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MONETARY POLICY AND ASSET PRICES: TO RESPOND OR NOT?

Q. Farooq Akram
Gunnar Bårdsen
Øyvind Eitrheim

Department of Economics

Norwegian University of Science and Technology
N-7491 Trondheim, Norway
www.svt.ntnu.no/iso/wp/wp.htm

Monetary policy and asset prices: To respond or not?*

Q. Farooq Akram
Norges Bank

Gunnar Bårdsen
NTNU and Norges Bank

Øyvind Eitrheim
Norges Bank

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Abstract

We investigate whether there is a case for asset prices in interest rates rules within a small econometric model of the Norwegian economy, modeling the interdependence of the real economy, credit and three classes of assets prices: housing prices, equity prices and the nominal exchange rate. We compare the performance of simple and efficient interest rate rules that allow for response to movements in asset prices to the performance of more standard monetary policy rules. We find that including housing prices and equity prices in the policy rules can improve macroeconomic performance in terms of both nominal and real economic stability. In contrast, a response to nominal exchange rate fluctuations can induce excess volatility in general and prove detrimental to macroeconomic stability.

Keywords: *Monetary policy, asset prices, simple interest rate rules, econometric model.*

JEL Codes: *C51, C52, C53, E47, E52*

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1 Introduction

A recent view of monetary policy is that central banks can improve macroeconomic performance by reacting to asset price changes—in addition to inflation deviations and the output gap—see e.g. Cecchetti et al. (2000), Borio and Lowe (2002), Bordo and Jeanne (2002). The main argument is that an asset price bubble may lead to excessive growth in investment and consumption—with corresponding fall when the bubble bursts. Macroeconomic performance may suffer in terms of excessive variability in output and inflation. A modest tightening or easing of monetary policy when asset prices rise above or below sustainable levels may help smoothing fluctuations in output and inflation. Such moves may also reduce the possibility of an asset price bubble forming in the first place. Hence, several authors argue that monetary policy makers should use asset prices not only as a part of their information set to assess future inflation, but also to let interest rates partly offset deviations of asset prices from their sustainable levels, see e.g. Chadha et al. (2004).

The main argument for the traditional view—that interest rates should be set in response to inflation and the output gap only—is that: not only are asset prices quite volatile, but asset price misalignments are also hard to identify. The end result could therefore be an overactive monetary policy that may prove to be destabilizing. The central bank should therefore react indirectly to asset price changes—by responding to their effects on inflation and output, see e.g. Bernanke and Gertler (2001) and Bean (2003). For example, exchange rates may have direct effects on inflation through imported inflation, while housing and equity prices may affect inflation and output through their effects on credit growth, aggregate consumption and investment.

The two positions on the role of asset prices in monetary policy have mostly been framed and analyzed within the framework of calibrated or stylized models with strong theoretical foundations, see e.g. Ball (1999), Batini and Haldane (1999), Svensson (2000), Walsh (1999), and Woodford (2000). Such models are not necessarily well-suited for the problem at hand. This is mainly because the impact of asset price volatility on the economy is economy-specific and generally differs across asset prices, and is hence more appropriately investigated within a well specified empirical framework.

We therefore investigate whether monetary policy should respond to asset prices by using a well specified econometric model of a small economy where exchange rates tend to play a more important role than in large economies. This model pertains to the Norwegian economy and embeds several relationships between three classes of asset prices, i.e. housing prices, equity prices and the nominal exchange rate, and the rest of the economy. The model is therefore well suited to evaluate the performance of interest rate rules that allow for direct response to misalignments in asset prices relative to standard rules for closed and open economies as in Taylor (1993).[1]

[1]The latter types of rules allow only an indirect response to assets prices through their effects on inflation and output.

We evaluate the performance of different interest rate rules by investigating how they would have performed historically, i.e. over a period of six years over the sample. We summarize the performance of a rule by a loss function based on the variability in inflation, output and implied interest rate volatility. We also use a new loss-measure that takes into account the extent to which a rule leads to deviation from the inflation target. This measure is termed "mean squared target errors" (MSTE) and takes into account two properties of a given interest rate rule: the implied variability in target variables (inflation and output) and bias, i.e., the average deviation from the target(s) implied by the rule; see (Bårdsen et al., 2005, Ch. 10) and references therein. This measure captures a central bank's concern for achieving its policy target in the short run.

In the next section we present a stylized version of the econometric model, emphasizing the role of asset prices. Section 3 gives an evaluation of the model in terms of effects of shocks to the asset prices and their response to shifts in short-term interest rates. Section 4 presents different interest rate rules and criteria for their evaluation. In Section 5 we compare the performance of different simple interest rate rules with asset price misalignments to standard Taylor-type rules. Then in Section 6, we derive the efficiency frontiers, which depict the trade-off between inflation and output-variability, for interest rate rules with and without response to asset prices. Section 7 presents our main conclusions. Three appendices provide a description of monetary policy in Norway since the 1970s, the data set, and the econometric model.

