Welfare analysis of non-fundamental asset price and investment shocks: implications for monetary policy

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1. Introduction

The occurrence of large asset price fluctuations in the late 1980s and early 1990s raised a good deal of discussion among economic researchers and policymakers regarding whether and how central banks should respond to asset price fluctuations. One view (eg Bernanke and Gertler (2000)) suggests that central banks should take into account asset price movements only as far as these fluctuations have an impact on expected future inflation and output. This view also seems to describe fairly well the point of view of many policymakers (eg Greenspan (2002) or Goodfriend in BIS/CEPR (1998)).[2] An alternative view (eg Borio and Lowe (2002)) is that central banks should lean against large run-ups in asset prices, even if this risks undershooting the short-term inflation objective, because excessive asset price booms may lead to a sudden collapse, undermining the stability of the financial system and leading to large negative knock-on effects on output and prices. This view has recently received some support from policymakers (eg Issing (2003)), although a number of difficulties are typically identified. First, the policy-controlled interest rate may only be a very blunt instrument to control asset price bubbles and their inherent risks for future financial stability. Second, policymakers may have no comparative advantage in identifying whether asset prices are driven by fundamentals or not.

As the most recent downturn coincided with a sharp decline in investment expenditures and falling stock markets, the role of asset prices in monetary policy has again become very topical. The over-accumulation of capital in various sectors, associated with the preceding spectacular run-up in stock prices, led to a capital overhang and contributed to the size and the duration of the investment decline. Monetary policy has therefore been accused by some observers of not having paid enough attention to the asset price bubble that developed in the second half of the 1990s.

This paper analyses the costs and benefits of alternative monetary policy responses to non-fundamental asset price or investment shocks in a New Keynesian general equilibrium model. One advantage of using a micro-founded model is that the utility of the representative consumers can be used as a natural benchmark for analysing welfare. The model used is estimated and discussed in Smets and Wouters (2003a) and includes, amongst various other estimated structural shocks, both an investment-specific technology shock and a non-fundamental shock to equity prices. This paper, first, analyses the welfare costs of the non-fundamental equity price shocks when monetary policy is characterised by the estimated policy reaction function. It identifies various components of the welfare cost - inefficient inflation and wage dispersion, the cost of variability in consumption and employment, costs of adjusting investment plans and inefficiencies in the intra- and intertemporal allocation of resources - and discusses their relative importance. One major finding of this analysis is that the welfare cost of the non-fundamental shocks strongly depends on the steady state level around which the economy is fluctuating. If the steady state output level is below the first-best competitive output level, positive booms in economic activity driven by non-fundamental shocks to stock prices can be

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[2] This result is also confirmed by empirical research on the Fed’s reaction function. Rigobon and Sack (2003) estimate the response of interest rates to equity price innovations, and find that this response seems to correspond with the impact that one can expect from these innovations on future output and inflation. Other policymakers have, however, mentioned that asset prices need some specific attention, for instance because of the imbalance between the time horizon of the typical forecast exercise for inflation and output on the one hand and the long-run implications of financial cycles on the real economy on the other hand (Issing (2003)).

welfare-improving, as they move the economy closer to the optimal output level. In contrast, recessions are extra-costly for the opposite reason.

In a second step, the paper then investigates the costs and benefits of alternative monetary policy rules. One finding is that the welfare costs of asset price shocks can be drastically reduced by a relatively strong response to inflation and the output gap. Another finding is that, in view of the asymmetry in the welfare costs of positive and negative asset price shocks, policymakers can improve welfare by responding less aggressively to booms than to busts. Such a policy will lead to a rise in average output, but at the cost of somewhat higher inflation.

Our analysis is most closely linked to Dupor (2001), who investigates the optimal monetary policy responses to asset price fluctuations under commitment from the perspective of the welfare of the representative household. He analyses the policy trade-off between goods price and asset price stability that arises when asset prices are influenced by inefficient shocks or bubbles and therefore cause inefficient real allocation decisions.[3] Overall, he shows that the optimal response to positive asset price shocks involves an undershooting of inflation in the short term.

A number of papers have analysed actual monetary policy behaviour during and following asset price booms (eg Borio and Lowe (2002) and Detken and Smets (2003)). Overall, asset price booms are characterised by a boom in output and investment and a more moderate increase in inflation. One interpretation of this evidence is that asset price booms tend to develop during periods with positive supply shocks that might increase expectations of future profits and productivity. Generally, periods of asset price booms also seem to be characterised by a relatively weak response of monetary policy (Detken and Smets (2003), Borio and Lowe (2002)). However, often the response to financial cycles is asymmetric: while monetary policy is rather reluctant to intervene in periods of booms, it intervenes much more aggressively in periods of financial crisis. During these periods, it is clear that an intervention of the monetary authorities is needed to stabilise the functioning of the financial markets and to avoid further disruptions in the financial system as a whole.

At the same time, the limitations of the current analysis for understanding the costs of financial volatility and imperfections need to be clearly spelled out. The model used does not contain a specified block for the financial sector. Moreover, the asset price shocks are introduced in an ad hoc and exogenous fashion. A full welfare analysis of the importance of non-fundamental asset price and investment cycles should be based on a model that can endogenously generate such asset price cycles. The optimal policy response may very well depend on the source of the financial market imperfections that lead to such non-fundamental financial and real volatility. One step in that direction has been taken by Bernanke and Gertler (2000). They develop a model in which information problems and capital market imperfections can explain why financial asset prices deviate from fundamentals and exert a specific influence on economic developments.[4] Bernanke and Gertler (2000) nevertheless conclude that a monetary policy that is concentrated on targeting inflation with a strong response on expected inflation and potentially the output gap is the appropriate monetary policy strategy. In their view there is no need to have a specific response to asset prices.[5] However, because the analysis is done in a linearised version of the model, they do not address the policy implications of the non-linear response of the external finance premium to various shocks. Indeed, one argument for a pre-emptive policy response to large asset price booms is that because of collateral constraints the output costs of an asset price collapse are larger than those of an asset price boom (eg Kent and Lowe (1997) and

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[3] Dupor (2002) extends this argument by noting that central banks are confronted with uncertainty and limited information on the nature of the asset price fluctuations. Such uncertainty makes the response of monetary policy to asset price shocks less aggressive. As discussed above, this is a traditional argument used by central bankers to motivate their non-response to rising asset price markets. Advocates for a more proactive policy argue that the uncertainty in evaluating financial markets and asset prices is perhaps not higher than that in interpreting output gaps. Some recent studies have established forecasting methods to evaluate different types of asset and credit market expansions (eg Borio and Lowe (2002)).

[4] Bernanke and Gertler (2000) develop a financial accelerator model that generates an impact of financial asset prices mainly via wealth effects on consumption and via net worth or collateral effects on firms' investment decisions. They do not include, however, a direct impact on investment via the non-fundamental asset price. Investment decisions are based on the fundamental value of the projects. In our model the non-fundamental asset price directly influences the investment decision.

[5] Cecchetti et al (2000), using a very similar model, draw less unambiguous conclusions. They observe that including a specific reaction to asset prices in the monetary policy rule will cause a higher inflation variability but a lower output variability and the final choice therefore depends on the policymakers' preferences.

Bordo and Jeanne (2002)). The model used in this paper does not capture such asymmetric costs and therefore cannot address the optimal policy response in such a context.

