optimal analysis results imply that first, asset price misalignments should have an independent role and not only be considered as instruments to help forecast output and inflation; and second, there should be a shift in the magnitude of reaction, away from the traditional variables, i.e. inflation and the output gap, and towards a direct response to financial imbalances.

4.5 Conclusions

Although there is still no widespread agreement among economists on whether central banks should explicitly target, or react to, asset price inflation, in addition to conventional consumer price targets, a vast consensus that emerges states that the financial-market channel plays an important role in the transmission of the monetary policy. Starting from these considerations, this chapter builds a backward-looking structural macro model where asset price fluctuations have an impact on aggregate demand and consequently on inflation. Initially, we assume that asset prices move on average in line with their fundamental value. In order to construct the optimal interest rate rule, we assume that the central bank solves a stochastic control problem to minimise intertemporally the variance of the output gap and inflation. The derived optimal reaction function conditions interest rates on inflation and the output gap. Comparing our results with the standard Taylor rule, we find that optimal policy in the presence of wealth effects attaches less interest rate weight on inflation. Furthermore, the higher the sensitivity of asset markets with respect to interest rates, the lower is the optimal response by the monetary authorities to deviations of output and inflation from their long term trends. This is alleged to be the result of a double effect of monetary policy on the real economy. In essence, along with the traditional interest rate channel, monetary policy affects aggregate spending via changes in asset prices. In the optimal interest rate rule, the inflation coefficient is negatively related to the magnitude of the wealth effects and to the preference for output stabilisation. An important result from the simulation evidence is that, if the central bank ignores wealth effects when setting interest rates, the implied policy leads to higher inflation and output volatility.

We then extended the asset price dynamics block of the model to allow for potential bubble buildup, in addition to the standard feature of reversion towards fundamentals. This change was important as it brings the model closer to the reality and it also implies a drastic change in the conduct of monetary policy. In this case, the derived optimal policy rule conditions the monetary policy instrument not only on inflation and demand pressures but also on financial imbalances, as represented by asset price misalignments from fundamentals. The magnitude of the interest rate reaction depends, among other factors, on the relative importance of wealth effects for aggregate demand. The response to asset price deviations from fundamentals becomes more aggressive as wealth effects build up. Thus, this chapter's main contribution was to extend the optimal monetary policy literature towards recognising that, in the presence of wealth effects, monetary authorities should grant an independent role to asset price misalignments and not only regard them as instruments to forecast inflation and output. Future work should consider an open economy model, where the firms' financing and the households' capital gains derive not only from domestic but also from foreign capital markets.

Chapter 5

Monetary Policy and Asset Price Misalignments

5.1 Introduction

The exuberant bull stock market associated with the 'new economy' and the 'dot com' boom of the 1990s came into an abrupt halt in early 2000. Since then, stock price indices have fallen and are far bellow the levels they reached in the late 1990s. Economic history provides plenty examples of asset price bubbles beginning as early as the seventeenth century[1]. Apart from the 'internet bubble', the previous century witnessed two

[1] See Garber (2000) for a discussion on the tulip mania in the early seventeenth century as well as other famous bubbles.

other major episodes of sudden asset price reversals after long periods of sustained rises: the 1929 US stock market crash and the Japanese experience of the late 1980s and early 1990s. Both episodes exhibited a regular characteristic of asset price boom-bust cycles, that is, the decline in asset prices was followed by a slowdown in economic activity as well as increased financial and banking sectors instability. Recent work by Detken and Smets (2003) on a large sample of industrial countries indicates that the boom phase typically features rising money, output and credit gaps, and low interest rates relative to a Taylor rule benchmark. It has been argued that the widespread financial deregulation of asset markets that began in the 1980s may have contributed to an increase in the frequency of such episodes (IMF, 2003).

As Bordo and Jeanne (2002) point out, during the boom period the domestic private sector accumulates high levels of debt on the expectation of further rises in asset prices, whilst the assets themselves serve as a collateral. When asset prices fall, the decline in the value of the collateral induces consumers to cut back expenditure and firms to reduce investment spending. In essence, the deterioration of balance sheets, following large asset price reductions, further exacerbates the negative 'wealth effect' on spending, leading to additional negative effects on asset prices, bank lending and economic output (collateral-induced credit crunch). In a number of articles, Charles Goodhart and Boris Hofmann establish empirically the link between output growth, credit aggregates, and asset price movements in a number of major economies[2]. A recent study by the IMF (2003) analyses the after-effects of sharp asset price reversals and finds that equity prices reductions are quite frequent and are associated with heavy GDP losses. In addition, Borio and Lowe (2002) stress that swings in asset prices have historically accompanied episodes of financial instability. In particular, there is concern that asset price boom and busts could create systemic financial risk[3].

An important issue related to the above concerns is the establishment of the appropriate monetary policy response to asset price fluctuations. Should the central bank care about financial instability? Nowadays, everyone recognizes price level stability as the

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[2] See Goodhart and Hofmann (2000, 2001, 2003). See also Kiyotaki and Moore (1997), for a theoretical model that exhibits a crucial interaction between collateral values, asset prices, credit and economic activity. Kocherlakota (2000) shows that in the presence of credit constraints which depend upon the collateral value, shocks to income may be amplified and produce asymmetric effects in that, negative shocks have larger effects than positive ones.

[3] We should mention, however, that the empirical evidence linking asset price reversals with banking crises is rather limited and inconclusive. See, among others, the paper by Vila (2000).

primary objective of monetary policy. Indeed, as Issing (2003) emphasizes, price stability and financial stability tend to mutually reinforce each other in the long-run. However, as the examples of the US in the 1920s and 1990s and Japan in the late 1980s demonstrate, financial imbalances may build up even in an environment of stable prices (Borio and Lowe, 2002). Exponents of the 'new environment' hypothesis argue that low and stable rates of inflation may even foster asset price bubbles, due e.g. to excessively optimistic expectations about future economic development. Thus, price stability is not a sufficient condition for financial stability. If, in fact, financial stability is defined narrowly, as the degree of interest rate smoothness in the economy, and not widely, as the prevalence of a financial system that continuously ensures the efficient allocation of savings to investment opportunities, then a trade-off between monetary (or price) stability and financial stability may arise[4].

The monetary policy response to asset price developments can take two forms, either *proactive*, or *reactive.* A reactive approach is consistent with an inflation targeting policy regime focusing on price stability and according to it, the monetary authorities should wait and see whether the asset price reversal occurs, and if it does, to react accordingly to the extent that there are implications for inflation and output stability. Hence, the reactive approach is consistent with an accomodative ex post response to asset price changes. Bernanke and Gertler (1999, 2001) simulate alternative variants of the Taylor rule in the context of the new keynesian model with sticky wages and a financial accelerator and find that a central bank dedicated to price stability should pay no attention to asset prices per se, except insofar as they signal changes to expected inflation [5]. They also argue that trying to stabilise asset prices is problematic since it is nearly impossible to know for sure whether a given change in asset values results from fundamental factors, non-fundamental factors, or both. Gilchrist and Leahy (2002) employ three alternative dynamic general equilibrium models and, in agreement with Bernanke and Gertler, reach the conclusion that asset prices should not be included in the monetary policy rule. They argue that policies which respond to inflation and output deviations will encompass most of the gains from responding to asset prices.

[4] For instance, in the presence aggregate demand shocks, the trade-off derives from the fact that the central bank would have to decide to which degree it prefers interest rate stabilisation over inflation and output stabilisation.

[5] See Appendix A5.1 for more details on the Bernanke and Gertler model

Against this, Cecchetti, Genberg, Lipsky and Wadhwani (2000), using the same theoretical model as Bernake and Gertler (1999), claim that "a central bank concerned with both hitting an inflation target at a given time horizon, and achieving as smooth a path as possible for inflation, is likely to achieve superior performance by adjusting its policy instruments not only to inflation (or to its inflation forecast) and the output gap, but to asset prices as well" (p.2). Ceccheti et al. argue that such a proactive response will reduce the likelihood of asset price bubbles forming, thus reducing the risk of boom-bust investment cycles. Bernanke and Gertler (2001) attribute their findings to, among other factors, the use of a misleading metric in the comparison between policy rules.

In this chapter we take another look at the interaction between monetary policy and asset prices using a small rational expectations model that takes into account the effect of asset prices on aggregate demand in order to capture investment and consumption wealth effects. Using stochastic simulations, we then examine how inflation, output, interest rates, and asset prices behave under alternative policy rules. Our results confirm previous findings by Cecchetti et al. (2000) in that, macroeconomic volatility can be reduced with a mild reaction of interest rates to asset price misalignments from fundamentals. Our main contribution lies in the fact that in our simulations we employ two alternative monetary policy rules, inflation forecast targeting, and the standard Taylor rule, with the main conclusions for the role of monetary policy with respect to asset prices remaining unchanged. We also incorporate an alternative partial adjustment mechanism of asset prices towards their fundamental value that allows for both 'momentum trading' and 'fundamentals pull'.

The remainder of the chapter is structured as follows. The next section discusses the issue of financial instability deriving from asset price boom-bust cycles, as well as the reactive versus proactive view of monetary policy response. Section 5.3 describes the theoretical model that will be employed in the simulations. In Section 5.3.1 we calibrate the model's structural parameters on the basis of previous econometric evidence for the UK economy. Section 5.3.2 presents the results from impulse response analysis, and section 5.4 compares the effect on macroeconomic uncertainty from alternative monetary policy choices. Section 5.5 provides conclusions.

5.2 Asset price fluctuations, financial stability and monetary policy

Over the last decade, inflation targeting has been adopted by a growing number of central banks. The experience of the inflationary 1970s induced policymakers to put institutional safeguards against monetary instability by endowing central banks with clear mandates to maintain price stability and with the necessary autonomy to pursue them. Compared to the 1970s and early 1980s, inflation rates (actual as well as expected) have become lower and less variable[6]. The disinflation process has been a global phenomenon since it is observed both in countries where formal inflation targets are in use, and in non-targeting countries. As we showed in chapter 2 though, the reduction in inflation uncertainty is more pronounced when an explicit target is announced. The decline in inflation has gone hand in hand with a similar decline in interest rates. In many countries, both short-term and long-term interest rates are close to, or even bellow, post-war lows. As Bean (2003) argues, price stability has not been achieved at the expense of the real economy, as unemployment has been decreasing in a number of countries, while growth has also been relatively stable. Borio, English and Filardo (2003) point out that since the mid 1980s lower and more stable inflation has coincided with lower output volatility (measured either by the size of output gaps, or the variability in growth rates). Borio et al. (2003) examine the aggregate (PPP-weighted) G7 GDP growth and find that, if the recent sharp global slowdown is excluded, output growth has been considerably less volatile, even in comparison with the 1960s[7].

Despite the good macroeconomic record of the past decade, there has been a growing concern among academics and policymakers that the achievement of price stability may be associated with an increased risk of financial instability. Some commentators claim that the lower cost of capital, due to lower interest rates, along with exuberant growth projections have boosted the late 1990s stock market bubble. Borio and Lowe (2002) argue that booms and busts in asset prices - which may reflect the presence of bubbles, but may also reflect shifts in assessments of the underlying fundamentals - should be considered as part of a broader set of symptoms that typically also include a build-up of debt and high rate of capital accumulation. Rising asset prices and debt accumulation lead to stretched household and corporate balance sheets, vulnerable to sharp corrections of the type

[6] See Kontonikas (2004) for UK evidence and Johnson (2002) for international evidence.

witnessed recently in global equity markets. During the boom period, balance sheets may look healthy as the increase in asset prices, and consequently the value of the collateral, offsets the build-up of debt. However, when optimism about further increases in asset values turns to pessimism, leading to a decrease in the net worth of households and firms, then financial distress may be the result of financial imbalances unwinding.

Borio and Lowe (2002) claim that, although low and stable inflation may promote financial stability in general, financial imbalances of the type described above can build up in a low inflation environment. As a matter of fact, positive supply shocks, resulting either from increases in productivity or structural / institutional reforms, are likely to reduce inflationary pressures, therefore encouraging the build up of such imbalances. As Bean (2003) argues, when monetary policy exhibits a high degree of credibility in keeping inflation low and stable, an expansion of aggregate demand beyond the natural rate of output may only have limited impact on inflationary pressures and as a result interest rates are lower and financial imbalances are likely to proceed further. All these arguments have resulted in a new view for the conduct of monetary policy that questions the current consensus. The current consensus stresses that monetary policy should be directed exclusively at achieving price stability, and its role in promoting financial stability should be restricted to restricted to minimising the negative effects from bubbles bursting and financial imbalances unwinding. This conventional view, has clearly been enunciated by Alan Greenspan (2002):

"The notion that a well-timed incremental tightening could have been calibrated to prevent the late 1990s bubble is almost surely an illusion. Instead, we...need to focus on policies to mitigate the fallout when it occurs and, hopefully, ease the transition to the next expansion." Ms Hesius (1999) from the Sveriges Risksbank also believes that the central bank response to asset price movements should be reactive, not proactive: ".... the general view nowadays is that the central banks should not try to use interest rate policy to control asset price trends by seeking to burst any bubbles that may form. The normal strategy is rather to seek, firmly with the help of a great variety of instruments, to restore stability on the few occasions when asset markets collapse."

The, so called, *continuity view* implies that despite the recent experience of longer output expansions, more volatile financial markets, and possible increases in the growth

[7] For supportive cross-country evidence, see Dalsgaard et al. (2002), and Blanchard and Simon (2001).

rate of underlying productivity, these events should be seen as exogenous idiosyncratic shocks hitting economies against the background of largely invariant structural relationships. In the context of the continuity argument, the role of financial developments in policy decisions is rather limited. For instance, potential financial imbalances due to rapid growth of credit and debt might be seen as suggesting risks to the economic outlook but they would not generally be expected to play a central role, since these developments are likely to regarded as episodic or exceptional.

Bernanke and Gertler (1999) argue that a central bank dedicated to a policy of flexible inflation targeting should pay little attention to asset inflation, since a proper setting of interest rates to achieve the desired inflation target will also stabilise asset prices. They (p. 18) "view price stability and financial stability as highly complementary and mutually consistent objectives to be pursued within a unified policy framework". The intuition behind the sufficiency of inflation targeting is as follows. As Hayford and Malliaris (2002) argue, inflation targeting guides the central bank to act appropriately, either by doing nothing in the case where the bubble has no effect on aggregate demand, or by tightening in the case that the bubble is expected to increase future aggregate demand and inflation.