2 Asset prices in a small open economy

The model explicitly takes into account several channels of interplay between credit, output and asset prices, see e.g. Kiyotaki and Moore (1997), by econometrically well specified representations of wage and price inflation, the determination of output and unemployment, credit, and three classes of asset prices: housing prices, domestic equity prices and the nominal exchange rate. Moreover, it captures features that are considered essential for the propagation of shocks, such as unemployment persistence.[2]

To highlight the transmission mechanism of asset prices in the Norwegian economy, we present a stylized version of the model in equations (1)–(8) below, following the approach of Bårdsen (2005). All variables except interest rates (r) are in natural logarithms, Δ denotes the first difference operator, and foreign variables are denoted with starred superscripts. Furthermore, the nominal exchange rate (in logs denoted e) expresses the number of domestic currency units per unit of foreign currency, while $q \equiv (e + p^* - p)$ denotes the log level of the real exchange rate, l represents nominal credit demand, while pr denotes labor productivity; see Appendix B for precise definitions

[2] The full model is documented in Appendix C.

of all of the variables.

$$\text{Output: } \Delta y_t = 0.02\Delta(s-p)_t + 0.3\Delta q_t \tag{1}$$
$$- 0.2\left[(y + (r-\Delta p) - 0.5q - 0.1(ph-p)\right]_{t-1}$$
$$\text{Real credit: } \Delta\left(l-p\right)_t = 0.1\Delta y_t + 0.05\Delta\left(ph-p\right)_t + 0.01\Delta\left(s-p\right)_t, \tag{2}$$
$$- 0.05\left[(l-p) - 0.5y + 3r - (ph-p)\right]_{t-1},$$
$$\text{Housing prices: } \Delta ph_t = 1.1\Delta p_t + 0.05\Delta s_t + 0.2\Delta y_t + \Delta\left(l-p\right)_t - 1.4\Delta r_t, \tag{3}$$
$$- 0.1\left[(ph-p) - 0.5y - 0.25\left(l-p\right) + 4\left(r-\Delta p\right)\right]_{t-1},$$
$$\text{Stock prices: } \left(\Delta s - r\right)_t = \left(\Delta s^* - r\right)_t - 5\Delta r_t, \tag{4}$$
$$\text{Exchange rate: } \Delta e_t = -0.5\Delta r_t - 0.1(r-r^*)_t - 0.1\left[e - (p-p^*)\right]_{t-1}, \tag{5}$$
$$\text{Unemployment: } \Delta u_t = -0.1u_{t-1} - 2.8\Delta y_t, \tag{6}$$
$$\text{Wages: } \Delta w_t = 0.7\Delta p_t - 0.1\left(w - p - pr + 0.1u\right)_{t-1}, \tag{7}$$
$$\text{Consumer prices: } \Delta p_t = 0.4\Delta w_t + 0.05\Delta y_t - 0.06\left[p - 0.7\left(w-pr\right) - 0.3\left(e+p^*\right)\right]_{t-1}, \tag{8}$$

The model is in equilibrium correction form, so the growth rates of the endogenous variables are functions of deviations from their steady-states. The formation of expectations is treated as backward-looking, which is consistent both with a credible inflation-targeting regime and with recent econometric evaluations of New Keynesian Phillips Curves—see e.g. Bårdsen et al. (2004, 2005).[3]

Output growth Δy_t is modeled from the demand side in (1)—affected by real stock-price inflation $\Delta\left(s-p\right)_t$, in addition to changes in the real exchange rate $\Delta q_t \equiv \Delta\left(e+p^*-p\right)_t$ and deviations from steady-state. In steady state, output demand depends on real housing prices $(ph-p)$, capturing changes in wealth and collateral effects —see Kiyotaki and Moore (1997), in addition to the real exchange rate $q \equiv (e+p^*-p)$ and the real interest rate $(r-\Delta p)$:

$$y = -\left(r-\Delta p\right) + 0.5q + 0.1\left(ph-p\right).$$

Growth in real credit demand $\Delta\left(l-p\right)_t$ reacts positively to growth in real stock prices, as well as to increases in real housing prices $\Delta\left(ph-p\right)_t$. The steady-state solution of (2) shows that real house prices, in addition to aggregate demand, affect the demand for real credit $(l-p)$:

$$(l-p) = 0.5y - 3r + (ph-p).$$

[3] Models of expectations formation can broadly be classified as static, adaptive or rational. The choice of model for expected inflation will depend on monetary policy regime and the volatility of inflation. Static or backward-looking expectations of inflation may be justified when monetary policy contributes to relatively stable inflation, as in Norway. Forward-looking rational expectations formation is probably more realistic with swift and strong changes in monetary policy and inflation.

The growth rate of nominal house prices Δph_t is modeled in (3) by growth in aggregate demand, real credit and consumer prices Δp_t, as well as interest rate changes and deviations from steady state. In steady state, real house prices are mainly determined by aggregate demand and real credit demand, in addition to the real interest rate:

$$(ph - p) = 0.5y + 0.25\,(l - p) - 4\,(r - \Delta p)\,.$$

Nominal stock prices are modeled in light of the Capital Asset Pricing Model (CAPM) by treating the Norwegian stock market portfolio as a "single" asset and the international stock market portfolio as the "market portfolio". The obtained relationship in (4) suggests that excess return on the Norwegian stock market portfolio $(\Delta s - r)_t$ moves fully with excess return on the international market portfolio. In addition, there is a strong negative relationship between changes in interest rates and excess returns on the domestic stock market.

Equation (5) of the nominal exchange rate Δe_t captures the appreciation effect of increases in the interest rate, the interest rate differential as well as deviations from PPP, see Akram (2005). In steady-state, the nominal exchange rate reflects the difference between domestic and foreign prices and the difference between domestic and foreign interest rates:

$$e = (p - p^*) - (r - r^*).$$

Equation (6) models the unemployment rate u_t as an Okun's law relationship, exhibiting slow reversion towards its equilibrium rate; an intercept term has been omitted from this equation for ease of exposition.