The rest of the paper is structured as follows. In Section 2, the model structure and its estimation are briefly discussed and the effects of a non-fundamental equity price shock are illustrated. Section 3 then presents the welfare costs of such shocks. Finally, Section 4 considers alternative monetary policies. Section 5 concludes.

2. Model structure and estimation results

The model used in this paper is a standard dynamic general equilibrium model with sticky prices and wages and with capital accumulation. The model contains several real and nominal frictions and is augmented with a complete set of structural shocks in order to fit the data. Two of those shocks directly influence investment spending. One captures the influence of technology shocks that affect the production of capital goods or the capital accumulation process. The second is related to shocks in the external financing conditions of the firms and is for simplicity labelled the equity price shock. This last shock should typically take up all the influences on investment expenditures that originate from non-fundamental fluctuations in financial markets or asset prices.

The model does not contain a financial sector and there are no financial frictions or capital market imperfections that might influence the behaviour of households or firms. In general, it is quite difficult to find evidence that financial variables provide significant additional explanatory power for investment expenditures. The type of financial variables that matter for investment seem to vary from country to country and over time. This indicates that the mechanisms at work are complicated and time-varying processes that are not easily modelled. For the time being, it seems acceptable therefore to consider the influence of financial markets and asset prices on the real sector as independent shocks that enter the model exogenously.[6]

In this section we briefly present the structure of the general equilibrium model and the parameter estimates of the model. For a more detailed discussion we refer to Smets and Wouters (2003a). The impulse response function following a non-fundamental investment shock is discussed in detail.

2.1 Model structure

In what follows we briefly explain the structure of the dynamic stochastic general equilibrium (DSGE) model, which is a standard New Keynesian general equilibrium model with monopolistic competition in the goods and labour market. Prices and wages are sticky and determined by a Calvo model that allows for indexation to past inflation levels for these price and wages that are not reset optimally. Nominal stickiness and indexation were estimated to be important. Capital accumulation is subject to adjustment costs that are expressed in terms of changes in the investment level. Household utility is characterised by habit persistence. These three features of the model will be important in the calculation and the evaluation of the welfare outcomes.

2.1.1 The household sector

Households maximise the following welfare function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_t^b \left(\frac{1}{1-\sigma_c} \left(C_t - hC_{t-1} \right)^{1-\sigma_c} - \frac{\varepsilon_t^L}{1+\sigma_l} \left(\ell_t \right)^{1+\sigma_l} \right) \tag{1}$$

[6] The ideal solution would be to have a model that is able to generate the bubble process endogenously. Gilchrist et al (2002) have recently developed a model where an increase in the dispersion of investors' beliefs under a short-selling constraint can result in a rise of the stock price above the fundamental value. The model predicts that managers will react to such an event by issuing new equity and increasing capital expenditures. Using the variance in the earnings forecasts to identify the bubble shocks in the asset price, they find that such orthogonalised bubble shocks have significant effects on Tobin's Q and real investment.

where β is the discount factor, ε_t^B and ε_t^L are the two preference shocks and the instantaneous utility function is separable in consumption, relative to the past consumption level reflecting the habit in preferences,[7] and labour effort. σ_c is the coefficient of relative risk aversion of households and σ_l represents the inverse of the elasticity of work effort with respect to the real wage.

Households maximise their objective function subject to the intertemporal budget constraint. Households' total income is given by the sum of wage income, rental returns on capital corrected for the costs related to the degree of capital utilisation and dividend payments. Total income is used for consumption or investment expenditures:

$$Y_t = w_t l_t + r_t^k z_t K_{t-1} - \Psi(z_t) K_{t-1} + Div_t = C_t + I_t \tag{2}$$

Utility maximisation results in first-order conditions for consumption:

$$E_t\left[\beta \frac{\lambda_{t+1}}{\lambda_t} \frac{1+R_t}{\pi_{t+1}}\right] = 1 \tag{3}$$

which states that the marginal rate of intertemporal subsitution should equal the real interest rate. The marginal utility of consumption λ_t is given by:

$$\lambda_t = \varepsilon_t^b \left(C_t - hC_{t-1}\right)^{-\sigma_c} - \beta \varepsilon_{t+1}^b h \left(C_{t+1} - hC_t\right)^{-\sigma_c} \tag{4}$$

Households own the capital stock that they rent out to the firm-producers of intermediate goods at a given rental rate of r_t^k. Households choose the capital stock, investment and the utilisation rate in order to maximise their intertemporal objective function subject to the intertemporal budget constraint and the capital accumulation equation, which is given by:

$$K_t = K_{t-1}[1-\tau] + \varepsilon_t^I \left[1 - S\left(I_t / I_{t-1}\right)\right] I_t , \tag{5}$$

where I_t is gross investment, τ is the depreciation rate and $S(.)$ the adjustment cost function, which is a positive function of changes in investment level. Fluctuations in the investment level will result in a higher adjustment cost, leading to lower net investment accumulation. The process ε_t^I represents shifts in investment-specific technological progress. This fundamental shock to the investment decision process is assumed to follow a first-order autoregressive process with an iid normal error term: $\varepsilon_t^I = \rho_I \varepsilon_{t-1}^I + \eta_t^I$.

The first-order conditions for capital, investment and the utilisation rate are given by:

$$Q_t = E_t\left[\beta \frac{\lambda_{t+1}}{\lambda_t}\left(Q_{t+1}(1-\tau) + z_{t+1} r_{t+1}^k - \Psi(z_{t+1})\right)\right] \varepsilon_t^P , \tag{6}$$

$$Q_t\left(1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\frac{\varepsilon_t^I I_t}{I_{t-1}}\right) + \beta E_t Q_{t+1} \frac{\lambda_{t+1}}{\lambda_t} S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{\varepsilon_{t+1}^I I_{t+1}}{I_t}\right)\frac{I_{t+1}}{I_t} = 1 \tag{7}$$

$$r_t^k = \Psi'(z_t) \tag{8}$$

Equation (6) states that the value of installed capital Q is equal to the discounted value of the expected future returns as captured by the rental rate times the expected rate of capital utilisation minus the utilisation costs. The value of installed capital is also influenced by an exogenous iid shock which we label the equity premium shock. Equation (7) determines the optimal investment level given

[7] In the welfare calculations we assumed the habit persistence is expressed relative to the household-specific past consumption level. In the estimated model, the habit preference was expressed in terms of the aggregate wide past consumption level. For the empirical estimation of the model the difference between the two models is not important. In the welfare evaluation, the external habit persistence yields quite complicated results because of the externality effects. By retaining the internal habit specification we avoid these problems.

the value of installed capital and the investment adjustment cost function. Equation (8) relates the optimal degree of capital utilisation to the rental rate.

Finally, households also supply labour effort and set the wage rate. Wages are set according to the Calvo model allowing for a partial indexation to the previous period's inflation level.