Blanchard (2000) argues that the relative merits of inflation targeting are conditional upon the bubble in asset prices affecting some components of spending more than others. For example, if the bubble increases consumption, via the wealth effect, that puts pressure on inflation, and policy tightening by the monetary authority may be optimal. What happens, however, if the bubble results in over-investment by the publicly-traded firms whose equity value has increased? Blanchard, Rhee and Summers (1993) provide evidence suggesting that firms may well increase investment beyond what is justified by fundamentals when there is a bubble. Since inflation targeting implies maintaining current and actual inflation at a constant level, it is equivalent to keeping output at its natural level. Hence, with output at its natural level, higher investment is associated with a corresponding decrease in consumption. Thus, inflation targeting may result in a change in the composition of output in favour of investment, thereby leading to excessive capital accumulation. When asset prices eventually correct, the excessive capital accumulation deters firms from investing and hence poses a threat to economic growth. Blanchard points out that inflation targeting does not address issues related to the impact of a bubble on the composition of output and the long-run impact of the bubble on capital accumulation and growth.

Bullard and Schalling (2002) examine the effects of introducing asset prices in the monetary policy block of a simple, small scale, micro-foundations based economic model. They argue that a policy that reacts to equity prices can be counterproductive since it may interfere with the policymaker's ability to minimise inflation and output volatility. They show that including asset prices in a Taylor-type policy rule will degrade economic performance by creating indeterminacy of the rational expectations equilibrium and hence more unpredictable volatility, than if asset prices were ignored.

The *new environment view* claims that many of the recent economic and financial developments are interrelated, forming a new background upon which monetary policy operates, and should not be treated as exogenous shocks[8]. In particular, liberalised financial markets, along with low and stable inflation, and positive supply-side developments produce a financial system that can accommodate and reinforce output fluctuations. As Borio et al. (2003, p.27) argue, "during the boom phase, virtuous cycles may develop, consisting of higher asset prices, muted risk perceptions, weakening external finance constraints, greater capital deepening rising productivity and higher profits. These processes then go into reverse during contractions". In such an environment, the absence of inflationary pressures adds to the sustainability of the boom, by removing the threat of interest rate increases. Therefore, from this perspective, the central bank by achieving credibility for its anti-inflation commitment may contribute to changes in the underlying economic structure that can mask the new risks facing the economy. The main risk generated by financial unbalances unwinding is a weak economy, which, along with low inflation, may lead to deflation.

The new heterodox view nicely summarised by Crockett (2003): "In a monetary regime in which the central bank's operational objective is expressed *exclusively* in terms of short-term inflation, there may be insufficient protection against the build up of financial imbalances that lies at the root of much of the financial instability we observe. This could be so if the focus on short-term inflation control meant that the authorities did not tighten monetary policy sufficiently pre-emptively to lean against excessive credit expansion and asset price increases. In jargon, if the monetary policy reaction function does not

[8] See among others, Borio and Lowe (2002), Borio, Furfine and Lowe (2001). We should mention that although the new environment view has recently been formalized, its roots are quite old, starting with the Austrian school. The Austrian School stresses the role of credit and deviations of interest rate from its equilibrium level (natural rate), in generating unsustainable booms through their interaction with capital

incorporate financial imbalances, the monetary anchor may fail to deliver financial stability".

Continuity view policy implications for the boom period

The two competing views, continuity vs. new environment suggest different monetary policy responses to financial imbalances, especially during the build-up stage. According to the continuity argument, if inflationary pressures remain subdued, following a boom in financial markets due e.g. to well anchored inflation expectations and strong productivity growth, then monetary policy should not be tightened as long as growth and expected inflation remain on track. Borio et al. (2003) identify three factors than may explain the reluctance to respond to financial imbalances by tightening policy. First, it is very difficult for central banks to identify imbalances and bubbles with a sufficient degree of confidence. Second, there is some concern about the effects of a pre-emptive tightening, specifically about causing more economic volatility rather than reducing it. Strong speculative pressures and high expected returns may partially insulate the build-up of imbalances from any attempts to restrain them, while at the same time other expenditure-sensitive sectors of the economy may be driven to recession. Third, there are some serious political economy issues raised by a tighter monetary policy. The decision to increase interest rates while inflation remains low is difficult to justify to the public. In essence, the central bank does not want to be seen as wealth destroyer. This has been suggested as an explanation for the inaction of the Fed to substantially increase interest rates during the first stage of the US equity bubble on 1996-97[9]. It is also consistent with the idea explored in the paper by Miller et al. (2002), that investors expected that the central bank would take decisive action to prevent the stock market from falling but not from rising, and believed that such intervention would be successful. They argue that the belief in the existence of an insurance against the possibility of a market crash reduced the estimated risk premium and pushed up equity prices.

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formation (see e.g. Wicksell, 1907; von Mises, 1912; Hayek, 1933). More recently, Kindleberger (1996) and Minsky (1982) further emphasized the potential destabilizing role of finance.

[9] As Baker (2002) argues, a likely explanation for the Fed's inaction is that Mr Greenspan and his colleagues may simply have felt constrained by their public mandate. The Fed, though operationally independent of political control, it derives its authority from Congress, which dictates the goals it should pursue through legislation. Another explanation suggested is that at the initial stages of the bubble Greenspan believed that the share price overvaluation reflected permanent increases in US labour productivity. Note however, that

New environment view policy implications for the boom period

The new environment view policy implications for the period while financial imbalances are developing are quite different, since imbalances are considered a serious threat to economic stability. While acknowledging that the identification of imbalances may be difficult, and that serious political economist constraints on a more pre-emptive monetary policy may continue to exist for some time, exponents of the new environment stress that policymakers already have to deal with substantial uncertainty when estimating output gaps, and that a pre-emptive tightening to limit the build-up of imbalances will help avoid future volatility.

The policy implications for the bust period, when financial imbalances start to unwind, are rather similar in both views since they call for a monetary policy easing in order to offset the adverse effects of declines in asset prices and tightening credit conditions. In fact, the policy response may be stronger in the case a new environment central bank, since the unwinding of financial imbalances will not be seen as a one-off negative shock but rather will be related to a broad set of adjustments in financial and goods & services markets. Thus, a rapid and more substantial easing, as compared to the continuity view, may result, in order to protect the economy from the perceived future risks.

Towards a new policy framework?

A practical issue that arises from the discussion above is whether financial stability should be an explicit central bank objective in line with price stability and sustainable economic growth. According to the continuity view, no changes in central bank policy are necessary, while according to the new environment view it should be made clear that a pre-emptive tightening of policy to counter growing financial imbalances is allowed even in the absence of obvious inflationary pressures. Most commentators agree that the new environment policy prescription is feasible without requiring a redefinition of policy objectives. As Ferguson (2003) argues, the Fed has always found it useful to focus on financial stability primarily through the lens of its two main macroeconomic goals, price stability and sustainable long-run growth.

Davis and Madsen (2001), by employing a century of data for OECD countries show that capital rather than labour productivity is indeed the productivity measure that is most closely link to stock returns.

There are many arguments pointing out that a redefinition of objectives would not be necessary or indeed desirable. First, if the central bank adopts an explicit financial stability objective then hard choices may arise at times in judging how much weight should be attached to it versus other central bank objectives and also in deciding the degree of activism to be employed in pursuing financial stability. In fact, a redefinition of policy objectives creates the risk that the central bank will deviate too much from its macroeconomic goals in order to address financial imbalances that may have only limited impact on inflation and output. This could in turn encourage imprudent behaviour, hence generating a moral hazard problem.

Second, a redefinition is not necessary since the traditional central bank objectives can accommodate a response to financial imbalances. If we follow Ferguson (2003) and define financial instability as a set of events characterised by: asset prices diverging significantly from fundamentals, distorted market functioning and credit availability, and aggregate demand deviating (or likely to deviate) significantly from potential output, then this definition of instability would be sufficient to ensure a pre-emptive monetary policy response, since financial imbalances would be seen as containing important information about the future prospects of inflation and output.

The third reason against redefining the traditional objectives is that central banks have long had a keen interest in maintaining financial stability, that in fact predates their focus on price stability especially ever since the highly inflationary 1970s[10]. Concerns about financial instability are historically associated with early evolution of central banks. The critical role of central banks as lenders of last resort in financial crises has long been recognised, dating back to Bagehot in the early 19th century. Central banks are expected to provide emergency liquidity assistance to the markets (via open market operations) or to particular institutions (via discount window lending) thereby requiring central banks to monitor markets for signs of financial instability. Finally, central banks are interested in financial stability due to their role of oversighting the payments system, and due to the fact that monetary policy is largely implemented via financial markets operations and therefore the transmission mechanism of monetary policy depends on the smooth functioning of financial markets and institutions.

[10] As Borio et al. (2003) point out, the importance of price stability started to develop during the inter-war period with the gradual emergence of fiat-money standards. With the Great Inflation of the post-war era, price stability became an overriding policy objective.

All these concerns have been fully or partially incorporated in the chapters of the central banks. For instance, in the case of the United States, the creation of the Federal Reserve system was a response to the financial instability of the US economy in the 19th and early 20th century. The Federal Reserve Act of 1913 states that the Federal Reserve was created "to provide for the establishment of Federal Reserve banks, to furnish an elastic currency, to afford means of rediscounting commercial paper, to establish a more effective supervision of banking in the United States, and for other purposes." As Ferguson (2003) points out, such references implicitly embodied financial stability as an objective for the Federal Reserve since they reflect concerns about financial market liquidity, and the need to develop an institutional framework that can deal with banking crises. During the Great Depression, revisions of the Federal Reserve Act awarded the Fed emergency lending powers. Apart from the Fed, other central banks' chapters also provide implicit or explicit references to financial stability. For instance, the ECB chapter states that: "the European System of Central Banks shall contribute to the smooth conduct of policies pursued by the competent authorities relating to the prudential supervision of credit institutions and the stability of the financial system." The Bank of England states that "There is a memorandum of understanding between the Bank of England and the government that delineates the Bank's responsibilities in the area of financial stability. It assigns the Bank of England responsibility in three broad areas including stability of the monetary system, stability of financial system infrastructure particularly in the area of payment systems, and monitoring of the financial system as a whole." Hence, central banks already take into account financial stability especially as far as banking and the efficient operation of the payment system are concerned.

Following the discussion on the links between financial stability and central bank policy, we proceed with the description of our theoretical model.

5.3 A forward-looking model

We use a structural model of the economy that allows for the effect of asset prices on aggregate demand and monetary policy. The model augments the standard three sectoı macro model (aggregate demand, aggregate supply, monetary policy rule) by taking intc

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account asset prices, which themselves are assumed to stochastically evolve influenced by both fundamentals and bubbles. The model is given by the following equations:

$$y_t = E_t[y_{t+1}] - a_1(i_{t-1} - E_{t-1}[\pi_t]) + a_2 q_{t-1} + \eta_t \quad (5.1)$$

$$\pi_t = (1-\varphi)E_t[\pi_{t+1}] + \varphi\pi_{t-1} + \beta y_t + \varepsilon_t \quad (5.2)$$

$$q_t = b_1 \Delta q_{t-1} - b_2(q_{t-1} - q_t^*) \quad (5.3)$$

$$q_t^* = -\delta_1(i_t - E_t[\pi_{t+1}]) + \delta_2 E_t[y_{t+1}] + u_t \quad (5.4)$$

$$i_t = (1-\gamma_4)\left[r + \pi_t + \gamma_1(\pi_t - \pi^*) + \gamma_2 y_t + \gamma_3(q_t - q_t^*)\right] + \gamma_4 i_{t-1} + \theta_t \quad (5.5)$$

$$i_t = (1-\gamma_4)\left[r + \gamma_1^*(E_t[\pi_{t+j}] - \pi^*) + \gamma_3(q_t - q_t^*)\right] + \gamma_4 i_{t-1} + \theta_t \quad (5.5)'$$

where, y_t is the deviation of log output from its steady-state level (output gap), $\pi_t = p_t - p_{t-1}$ is the inflation rate, p_t is (log) price level, i_t is the monetary policy instrument (one-period nominal interest rate, e.g. repo rate, r is the equilibrium real interest rate and π^* is the inflation target. q_t denotes (log) real asset prices and q_t^* the fundamentals. Different interpretations of q_t are possible (e.g. house prices, stock prices or the value of a portfolio containing both housing and equity investment), in what follows though we mainly treat it is an equity index. η_t, ε_t, θ_t, u_t represent exogenous random shocks to output gap, inflation, nominal interest rates and asset price fundamentals. For simplicity, we assume that they are mutually uncorrelated *i.i.d.* processes with zero means and constant variances: σ_η^2, σ_θ^2, σ_ε^2, σ_u^2. The structural parameters can be interpreted as partial elasticities with the following properties: a_1, β, γ_1, γ_2, δ_1, δ_2, b_1, $b_2 > 0$, a_2, $\gamma_3 \geq 0$, $\varphi > 0$, $\gamma_4 < 1$.

Eq. (5.1) represents the demand side of the economy as an optimizing *IS*-type of relationship where current output gap depends positively on its expected future value and negatively on the lagged real interest rate, $i_{t-1} - E_{t-1}[\pi_t]$. The forward-looking nature of *IS* intends to capture the effect of expected income on current spending and is theoretically justified by McCallum and Nelson (1999), among others, in the context of an optimizing general equilibrium model[11].

[11] The expectational aggregate demand equation can be derived from the first order Euler condition for the representative household's optimal consumption choice problem assuming constant relative risk aversion and separability between consumption and leisure.

Aggregate demand depends positively on the past level of asset prices via consumption wealth effects and investment balance sheet effects. For example, a persistent decrease in the level of stock prices increases the perceived level of households' financial distress causing a reduction in consumption spending. The balance sheet channel implies a positive relationship between the firms' ability to borrow and their net worth which in turn depends on asset valuations. There is a vast amount of empirical evidence indicating that stock and house price movements are strongly correlated with aggregate demand in most major economies[12]. In our model, the central bank takes into account the effect of wealth on aggregate demand, that is, it is fully aware of the effect of q_{t-1} on y_t and its magnitude.

Eq. (5.2) depicts the price adjustment relation taking the form of a hybrid Phillips curve where current inflation is positively affected by its past and expected future value as well as the output gap. Hybrid Phillips have been developed in the literature in an effort to reduce the inconsistencies between purely forward-looking models and actual inflation data (see e.g. Clarida, Galí and Gertler, 1999).