Consumer price inflation Δp and wage inflation Δw are simultaneously determined in (7)–(8) and are affected by demand pressure Δy_t and steady-state deviations. In steady state, real wages, corrected for productivity pr, depend upon unemployment with an elasticity of -0.1, corresponding to the "wage-curve law" of Blanchflower and Oswald (1994), while prices are set as a mark-up on a weighted average of unit labor costs and import prices:[4]

$$\begin{aligned} w - p - pr &= -0.1u, \\ p &= 0.7\,(w - pr) + 0.3\,(e + p^*)\,. \end{aligned}$$

Norwegian monetary policy since March 2001 is aimed at targeting the underlying inflation rate (Δpu) at 2.5%, see Appendix A. In the model, underlying inflation rate is linked to the headline inflation rate (Δp) by a technical equation.

[4]The constant mark-up term is suppressed. In the full econometric model, productivity pr is also an endogenous variable that depends on real wages $w - p$, unemployment u and a deterministic trend.

A couple of the steady-state properties of our model are worth pointing out: First, the steady-state solution implies that domestic and foreign inflation rates are equilibrated, assuming a constant interest rate differential:

$$\Delta p = \Delta e + \Delta p^{*}.$$

And second, the model implies that equilibrium unemployment is a function of the steady-state growth rate of the economy:

$$u = \text{Intercept} + f(\text{factors determining steady-state growth of } y).$$

That is, the model implies no long-run trade-off between inflation and unemployment.

3 Model properties and effects of asset prices

The complete model is econometrically well specified with seemingly constant parameters over estimation periods, see Appendix C for more details. This is partly demonstrated in Figure 1, which displays tracking properties of the model for key variables. The tracking properties are quite satisfactory and do not deteriorate over the relatively long simulation horizon of 18 years: 1984:1–2001:1.

[Figure 1 about here]

[Figure 2 about here]

Figures 2–4 display the response of key variables to transitory partial increases in the nominal exchange rate, housing prices and equity prices, respectively. We assume that these asset prices rise by 10% and track their dynamic behavior as well that of other key macroeconomic variables over a six year simulation horizon: 1995:1–2000:4. The results are largely invariant to the choice of simulation horizon, because the model is (log) linear.

The figures show that almost all of the key variables are affected by movements in asset prices. The exception is the equity prices that remain unaffected by the fluctuations in the nominal exchange rate and housing prices, since the short-term interest rate is kept fixed in these simulations. However, if the interest rate was allowed to move in response to these shocks, it would have increased owing to the positive effects on inflation and output growth of the shocks. Accordingly, equity prices would have fallen and contributed to slightly modifying these positive effects. Figure 4 indicates that equity prices affect the other variables, but the effects are numerically small.

[Figure 3 about here]

[Figure 4 about here]

[Figure 5 about here]

The figures clearly suggest that fluctuations in the nominal exchange rate have stronger and more immediate effects on (underlying) inflation, $\Delta_4 pu$, and output growth ($\Delta_4 y$) than housing prices and equity prices. The latter asset prices affect the inflation and output growth with some lags. Housing prices, on the other hand, tend to have relatively larger effects on credit growth than the nominal exchange rate and equity prices.

Figure 5 displays the responses of key variables to a one percentage point rise in the short-term interest rate from 1990:1 and onwards. We note that e.g. responses of inflation and GDP to an interest rate change of this size are comparable to those reported in other studies, see Angeloni et al. (2003) and the references therein.

Some additional features of the model emerging from Figure 5 are also worth pointing out. First, asset prices respond strongly to interest rate changes: while the mean response of inflation is of the magnitude of 1/4 of a percentage point at most, the reaction of house prices is seven times higher than that of inflation. There is also a permanent appreciation of the nominal exchange rate by one percentage point, while the real exchange rate appreciates only temporarily. We also note that nominal credit falls at most by 1 1/2 percentage point per annum in the face of the interest rate increase. Finally, the figure indicates that interest rate changes have no long-run effects, since the deviations of the real exchange, GDP growth and unemployment from their base values converge to zero in the long run.

4 Interest rate rules

Several extensions of the simple three-parameter family of interest rate rules (inflation, output gap, smoothing) have been proposed in the literature. Open economy extensions have been proposed by *inter alia* Ball (1999) and Batini et al. (2001), where they let interest rates also respond to real exchange rate misalignments. Several authors have argued for the inclusion of asset prices such as real estate and equity prices in addition to exchange rates in interest rate rules, cf. e.g. Cecchetti et al. (2000), and Bernanke and Gertler (2001).

The different interest rate rules considered can be obtained as special cases of the following general interest rate rule, specified for quarterly data:

$$\begin{aligned} r_t = {} & \omega_r r_{t-1} + (1-\omega_r)(\bar{\pi} + \overline{rr}) + \omega_\pi(\Delta_4 pu_t - \bar{\pi}) + \omega_y(\Delta_4 y_t - \bar{g}_y) \\ & + \omega_{q0}(q_t - \bar{q}) + \omega_{q1}(q_{t-1} - \bar{q}) + \omega_{ph}(\Delta_4 ph_t - \bar{\pi}) + \omega_s(\Delta_4 s_t - \bar{g}_s), \end{aligned} \tag{9}$$

where target values are denoted by parameters with bars. This general interest rate rule is specified in terms of the underlying inflation rate (Δpu_t) in line with the official monetary policy target in

Norway. Furthermore, we include output growth instead of output gap in the interest rate rules.[5]

The target rates or steady state values for the arguments in the interest rate rule are determined mostly in light of their historical values. The exceptions are the target rate for underlying annual inflation rate, which is set to 2.5% per annum, and the equilibrium value for the real interest rate ($\overline{rr}$), which is set to 3.5. In addition, the steady state value for the nominal exchange rate is set equal to the difference between domestic and foreign prices in line with PPP.