This maximisation problem results in the following markup equation for the optimal wage:

$$\frac{\tilde{w}_t}{P_t} E_t \sum_{i=0}^{\infty} \beta^i \xi_w^i \left(\frac{(P_{t+i-1}/P_{t-1})^{\gamma_w}}{P_{t+i}/P_t} \right) \frac{l_t^l +_i U_{t+i}^C}{1+\lambda_{w,t+i}} = E_t \sum_{i=0}^{\infty} \beta^i \xi_w^i l_{t+i}^l U_{t+i}^{\ell} \quad (9)$$

where U_{t+i}^{ℓ} is the marginal disutility of labour, U_{t+i}^C is the marginal utility of consumption, γ^w is the degree of indexation, ξ^w the Calvo probability and λ_w the markup included in wages. Equation (9) shows that in a flexible wage context, this equation would simplify to the traditional condition that wages equal a markup over the marginal disutility of work divided by the marginal utility of consumption. The aggregate wage process is described by:

$$(W_t)^{-1/\lambda_{w,t}} = \xi_w \left(W_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} \right)^{-1/\lambda_{w,t}} + (1-\xi_w)(\tilde{w}_t)^{-1/\lambda_{w,t}} \quad (10)$$

reflecting the Dixit-Stiglitz aggregator function to define the aggregate labour supply index.

2.1.2 The firm sector

Output in the intermediate goods sector is produced by the following technology:

$$y_t^j = \varepsilon_t^{\alpha} \tilde{K}_{j,t}^{\alpha} L_{j,t}^{1-\alpha} - \Phi\,, \quad (11)$$

where ε_t^{α} is the productivity process, $\tilde{K}_{j,t}$ is the effective utilisation of the capital stock given by $\tilde{K}_{j,t} = z_t K_{j,t-1}$, $L_{j,t}$ is an index of different types of labour used by the firm and Φ is a fixed cost. Capital is assumed to be perfectly mobile between firms within each period. Cost minimisation implies that the income shares are constant:

$$\frac{W_t L_{j,t}}{r_t^k \tilde{K}_{j,t}} = \frac{1-\alpha}{\alpha} \quad (12)$$

Under these assumptions the firms' marginal cost is independent of the production level and only a function of the factor prices and productivity level:

$$MC_t = \frac{1}{\varepsilon_t^a} W_t^{1-\alpha} r_t^{k^{\alpha}} \left(\alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)} \right) \quad (13)$$

Firms set prices according to the Calvo model with partial indexation:

$$E_t \sum_{i=0}^{\infty} \beta^i \xi_p{}^i \lambda_{t+i} y_{t+i}^j \left(\frac{\tilde{p}_t^j}{P_t} \left(\frac{(P_{t-1+i}/P_{t-1})^{\gamma_p}}{P_{t+i}/P_t} \right) - (1+\lambda_{p,t+i}) mc_{t+i} \right) = 0 \quad (14)$$

where γ_p is the degree of indexation, ξ_p the Calvo probability and λ_p the markup incorporated in the price.

The law of motion of the aggregate price index is given by:

$$(P_t)^{-1/\lambda_{p,t}} = \xi_p \left(P_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} \right)^{-1/\lambda_{p,t}} + (1-\xi_p)(\tilde{p}_t^j)^{-1/\lambda_{p,t}} \quad (15)$$

2.1.3 The central bank

The monetary authorities follow a generalised Taylor rule by gradually responding to deviations of lagged inflation from an inflation objective (normalised to be zero) and the lagged output gap defined as the difference between actual and potential output (Taylor (1993)). Consistently with the DSGE model, potential output is defined as the level of output that would prevail under flexible prices and wages.

$$R_t = \rho R_{t-1} + (1-\rho)\{\overline{\pi}_t + r_\pi(\pi_{t-1} - \overline{\pi}_t) + r_Y(Y_t - Y_t^p)\} + r_{\Delta\pi}(\pi_t - \pi_{t-1}) + r_{\Delta y}(Y_t - Y_t^p - (Y_{t-1} - Y_{t-1}^p)) + \eta_t^R \quad (16)$$

The parameter ρ captures the degree of interest rate smoothing. In addition, there is also a short-run feedback from the current changes in inflation and the output gap. η_t^R and $\overline{\pi}_t$ are two monetary policy shocks: the first one represents the typical iid interest rate shocks, while the second one captures the long-run trends in the inflation objective of the central bank.

2.2 Estimation results and evidence on the non-fundamental investment shock

Smets and Wouters (2003a) estimate a linearised version of the model discussed above. The parameter estimates are summarised in Table 1. For estimation purposes, a linear approximation is sufficient, because the impact of the different identified shocks over a finite horizon is not significantly influenced by the higher-order terms. Of course, as discussed in Kim et al (2003), this argument does not apply for the welfare analysis performed in the next section.

The left-hand column of Table 1 contains the estimated parameters describing the behaviour of the stochastic shocks in the model. Smets and Wouters (2003a) estimate a whole series of shocks that can potentially influence the economy: a shock to total factor productivity, a shock to the intertemporal time preference of households, a shock to the relative weight of consumption and labour supply in the utility function, a government expenditures shock and a shock to the investment adjustment cost function (or to the capital good-specific technology). These five fundamental shocks to technology or preferences are assumed to follow a persistent first-order autoregressive process. In addition, Smets and Wouters (2003a) also allow for three markup shocks that affect the pricing in the goods market, the labour market and the market for existing capital goods. These three shocks produce inefficient price and allocation decisions and are assumed to be iid.[8]

The analysis in this paper concentrates on the latter of those three markup shocks, the inefficient equity price shock, which creates non-fundamental movements in investment expenditures. This iid shock, which can take a positive or negative sign, is of a somewhat different nature than the much more persistent asset price bubble shocks that are typically considered in the research on monetary policy and asset prices.[9] However, it has the same qualitative effects on output, investment and inflation as those shocks. As discussed in the introduction, a more sophisticated approach would model the underlying distortions that generate the bubble and the way firms react to such non-fundamental movements (see Gilchrist et al (2002) for such a model).

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[8] We motivate this identification sheme in Smets and Wouters (2003b). Under uncertainty about the nature of the shocks, a robust discretionary monetary policy will favour interpreting persistent shocks as fundamental shocks that affect the natural output level and therefore need to be accommodated. Short-run fluctuations that do not seem to produce a persistent effect can be excluded in the estimation of the natural or efficient output level without creating risks of large errors. This implies that a persistent negative shock to the investment expenditures will be considered to have a negative effect on the natural output level the central bank is targeting. If the central bank were to consider it wrongly as an inefficient low investment level, and react by lowering the interest rate, this would lead to a rise in inflation and inflation expectations that would be very costly to overcome later. Under discretion, a more careful conservative monetary policy is beneficial. This argument is, however, less applicable for shocks that are less or not persistent. Therefore iid shocks can be classified as non-efficient shocks.

[9] Bernanke and Gertler (2000), Cecchetti et al (2000) and Dupor (2002) all consider persistent asset price bubbles, with or without a random duration. As in our case, the shocks are, however, introduced in an exogenous and ad-hoc fashion.

Table1

Estimated parameters of the DSGE model

Parameters defining shock processes		Parameter describing private agents	
Standard errors of the innovations:			
Productivity shock	0.59	Investment adjustment cost	5.91
Inflation objective shock	0.02	σ consumption utility	1.61
Consumption preference shock	0.25	h consumption habit	0.54
Government spending shock	0.32	σ labour utility	0.75
Labour supply shock	1.35	Fixed cost	1.49
Investment shock	0.10	Calvo employment	0.59
Interest rate shock	0.12	Capital utilisation adjustment cost	0.17
Equity premium shock	0.60		
Price markup shock	0.16	Calvo wages	0.76
Wage markup shock	0.28	Calvo prices	0.91
		Indexation wages	0.66
		Indexation prices	0.41
Persistence of the processes:		**Parameter describing monetary policy rule:**	
Productivity shock	0.83	r inflation	1.66
Inflation objective shock	0.92	r d(inflation)	0.20
Consumption preference shock	0.91	r lagged interest rate	0.94
Government spending shock	0.97	r output	0.15
Labour supply shock	0.96	r d(output)	0.17
Investment shock	0.94		

Source: Smets and Wouters (2003a).