Eqs. (5.3) and (5.4) represent the dynamic evolution of asset prices and their underlying fundamentals, respectively. We assume a partial adjustment mechanism of actual asset prices towards their fundamental value that allows for the appearance of a bubble buildup. As Eq. (5.3) indicates, if asset prices have increased in the past ($\Delta q_{t-1} > 0$) there is a positive 'momentum' effect on their current level ($b_1 > 0$). The higher the value of b_1 the stronger the effect from past capital gains/losses and therefore q_t can diverge significantly from its fundamental value, q_t^*, albeit not permanently. But once asset prices revert, at an unknown future date, the downward effect on aggregate demand could be large. We allow for reversion to fundamentals since if there is an decrease in the fundamentals ($q_t^* < q_{t-1}$) there is a negative pressure on q_t. The higher is b_2, the closer will be the co-movement between observed prices and the underlying fundamentals. Kontonikas and Ioannidis (2003) employ a similar asset price specification.

Eq. (5.4) describes fundamental asset prices in line with the standard dividend model of asset pricing. There is a positive effect from expected future dividends (assumed to depend on expected output[13]) and a negative effect from real interest rates. The time

[12] See among others, Goodhart and Hoffmann (2000, 2001).

[13] Note that Eq. (5.4) relates the fundamental real asset price with the expected value of the output gap. Strictly speaking, the asset price should be a function of expected output. Since, however, output is the sum of the output gap plus the potential output, it is implied that higher output gap is associated with higher output and hence higher fundamental asset price.

series process of the fundamental asset price is augmented for uncertainty by including the random disturbance term, u_t.

In order to complete the model we need another equation describing the behaviour of the central bank. We will consider two types of rules for the period-by-period setting of the monetary policy instrument, i_t. Eq. (5.5) depicts a monetary policy rule that conditions the interest rate on concurrent inflation deviations from the target, the output gap[14], as well as on asset price misalignments, $q_t - q_t^*$. If there is no response to the asset price misalignments, $\gamma_3 = 0$, then Eq. (5.5) reduces to the standard Taylor rule (Taylor, 1993). In addition, we examine the case of an augmented inflation-forecast targeting rule, as given by Eq. (5.5′). In pure inflation-forecast based rules, $\gamma_2 = \gamma_3 = 0$, and the only feedback variable for monetary policy is the deviation of inflation forecast from the target, $E_t[\pi_{t+j}] - \pi^*$ [15]. In this case, the authorities' policy choice variables are the parameter triplet $\{\gamma_1^*, \gamma_4, j\}$. Parameter γ_1^* has to be greater than one to satisfy the stability condition that real rates increase in response to expected inflation, with higher values implying a more aggressive response[16]. Parameters γ_4 and j indicate the degree of interest rate smoothing by the central bank, and the horizon of the inflation forecast.

The system of equations (5.1-5.5) can be expressed compactly as:

$$AE_t[X_{t+1}] = BX_t + CZ_t \tag{5.6}$$

where, the (12x1) endogenous variables vector
$X_t = [\ y_t \ \ \pi_t \ \ i_t \ \ q_t \ \ q_t^* \ \ E_t[y_{t+1}] \ \ E_t[\pi_{t+1}] \ \ E_{t-1}[\pi_t] \ \ q_{t-1} \ \ q_{t-2} \ \ \pi_{t-1} \ \ i_{t-1}\ ]'$ contains seven variables non-predetermined at time t, and five predetermined variables (4 lags of endogenous variables and one backward looking expectation). Z_t is a (5x1) vector of

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[14] We should point out that McCallum and Nelson (1999), and Orphanides et al. (2000) among others, question the usual presumption that policymakers can actually observe y_t when setting i_t. In an effort to enhance realism in the model, we replaced y_t with $E_{t-1}[y_t]$ in the Taylor rule. The effect of this change on the simulation results, however, was quite small, as in McCallum (2001b). The results are not presented here, but are available upon request from the authors.

[15] In some inflation targeting countries, e.g. United Kingdom, Sweden, Finland, actual monetary policy is linked to *explicit* (and often published) inflation forecasts. In other targeting countries though, e.g. Australia, inflation forecasts are less explicitly used in policy formulation. See Batini and Haldane (1999) for simulation evidence using forward-looking rules in a calibrated model of the UK economy.

exogenous variables containing the four stipulated random processes (η_t, ε_t, θ_t, u_t) plus a constant[17]. **A**, **B** and **C** represent (12x12), (12x12) and (12x5) matrices of coefficients, respectively.

5.3.1 Calibrating the model

Prior to using stochastic simulations, we need to calibrate the model's behavioural parameters and perform impulse response analysis to ensure the plausibility of the chosen system.

Table 5.1: Model Calibration.

Parameter			
a_1	0.4	γ_1	0.8
a_2	0.1	γ_1^*	3
φ	0.8	γ_2	0.1
β	0.1	γ_3	0.1
δ_1	0.4	γ_4	0.85
δ_2	0.8	r	0.035
b_1	0.5	π	0.025
b_2	0.3		

In the aggregate demand Eq. (5.1), the interest rate slope, a_1, is set to 0.4 while the demand elasticity with respect to the past level of asset prices, a_2, is 0.1. In Eq. (5.2), we assume a strong effect from the backward-looking component of inflation by setting $\varphi = 0.8$, while the slope of the Phillips curve, β, is 0.1. The asset price adjustment Eq. (5.3) allows both for 'momentum trading' and 'fundamental pull' since b_1, $b_2 \neq 0$, with the

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[16] Similarly, γ_1 has to be greater than zero in Eq. (5.5) to ensure inflation stabilisation in the Taylor rule.
[17] See A5.2 in Appendix V for more technical details.

former effect being rather stronger (0.5, as opposed to 0.3). In Eq. (5.4), the expected output effect on current fundamentals, δ_2, is assumed to be twice as large as the interest rate effect, δ_1, (0.8 as opposed to 0.4).

The baseline monetary policy rule parameters in Eqs. (5.5) and (5.5′) posit a strong response to inflation, expected inflation[18] (γ_1 = 0.8, γ_1^* = 3), a mild response to output gap and asset price misalignments ($\gamma_2 = \gamma_3$ = 0.1), and a high level of interest rate persistence (γ_4 = 0.85). The long-run real interest rate, r, is 3.5 %, and the inflation target, π^* is set to 2.5%[19]. The standard deviations of the random shocks: σ_η, σ_θ, σ_ε, σ_u are 0.015, 0.003, 0.002, 0.1 respectively (see also McCallum, 2001b). This configuration of standard deviations allows asset price volatility to exceed output gap volatility by a factor of about 7, and inflation volatility by a factor of 50. Hence, the asset price, via the influence of the shocks to fundamentals, u_t, is assumed to be the most volatile variable, in line with actual financial market behaviour, while inflation is the least volatile variable, capturing the price stability environment in which most central banks operate nowadays.

5.3.2 Impulse response functions

The results from the theoretical impulse response functions are presented in Figures 5.1-5.4 [20]. Figure 5.1 plots the responses of output, inflation, interest rate, asset prices to a monetary policy shock. Following an increase in interest rates, inflation, output and asset prices decrease, a result consistent with a number of VAR studies (see e.g. Thorbecke, 1997). Figure 5.2 shows the impulse responses after a negative supply shock. Output and asset prices decline, while inflation and interest rates increase. In the case of positive demand shock (Figure 5.3), the initial response of all four variables is positive.

[18] In the inflation-forecast targeting rule we employ j = 2, that is we allow for 2 year ahead forecast horizon. This is weakly consistent with actual behaviour by the Bank of England, since as Batini and Haldane (1999, p.9) point out, "…j defines the *feedback* horizon under the rule, whereas in practice in the United Kingdom, two years refers to the *policy* horizon (the point at which expected inflation and the inflation target are in line)."

[19] The average nominal interest rate in the United Kingdom over the inflation targeting period 1992:10-2002:01 was about 6%.

[20] Figures 5.1-5.4 plot the impulse responses for the asset price-augmented Taylor rule case. Similar patterned results, were obtained using inflation-forecast targeting monetary policy rule.

Figure 5.1: Impulse responses to unit shock to the interest rate.

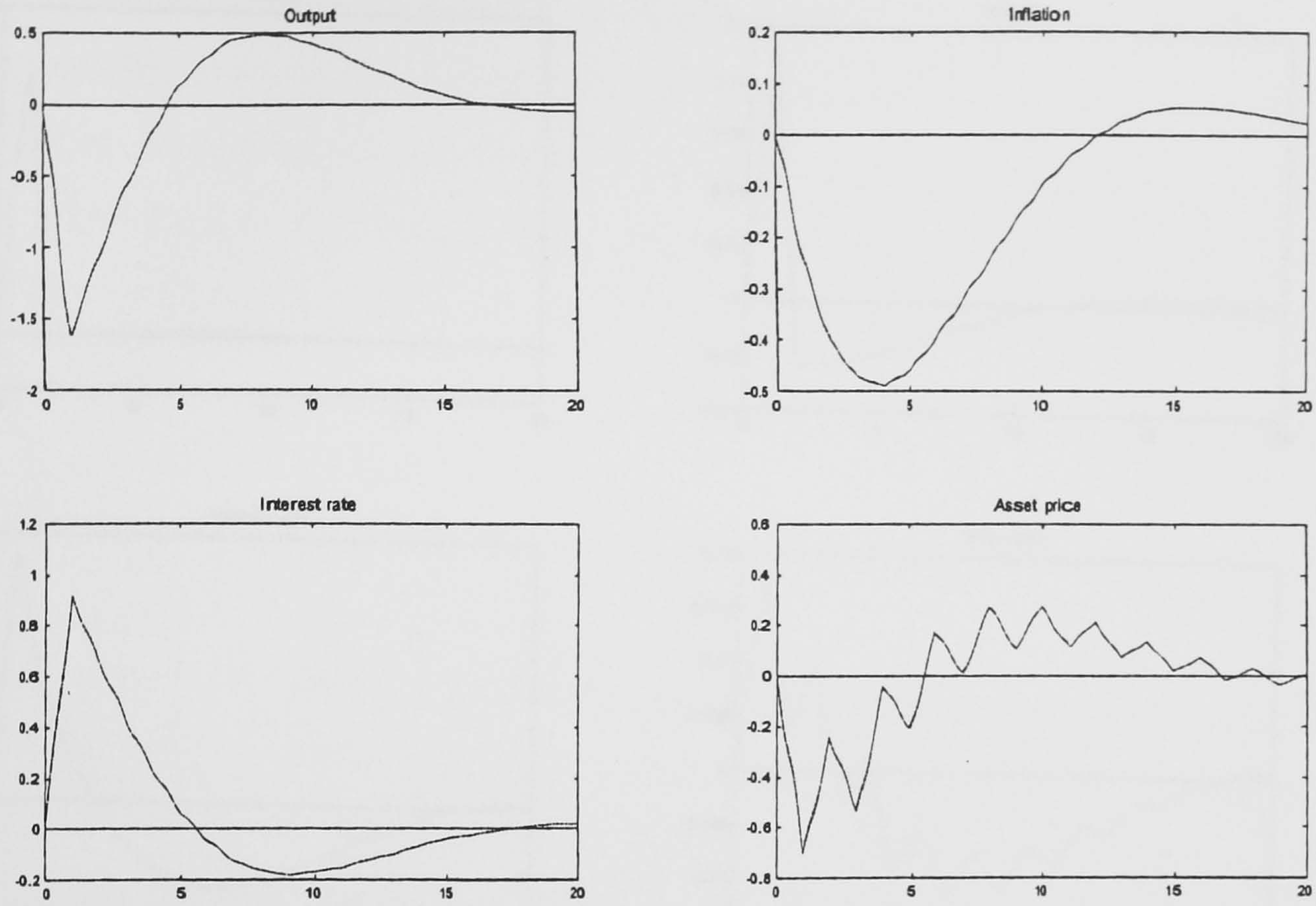


Figure 5.2: Impulse responses to unit shock to the inflation rate.