First we determine the values of the response coefficients (ωs) in light of previous studies and then through simulations of our econometric model. In the latter case, we also derive efficient interest rate rules. These are rules with response coefficients that minimize inflation volatility conditional on a given level of output volatility and vice versus.

5 Performance of different simple interest rate rules

In this section, we examine the merits of some of the proposed simple interest rate rules within the context of our econometric model. The different simple interest rate rules are specified in Table 1.

[Table 1 about here]

The first line shows the different variables, their target values and the associated response parameters (weights). Each rule corresponds to a line in Table 1 and the weights attached to the different variables are shown in the columns.

The rules in Table 1 fall into four categories. The first rule (FLX) is a variant of the standard Taylor rule for a closed economy ("flexible"rule) where interest rates respond to (underlying) inflation and output growth.[6] The next rule introduces interest rate smoothing (SM) ("smoothing" rule), where we add the lagged interest rate to FLX. The third group contains three rules which can be labelled as "asset price" rules. This group includes a rule with response to the real exchange rate, q_t, which has previously been used in the open economy models proposed by *inter alia* Ball (1999) and Batini et al. (2001). One may alternatively consider this a rule where the (log of) nominal exchange rate responds to deviations from its steady state value defined by the difference between domestic and foreign prices. This rule is termed MCI. The second rule in this group admits a response to housing prices while the third rule allows monetary policy to respond to domestic stock prices, cf. Chadha et al. (2004). These rules are denoted as PH and OSE, respectively. Finally, we consider a "composite"rule (CMP) which is equal to the general rule itself and encompasses the other interest rate rules in terms of target variables.

[5]There are several arguments for considering output growth rather than the output gap. In addition to the inherent possibility of measurement error in the output gap, as emphasized by Orphanides (2003), there are also theoretical reasons why targeting output growth may be preferable to targeting output. Walsh (2003) argues that changes in the output gap—growth in demand relative to growth in potential output—can lead to better outcomes of monetary policy than using the output gap.

[6]Bernhardsen and Bårdsen (2004) show that such a rule with output growth offers a better fit to the actual interest rate setting in comparison with a rule with the output gap. The estimated weight on output growth was found to be 0.6 in this study, while the degree of interest rate smoothing was found to be 0.7.

We let the FLX rule serve as a benchmark for comparison with all other rules in Table 1. In order to facilitate comparisons between the different interest rate rules we maintain the weights on inflation ($\omega_\pi = 1.5$) and output growth ($\omega_y = 0.5$) that define FLX in all rules in Table 1. This helps to bring forward potential value added in terms of improved macroeconomic performance by additional response to e.g. asset prices. Our conclusions regarding possible value added of responding to asset prices are robust to the choice of these weights, as demonstrated in Section 6.

The performance of the different rules is examined by measuring their performance in counterfactual simulations of the model over a six year period, 1995–2000.[7] Arguably, the monetary policy regime in this period has been close to that pursued under the floating exchange rate and inflation targeting regime period since Mars 2001, see Appendix A.[8, 9]

The performance of a rule is summarized by the monetary authorities' loss function, such as:

$$\pounds(\lambda, \phi) = V[\Delta_4 pu_t] + \lambda V[\Delta_4 y_t] + \phi V[\Delta r_t], \tag{10}$$

where λ and ϕ express monetary authorities' aversion to variation $V[.]$ in output growth ($\Delta_4 y_t$) and interest rate volatility (Δrs_t), relative to that in underlying (core) inflation ($\Delta_4 pu_t$). The performance of a rule will be examined under different choices of these preference parameters.

The monetary authorities may also care about the ability of an interest rate rule to achieve their targets in the short run, i.e. to what extent a rule is biased relative to the targets. Such bias and variation in a target variable x can be measured by MSTE (Mean Squared Target Error):

$$\mathsf{MSTE}(x) = \frac{1}{T}\sum_{t=1}^{T}(x_t - x^*)^2 = V[x] + (\bar{x} - x^*)^2,$$

where x^* denotes the target value of x, while $\bar{x}$ is the sample mean of x over the simulation period. It represents an estimate of the expected level of x, $E[x]$. When evaluating the rules, we calculate values of the loss function using estimated values of MSTE as arguments, cf. (Bårdsen et al., 2005, Ch. 10).

Table 2 summarizes the vast amount of information from these simulations. For each interest rate rule, it records the mean and standard deviation relative to that in the sample over the simulation horizon.

[Table 2 about here]

[7]Our main conclusions are robust to the choice of a typical simulation period; the results are available on request from the authors.

[8]The Norwegian monetary policy was aimed at stabilizing the exchange rate against the ECU and subsequently the euro, but without any formal band, during the simulation period. Moreover, this stabilization policy was often relaxed in the face of strong appreciation or depreciation pressure. The headline and the underlying inflation rates were quite low in this period, ca. 2.5% and 2%, respectively.

[9]In line with common practice, when undertaking counterfactual simulations, we assume that the model's parameters are invariant to the specified changes in the interest rate rules. This assumption may be innocuous if the Lucas critique is quantitatively not that important, especially in the face of marginal changes in monetary policy, see e.g. Rudebusch (2005).