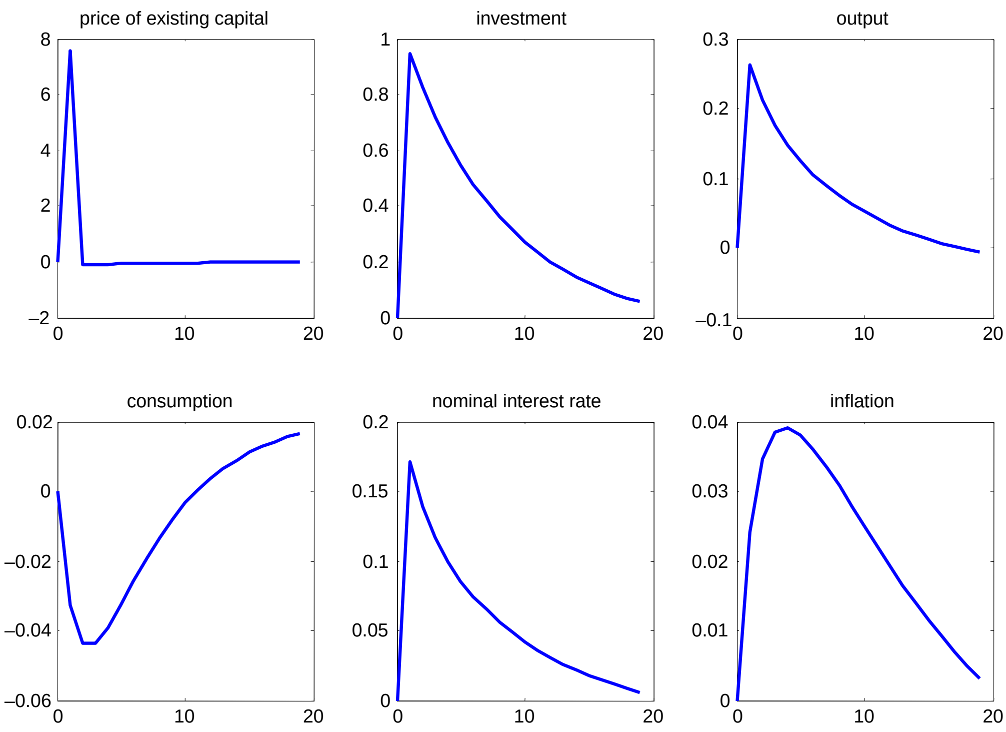
In Graph 1, we reproduce the impulse response of the non-fundamental investment shock using the non-linear model.[10] It is worth noting that this impulse response is very close to one in the estimated linear version of the model.

The shock immediately affects the price of installed capital, but due to its temporary nature only for one quarter. The price of existing capital increases by some 7% for a one standard error shock. Firms react immediately to the higher value of existing capital stock by increasing investment expenditures. The presence of capital accumulation costs in the form of changes in the level of investment implies that investment will only gradually return to its steady state level. Investment expenditures increase by 1% for the average shock and the shock dies out completely after four or five years.

[10] The non-linear model is solved under the assumption of perfect foresight using Dynare (Julliard (2003)). For the deterministic simulations Dynare uses a Newton-type algorithm.

Graph 1

Impulse response function following the non-fundamental investment shock in the non-linear model



Higher investment expenditures increase total aggregate demand by 0.2% and aggregate employment by 0.1%. The positive output gap will lead to an increase in the marginal cost as a consequence of rising wages and lower productivity. The impact on inflation is limited for several reasons. First, the estimated degree of nominal stickiness is relatively large. Second, monetary policy responds relatively strongly to the positive output gap. This restrictive policy reaction will create a crowding-out effect on private consumption, which lowers the overall aggregate demand expansion. Lower consumption also lowers the pressure on wage demands via the higher marginal utility of wages. Finally, the investment expansion also contributes to production capacity, increasing labour productivity. Summing up, the non-fundamental equity price shock increases investment and output significantly over a horizon of two to three years, but under the estimated monetary policy response the impact of the shock on inflation is very moderate. Although the size and the persistence of the effect of our shock on asset prices is not comparable to the much more persistent movements in asset prices during typical asset price booms, the qualitative effects are relatively similar to those of a standard asset price bubble as, for example, described in Borio and Lowe (2002) and Detken and Smets (2003).

Smets and Wouters (2003a) discuss the contribution of the various shocks to unconditional variance of the forecast errors in the observable variables. This variance decomposition indicates that the non-fundamental investment shocks explain around half of the forecast error of investment at the one quarter ahead horizon, but this contribution decreases very quickly for longer horizons. The contribution to the one quarter ahead forecast error in output is between 10 and 20% and also decreases quickly afterwards. The low persistence in the effects also explains why the contribution to the inflation process is very small. A historical decomposition (Smets and Wouters (2003c)) nevertheless shows that during specific periods the shocks have a significant impact on investment and output, but not on inflation. At longer forecast horizons, the fundamental investment shocks explain most of the fluctuations in investment and around 20% of output fluctuations. However, it is important to note that it is very difficult to distinguish the fundamental (persistent) from the non-fundamental (temporary) shocks, in particular because equity prices were not used in the estimation of the model. As the empirical identification is purely based on whether the shocks are persistent or not, one could also treat the persistent investment shock as non-fundamental. Obviously, this would increase the role of non-fundamental equity price shocks. Ultimately, a more realistic estimate of the importance of non-fundamental asset price shocks needs to be obtained by including information from asset prices in the estimation of the model.

3. The welfare implications of non-fundamental investment shocks

Non-fundamental equity price and investment shocks create several types of inefficiencies. First of all, they result in an inefficient intertemporal allocation of resources. An overestimation of the present value of the future returns from current investment expenditure leads to an over-accumulation of capital. The actual return on capital will not compensate for the forgone utility from present consumption. Second, positive demand effects from an asset price and investment shock lead to positive inflation in prices and wages. In our Calvo model this creates welfare costs through the dispersion in prices and wages and the resulting misallocation of resources among firms in the monopolistically competitive sector. Different prices and wages for otherwise similar products result in a lower consumption or labour bundle for a given nominal budget. Inflation also implies that prices deviate from the marginal cost plus markup. Finally, there are the costs of changing investment plans.

In general, these welfare costs will create a trade-off problem for optimal monetary policy. As shown in Dupor (2002), inflation stabilisation can more or less be obtained by setting the interest rate so as to stabilise total aggregate demand. However, stabilising the equity price and the resulting investment response will typically require a more restrictive policy and a larger crowding-out of other private expenditures. This will lead to an undershooting of the short-run inflation response. In deciding how strongly to respond to the non-fundamental investment shock, it is therefore important to have an idea of the relative size of the different costs that are involved.