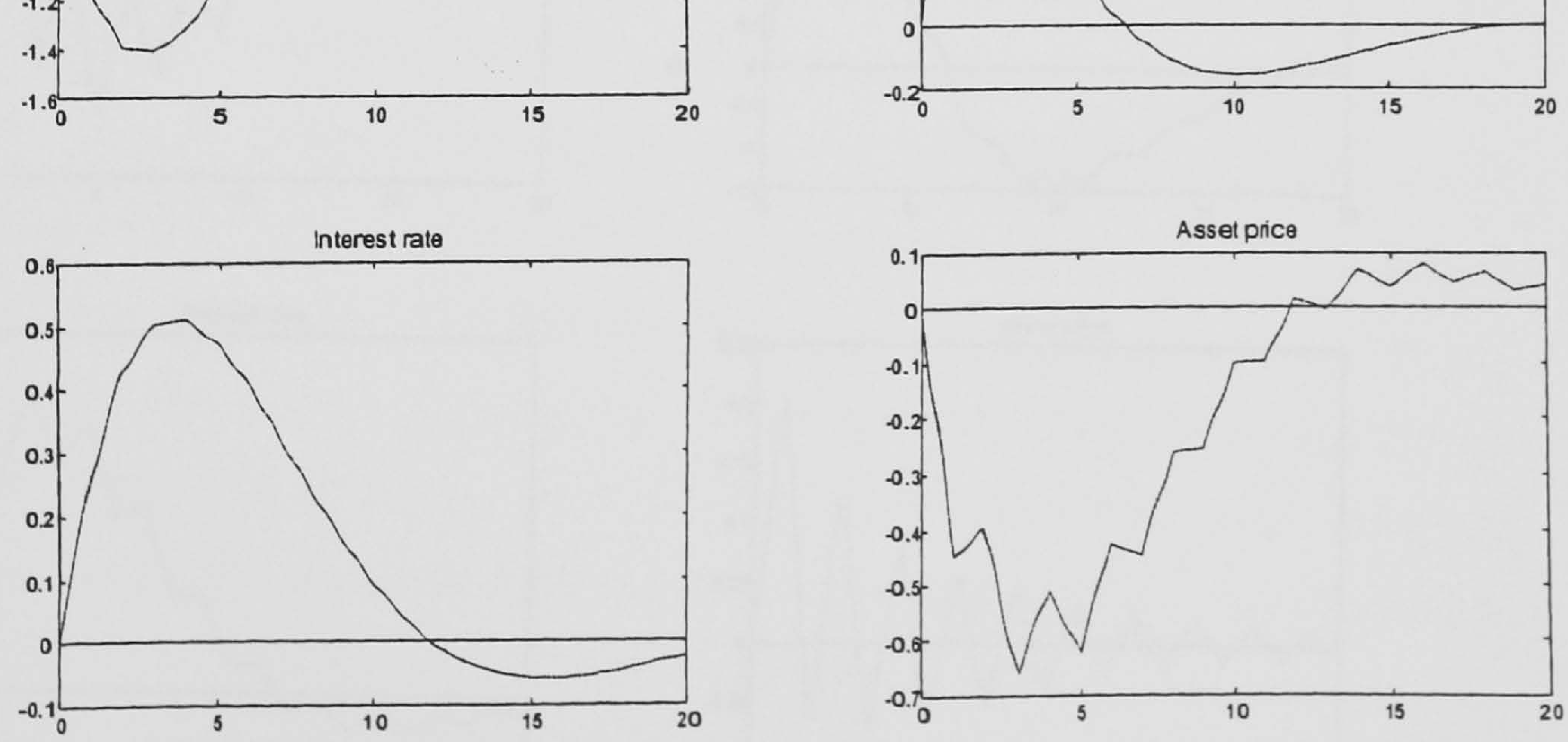


Figure 5.3: Impulse responses to unit shock to the output gap

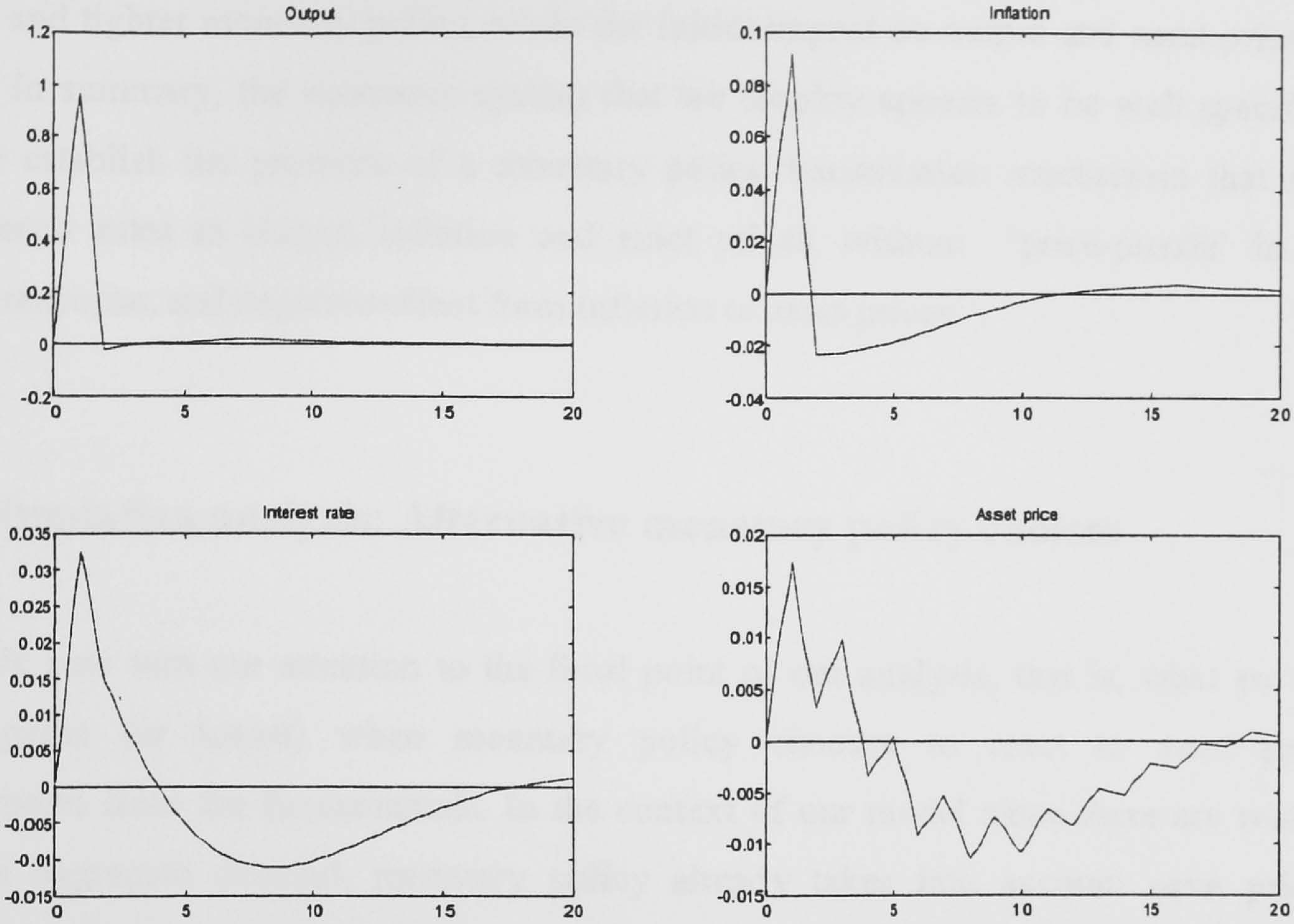
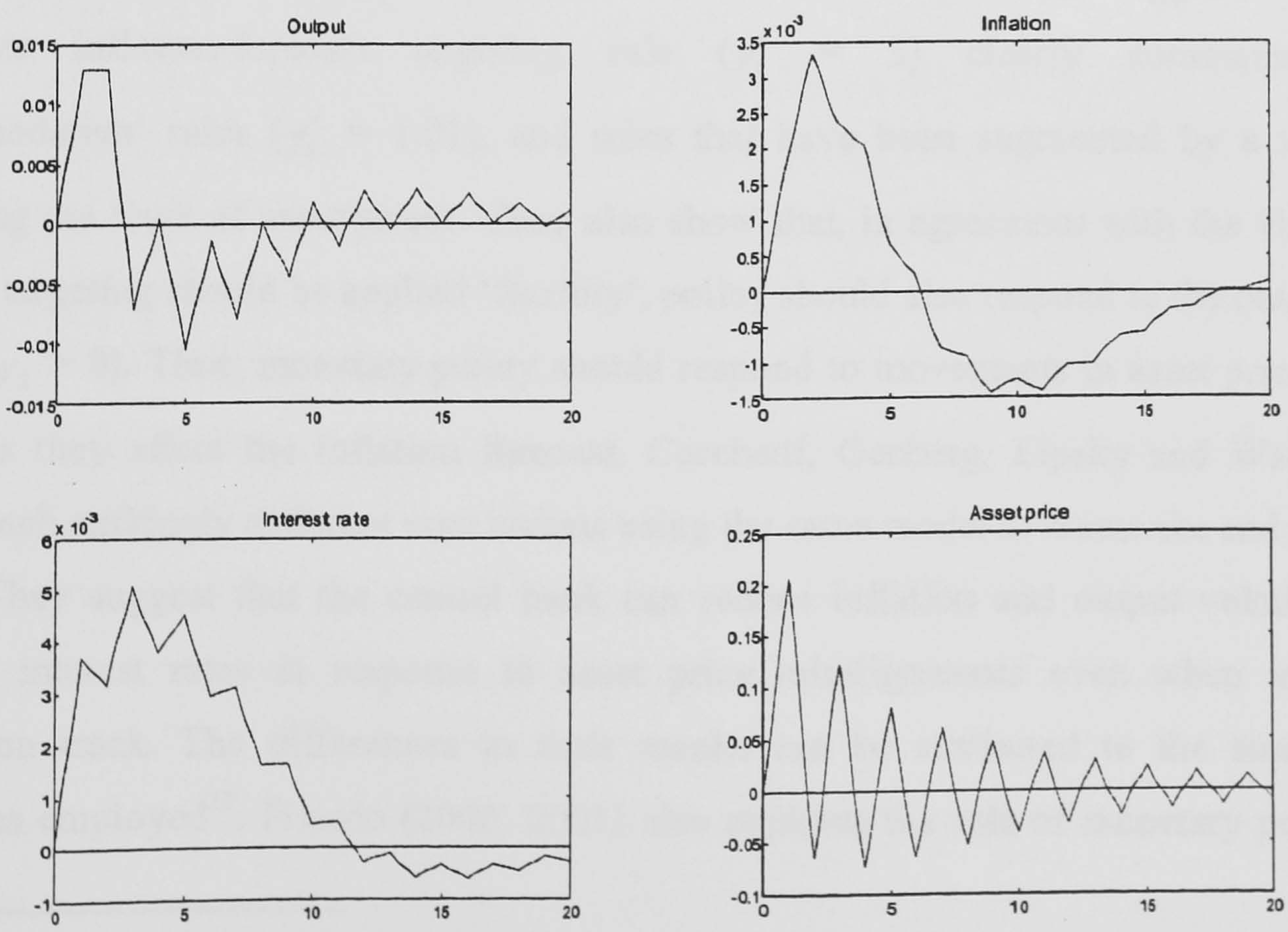


Figure 5.4: Impulse responses to unit shock to the fundamentals.



Finally, as Figure 5.4 indicates, a positive shock in fundamentals leads to higher inflation and tighter monetary policy, while the initial impact on output and asset prices is positive. In summary, the economic system that we employ appears to be well specified, since we establish the presence of a monetary policy transmission mechanism that runs from interest rates to output, inflation and asset prices, without 'price-puzzle' in the inflation response, and negative effect from inflation to asset prices[21].

5.4 Simulation analysis: Alternative monetary policy choices

We now turn our attention to the focal point of our analysis, that is, what are the welfare gains (or losses) when monetary policy chooses to react to asset price misalignments from the fundamentals. In the context of our model since there are wealth effects in aggregate demand, monetary policy already takes into account asset prices indirectly (and with lag) by responding to output movements. The question that then arises is whether an extra direct reaction to deviations from fundamentals is stabilizing the economic system or not.

Bernanke and Gertler's (1999, 2001) simulation evidence suggests that an aggressive inflation-forecast targeting rule ($\gamma_1^* = 3$) clearly dominates both 'accommodative' rules ($\gamma_1^* = 1.01$), and rules that have been augmented by a variable expressing the level of asset prices. They also show that, in agreement with the view that inflation targeting should be applied 'flexibly', policy should also respond to the output gap as well ($\gamma_2 > 0$). Thus, monetary policy should respond to movements in asset prices only insofar as they affect the inflation forecast. Cecchetti, Genberg, Lipsky and Wadhwani (2000) reach strikingly different conclusions using the same model as Bernanke and Gertler (1999). They suggest that the central bank can reduce inflation and output volatility by adjusting interest rates in response to asset price misalignments even when inflation remains on track. The differences in their results can be attributed to the simulation procedures employed[22]. Filardo (2000, 2001) also explores the role of monetary policy in

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[21] See among others, Canova and De Nicolo (1997) for relevant empirical evidence.

[22] As Bernanke and Gertler (2001, p.257) comment on the divergent findings, while the models used are much the same, the nature of the shock processes for non-fundamental stock prices is significantly different. In effect, Ceccetti et al. (2000) assume that the policymaker knows with certainty that the observed stock price

an economy with asset bubbles by developing and simulating a small-scale macroeconomic model. He finds that if the monetary authority is uncertain about the impact of asset prices on inflation and output, then it is preferable to remain neutral.

Representative simulation results using the Taylor rule and the inflation forecast-targeting rule are shown in Tables 5.2-5.3, respectively. The first column of Tables 5.1-5.3 presents the response of the nominal interest rate to asset price misalignments, $q_t - q_t^*$. The second to fourth column show the unconditional variances (in percentage points) of output gap, σ_y, inflation, σ_π, interest rates, σ_i, and asset prices, σ_q. In the absence of discounting, quadratic losses for alternative policy rules can be calculated as linear combinations of the unconditional variances of these variables:

$$L = a\sigma_\pi + b\sigma_y + c\sigma_i + d\sigma_q \tag{5.7}$$

where, (α, b, c, d) denote the respective weights that the central bank attaches on inflation, output gap, interest rate and asset price volatility[23].

We consider four alternative sets of weights:

(α, b, c, d) = (1, 0.5, 0.3, 0), (1, 0.5, 0.3, 0.1), (1, 1, 0.3, 0), (1, 1, 0.3, 0.1), via which we obtain the alternative loss functions L_1, L_2, L_3 and L_4 respectively. L_1 and L_3 put zero weight on asset price volatility, while L_2 and L_4 penalise asset price volatility with a factor of 0.1. L_3 and L_4 correspond to the case of equal weight on inflation and output gap volatility, while L_1 and L_2 recognise price stability as the primary objective of monetary policy, as the weight on inflation volatility is double the weight on output volatility. Penalising inflation and output volatility reflects a wide agreement that they represent important concerns for monetary policymakers[24]. Inclusion of asset price volatility in L_2 and L_4 stems from the arguments put forth in Borio and Lowe (2002), where it is acknowledged that apart from monetary stability (defined mainly as price stability), financial stability is also crucial and should be taken into account explicitly by

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movements are not fundamental in nature and, importantly, when the exogenous bubble is going to burst. Bernanke and Gertler (2001) argue that these conditions are unlikely to hold in actual economies.

[23] We should point out that as McCallum (2001b) argues, no actual central bank has yet publicly disclosed an explicit objective/loss function and the weights given to each variable. Hence, in analysing the effects of monetary policy rules on macroeconomic volatility, McCallum opts for the evaluation of alternative rules that are *not* necessarily derived from optimisation subject to a loss/objective function of the monetary authority.

[24] See for instance the discussion in Rudebusch and Svensson (1999).

policymakers, since price stability doesn't necessarily guarantee or promote financial stability. All the above specifications penalise instrument (interest rate) volatility with a factor of 0.3 [25].

The results in Tables 5.2, 5.3 indicate a mild response to asset price misalignments, i.e. γ_3 = 0.1, is successful in reducing overall macroeconomic volatility using all the alternative loss functions and monetary policy rules under investigation. Using both the Taylor rule and the inflation-forecast targeting rule, we notice that if the monetary authority reacts too strongly to asset prices ($\gamma_3 > 0.1$), aggregate welfare losses, as indicated by all the loss functions, increase due to the higher inflation, output and interest rate volatility, despite the decrease in asset price volatility (in the case of L_1 and L_4). Our results differ from the findings of Bernanke and Gertler (2001) since, as we show in Table 5.3, there is an incentive for the central bank to take into account asset prices even conditional to a strong response to expected inflation, as the inflation-forecast targeting suggests. The differences may derive, among other factors, from the fact that in our policy rules we consider asset price deviations from fundamentals, instead of the price of capital (Tobin's q) as in Bernanke and Gertler. Our results agree with Cecchetti et al. (2000) in that there are welfare gains from responding to asset price misalignments[26].