The different interest rate rules mainly contribute to different degrees of volatility in key variables rather than changing their average values over the simulation horizon. We note that the mean values of different variables under different interest rate rules are close to their sample counterparts. One exception is the average of the real exchange rate under the smoothing rule SM which becomes 2.4% against 1.3% in the sample, suggesting a relatively weaker real exchange rate. In contrast, we observe large variation in the relative standard deviations of different variables across the rules. We shall therefore focus on the contribution of the rules to the volatility of the variables.

All of the rules contribute to lower variance in (underlying) inflation and output growth than their actual values over the simulation horizon. For example, under the flexible rule (FLX), the standard deviations of these variables are 15% and 19%, respectively, lower than those in the sample. On the other hand, this relative stability seems to be achieved at the expense of substantially higher volatility in interest rates, exchange rates and housing prices. Interestingly, the increased interest rate volatility reduces the volatility in equity prices (e.g. by about 33% in the case of FLX).

Second, it appears that the volatility in interest rates, exchange rates, housing prices and equity prices can be reduced relative to that in the flexible rule (FLX) by allowing for additional interest rate response to these variables. We note that the relative standard deviations of interest rates, exchange rates, housing prices and stock prices attain their minimum values relative to those in the flexible rule (FLX) in the rule with smoothing (SM), the exchange rate (MCI), house prices (PH) and stock prices (OSE), respectively. Clearly, a direct response to a variable (lagged interest rate or an asset price) contributes to lower its variance as much as possible relative to that in the FLX rule, but often at the expense of higher volatility of other variables relative to that under the FLX rule. Thus under the composite rule (CMP), which allows for direct response to all of these variables jointly, the outcome is mixed. Here, only interest rates, stock prices and output growth achieve lower volatility than under the FLX rule.

In more detail, under the (SM) rule, interest rates become as stable as possible (relative to the FLX). On the other hand, this is achieved at a substantially higher relative volatility for all the other variables, except for the stock prices.

Similarly, the MCI rule, contributes to minimize the exchange rate volatility, but at the expense of increased volatility of almost all of the other variables, and especially for interest rates. The increased volatility of interest rates seems to be the driving force behind the higher relative volatility of the other variables, especially that of housing prices, credit growth, equity prices, output demand and inflation, see equations (1)–(4). Moreover, the exchange rate acts as a shock absorber and contributes to eliminate shocks to terms of trades (changes in the real exchange rate), owing to shocks from the labor market through domestic inflation or from foreign prices, see equation

(5). However, when interest rates respond to the exchange rate, it becomes stable and largely unable to counteract the terms of trade shocks, which directly and indirectly affect inflation and output. Thus, exchange rate stabilization proves detrimental to macroeconomic stability. This illustrates nicely the view that an interest rate response to volatile asset prices can lead to excessive fluctuations in interest rates and in the economy.

In contrast, stabilization of housing prices through the PH rule reduces volatility of all of the variables. That is, it contributes to higher stability especially in inflation, interest rates, the exchange rate and credit growth without inducing higher volatility in output and stock prices, which remain the same as in the FLX rule. This general improvement in economic stability can be partly ascribed to the substantial reduction in the relative volatility of credit growth when housing prices become more stable. The stability of output remains as in the FLX rule while that of inflation becomes substantially lower, contributing to more stable interest rates.

In details, e.g. a rise in housing prices affects output directly due to the wealth effect and thereby inflation, see equation (3). In addition, it leads to higher credit growth which contributes to a further increase in especially housing prices and thereby in aggregate demand, unemployment and inflation; see equations (2), (1), (6) and (8). Output itself tends to have substantial effects on housing prices. Thus, due to the strong interdependence between housing prices and output, and between output and inflation, an interest rate response to housing prices contributes not only to stable housing prices but also to stable credit growth and output as well as inflation.

Under the OSE rule, the volatility of stock prices is reduced considerably relative to that in the FLX rule. This partly results in more volatile interest rates, increasing the volatility of the exchange rate to a maximum relative to all of the other rules. However, the high volatility of the exchange rate leads to a large reduction in the volatility of output, which in itself contributes to more stable interest rates. The volatility of inflation remains as in the FLX rule. More specifically, stock prices affect output (and thereby inflation) directly and indirectly via credit growth and housing prices. If stock prices increase, interest rates becomes higher under the OSE rule, which contribute directly to an exchange rate appreciation. The increased interest rates and the appreciation substantially counteract the (direct and indirect) effect of stock prices on especially output.

Finally, in the CMP rule, the net effect of interest rate smoothing and response to the three asset prices is mainly more stable interest rates and stock prices than under the FLX rule.

5.1 Evaluating the performance

In the following, we evaluate the different interest rate rules relative to the FLX rule for different values of the preference parameters for output smoothing λ and interest-rate smoothing ϕ. We focus on three main questions. First, would additional response to asset prices improve the performance of a rule relative to the FLX rule, in the view of a central bank that primarily cares about nominal stability (i.e. strict inflation targeting and low interest rate volatility)? Second, should a central bank that cares about both nominal and real economic stability also respond to misalignment in asset prices? And third, is there a rule which would be preferred by central banks in general, i.e. irrespective of λ and ϕ?

[Figure 6 about here]

Figure 6 summarizes the performance of different rules relative to the FLX rule for different values of preference parameters λ and ϕ. This figure is based on loss calculations using the variances of inflation, output and interest rates. In the figure, values below 1 on the vertical axis suggest that the rule would be perceived to outperform the FLX rule at the given values of the preference parameters.[10]

Figure 6 shows that the SM rule would be preferable to the FLX rule to a central bank preoccupied with nominal stability, but not to one that also cares about real economic stability. As noted above, the addition of smoothing in monetary policy making increases nominal stability, but at considerable expense for output stability.