The relative importance of these different costs is dependent on the steady state situation around which the fluctuations occur. If the steady state is around the optimal competitive output level, all non-fundamental fluctuations, both positive and negative, will be costly. However, if output is far below the efficient output level due to the markup distortion, higher demand can move the output level towards the first-best level and this generates welfare gains. These welfare gains have to be balanced against the rise in inflation that may result from an asymmetric response to the equity price shocks, further complicating the welfare analysis. Dupor (2001) studies the impact of a deterministic non-fundamental shock on welfare around the efficient steady state output level. He analyses the problem in a model with monopolistic competition and markup pricing, but he introduces an output subsidy financed by a lump sum tax, so that the steady state output equals the competitive level.

In the next section, we first calculate the welfare effects of a deterministic non-fundamental equity price shock. Given the identification problem discussed above, we analyse the effects of both the temporary and persistent investment shock. The latter type of shock compares well to the typical bubble shocks that are considered in Dupor (2002) and Bernanke and Gertler (2001). For comparison reasons, we also report the welfare effects of a fundamental investment shock that is caused by a change in the relative price of capital goods. For each of these three types of shocks, we study the welfare effects around the competitive equilibrium steady state output level and around the lower monopolistic competition equilibrium. We try to disentangle the different components of the welfare effects and show how the different frictions influence the relative size of the welfare effects. Next, we discuss the outcomes from a stochastic simulation exercise, based on a second-order approximate solution of the model. Also in this case, we calculate the different components of the welfare loss.[11]

[11] The welfare evaluation is based on the exact perfect foresight solution to the non-linear first-order equations for the deterministic shocks and on the second-order approximation solution of the model for stochastic simulations. These calculations were performed using Dynare (Julliard (2003), Schmitt-Grohe and Uribe (2002)).

3.1 Welfare analysis of a deterministic non-fundamental investment shock around the competitive equilibrium (CE) output level

Table 2 summarises the results for each of the three types of shocks around the CE output level. The first shock corresponds to the estimated temporary equity premium shock in Smets and Wouters (2003a) (illustrated in Graph 1). The shock has a standard error of 0.08. The effects of a positive and a negative shock are reported for later use when discussing issues of asymmetry.

Overall, the impact on welfare of this shock is small. This is not surprising as all the first-order conditions are fulfilled around the CE output level and therefore small disturbances do not create large inefficiencies. To assess the size of the impact on welfare, we follow the literature and express the change in welfare in terms of consumption equivalents. We calculate the change in certainty-equivalent consumption in percentage of its steady state level that yields exactly the same variation in the expected lifetime utility that follows from the shock. Since we consider one-time deterministic shocks in this exercise, we also express the consumption effect as a percentage of a one-period consumption level. The benchmark non-fundamental investment shock has an impact on welfare that is comparable to a 0.02% change in the consumption level.

Table 2

Welfare effects of a distortionary investment shock around the CE output level

	Iid shock		Persistent shock		Fundamental shock	
	+ shock	– shock	+ shock	– shock	+ shock	– shock
Total welfare effect	–0.0003	–0.0004	–0.0005	–0.0005	0.0725	–0.0721
In % of steady state consumption level	–0.0176 100.00%	–0.0239 100.00%	–0.0332 100.00%	–0.0312 100.00%	4.5317 100.00%	–4.4992 100.00%
Price dispersion cost	–0.0007 3.99%	–0.0010 4.12%	–0.0019 5.87%	–0.0019 6.18%	–0.0027 –0.06%	–0.0026 0.06%
Wage dispersion cost	–0.0011 6.19%	–0.0015 6.38%	–0.0037 11.14%	–0.0036 11.63%	–0.0015 –0.03%	–0.0014 0.03%
Capital adjustment cost	–0.0072 40.70%	–0.0098 40.83%	–0.0035 10.44%	–0.0035 11.21%	–0.0037 –0.08%	–0.0038 0.08%
Variance cost	–0.0042 24.09%	–0.0059 24.78%	–0.0149 44.77%	–0.0147 47.21%	–0.0161 –0.36%	–0.0162 0.36%
Intra-/intertemporal inefficiency	–0.0044 25.03%	–0.0057 23.89%	–0.0092 27.77%	–0.0074 23.77%	4.5555 100.53%	–4.4752 99.47%

The second column reports the welfare effects of the more persistent shock, which corresponds to the persistent investment shock in Smets and Wouters (2003a). This shock has a much more persistent and hump-shaped effect on investment and output and is very similar to the shock considered in Dupor (2002). Taking into account that the shock considered in Dupor (2002) is some five times bigger, the welfare effects of the shocks are somewhat smaller in our setup, but the size is of the same magnitude. Differences are partly due to differences in the modelling of the investment adjustment cost function and the habit persistence process.

Table 2 also decomposes the welfare effects into the most important elements. First of all, there is the cost of inflation measured by the degree of price and wage dispersion. This cost is estimated by using the index for price and wage dispersion (similar to the expression presented in Benigno and Woodford (2003)). The expression for wage dispersion is:

$$\Lambda_t^w = \xi_w \Lambda_{t-1}^w \pi_{w,t}^{\theta(1+\sigma l)} \pi_{p,t-1}^{-\gamma w \theta(1+\sigma l)} + (1-\xi_w) * \left(\frac{1-\xi_w \pi_{w,t}^{\theta-1} \pi_{p,t-1}^{-\gamma w(\theta-1)}}{1-\xi_w} \right)^{-\frac{\theta(1+\sigma l)}{1-\theta}} \quad (17)$$

where θ is the price elasticity of demand, which is itself related to the markup $1+\lambda w = \theta/(\theta-1)$.

The moderating impact of partial indexation on the dispersion measure is clear from this expression. The corresponding equation for price dispersion is:

$$\Lambda_t^p = \xi_p \Lambda_{t-1}^p \pi_{p,t}^{\theta(1+\sigma l)} \pi_{p,t-1}^{-\gamma p \theta)} + (1-\xi_p) * \left(\frac{1-\xi_p \pi_{p,t}^{\theta-1} \pi_{p,t-1}^{-\gamma p(\theta-1)}}{1-\xi_p} \right)^{-\frac{\theta}{1-\theta}} \quad (18)$$

These dispersion measures appear in the aggregate utility function as a cost that augments the input of labour to produce the given aggregate output of consumption goods:

$$U_t = \varepsilon_t^b \left(\frac{1}{1-\sigma_c} (C_t - hC_{t-1})^{1-\sigma_c} - \frac{\varepsilon_t^L}{1+\sigma_l} (L_t)^{1+\sigma_l} * \Delta_t^w * \Delta_t^{p^{(1+\sigma l)/(1-\alpha)}} \right) \quad (19)$$

The size of these inflation dispersion costs taken together only makes up some 10% of the total welfare cost. This relatively small size is somewhat surprising especially within the framework of a Calvo model. Erceg and Levin (2002) have stressed that the Calvo model produces very large welfare effects of price stickiness, compared for instance to the Taylor-type stickiness with fixed duration contracts. Rotemberg and Woordford (1997) also find a very high coefficient on the inflation dispersion term in their second-order approximation of the welfare function. In our model, indexation to past inflation and habit persistence in the utility function reduce the relative weight of inflation dispersion in this approximation. The impact of partial indexation to past inflation on the inflation dispersion costs can easily be evaluated. Keeping all other parameters constant, the assumption of indexation reduces the welfare costs of price and wage dispersion in our model by half. A more important explanation for the small inflation costs is the very mild response of inflation following this type of non-fundamental investment shock. As explained above, this is due to the estimated monetary policy rule together with the flexible technology assumptions.