Table 5.2: Standard deviations of output gap, inflation, interest rates, asset prices, using the Taylor rule.

γ_3	σ_y	σ_π	σ_i	σ_q	L_1	L_2	L_3	L_4
0	2.13	0.89	0.84	11.06	2.21	3.31	3.27	4.38
0.1	1.93	0.94	0.83	10.17	2.15	3.17	3.12	4.14
0.5	1.95	1.45	1.31	8.60	2.79	3.65	3.73	4.59
1	2.14	2.08	2.11	7.62	3.78	4.55	4.85	5.62

Note:
(a) The standard deviations have been calculated using the baseline parameter values from Table 5.1.
(b) L_1, L_2, L_3, L_4 denote the value of the Loss function, $L = a\sigma_\pi + b\sigma_y + c\sigma_i + d\sigma_q$, for $(a,b,c,d) = (1, 0.5, 0.3, 0)$, (1, 0.5, 0.3, 0.1), (1, 1, 0.3, 0), (1, 1, 0.3, 0.1) respectively.

[25] Woodford (1999) provides an incentive for considering instrument volatility by stressing that more variable interest rates may undermine the central bank's credibility.
[26] Our results agree also with Dupor (2002), who builds a sticky price model in which firms over-invest in physical capital when stocks become overvalued. The optimal monetary policy response in his model is to raise interest rates to drive down employment, thereby reducing the marginal product of capital and its price. His approach differs from Bernanke and Gertler in that the monetary authority can distinguish fundamental from non-fundamental changes. Also, in Dupor's simulations, the policy rule does not respond to asset prices directly, but instead to the underlying shock that drives asset price movements.

Table 5.3: Standard deviations of output gap, inflation, interest rates, asset prices, using the inflation-forecast targeting rule.

γ_3	σ_y	σ_π	σ_i	σ_q	L_1	L_2	L_3	L_4
0	1.93	0.77	0.82	10.81	1.98	3.06	2.95	4.03
0.1	1.70	0.84	0.88	10.59	1.95	3.01	2.80	3.86
0.5	1.74	1.08	1.18	8.81	2.30	3.19	3.17	4.06
1	1.95	1.39	1.75	7.90	2.89	3.68	3.87	4.66

Note:

(a) The standard deviations have been calculated using the parameter values from Table 5.1.
(b) L_1, L_2, L_3, L_4 denote the value of the Loss function, $L = a\sigma_\pi + b\sigma_y + c\sigma_i + d\sigma_q$, for $(a,b,c,d) = (1, 0.5, 0.3, 0)$, $(1, 0.5, 0.3, 0.1)$, $(1, 1, 0.3, 0)$, $(1, 1, 0.3, 0.1)$ respectively.

The reduction in welfare losses that we obtain with our preferred rule (γ_3 = 0.1) derives from the lower asset price and output gap volatility, as compared to the baseline rule (γ_3 = 0). The increased inflation and interest rate variability has been more than compensated from the sharp decreases in output and asset price volatility. For example, in the inflation-forecast targeting case, σ_y declines from 1.93 to 1.70, and σ_q from 10.81 to 10.59.

In Tables 5.4, 5.5 we evaluate the behaviour of the economic system by varying simultaneously the parameter responding to inflation (γ_1, γ_1^*) and the parameter associated with asset price misalignments (γ_3). Specifically, we are postulating two regimes regarding the response of interest rates to inflation: an accommodating regime ($\gamma_1 = 0.05$, $\gamma_1^* = 1.05$), and an aggressive regime ($\gamma_1 = 2$, $\gamma_1^* = 3$), while with each of the regimes we allow two different values of the parameter associated with asset price misalignments: $\gamma_3 = 0$, and $\gamma_3 = 0.1$. In addition, we allow for three instances where the parameter associated with the output gap, γ_2, assumes a value of 0.5. This value was chosen because it was advocated by Taylor (1993) as the appropriate response of the central bank to the output gap, independently of its attitude towards inflation. The simulation evidence reveals the existence of inflation-output gap volatility frontiers, since when γ_2 increases from 0 to 0.5, output gap volatility declines and inflation volatility increases, for any given γ_1. For instance, in the case of the accommodative rule (first & second row of Table 5.4) with γ_3 = 0.1, σ_y declines from 2.42 to 2.03, while σ_π increases from 1.64 to 2.36.

Table 5.4: Standard deviations of output gap, inflation, interest rates, asset prices, using the Taylor rule and alternative values of $(\gamma_1, \gamma_2, \gamma_3)$.

(γ_1, γ_2)	γ_3	σ_y	σ_π	σ_i	σ_q	L_1	L_2	L_3	L_4
(0.05, 0)	0	2.51	1.43	0.90	11.04	2.96	4.06	4.21	5.32
	0.1	2.42	1.64	0.96	10.33	3.14	4.17	4.35	5.38
(0.05, 0.5)	0	2.22	1.90	1.20	10.88	3.37	4.46	4.48	5.57
	0.1	2.03	2.36	1.68	10.20	3.88	4.90	4.89	5.91
(1, 0)	0	1.98	0.87	0.92	10.58	2.13	3.19	3.12	4.18
	0.1	1.82	0.92	0.93	10.08	2.11	3.11	3.02	4.03
(1, 0.5)	0	1.78	0.99	0.94	10.53	2.16	3.21	3.04	4.10
	0.1	1.68	1.03	0.93	10.05	2.14	3.15	2.98	3.99
(2, 0)	0	1.99	0.71	1.01	10.68	2.00	3.07	3.00	4.07
	0.1	1.89	0.73	0.97	10.28	1.97	2.99	2.92	3.95
(2, 0.5)	0	1.80	0.75	0.95	10.49	1.93	2.98	2.83	3.88
	0.1	1.67	0.80	0.94	10.22	1.92	2.95	2.76	3.79

Note:

(a) The standard deviations have been calculated using the parameter values from Table 5.1.
(b) L_1, L_2, L_3, L_4 denote the value of the Loss function, $L = a\sigma_\pi + b\sigma_y + c\sigma_i + d\sigma_q$, for $(a,b,c,d) = (1, 0.5, 0.3, 0)$, $(1, 0.5, 0.3, 0.1)$, $(1, 1, 0.3, 0)$, $(1, 1, 0.3, 0.1)$ respectively.

Table 5.5: Standard deviations of output gap, inflation, interest rates, asset prices using the inflation-forecast targeting rule and alternative values of (γ_1^*, γ_3).

γ_1^*	γ_3	σ_y	σ_π	σ_i	σ_q	L_1	L_2	L_3	L_4
1.05	0	2.66	1.51	0.80	11.47	3.08	4.23	4.41	5.55
	0.1	2.48	1.77	0.93	10.58	3.28	4.34	4.52	5.58
2	0	2.06	0.93	0.82	10.93	2.20	3.29	3.23	4.32
	0.1	1.85	0.98	0.81	10.20	2.15	3.17	3.07	4.09
3	0	1.96	0.77	0.83	10.88	2.00	3.09	2.98	4.07
	0.1	1.83	0.80	0.84	10.30	1.97	3.00	2.88	3.91

Note:

(a) The standard deviations have been calculated using the parameter values from Table 5.1.
(b) L_1, L_2, L_3, L_4 denote the value of the Loss function, $L = a\sigma_\pi + b\sigma_y + c\sigma_i + d\sigma_q$, for $(a,b,c,d) = (1, 0.5, 0.3, 0)$, $(1, 0.5, 0.3, 0.1)$, $(1, 1, 0.3, 0)$, $(1, 1, 0.3, 0.1)$ respectively.

When, however, the monetary authority becomes more averse with respect to inflation, not only inflation but also output gap volatility declines in agreement with previous work of McCallum (2001b). For example, switching from (γ_1, γ_2, γ_3) = (0.05, 0, 0), to (2, 0, 0) reduces σ_π by 50 % and σ_y by about 20 %. Considering the reaction to asset prices, we find that when monetary policy responds to misalignments, asset market and output volatility always decline leading to lower L's, conditional upon non-inflation accommodation, i.e. $\gamma_1 > 0.05$. The smallest realisations of the alternative loss functions occur at (γ_1, γ_2, γ_3) = (2, 0.5, 0.1).

As we see in Table 5.5, using the inflation-forecast based rule, there are welfare gains from monetary policy reaction to misalignments only when $\gamma_1^* > 1.05$, that is, aggressive inflation-forecast targeting. The stronger the reaction to expected inflation the greater the reduction in macroeconomic volatility. Comparing the last row of Tables 5.4 and 5.5 respectively, that correspond to the inflation-averse case, we notice that the Taylor rule that includes both asset price misalignments and the output gap leads to lower aggregate volatility as compared to the augmented (by asset price misalignments) inflation-forecast rule. Hence, we agree with Bernanke and Gertler (2001) that inflation targeting should be 'flexible' with an independent role for the output gap.

5.5 Conclusions

This chapter examined the relationship between monetary policy and asset prices using a structural model of the economy that allows for the effect of asset prices on aggregate demand. The sharp reduction in stock prices on early 2000, and the continuing worldwide increases in house prices have resulted in growing interest among academics and policymakers to study the links between monetary policy, asset market developments and the real economy. Financial imbalances and the economic instability associated with pronounced asset price misalignments pose important challenges for monetary policymakers. Concentrating on price stability alone, as a growing number of inflation targeting countries do, is no guarantee that financial instability and the serious after-effects of bubbles bursting can be avoided. Taking these arguments into consideration, we start from a small-scale rational expectations macro model where, in line with recent empirical findings and theoretical intuition, the current level of output is positively related to lagged real asset prices. In this study, we contribute to the existing literature by employing an alternative model for the dynamic evolution of asset prices. We assume that asset prices follow a partial adjustment mechanism in the context of which, they are positively affected by past changes, while at the same time we also allow for reversion towards their fundamental value.

Analyzing whether the central bank should take into account asset price misalignments when setting interest rates, we consider both the inflation-forecast targeting rule and the standard Taylor rule. The main result of our simulations is that a mild response to asset price deviations from fundamentals promotes overall macroeconomic stability. This result is robust to all alternative loss functions and policy rules. Monetary policy should not only react strongly to inflation (or its forecast) but should also take into account output developments and asset price misalignments. We acknowledge that it may be difficult to interpret asset price movements and distinguish between fundamental and non-fundamental components, but the same type of uncertainty exists when policy makers are faced with stochastic trend output. Hence, there is scope for the monetary authorities to take into account asset price misalignments in the conduct of monetary policy despite the measurement errors that they might face.

Conclusions

The purpose of this thesis was to provide a thorough analysis of the interaction between monetary policy, inflation, and asset prices. This area of the literature is related to the monetary economics and financial economics disciplines and has important implications for the conduct of monetary policy and investor behaviour, given the crucial changes in the underlying financial and macroeconomic framework over the 1990s. During that decade, inflation targeting, either explicit or implicit, became the monetary policy regime of choice for many central banks. Compared with the inflationary 1970s, inflation rates became lower and less volatile reducing the significant economic costs associated with high and variable inflation. However, greater price stability did not bring along smaller financial volatility, as after the mid-1990s stock prices and house prices appreciated to record levels in many advanced economies. The stock market 'dot com' bubble eventually burst in early 2000, while house prices continue to rally creating concerns to policymakers about the macroeconomic effects of a possible correction in the property market.

The recent volatility in financial markets has drawn academics and monetary policymakers in an intense debate on whether monetary policy should respond to asset price misalignments. Asset prices play an important role in the transmission mechanism of monetary policy via their effect on consumption spending (consumption wealth effects) and investment spending (investment balance sheet effects). The 'new environment' hypothesis stresses that in a macroeconomic environment characterised by low inflation, low interest rates and exuberant growth projections, financial imbalances can easily build up. However, when optimism about further increases in asset price turns to pessimism, financial imbalances unwind and the result may be financial distress. The new view for the conduct of monetary policy acknowledges the benefits brought by inflation targeting, pointing out, though, that central banks should be more proactive in their effort to preserve financial stability. This thesis was motivated by the aforementioned developments and attempted to investigate the impact of inflation targeting and the feedback relationship between monetary policy and asset prices using a variety of econometric and theoretical frameworks. We now present a synopsis of our findings and the related policy implications.

Chapter 1 examined the impact of monetary conditions on stock market returns in the context of the present value model of equity valuation. According to it, monetary policy plays an important role in determining equity returns either by altering the discount rate used by market participants or by influencing market participants' expectations of future economic activity. In chapter 1 we focused on the discount rate link and utilised proxies for shifts in monetary policy that were based on interest rate variables, including the change in the short-term Treasury Bill rate and a dummy variable reflecting changes in the central bank discount rate. Our dataset comprised of 13 OECD countries over the period 1972-2002, covering the crucial period of the recent boom-bust cycle in international stock markets. Our main contributions to the existing empirical literature were that we took into account the non-normal distribution of stock returns, through bootstrap analysis, as well as the co-movement in international stock markets, via SUR system estimation. The results suggested that in the majority of the countries under investigation, periods of tight money were associated with contemporaneous declines in stock market value. We also showed that shifts in interest rates contain significant information that can be used to forecast expected stock returns. Specifically, we found that a restrictive (expansive) monetary policy stance decreases (increases) expected stock returns in most sample countries.

Such shifts in expected returns do not run against the paradigm of market efficiency, since monetary authorities typically turn to expansive policies when there is concern about the prospects of economic growth. Hence, it may be reasonable to expect that during such periods, investors may require a higher rate of return in order to invest in the stock market. The results in chapter 1 verified the existence of a link between monetary policy decisions and stock market wealth. This has important implications for both stock market participants and central bankers, since the former are interested in the broader topic of stock market determination and portfolio formation, while the latter are interested in whether monetary policy actions are transmitted through financial markets. Our findings suggest that investors should be aware of the international diversification opportunities across countries with different monetary environments, while central bankers should keep in mind that, in case they need to, they have the ability to affect the stock market through interest rate changes.