More specifically, for $\lambda = 0$ and ϕ=1, the SM rule reduces the loss by about 18% relative to the FLX rule. On the other hand, for $\lambda = 2$, the smoothing rule SM gives higher loss relative to FLX rule.

Additional response to the real exchange rate (MCI), however, leads to higher volatility in general and hence to a less preferable performance relative to the FLX rule. Thus, this rule would not be preferred to the FLX rule in this context, irrespective of a central bank's preferences.

Additional response to housing prices (PH) or equity prices (OSE), however, leads to a more preferable performance relative to the FLX rule, irrespective of the preference parameters. The improvement is especially noticeable for a central bank preoccupied with nominal stability. It also appears that a preference for output stabilization reduces the attractiveness of these rules, but they would still be preferable to the FLX rule for a central bank that cares about both nominal and real economic stability.

Finally, it appears that the composite rule (CMP), which embeds some smoothing and response to asset prices, leads to an outcome preferable to the FLX rule, both in terms of nominal and real economic stability. This finding may be ascribed to the combined effects of factors that each contribute to lower the relative loss compared to the FLX rule. These factors are the two domestic asset prices, which enter with weights $\omega_{ph} = \omega_{ose} = 0.05$ and some degree of interest rate smoothing where we have set $\omega_r = 0.25$. Response to the real exchange rate may contribute to deteriorate its relative performance. It should, however, be noted that this rule responds to volatility in the real exchange rate rather than its level in contrast with the MCI rule.

[10] A detailed account of the performance, presented in tables, using both the volatility criterion (variances) and the volatility and bias criteria (MSTE), are available upon request. The tables shows that the relative performance of a rule is largely unaffected by the way the loss function is defined.

To summarize, this evaluation exercise clearly suggests value added from responding to both housing prices and equity prices in addition to output and inflation. In contrast, additional response to exchange rates generally leads to an inferior outcome in terms of nominal and real economic stability. The next section demonstrates that this conclusion also emerges under efficient interest rate rules, where the response coefficients (ωs) are based on extensive model simulations.

6 Efficient interest rate rules with and without asset prices

This section examines the performance of efficient interest rate rules with and without allowance for response to the asset prices. These are based on efficiency frontiers (so-called Taylor curves) that have been derived under interest rate rules without and with additional response to asset prices, see Figure 7.[11] It indicates the performance of the interest rate rules in terms of inflation and output variability.

[Figure 7 about here]

The circled line in Figure 7 depicts the efficiency frontier for rules that do not admit a response to asset prices. As examples, the weights associated with interest rate rules corresponding to points denoted as TR1–TR3 are represented in Table 3. The starred line in the figure sketches the efficiency frontier for rules that admit response to asset prices, in addition to inflation and output. As examples, Table 3 also records the weights defining interest rate rules associated with the points AP1 and AP2 on the latter efficiency frontier. The figure also indicates the performance of the simple interest rate rules considered in the previous section. The simple rules considered earlier do not lie on the efficiency frontiers, but some of them are fairly close.

[Table 3 about here]

The figure shows that allowance for additional response to asset prices contributes to a shift in the efficiency frontier towards origo, and hence provides lower variability in both inflation and output growth. Notably, the efficient weight on the exchange rate turned out to be zero, as a positive weight tended to increase the variability in both inflation and output and thus led to a shift outwards from the origo. Hence, the different points on the starred efficiency frontier refer only to different combinations of weights on all variables other than the exchange rate. The points where the two efficiency frontiers merge with each other include combinations of weights where the response coefficient of output growth becomes zero.

[11] The two efficiency frontiers have been obtained by model simulations with 891 and 57024 different combinations of the response coefficients ωs respectively, for rules without and with response asset prices. The outcome of each simulation in terms of inflation and output variability has thereafter been depicted in a two-dimensional diagram. These points are thereafter enveloped from below to define the efficiency frontier. Combinations of response coefficients ωs that correspond to the points on this curve define efficient interest rate rules, i.e. rules that would minimize the variability of inflation conditional on that of output and vice versus. Accordingly, it would not be possible to reduce the inflation volatility without inducing higher output volatility.

A choice between the different efficient rules cannot be made without introducing the preferences of a central bank. Yet, it clearly appears that a central bank that cares about stability of output and inflation would prefer the rules with housing prices and/or equity prices rather than the rules that do not admit response to these asset prices. Moreover, with such preference, a central bank would not respond to exchange rate movements.

7 Conclusions

We have evaluated the performance of interest rate rules with and without additional response to asset prices, considering simple interest rate rules proposed for closed and open economies with response coefficients proposed in the literature as well as based on our econometric model. We find that additional response to housing prices and equity prices generally outperform a standard Taylor-type rule in terms of nominal and real economic stability. It appears that such rules would be preferred by central banks with widely different preferences for output and nominal interest rate stability. On the other hand, a response to nominal exchange rates would not be permitted by a central bank with such preferences, as such a rule would contribute to higher volatility in general. We also show that the efficiency frontier associated with rules that allow for response to housing and equity prices is closer to origo in the diagram with inflation and output standard deviations on the y- and x-axes than the efficiency frontier of rules that do not include asset prices. Interest rate rules with a positive response coefficient on the exchange rate do not appear on the efficiency frontier.