The second important component of the welfare loss refers to the adjustment costs that have to be incurred when firms change their investment plans. These costs take the form of a fraction of investment expenditures that does not result in an increase in the capital stock. The higher the volatility of the investment flows, the higher the fraction of investment that will be lost. These investment adjustment costs account for 40% of the total welfare cost following the temporary equity price shock and for about 10% following the more persistent investment shock.

A third component of the welfare cost that can be identified is the loss that results from the variance in the consumption and labour supply flow. We calculate this component from the second-order approximation to the utility function:

$$0.5 * (1-h)\overline{C} * ((1-h)\overline{C})^{-\sigma} (1+\sigma)\hat{C}_t^2 + cte * 0.5 * \overline{L} * \overline{L}^{\sigma_l} (1+\sigma_l)\hat{L}_t^2 \quad (20)$$

Finally, the remaining loss is due to inefficiencies in both the intra- and intertemporal allocation of resources. Intratemporal inefficiencies are caused by the frictions in prices and wages, which imply that prices and wages do not reflect the marginal cost of production or the marginal disutility from labour effort. The intertemporal inefficiencies are caused by the non-fundamental shock as discussed above.[12] The variance terms and the remaining first-order inefficiencies explain about 25% of the total welfare cost.

For the more persistent shock the composition of the welfare loss changes slightly. Inflation raises relatively more under the persistent shock and the contribution in the costs is therefore somewhat higher. The same applies for the responses in consumption and labour and this increases the variance term. The more persistent shock is better anticipated by definition and therefore creates less volatility in investment and less capital adjustment costs.

[12] Both components could be identified if we were to consider the impact of the shock in the flexible price-wage model. However, the overall impulse response function of the shock changes strongly in the flexible price model and this makes the comparison less interesting.

The fundamental investment shock, caused by a persistent shift in the relative price of the capital goods, produces a totally different picture. The welfare effects of such a shock depend of course on the sign of the shock: a positive shock implies a temporal increase in the productivity of the capital good producing sector and therefore leads to an expansion of the production potential of the economy. The size of the welfare effect is much higher compared to the costs discussed above. Of course, over time positive and negative shocks cancel each other out and therefore the welfare implications of these shocks have to be analysed in a stochastic simulation. This analysis will be performed in the next section.

3.2 Welfare analysis of a deterministic non-fundamental investment shock around an inefficiently low (MCE) output level

Now we turn to the discussion of the welfare effects of a non-fundamental investment shock around an inefficiently low steady state level of output caused by the markups in a monopolistic competitive world. The welfare effects of the non-fundamental shock are strongly asymmetric under this assumption and the effect of a positive shock on welfare even turns out to be positive. A positive shock increases the output level and employment. Nominal stickiness prevents prices and wages from adjusting quickly to the higher marginal costs and marginal disutility levels, so that the markups are temporally reduced. This will move the economy towards the efficient output level that would prevail in the absence of markup distortions. In the estimated model, these welfare gains turn out to be much higher in magnitude than the costs from inflation, capital adjustment or increased variances.

Table 3

Welfare effects of a distortionary investment shock around the lower MCE output level

	Iid shock		**Persistent shock**		**Fundamental shock**	
	+ shock	**– shock**	**+ shock**	**– shock**	**+ shock**	**– shock**
Total welfare effect	0.0095	–0.0117	0.0297	–0.0304	0.0932	–0.0927
In % of steady state consumption level	0.5921 100.00%	–0.7307 100.00%	1.8569 100.00%	–1.8974 100.00%	5.8208 100.00%	–5.7855 100.00%
Price dispersion cost	–0.0002 –0.04%	–0.0003 0.04%	–0.0006 –0.03%	–0.0006 0.03%	–0.0007 –0.01%	–0.0007 0.01%
Wage dispersion cost	–0.0003 –0.04%	–0.0004 0.05%	–0.0014 –0.08%	–0.0014 0.07%	–0.0007 –0.01%	–0.0006 0.01%
Capital adjustment cost	–0.0071 –1.21%	–0.0098 1.34%	–0.0033 –0.18%	–0.0033 0.17%	–0.0035 –0.06%	–0.0036 0.06%
Variance cost	–0.0012 –0.21%	–0.0017 0.24%	–0.0068 –0.37%	–0.0068 0.36%	–0.0076 –0.13%	–0.0076 0.13%
Intra-/intertemporal inefficiency	0.6010 101.49%	–0.7185 98.34%	1.8689 100.65%	–1.8854 99.37%	5.8333 100.22%	–5.7729 99.78%

The welfare gain from a positive non-fundamental shock in the benchmark case is similar to a 0.6% increase in the steady state consumption level. The cost of a negative shock is somewhat larger because all the welfare effects go in the same direction but also because of the concave relation between welfare and output, which implies that the welfare costs are increasing as one moves further and further away from the first-best output level.

Gali et al (2001) derive similar welfare effects from business cycle fluctuations that are driven by stochastic movements in the inefficient wage markup. If business cycle fluctuations are associated with variations in economic efficiency, they show that periods of booms imply lower inefficiency and therefore higher welfare, while recessions are leading to lower efficiency and welfare losses. These welfare losses of recessions are higher than the welfare gains of booms because of the concave relationship between welfare and their efficiency gap measure. They also indicate that these welfare costs are potentially important compared to the traditional costs from efficient fluctuations around the competitive steady state level. However, they do not discuss fully the implications for monetary policy that follow from these asymmetric welfare effects.

3.3 Welfare analysis: the stochastic case

In order to approximate the welfare effects in the stochastic case we use a second-order approximation to the model solution.[13] We compare again the welfare results around the CE efficient steady state output level and the lower MCE output level.

Table 4

Welfare effects of a distortionary iid investment shock in a stochastic simulation

	Steady state output CE	**Steady state output MCE**
Total welfare effect	–0.1020	–0.0847
In % of steady state consumption level	–6.3052 100.00%	–5.2347 100.00%
Price dispersion cost	–0.1013 1.61%	–0.0338 0.65%
Wage dispersion cost	–0.1442 2.29%	–0.0343 0.66%
Capital adjustment cost	–1.4341 22.74%	–1.4321 27.36%
Variance cost	–0.5205 8.25%	–0.1558 2.98%
Intra-/intertemporal inefficiency	–4.1051 65.11%	–3.5787 68.36%

The welfare effects of both exercises are very similar. The temporary non-fundamental shocks generate a welfare loss that is equivalent to around 5% of the steady state output level (one period). Price and wage dispersion and the variance term make up only a small fraction of this cost. Capital adjustment costs explain 25 to 30% of the cost and the linear inefficiency term explains the remaining 60-65%. This high proportion of the cost that is related to the inefficiencies caused by the investment shock suggests that a monetary policy that takes into account the non-symmetric welfare effects of the shock might have a substantial impact on these welfare costs. This point will be further analysed in the next section.