In Chapter 2 we turned our attention to the relationship between average inflation-inflation uncertainty and the impact of explicit targeting in the context of the UK economy. The 'new environment' hypothesis suggests that the increased aversion of monetary authorities to inflation and its volatility brought credibility gains and allowed for lower interest rates, which had had a positive impact on stock market capitalisation. Using a variety of GARCH models for the mean and the variance of inflation, the empirical results in chapter 2 suggested a positive relationship between past price changes and uncertainty about future changes. Hence, the decrease in average inflation over the 1990s reduced the negative consequences of inflation uncertainty. They key contribution of chapter 2 was that we modelled explicitly the establishment of inflation targeting in the UK, which allowed us to examine its effects on inflationary dynamics and uncertainty. Estimates from symmetric and threshold-GARCH models indicated that post-targeting UK inflation was less persistent and less variable. Most interestingly, evidence from component-GARCH estimation showed that a direct negative impact on long-run uncertainty could still be identified, even after we controlled for the indirect effect of lower average inflation throughout the period 1992-2002. These findings have important implications for monetary policy design. Monetary authorities of high inflation countries should consider the long-run benefits associated with explicit inflation targeting, keeping in mind, though, that focusing on consumer price stability alone does not necessarily guarantee financial stability.

Following the examination of the stabilisation properties exhibited by inflation targeting monetary policy regimes, in chapter 3 we took a look at the operational aspects of such frameworks. Simplified inflation targeting models typically include an aggregate supply and an aggregate demand equation, as well as a rule for the monetary policy setting. We innovated, though, by augmenting the standard framework to take into account the role of asset prices. The intuition for monetary policy to consider asset prices lays on the fact that asset price fluctuations may destabilise aggregate demand and inflation, through their effect on consumption and investment. Indeed, empirical evidence from the UK over the inflation targeting period 1992-2003 indicated that movements in asset prices, especially house prices, exert a significant positive effect on aggregate demand, that feeds into higher future inflation. Hence, there is scope for an inflation targeting central bank, like the Bank of England, to include asset prices in its reaction function.

Based on those arguments, we extended the standard forward-looking Taylor rule to incorporate measures of house price and stock price inflation. Using data from the UK and the US, we found that US monetary policymakers appear to be more concerned about stock market developments, while their UK counterparts assign a higher weight on house price inflation. In addition, we modelled the effect of Bank of England independence on policy preferences towards expected inflation and found that post-independence inflation aversion increased, while the relationship between interest rates and asset price changes remained unaffected. Hence, our key contribution to the empirical Taylor rules literature was to show that monetary policy *has* reacted to asset price movements, with the result being robust to whether an explicit or implicit inflation targeting regime was at work, and to the impact of central bank independence. In the last two chapters of the thesis we revisited the relationship between monetary policy and asset prices from the perspective of whether policy makers *should* respond to asset price misalignments.

In chapter 4 we utilised a backward-looking structural macro model where a positive effect was postulated from asset price increases on aggregate demand and consequently on inflation. Central bank preferences were characterised by a quadratic loss function penalising deviations of inflation from its target value and output from its potential level. In order to derive the optimal interest rate rule, we solved the model and then used stochastic control techniques to minimise intertemporally the central bank's loss function. The functional form of the implied optimal reaction function depended on the assumption underlying the dynamic evolution of asset prices. In the simple case where asset prices are always equal their fundamental value the optimal rule conditioned short-term nominal interest rates on inflation and the output gap.

Our main contribution to the literature on optimal rules stemmed from extending the asset price block of the model to allow for potential bubble build-up, in addition to reversion towards fundamentals. This modification, apart from bringing the model closer to reality, implied a drastic change in the optimal interest rate rule, since it conditioned the monetary policy instrument not only on inflation and demand pressures but also on asset price misalignments. We also showed that the magnitude of the interest rate reaction to financial imbalances depends on the relative importance of wealth effects for aggregate demand. The greater the impact of asset price fluctuations on the demand side of the economy, the more aggressive should be the response of interest rates to asset price misalignments. These results have important policy implications given the sustained deviations from fundamental values often exhibited by stock markets and property markets. Monetary authorities should acknowledge that the role of asset prices goes far beyond their use as instruments to forecast inflation and output.

Given the prevalence of microfoundations consistent New Keynesian models in the recent literature, in chapter 5 we took a final look at the interaction between monetary policy and asset price misalignments in the context of a small-scale macroeconomic model that incorporates forward-looking elements and an impact from asset prices on output. Aggregate demand was represented by an optimising IS type of relationship, inflation by a hybrid Phillips curve, while asset prices were assumed to be affected both by momentum trading and reversion towards fundamentals. We then resorted to stochastic simulations to analyse whether the central bank should respond to asset price misalignments when setting interest rates. Doing so, we employed two alternative interest rate rules, the forward-looking Taylor rule and the inflation-forecast targeting rule, in order to examine the robustness of our findings to the rule specification. Our simulation evidence indicated that, given reasonable values for the calibration of the behavioural coefficients, a mild reaction to asset price misalignments promotes overall macroeconomic stability. This result holds across all the alternative loss functions that we employed, under the condition that the central bank is not accommodating inflation. Hence, monetary policy should not only respond to inflation (or its forecast) but should also take into account output developments and asset price misalignments, despite the measurement errors associated with proxying trend output and asset price fundamentals.

APPENDICES

APPENDIX CHAPTER I

Table A1.1: Correlation of local three month Treasury Bill rates with local central bank discount rates, 1972:01- 2002.07.

Country	Correlation Coefficient
Belgium	0.94
Canada	0.97
Finland	0.97
France	0.94
Germany	0.90
Italy	0.85
Japan	0.96
Sweden	0.95
Switzerland	0.58
United Kingdom	0.98
United States	0.96

Note: The discount rate data for Belgium, France, Finland, Germany, Italy (Euro members) ends on December 1998. Thereafter, we used the ECB refinancing rate. Netherlands and Spain have not been included due to the lack of adequate number of discount rate observations in the Datastream series.

Table A1.2: Local monetary policy environments, 1972:01- 2002.07.

Belgium

Expansive Periods	Date of first rate change	Duration in months	**Restrictive Periods**	Date of first rate change	Duration in months
1	1972.02	9	1	1972.11	26
2	1975.01	14	2	1976.03	10
3	1977.01	11	3	1978.07	24
4	1978.01	6	4	1982.04	3
5	1980.07	8	5	1983.11	18
6	1981.04	8	6	1985.12	4
7	1982.01	3	7	1988.06	5
8	1982.07	16	8	1988.12	30
9	1985.09	3	9	1991.08	13
10	1986.04	9	10	1997.10	15
11	1987.03	15			
12	1992.09	12			
13	1993.10	48			

Canada

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1974.11	10	1	1973.04	19
2	1976.11	16	2	1975.09	14
3	1994.07	3	3	1978.03	24
4	1995.04	5	4	1994.02	5
5	1995.11	3	5	1994.10	6
6	1996.03	16	6	1997.07	15
7	1998.10	13	7	1999.11	14
8	2001.01	15	8	2002.04	4

Finland

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1977.10	25	1	1973.07	51
2	1982.06	13	2	1979.11	31
3	1985.02	39	3	1983.07	19
4	1989.01	10	4	1988.05	8
5	1993.01	72	5	1989.11	38

France

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1975.01	15	1	1972.09	28
2	1977.09	21	2	1976.04	17
3	1980.04	11	3	1979.06	10
4	1981.07	90	4	1981.03	4
5	1990.04	20	5	1989.01	15
6	1992.05	7	6	1991.12	5
7	1993.04	17	7	1992.12	4
8	1995.11	24	8	1994.10	12
			9	1997.11	14

Germany

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1974.10	53	1	1972.10	24
2	1982.08	22	2	1979.03	41
3	1985.08	35	3	1984.06	14
4	1992.09	76	4	1988.07	50

Italy

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1972.04	17	1	1973.09	15
2	1974.12	14	2	1976.02	16
3	1977.06	28	3	1979.10	34
4	1982.08	25	4	1984.09	4
5	1985.01	31	5	1987.08	34
6	1990.05	19	6	1991.12	8
7	1992.10	22	7	1994.08	23
8	1996.07	30			

Japan

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1972.06	10	1	1973.04	24
2	1975.04	48	2	1979.04	16
3	1980.08	105	3	1989.05	26
4	1991.07	133			

Sweden

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1975.08	10	1	1974.04	16
2	1978.02	18	2	1976.06	20
3	1981.10	32	3	1979.07	27
4	1985.07	33	4	1984.06	13
5	1990.05	6	5	1988.04	25
6	1991.02	11	6	1990.11	3
7	1993.01	18	7	1992.01	12
8	1995.10	48	8	1994.07	15
9	2000.06	13	9	1999.10	8
10	2002.01	3	10	2001.07	6
			11	2002.04	4

Switzerland

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1975.03	56	1	1973.01	26
2	1982.03	77	2	1979.11	28
3	1992.09	88	3	1988.08	49
4	2001.09	5	4	2000.01	4
5	2002.03	5	5	2000.06	4
			6	2000.11	4
			7	2001.05	4

United States

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1974.12	32	1	1973.01	23
2	1980.05	4	2	1977.08	33
3	1981.11	29	3	1980.09	14
4	1984.11	34	4	1984.04	7
5	1990.12	41	5	1987.09	39
6	1996.01	43	6	1994.05	20
7	2001.01	19	7	1999.08	17

United Kingdom

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1973.01	6	1	1972.06	7
2	1974.01	16	2	1973.07	6
3	1975.11	5	3	1975.05	6
4	1976.11	12	4	1976.04	7
5	1978.01	3	5	1978.04	11
6	1979.03	3	6	1979.06	13
7	1980.07	13	7	1981.08	3
8	1981.11	12	8	1982.11	4
9	1983.03	14	9	1986.10	5
10	1984.08	5	10	1988.06	15
11	1985.03	10	11	1989.10	10
12	1986.03	7	12	1994.09	15
13	1987.03	5	13	1996.10	24
14	1987.10	4	14	1999.09	17
15	1988.03	3			
16	1990.10	47			
17	1995.12	10			
18	1998.10	11			
19	2001.02	18			

European Central Bank

Expansive Periods	Date of first rate change	Duration in months	Restrictive Periods	Date of first rate change	Duration in months
1	1999.04	7	1	1999.11	18
2	2001.05	15			

Note:

(a) The monetary policy environment is classified as expansive (restrictive) if the previous discount rate change was a decrease (increase).
(b) The data excludes months when the central bank discount rate was pegged to a market rate than being set by the central bank itself. This results in elimination of data for Canada from March 1980 to December 1993. The discount rate data for Belgium, France, Finland, Germany, Italy (Euro members) ends on December 1998. The ECB refinancing rate is effective from January 1999.

Table A1.3a: Unit root tests for real stock returns, 1972.02 - 2002.07.

		Belgium	Canada	Finland	France	Germany	Italy	Japan
ADF	UB	-3.46 ***	-3.85 ***	-2.59 *	-3.66 ***	-3.52 ***	-3.31 **	-3.27 **
	LB	-7.91 ***	-7.73 ***	-7.14 ***	-6.93 ***	-8.37 ***	-7.52 ***	-7.54 ***
	SIC	-13.02 ***	-17.17 ***	-13.97 ***	-17.19 ***	-17.77 ***	-17.42 ***	-17.53 ***
ADF Trend	UB	-3.61 **	-3.97 **	-2.37	-3.72 **	-3.33 *	-3.37 *	-3.34 *
	LB	-8.01 ***	-7.93 ***	-7.18 ***	-6.97 ***	-8.36 ***	-7.62 ***	-7.57 ***
	SIC	-13.09 ***	-17.78 ***	-13.99 ***	-17.21 ***	-17.36 ***	-17.43 ***	-17.57 ***

		Netherlands	Spain	Sweden	Switzerland	UK	US
ADF	UB	-3.16 **	-2.69 *	-2.59 *	-3.71 ***	-3.42 ***	-3.62 ***
	LB	-7.78 ***	-7.21 ***	-7.62 ***	-7.31 ***	-8.76 ***	-8.06 ***
	SIC	-16.69 ***	-14.26 ***	-15.88 ***	-15.46 ***	-16.86 ***	-18.61 ***
ADF Trend	UB	-2.69	-2.62	-3.17 *	-3.45 **	-3.22 *	-3.94 **
	LB	-7.81 ***	-7.47***	-7.61 ***	-7.34 ***	-8.81 ***	-8.25 ***
	SIC	-16.71 ***	-14.41 ***	-15.86 ***	15.52 ***	-16.88 ***	-18.73 ***

Note:

(a) The reported *t*-statistics test the null hypothesis of unit root in monthly real stock returns.
(b) In order to correct for serial correlation, the Augmented Dickey Fuller test (ADF) uses lagged differences of the variable into question. UB = 24, is the upper bound of lagged difference terms; LB = 4, is the lower bound of lagged difference terms. SIC is the order of augmentation of the ADF that minimises the Schwartz information criterion starting from upper bound UB.
(c) *, **, *** indicate rejection of the null-unit root hypothesis at 10, 5, 1 % level of significance respectively.

Table A1.3b: Unit root tests for dividend adjusted nominal stock returns.

		Belgium	Canada	Finland	France	Germany	Italy	Japan
ADF	UB	-3.15 **	-3.98 ***	-1.24	-3.59 **	-3.16 **	-3.16 **	-2.89 **
	LB	-8.69 ***	-7.89 ***	-5.04 ***	-7.26 ***	-8.41 ***	-7.61 ***	-7.43 ***
	SIC	-16.49 ***	-17.78 ***	-9.77 ***	-16.78 ***	-17.01***	-17.15 ***	-17.77 ***
ADF Trend	UB	-3.15 *	-3.91 **	-1.32	-3.78 **	-3.19 *	-3.16 *	-3.43 **
	LB	-8.70 ***	-7.86 ***	-5.02 ***	-7.11 ***	-8.36 ***	-7.61 ***	-7.61 ***
	SIC	-16.47 ***	-17.76 ***	-9.74 **	-5.85 ***	-16.97 ***	-12.14 ***	-17.87 ***

		Netherlands	Spain	Sweden	Switzerland	UK	US
ADF	UB	-3.11 **	-1.37	-2.35 *	-3.62 ***	-3.21 **	-3.38 **
	LB	-7.68 ***	-7.12 ***	-6.31 ***	-7.41 ***	-8.65 ***	-7.61 ***
	SIC	-16.27 ***	-11.61 ***	-12.65 ***	-15.64 ***	-13.85 ***	-18.27 ***
ADF Trend	UB	-2.97	-1.21	-2.33	-3.37 *	-4.23 **	-3.21 *
	LB	-7.63 ***	-7.11 ***	-6.49 ***	-7.42 ***	-8.67 ***	-7.59 ***
	SIC	-16.24 ***	-11.60 ***	-12.75 ***	-15.66 ***	-13.88 ***	-18.24 ***

Note:

(a) The reported t-statistics test the null hypothesis of unit root in monthly dividend adjusted nominal stock returns. The Datastream return series are available from 1973.02 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US, and 1982.02, 1987.04 and 1988.05 for Sweden, Spain, and Finland, respectively.
(b) In order to correct for serial correlation, the Augmented Dickey Fuller test (ADF) uses lagged differences of the variable into question. UB = 24, is the upper bound of lagged difference terms; LB = 4, is the lower bound of lagged difference terms. SIC is the order of augmentation of the ADF that minimises the Schwartz information criterion starting from upper bound UB.
(c) *, **, *** indicate rejection of the null-unit root hypothesis at 10, 5, 1 % level of significance respectively.