In a small economy such as the Norwegian, the exchange rate acts as a shock absorber and contributes to eliminate shocks to terms of trades in particular, owing to e.g. shocks from the labor market as well as from foreign prices. However, when interest rates are set to stabilize the exchange rate, it becomes largely unable to counteract the terms of trade shocks, which directly and indirectly affect inflation as well as output. Moreover, the policy rates need to be used quite actively in order to stabilize the exchange rate. In itself this will induce excess volatility in housing prices, equity prices, credit growth, output demand and inflation. Consequently, exchange rate stabilization prove detrimental to macroeconomic stability.

In contrast, stabilization of housing prices also contributes to stabilize output and inflation. This effect is due to the strong interdependence between housing prices and output, through the wealth effect and the credit channel. Stabilization of equity prices, also contributes to interest rate movements that help stabilize output, directly and indirectly via the exchange rate in particular, but also through the demand and credit channels.

Even though our results clearly favor a concern for movements in housing and equity prices in monetary policy making and warns against a response to the exchange rate, it must be borne in mind that our findings are conditional on some simplifying assumptions. First, we have not touched upon the difficulties of identifying asset price misalignments, especially of equity prices. And second, our results are based on a particular model. Further research is therefore needed to investigate the generality of our conclusions.

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Appendix

A Monetary policy in Norway

[Table 4 about here]

B Data

The econometric model is based on seasonally unadjusted quarterly data. All time series have been extracted from the database of RIMINI, the quarterly macroeconometric model of Norges Bank. In the following, for each time series, the corresponding name in the RIMINI database is given in square brackets [variable name].

E Effective import weighted value of the NOK; 1991 = 1. [CPIVAL].

cap A step dummy for the liberation of capital flows. It takes on a value of 1 from 1990:3 and onwards.

G Public consumption expenditure, fixed 1991 prices. Mill. NOK. [CO].

H Standard working hours per week. [NH]

L/P Real credit volume. Mill. NOK. [K1M/CPI]. $l - p$ log of real credit volume.

$N1649AT$ Labor force in the age group 16-49 years. [N1649AT]

OIL Brent Blend crude oil prices per barrel in USD. [SPOILUSD].

P Norwegian Consumer Price Index. [CPI].

P^* Index for consumer prices in Norway's trading partners in foreign currency. [PCKONK].

PE Index for electricity prices that consumers face. [CPIEL].

PH Index for housing prices in Norway. [PH].

PM Deflator of total imports; 1991=1. [PB].

PR Mainland economy value added per man hour at factor costs, fixed base year (1991) prices. Mill. NOK. [ZYF].

PU Underlying Consumer price index. [KPIJAE].

r Euro-krone interest rate with 3 month maturity. [RS].

rl Bank lending rate [RLB].

rb Yield on Norwegian 6 year government bonds. [RB].

S Stock Price Index for Oslo Stock Exchange. [OSE].

S^* Morgan Stanley World Index (MSCI).

τ_1 Employers tax rate. [T1F].

τ_2 Marginal tax rate for households.[TMNI50].

τ_3 Indirect tax rate. [T3].

U Unemployment rate.[UR2].

W Hourly wages in mainland Norway.

Y Total value added at market prices in the mainland economy. Fixed base year (1991) prices. Mill. NOK. [YF].

Y^* Weighted average of GDP of trading countries, using share of Norwegian exports in 1985 as weights; 1991=1. [UEI].

C The econometric model

In this section, we present the main equations of the model, which is largely an extension of the model in Bårdsen and Nymoen (2001) and Bårdsen et al. (2003). For the sake of brevity, we have suppressed seasonal dummies and other dummies that are mainly related to changes in government policies, e.g. labor market reforms, caps on growth in wages and prices, and devaluations. In addition, we have left out equations for interest rates on lending, borrowing and Norwegian government bond yields. These interest rates depend on each other, short term interest rates (r) and foreign interest rates. Equations for these variables are very close to those documented in Bårdsen and Nymoen (2001) and Bårdsen et al. (2003). Details about the dummy variables used in this paper can also be found in these two references.

The complete model is block recursive in nature, so the simultaneous part of the model is estimated by FIML, while the equations constituting the recursive part are estimated by OLS. The estimation period ends in 2001:4 for all of the equation, but the start dates differ. More specifically, the equations for housing prices, stock prices, credit and aggregate demand are estimated using data from about the mid 1980s in order to control for the effects of deregulations of housing and credit markets. The remaining equations, which were found to be largely unaffected by possible structural and policy changes, when controlling for caps on price and wage growth of the late 1970s and early 1980s, have been estimated using data from 1972.

Split-sample tests of parameter constancy are reported below the equations. Recursive estimates of the coefficients and parameter constancy test statistics are not shown due to space limitations, but are available upon request. In addition to the Chow tests for parameter constancy, we also report the outcomes of tests for normality (nd), autocorrelation and heteroscedasticity.