4. Welfare implications from alternative monetary policy responses to the non-fundamental investment shock

The previous welfare analysis assumed that monetary policymakers were following the estimated generalised Taylor rule. In this section, we perform stochastic simulations assuming alternative monetary policy rules in order to analyse the impact of monetary policy behaviour on the welfare effects of the shock.[14] Again we start by assuming, first, that the economy is fluctuating around the

[13] We performed these calculations with Dynare (Julliard (2003)) using the Schmitt-Grohe and Uribe (2001) algorithm for the second-order approximation solution.

[14] We leave an analysis of the optimal monetary policy response for future research.

efficient competitive economy output level. This exercise will allow us to compare our results with the discussion in the literature on how monetary policy should react to asset price shocks. Next, we consider the same exercise around the lower monopolistic competitive equilibrium (MCE) output level and discuss how this affects the implications for monetary policy.

4.1 Monetary policy and non-fundamental investment shocks around the CE output level

Under these assumptions, optimal monetary policy from a welfare perspective is faced with a trade-off between stabilising inflation and stabilising investment. Stabilising investment will imply a stronger reaction to the non-fundamental shock, so that other private expenditures are crowded out further and inflation will become negative. In order to illustrate the impact of monetary policy on the welfare outcome, we consider some simple policy rules starting with a rule that responds only to inflation.

The simple policy rule with a very moderate response to inflation (a coefficient of 1.1) does a poor job in terms of welfare outcome. Under this rule, the standard deviation in the inflation process is twice as high as under the more aggressive inflation policies, and this increases the welfare costs of the price and wage dispersion by a factor of four or more. However, all components of the welfare cost increase under the weak inflation policies. A stricter anti-inflation policy (with a reaction coefficient of 1.7) not only reduces the cost of inflation but also helps to overcome part of the other inefficiencies related to the non-fundamental investment shocks. Augmenting this rule with a reaction to the output gap (to 0.5 as in the traditional Taylor rule) further reduces the efficiency costs. These outcomes confirm the results presented by Bernanke and Gertler (2000). The estimated policy rule, which is close to a first difference rule with a relatively strong coefficient on inflation, performs reasonably well in terms of the welfare implications.

The next step would be to evaluate whether the inclusion of a specific response to the price of installed capital in the policy rule might improve the outcome in the fully stochastic model with multiple sources of disturbances. However, with larger and more persistent shocks in the model, the second-order approximation methods often generate unstable solution paths.[15]

To take into account the possible complications that arise due to the non-linearity of the model, we also consider the estimated policy rule augmented with an asymmetric reaction on the growth rate. The asymmetric policy rule that we consider is of the following type:

$$\begin{aligned} R_t &= \rho R_{t-1} + (1-\rho)\left\{\overline{\pi}_t + r_\pi\left(\pi_{t-1} - \overline{\pi}_t\right) + r_Y\left(Y_t - Y_t^p\right)\right\} + \\ &\quad r_{\Delta\pi}\left(\pi_t - \pi_{t-1}\right) + \left(r_{\Delta y}/\kappa\right)\left(1 - \exp\left(\kappa * \left(Y_t - Y_{t-1}\right)\right)\right) + \eta_t^R \end{aligned} \tag{21}$$

The linear impact of output growth in the policy reaction function (16) is replaced by a non-linear asymmetric relation. The parameter κ determines the degree of asymmetry. In Graph 2, the impact of output growth on the interest rate is compared for the linear relation and a weak (κ =10) and a strong (κ =25) asymmetric relation. The persistence in the policy rule spreads this asymmetric effect through time but the degree of asymmetry that is considered remains very moderate.

Although we did not expect a major impact for the case around the CE output level, this rule does seem to improve the welfare results. An asymmetric policy response is able to generate positive efficiency gains in this stochastic setting compared to the deterministic steady state result.[16] These efficiency gains, which are calculated as the residual in Table 5 between the total welfare effect and the identified components, are of a similar magnitude to the costs from inflation, capital adjustment and volatility.

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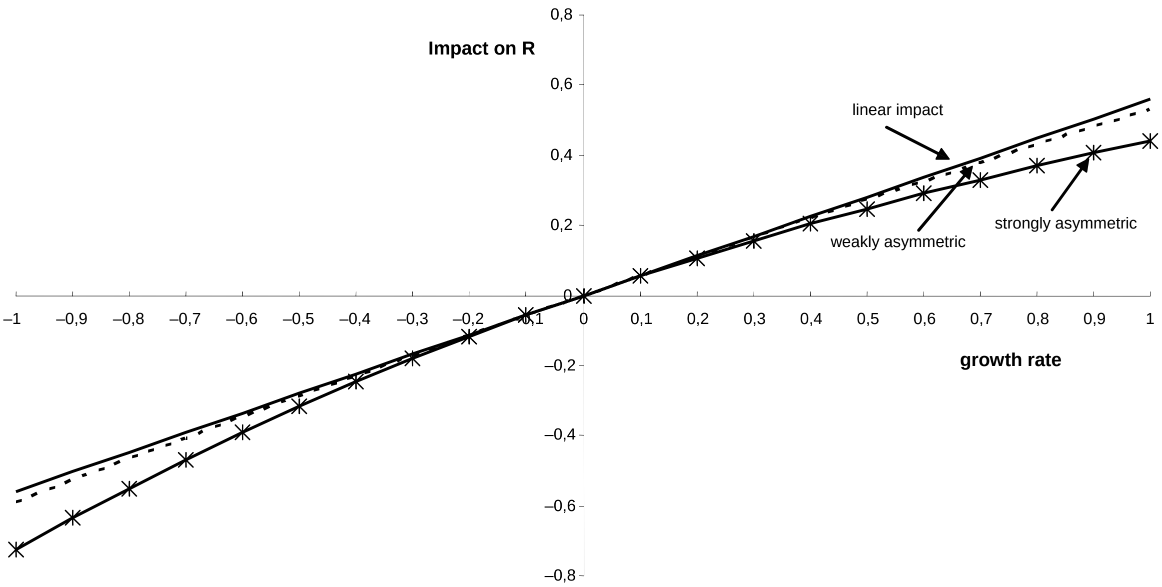
15 Kim et al (2003) discuss the issue of instability of the second-order approximation methods and possible solutions.

16 At this point, we have no intuition to explain this puzzling result. But given the highly non-linear nature of the model and the utility function, the result is not impossible.

Graph 2

Reaction coefficient on impact of the interest rate on GDP growth



4.2 Monetary policy and non-fundamental investment shocks around the lower MCE output level

The results for the simple rules remain valid for the stochastic simulations around the lower output level in a monopolistic competition context with level distortions. A stricter inflation policy and a reaction to the output gap can limit the costs of the non-fundamental shock, but the impact on the linear term measuring the inefficiency is less sensitive to the monetary policy rule here than it was in the previous table.

In this case, the benefits from an asymmetric monetary policy response to the non-fundamental shock are clear. An asymmetric policy response is able to take full benefit from the positive investment shocks that move output towards the more efficient production level. In contrast, policy is relaxed more rapidly at times of negative investment shocks in order to minimise the negative consequences for output. On average, this asymmetric policy response can be considered as a more accommodating monetary policy because the real interest rate will be lower on average while inflation and the nominal rate will be higher on average. The question then arises whether such a policy can be credible and whether the assumption of commitment to the policy rule is still valid in this context.