Table A1.3c: Unit root tests for dividend adjusted real stock returns.

		Belgium	Canada	Finland	France	Germany	Italy	Japan
ADF	UB	-3.69 ***	-3.76 ***	-1.25	-3.62 ***	-3.11 **	-3.24 **	-3.11 **
	LB	-8.40 ***	-7.69 ***	-4.99 ***	-7.11 ***	-8.37 ***	-7.55 ***	-7.36 ***
	SIC	-16.31 ***	-17.68 ***	-9.83 ***	-16.75 ***	-16.88 ***	-17.07 ***	-17.56 ***
ADF Trend	UB	-3.14 *	-3.76 ***	-2.37	-3.48 **	-3.18 *	-3.15 *	-3.33 *
	LB	-8.49 ***	-7.71 ***	-4.97 ***	-7.12 ***	-8.33 ***	-7.58 ***	-7.38 ***
	SIC	-16.33 ***	-17.72 ***	-9.81 **	-16.76 ***	-16.85 ***	-17.06 ***	-17.55 ***

		Netherlands	Spain	Sweden	Switzerland	UK	US
ADF	UB	-2.98 **	-1.39	-2.15	-3.71 ***	-3.72 ***	-3.37 **
	LB	-7.49 ***	-7.09 ***	-6.37 ***	-7.32 ***	-8.71 ***	-7.44 ***
	SIC	-16.06 ***	-11.51 ***	-12.70 ***	-15.46 ***	-13.74 ***	-18.04 ***
ADF Trend	UB	-2.72	-1.17	-2.16	-3.45 **	-3.68 **	-3.14 **
	LB	-7.45 ***	-7.08 ***	-6.38 ***	-7.34 ***	-8.72 ***	-7.45 ***
	SIC	-16.04 ***	-11.48 ***	-12.74 ***	-15.52 ***	-13.71 ***	-18.07 ***

Note:

(a) The reported *t*-statistics test the null hypothesis of unit root in monthly dividend adjusted real stock returns. The Datastream return series are available from 1973.02 for Belgium, Canada, France, German, Italy, Japan, Netherlands, Switzerland, UK, and US, and 1982.02, 1987.04 and 1988.05 for Sweden, Spain, and Finland, respectively.
(b) In order to correct for serial correlation, the Augmented Dickey Fuller test (ADF) uses lagged differences of the variable into question. UB = 24, is the upper bound of lagged difference terms; LB = 4, is the lower bound of lagged difference terms. SIC is the order of augmentation of the ADF that minimises the Schwartz information criterion starting from upper bound UB.
(c) *, **, *** indicate rejection of the null-unit root hypothesis at 10, 5, 1 % level of significance respectively.

Table A1.4: Bootstrap results for nominal stock returns equation.

Country	Lower Bound	Upper Bound	OLS t-statistic
Belgium	-1.969	1.967	-3.642
Canada	-2.091	1.810	-2.923
Finland	-1.975	1.805	-0.509
France	-1.855	1.829	-3.032
Germany	-1.901	2.035	-1.928
Italy	-1.874	2.100	-2.283
Japan	-1.919	2.013	-1.327
Netherlands	-1.933	1.840	-2.251
Spain	-1.991	2.096	0.99
Sweden	-1.928	1.952	-2.286
Switzerland	-1.922	1.988	-1.95
United Kingdom	-2.040	1.770	-5.406
United States	-1.999	1.955	-2.302

Note:

(a) Upper bound and lower bound denote the 5% bootstrap critical values using the residuals of the regression equation $\Delta S_t = \alpha + \beta \Delta i_t + u_t$ where ΔS_t is the monthly nominal stock return and Δi_t is the change in the short-term interest rate.

(b) The critical values are averages obtained from 100 repetitions of 1000 iterations. At each repetition, the 1000 test statistics are sorted and the 5% critical values are selected as the 25th (upper bound) and 975th (upper bound) values of the series.

Table A1.5: Bootstrap results for real stock returns equation.

Country	Lower Bound	Upper Bound	OLS t-statistic
Belgium	-2.057	1.733	-3.77
Canada	-2.042	1.975	-2.972
Finland	-2.128	2.017	-0.689
France	-2.011	1.929	-3.161
Germany	-1.912	1.925	-1.941
Italy	-1.954	1.960	-2.476
Japan	-1.843	1.978	-1.806
Netherlands	-2.037	2.041	-2.563
Spain	-1.959	1.907	0.896
Sweden	-1.998	1.984	-2.627
Switzerland	-1.801	1.954	-1.915
United Kingdom	-2.129	1.999	-5.416
United States	-1.767	1.993	-2.194

Note:

(a) Upper bound and lower bound denote the 5% bootstrap critical values using the residuals of the regression $\Delta s_t = \alpha + \beta \Delta i_t + u_t$ where Δs_t is the monthly ex post real stock return and Δi_t is the change in the short-term interest rate.

(b) The critical values are averages obtained from 100 repetitions of 1000 iterations. At each repetition, the 1000 test statistics are sorted and the 5% critical values are selected as the 25th (upper bound) and 975th (upper bound) values of the series.

Table A1.6: Bootstrap results for dividend adjusted nominal stock returns equation.

Country	Lower Bound	Upper Bound	OLS t-statistic
Belgium	-2.048	1.839	-4.505
Canada	-1.901	1.909	-3.956
Finland	-2.025	2.181	-1.836
France	-1.962	1.958	-2.98
Germany	-1.809	1.911	-1.898
Italy	-1.954	1.991	-2.478
Japan	-1.998	1.962	-1.573
Netherlands	-2.043	2.061	-2.249
Spain	-2.079	1.886	-0.035
Sweden	-1.980	1.931	-2.221
Switzerland	-2.139	2.013	-1.658
United Kingdom	-2.116	1.920	-4.702
United States	-2.042	1.881	-2.064

Note:

(a) Upper bound and lower bound denote the 5% bootstrap critical values using the residuals of the regression equation $\Delta S_t^D = \alpha + \beta \Delta i_t + u_t$ where ΔS_t^D is the monthly dividend adjusted nominal stock return and Δi_t is the change in the short-term interest rate.
(b) The critical values are averages obtained from 100 repetitions of 1000 iterations. At each repetition, the 1000 test statistics are sorted and the 5% critical values are selected as the 25th (lower bound) and 975th (upper bound) values of the series.

Table A1.7: Bootstrap results for dividend adjusted real stock returns equation.

Country	Lower Bound	Upper Bound	OLS t-statistic
Belgium	-2.042	2.051	-4.536
Canada	-2.019	1.973	-2.99
Finland	-1.881	1.944	-1.874
France	-2.070	1.867	-3.107
Germany	-2.051	1.976	-2.22
Italy	-1.866	1.978	-2.67
Japan	-2.036	1.957	-1.896
Netherlands	-1.910	1.989	-2.155
Spain	-1.825	2.005	-0.041
Sweden	-2.007	1.897	-2.267
Switzerland	-2.073	2.031	-1.609
United Kingdom	-2.018	1.923	-4.709
United States	-1.941	2.031	-2.146

Note:

(a) Upper bound and lower bound denote the 5% bootstrap critical values using the residuals of the regression equation $\Delta s_t^D = \alpha + \beta \Delta i_t + u_t$ where Δs_t^D is the monthly dividend adjusted ex post real stock return and Δi_t is the change in the short-term interest rate.
(b) The critical values are averages obtained from 100 repetitions of 1000 iterations. At each repetition, the 1000 test statistics are sorted and the 5% critical values are selected as the 25th (lower bound) and 975th (upper bound) values of the series.

Table A1.8: Summary of results on the relationship between stock returns and changes in the short-term interest rate.

	Nominal			Real			Nominal Dividend Adjusted			Real Dividend Adjusted		
Country	**OLS**	**Bootstrap**	**SUR**	**OLS**	**Bootstrap**	**SUR**	**OLS**	**Bootstrap**	**SUR**	**OLS**	**Bootstrap**	**SUR**
Belgium	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Canada	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Finland	N	N	N	N	N	N	N	N	N	N	N	N
France	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Germany	N	Y	N	N	Y	N	N	Y	N	Y	Y	N
Italy	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Japan	N	N	N	N	N	N	N	N	N	N	N	N
Netherlands	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Spain	N	N	N	N	N	N	N	N	N	N	N	N
Sweden	Y	Y	N	Y	Y	N	Y	Y	N	Y	Y	N
Switzerland	N	Y	N	N	Y	N	N	N	N	N	N	N
UK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
US	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pass	**8/13**	**10/13**	**7/13**	**8/13**	**10/13**	**7/13**	**8/13**	**9/13**	**7/13**	**9/13**	**9/13**	**7/13**

Note:

(a) This table summarizes the results of Tables 1.4-1.7.1 and Appendix Tables A1.4-A1.7, considering the statistical significance of the change in the short-term interest rate in the regression models (1.2) -(1.3)′. *Y* indicates significance of Δi_t at the 5% level of significance, otherwise *N*.
(b) Pass shows the number of *Y*'s in each case, divided by the total number of sample countries.

APPENDIX CHAPTER II

Table A2.1: Studies on the relationship between the inflation rate and its conditional variance.

Study	Sample	Price index	Model	Major findings
Engle (1982)	U.K. 1958Q2 – 1977Q2	CPI	ARCH	Time varying inflation uncertainty; higher in the 1970's than in the late 1960's.
Engle (1983)	U.S. 1947Q4 – 1979Q4	CPI, PPI, GNP deflator	ARCH	Time varying inflation uncertainty; slightly higher in the 1970's than in the late 1960's, and bellow the 1940's and early 1950's levels.
Bollerslev (1986)	U.S. 1948Q2 – 1983Q4	GNP deflator	GARCH	Similar to Engle (1983).
Evans (1991)	U.S. 1960M1 – 1988M6	CPI	GARCH with time-varying parameters	Positive link between long-run uncertainty and the level of inflation.
Bruner and Hess (1993)	U.S. 1947Q1 – 1992Q4	CPI	State-dependent model EGARCH	Asymmetric effects in inflation uncertainty; significant relationship between inflation and short-run uncertainty.
Joyce (1995)	U.K. 1950Q1 – 1994Q1	RPI	GARCH AGARCH EGARCH TGARCH	Asymmetric effects; Positive relationship between uncertainty and lagged inflation.
Crawford and Kasumovich (1996)	Canada 1916Q2 – 1994Q3 1963Q3 – 1994Q3	CPI CPIXFET	GARCH AGARCH TGARCH	No asymmetric effects; Positive relationship between uncertainty and lagged inflation.
Baillie (1996)	G7 plus Argentina, Brazil, Israel 1948M1 – 1990M12	CPI	Fractionally Integrated GARCH-M	Positive bi-directional relationship between inflation and uncertainty only in U.K., and the three high inflation countries.
Grier and Perry (1998)	G7 countries 1948M1 - 1993M12	CPI	GARCH TGARCH Component GARCH	Inflation Granger-causes inflation uncertainty.
Fountas et al. (2000)	U.S. 1960M1 – 1999M2	CPI	GARCH-M	Positive bi-directional relationship between inflation and uncertainty.

Note:

CPIXFET denotes CPI excluding food, energy and the effect of indirect taxes

APPENDIX CHAPTER III

Figure A3.1: Annual US House Price and Stock Price inflation, 1992:10-2003:01.

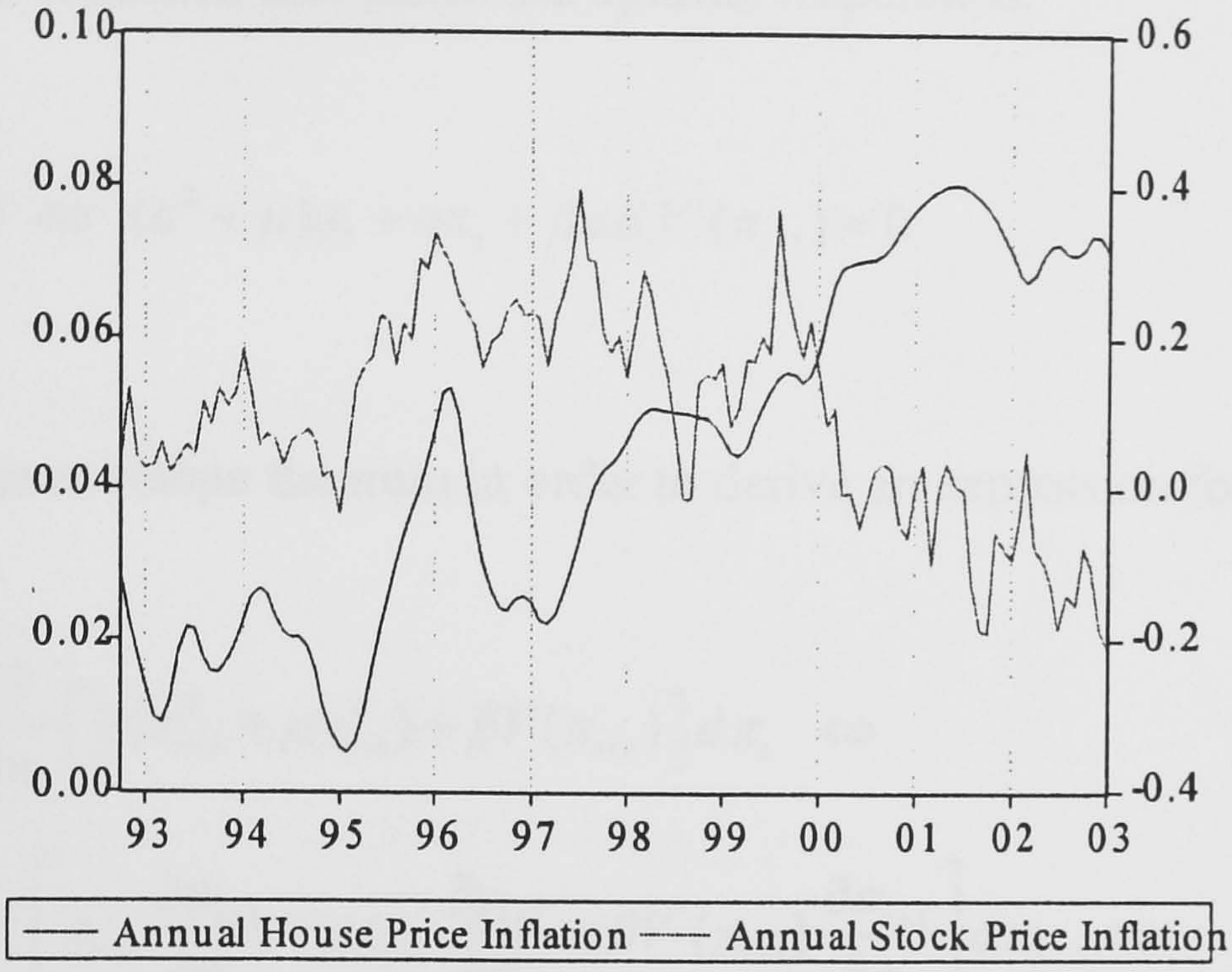
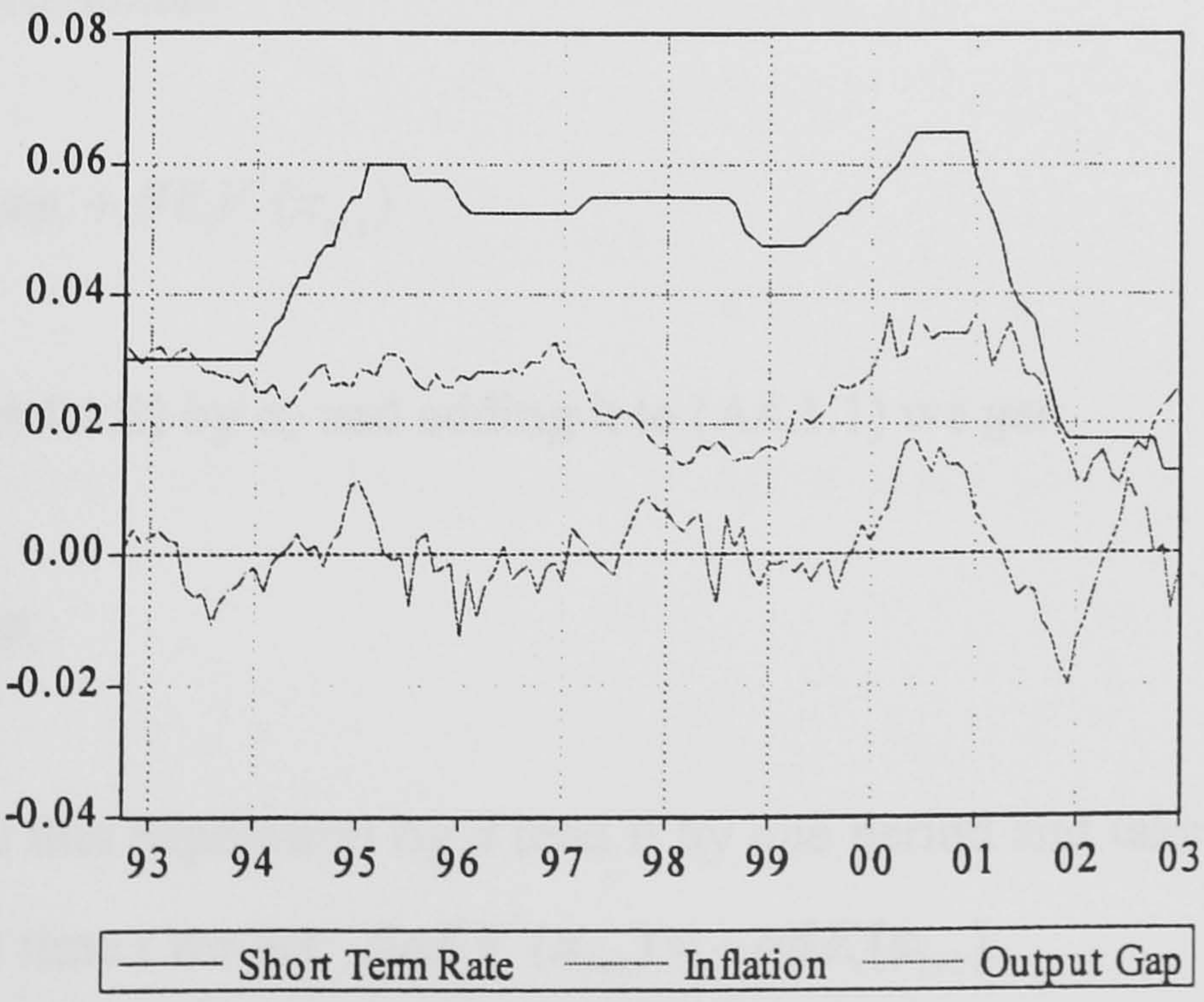


Figure A3.2: US Output Gap, Short term interest rate, inflation, 1992:10-2003:01.



APPENDIX IV

A4.1: Deriving the optimal path for the control variable, φ_t.

The first order condition that yields the optimal response is:

$$\frac{\partial}{\partial \varphi_t}V(\pi_t)=0 \Leftrightarrow (a^2+\mu)\varphi_t + a\pi_t + \beta a E_t V'(\pi_{t+1})=0 \qquad \text{(A4.1.1)}$$

We employ the envelope theorem in order to derive an expression for $E_t V'(\pi_{t+1})$:

$$dV(\pi_t)=E_t\frac{\partial}{\partial \pi_t}\left[\tfrac{1}{2}(\pi_{t+1}^2+\mu y_{t+1}^2)+\beta V(\pi_{t+1})\right]d\pi_t \Leftrightarrow$$

$$V'(\pi_t)d\pi_t = E_t\left[\pi_{t+1}\frac{\partial \pi_{t+1}}{\partial \pi_t}+\mu y_{t+1}\frac{\partial y_{t+1}}{\partial \pi_t}+\beta V'(\pi_{t+1})\frac{\partial \pi_{t+1}}{\partial \pi_t}\right]d\pi_t \Leftrightarrow$$

$$V'(\pi_t)=E_t\left[\pi_{t+1}+\beta V'(\pi_{t+1})\right]$$

Using (4.1)′ we obtain:

$$V'(\pi_t)=\pi_t + a\varphi_t + \beta E_t V'(\pi_{t+1}) \qquad \text{(A4.1.2)}$$

Multiplying (A4.1.2) by α_1 and adding it to (A4.1.1) we get:

$$aV'(\pi_t)=-\mu\varphi_t. \qquad \text{(A4.1.3)}$$

If we multiply this expression by β lead it by one period and take expectations based in information at time t we get: $\beta a E_t V'(\pi_{t+1})=-\mu\beta E_t[\varphi_{t+1}]$.

Thus, (A4.1.1) can be re-written as:

$$(a^2+\mu)\varphi_t + a\pi_t - \mu\beta E_t[\varphi_{t+1}]=0 \Leftrightarrow$$

$$\varphi_t = -\left(\frac{a}{a^2+\mu}\right)\pi_t + \left(\frac{\mu\beta}{a^2+\mu}\right)E_t[\varphi_{t+1}] \qquad \text{(A4.1.4)}$$

A4.2: Stability criterion.

The quadratic equation whose solution gives the optimal c value is:

$$(\mu\beta a)c^2 + (\mu\beta - a^2 - \mu)c - a = 0 \qquad \text{(A4.2.1)}$$

The two roots of (A4.2.1) are given by

$$c = \frac{-\mu\beta + a^2 + \mu \pm \sqrt{\mu^2\beta^2 + 2\mu\beta a^2 - 2\mu^2\beta + a^4 + 2a^2\mu + \mu^2}}{2\mu\beta a} \qquad \text{(A4.2.2)}$$

Recalling that according to Eq. (4.1)′ inflation is given by:

$$\pi_{t+1} = \pi_t + a\varphi_t + \omega_{t+1} = \pi_t + a(c\pi_t) + \omega_{t+1} \Leftrightarrow \pi_{t+1} = (1 + a_1 c)\pi_t + \omega_{t+1}$$

Therefore, stability of the inflation process requires that

$$|1 + ac| < 1 \Leftrightarrow -1 < 1 + ac < 1 \Leftrightarrow \frac{-2}{a} < c < 0 \qquad \text{(A4.2.3)}$$

Since $a > 0$ it implies that only the negative c-root is accepted.

A4.3: Inflation coefficient restriction.

The inflation parameter in the interest rate reaction function, f_π, has to be greater than one in order to satisfy the stability condition that real rates increase in response to inflation, with higher values implying a more aggressive response:

$$f_{\pi} = 1 - \frac{c[1-A]}{\beta_3\gamma_1 + \beta_2} > 1 \tag{A4.3.1}$$

This condition can be re-expressed as:

$$\frac{c[1-A]}{\beta_3\gamma_1 + \beta_2} < 0 \tag{A4.3.2}$$

As we showed in Appendix A4.2, only negative values of parameter c are accepted. Since $\beta_3\gamma_1 + \beta_2 > 0$, it is implied that:

$$1 - A > 0 \Leftrightarrow A < 1 \tag{A4.3.3}$$

APPENDIX V

A5.1: Bernanke and Gertler model.

The Bernanke and Gertler (1999, 2001) model is an extension of the Bernanke, Gertler, and Gilchrist (1996, 1998) model, allowing for exogenous bubbles in asset prices. The model is a standard dynamic new Keynesian model, modified to allow for financial accelerator effects. In the context of this model, there are important links between asset prices and the real economy, operating through the 'balance sheet' channel. That is, contrary to the assumptions of the benchmark neoclassical model, credit markets are not frictionless and credit can be extended more freely and at a lower cost to borrowers who already have a strong financial position. Hence, borrowing ability is determined by cash flows and the condition of balance sheets. Following a decline in asset prices, deteriorating balance sheets and reduced credit flows affect negatively spending and aggregate demand in the short-run, although the may also have important adverse long-run effects on aggregate supply by inhibiting capital formation and reducing working capital. As Bernanke and Gertler (1999, p.20) argue, "there are also likely to be significant feedback and magnification effects".

The decline in aggregate sales and employment, following a decrease e.g. in home equity value, imply further deterioration of cash flows and collateral and hence, further decreases in spending. This magnification effect constitutes the 'financial accelerator' analysed in Bernanke, Gertler, and Gilchrist (1996). A key implication of the model is that the degree to which asset price fluctuations affect the real economy is dependent upon the initial financial conditions. In particular, it depends on the initial state state of household, firms, and financial intermediaries balance sheets. Thus, the effect of asset prices on spending is highly non-linear (Bernanke and Gertler, 1989). If balance sheets are initially weak with high levels of debt and inadequate cash flows, then even small decreases in asset prices are likely to put firms and households in a state of financial distress, or lead to capital problems for the banking system. On the other hand, if balance sheets are initially strong, then even large declines in asset prices are less likely to have real economic effects.

The main difference between the Bernanke and Gertler (1999, 2001) and the Bernanke, Gertler, and Gilchrist (1996, 1998) models is that while the latter assumes that only fundamentals drive asset prices, so that the financial accelerator amplifies only fundamental shocks (such as shocks to productivity or spending), the former allows for the effect of non-fundamental changes in asset prices on the real economy, via the financial accelerator. The crucial underlying assumption is that the market price of capital, may be different from its fundamental value, leading to the creation of bubbles. The consumption of firms' owners and the quality of firms' balance sheets is assumed to depend on the market values of their assets, rather than the fundamental values. It is implied therefore that a bubble in asset prices affects firms' financial positions and the premium for external finance.

A5.2: Simulation technical details.

Using the fact that the asset price Eq. (5.3) can be re-written as:

$$q_t = (b_1 - b_2)q_{t-1} - b_1 q_{t-2} + b_2 q_t^* \tag{6.3$'$}$$

Equations (5.1-5.5) can be compactly expressed as:

$$AE_t[X_{t+1}] = BX_t + CZ_t$$

where

$$\mathbf{X}_t = \begin{bmatrix} y_t \\ \pi_t \\ i_t \\ q_t \\ q_t^* \\ E_t[y_{t+1}] \\ E_t[\pi_{t+1}] \\ E_{t-1}[\pi_t] \\ q_{t-1} \\ q_{t-2} \\ \pi_{t-1} \\ i_{t-1} \end{bmatrix} \qquad E_t[\mathbf{X}_{t+1}] = \begin{bmatrix} E_t[y_{t+1}] \\ E_t[\pi_{t+1}] \\ E_t[i_{t+1}] \\ E_t[q_{t+1}] \\ E_t[q_{t+1}^*] \\ E_t[y_{t+2}] \\ E_t[\pi_{t+2}] \\ E_t[\pi_{t+1}] \\ q_t \\ q_{t-1} \\ \pi_t \\ i_t \end{bmatrix} \qquad \mathbf{Z}_t = \begin{bmatrix} \eta_t \\ \varepsilon_t \\ \theta_t \\ u_t \\ 1 \end{bmatrix}$$

$$
\mathbf{A} = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

$$
\mathbf{B} = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-1 & 0 & 0 & 0 & 0 & 1 & 0 & a_1 & a_2 & 0 & 0 & -a_1 \\
\beta & 0 & 0 & 0 & 0 & 0 & 1-\varphi & 0 & 0 & 0 & \varphi & 0 \\
(1-\gamma_4)\gamma_2 & (1-\gamma_4)(1+\gamma_1) & 0 & (1-\gamma_4)\gamma_3 & -(1-\gamma_4)\gamma_3 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_4 \\
0 & 0 & 0 & 0 & b_2 & 0 & 0 & 0 & b_1 - b_2 & -b_1 & 0 & 0 \\
0 & 0 & -\delta_1 & 0 & -1 & \delta_2 & \delta_1 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
$$

$$
\mathbf{C} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & (1\text{-}\gamma_4)(r-\gamma_1\pi^*) \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix}
$$

The above multivariate linear rational expectations (RE) model is solved in Matlab using the generalized Schur form. The core algorithm that we used to calculate numerical solutions is solvek.m, whose more detailed analysis may be found in McCallum (1998). It is a modified version of the Klein (2000) algorithm.

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