The results in Table 6 show that the average inflation rate under the asymmetric policy rule is above the deterministic steady state level. At the same time the average investment and output level in the stochastic simulation are also above the deterministic steady state. The asymmetric policy creates a positive relation between the average long-run inflation outcome and the average output level.

Table 5

Welfare effects of a distortionary iid investment shock under alternative monetary policy rules

Results from the stochastic simulation with the second-order approximation methods
Stochastic simulations around the CE steady state output level

	Benchmark	**Simple rules**			**Asymmetric policy**	
	Estimated rule	**Weak π policy**	**Strong π policy**	**+ Output –gap**	**Weak**	**Strong**
Total welfare effect	–0.1020	–0.1700	–0.1093	–0.0878	–0.0640	–0.0092
In % of steady state consumption level	–6.3052 100.00%	–10.5122 100.00%	–6.7594 100.00%	–5.4316 100.00%	–3.9575 100.00%	–0.5708 100.00%
Price dispersion cost	–0.1013 1.61%	–0.5067 4.82%	–0.1351 2.00%	–0.0676 1.24%	–0.1351 3.41%	–0.3209 56.22%
Wage dispersion cost	–0.1442 2.29%	–0.4532 4.31%	–0.2335 3.45%	–0.1133 2.09%	–0.1614 4.08%	–0.2506 43.91%
Capital adjustment cost	–1.4341 22.74%	–1.5763 14.99%	–1.4829 21.94%	–1.3872 25.54%	–1.4366 36.30%	–1.4401 252.28%
Variance cost	–0.5205 8.25%	–0.9913 9.43%	–0.5843 8.64%	–0.3845 7.08%	–0.5257 13.28%	–0.5509 96.51%
Intra-/intertemporal inefficiency	–4.1051 65.11%	–6.9848 66.44%	–4.3236 63.96%	–3.4790 64.05%	–1.6987 42.92%	1.9917 –348.91%
Average inflation rate q-to-q Standard error	–0.0033 0.0314	–0.0184 0.0699	0.0112 0.0367	0.0214 0.0262	0.0071 0.0308	0.0226 0.0302
Average output level % deviation from steady state Standard error	0.0055 0.5127	–0.0182 0.7298	–0.0378 0.5467	–0.0393 0.4328	0.0671 0.5143	0.1695 0.5206

Table 6

Welfare effects of a distortionary iid investment shock under alternative monetary policy rules

Results from the stochastic simulation with the second-order approximation methods
Stochastic simulations around the lower MCE steady state output level

	Benchmark	Simple rules			Asymmetric policy	
	Estimated rule	**Weak π policy**	**Strong π policy**	**+ Output –gap**	**Weak**	**Strong**
Total welfare effect	–0.0847	–0.1373	–0.1341	–0.1129	0.0126	0.1650
In % of steady state consumption level	–5.2347 100.00%	–8.4884 100.00%	–8.2932 100.00%	–6.9803 100.00%	0.7775 100.00%	10.2053 100.00%
Price dispersion cost	–0.0338 0.65%	–0.1802 2.12%	–0.0450 0.54%	–0.0225 0.32%	–0.0450 –5.79%	–0.1126 –1.10%
Wage dispersion cost	–0.0343 0.66%	–0.1442 1.70%	–0.0710 0.86%	–0.0298 0.43%	–0.0412 –5.30%	–0.0755 –0.74%
Capital adjustment cost	–1.4321 27.36%	–1.5928 18.76%	–1.5114 18.22%	–1.4052 20.13%	–1.4358 –184.67%	–1.4418 –14.13%
Variance cost	–0.1558 2.98%	–0.3115 3.67%	–0.1989 2.40%	–0.1283 1.84%	–0.1568 –20.16%	–0.1637 –1.60%
Intra-/intertemporal inefficiency	–3.5787 68.36%	–6.2597 73.74%	–6.4669 77.98%	–5.3945 77.28%	2.4563 315.92%	11.9988 117.57%
Average inflation rate q-to-q Standard error	–0.0033 0.0219	–0.0034 0.0520	0.0071 0.0276	0.0165 0.0180	0.0047 0.0220	0.0166 0.0228
Average output level % deviation from steady state Standard error	0.0025 0.4691	–0.0122 0.6956	–0.0343 0.5422	–0.0346 0.4154	0.0570 0.4701	0.1449 0.4740

These results illustrate that if output is fluctuating below the first-best output level, the task for an optimal monetary policy from the welfare point of view is much more complicated. Our conclusions are in contrast with most of the results presented in the literature, where the optimal monetary policy is derived as the linear policy rule that is optimising a quadratic approximation of the welfare function subject to the linearised model (Rotemberg and Woodford (1997)). Most of this literature assumes, however, that there exist lump sum taxes and subsidies that compensate for the impact of markups on the steady state equilibrium level. These instruments can be used by fiscal policy to offset the distortions in the economy. The recent paper by Benigno and Woodford (2003) drops this assumption but still retains the assumption that the optimal fiscal policy is stabilising the markup distortion over time, so that the optimal monetary policy can still be described as the solution from a linear-quadratic problem. In the real world it is difficult to imagine that fiscal policy is indeed able to reproduce the first-best outcome or to adjust optimally from period to period. Therefore, the analysis of optimal monetary policy in the presence of markup distortions is more appropriate to mimic real world policy questions.

5. Conclusions

Large asset price and investment cycles that are difficult to motivate by fundamental factors generate complicated decision problems for monetary policymakers. General equilibrium models can be helpful in sorting out the welfare effects of the different inefficiencies that are generated by these cycles. Model solution methods based on higher-order approximations are necessary for this welfare analysis and can increase our understanding of the issues involved. This paper is a first attempt to perform such an analysis using a standard estimated sticky price and wage general equilibrium model.

However, a lot of work remains to be done. First, the estimated non-fundamental equity price shock we analyse in this paper is different from what observers traditionally understand as a typical asset price bubble. More realistic, but exogenously generated bubble processes could be introduced in the model quite easily. These might already change part of our conclusions because these bubble processes are expected to burst at a certain point in the future and generate negative investment and output consequences at that point. If the size of these negative output effects is sufficiently important, this might change the policy reaction drastically as the welfare effects of possible future output declines can easily dominate the welfare gains from more moderate short-run output expansions. This last effect might even be strengthened if the transmission effect of asset price fluctuations to the real economy is also asymmetric with a much larger impact during the bursts. In such a scenario monetary policy actions today may serve as an insurance policy against larger losses in the future.[17] In reality the decision problem might therefore be a much more complicated and dynamic problem.

Furthermore, there is also the identification issue to distinguish between fundamental and non-fundamental asset price movements. However, if the efficiency gains from higher output levels are the dominant factor in the welfare analysis, this difference might not be as important as it is in the case of fluctuations around the first-best output level.

Ideally, asset price booms should be modelled as endogenous processes, probably related to the uncertainty and heterogeneous expectations about fundamental shocks. Alternative monetary policy rules may affect the probability of asset price booms and bursts in such a setup. Asymmetric policy rules may also create a moral hazard issue by providing one-sided protection against the negative risks. Understanding these mechanisms together with more knowledge about the transmission mechanism from these financial variables to the real economy would make the policy conclusions of this type of research much more robust. Introducing financial frictions, firm-specific capital and heterogeneous agents will certainly be ingredients for future research in this context.

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[17] See Bordo and Jeanne (2002) for an analysis of this argument.

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