C.1 The equations

Aggregate demand

$$\Delta\hat{y}_t = -\underset{(0.092)}{0.39}\ \Delta y_{t-1} + \underset{(0.013)}{0.024}\ \Delta(s-p)_{t-2} + \underset{(0.06)}{0.27}\ \Delta g_t\ +\ \underset{(0.11)}{0.46}\ cap_t \times \Delta\left(e+p^*-p\right)_t$$
$$-\underset{(0.076)}{0.3}\ \left[(y-0.5g-0.3y^* + (rl\,(1-\tau_2)-\Delta_4 p) - 0.1(ph-p)_{t-1} - 0.5\left(e+p^*-p\right)_{t-3}\right]$$

$$OLS;\ \mathrm{T} = 61,\ 1986{:}4\text{-}2001{:}4;\ \hat{\sigma} = 0.010$$

$$\begin{array}{llll}
\mathsf{F}_{\mathsf{Chow}(1994:2)}(31,21) & = 1.215\ [0.325] & \mathsf{F}_{\mathsf{ar}(1-4)}(4,48) & = 1.165\ [0.338] \\
\mathsf{F}_{\mathsf{Chow}(2000:2)}(7,45) & = 1.574\ [0.167] & \mathsf{F}_{\mathsf{arch}(1-4)}(4,53) & = 0.430\ [0.786] \\
\chi^2_{\mathsf{nd}}(2) & = 2.502\ [0.286] & \mathsf{F}_{\mathsf{het}}(13,47) & = 2.094\ [0.033]
\end{array}$$

Real credit demand

$$\Delta\widehat{(l-p)}_t \quad = \quad \underset{(0.023)}{0.07}\ \Delta y_t + \underset{(0.024)}{0.06}\ \Delta(ph-p)_t + \underset{(0.006)}{0.01}\ \Delta(s-p)_{t-2}$$
$$-\underset{(0.005)}{0.06}\ \left[(l-p)-0.5y-(ph-p)+3\,(rl-rb)\right]_{t-1}$$

$$OLS;\ \mathrm{T} = 61,\ 1986{:}4\text{–}2001{:}4;\ \hat{\sigma} = 0.005$$

$$\begin{array}{llll}
\mathsf{F}_{\mathsf{Chow}(1994:2)}(31,24) & = 0.845\ [0.674] & \mathsf{F}_{\mathsf{ar}(1-4)}(4,51) & = 0.821\ [0.518] \\
\mathsf{F}_{\mathsf{Chow}(2000:2)}(7,48) & = 0.978\ [0.458] & \mathsf{F}_{\mathsf{arch}(1-4)}(4,53) & = 0.800\ [0.531] \\
\chi^2_{\mathsf{nd}}(2) & = 1.089\ [0.580] & \mathsf{F}_{\mathsf{het}}(10,50) & = 0.739\ [0.685]
\end{array}$$

Housing prices

$$\widehat{\Delta ph}_t \quad = \quad \underset{(0.402)}{1.12}\ \Delta p_{t-2} + \underset{(0.021)}{0.04}\ \Delta s_{t-2} - \underset{(0.391)}{1.44}\ \Delta rl_t + \underset{(0.093)}{0.17}\ \Delta y_{t-2}$$
$$+\underset{(0.224)}{1.04}\ \Delta cr_{t-2} - \underset{(0.026)}{0.10}\ \Delta u_{t-3}$$
$$-\underset{(0.028)}{0.11}\ \left[ph-p-0.5y-0.25cr+4(rl(1-\tau_2)-\Delta_4 pu)\right]_{t-1}$$

$$OLS;\ \mathrm{T} = 73,\ 1983{:}4\text{–}2001{:}4;\ \hat{\sigma} = 0.017$$

$$\begin{array}{llll}
\mathsf{F}_{\mathsf{Chow}(1992:4)}(37,25) & = 0.478\ [0.980] & \mathsf{F}_{\mathsf{ar}(1-4)}(4,58) & = 2.033\ [0.102] \\
\mathsf{F}_{\mathsf{Chow}(2000:1)}(8,54) & = 1.050\ [0.411] & \mathsf{F}_{\mathsf{arch}(1-4)}(4,65) & = 1.684\ [0.164] \\
\chi^2_{\mathsf{nd}}(2) & = 0.268\ [0.875] & \mathsf{F}_{\mathsf{het}}(18,54) & = 1.924\ [0.033]
\end{array}$$

Domestic stock prices

$$\widehat{\Delta s - r}_t \quad = \quad \underset{(0.101)}{0.37}\ (\Delta s^*_t - r) + \underset{(0.0982)}{0.62}\ (\Delta s^*_{t-1} - r_{t-1}) - \underset{(1.09)}{5.44}\ \Delta r_t + \underset{(0.0733)}{0.14}\ \Delta oilp_t$$

$$OLS;\ \mathrm{T} = 61,\ 1986{:}4\text{–}2001{:}4;\ \hat{\sigma} = 0.083$$

$$\begin{array}{llll}
\mathsf{F}_{\mathsf{Chow}(1994:2)}(31,26) & = 0.512\ [0.962] & \mathsf{F}_{\mathsf{ar}(1-4)}(4,53) & = 0.979\ [0.427] \\
\mathsf{F}_{\mathsf{Chow}(2000:2)}(7,50) & = 0.742\ [0.638] & \mathsf{F}_{\mathsf{arch}(1-4)}(4,53) & = 0.486\ [0.746] \\
\chi^2_{\mathsf{nd}}(2) & = 0.400\ [0.819] & \mathsf{F}_{\mathsf{het}}(8,52) & = 0.569\ [0.799]
\end{array}$$

Nominal exchange rate

$$\Delta\hat{e}_t = \underset{(0.0772)}{0.22}\ \Delta e_{t-1} - \underset{(0.0323)}{0.14}\ (e-p+p^*)_{t-1} - \underset{(0.173)}{0.28}\ \Delta p_t^* - \underset{(0.101)}{0.34}\ \Delta r_t$$
$$- \underset{(0.144)}{0.21}\ \Delta(rb_{t-1} - \Delta p_{t-2}) - \underset{(0.0321)}{0.13}\ \frac{\Delta oil_t}{1+exp(4(OIL_t - 14.21))}$$
$$- \underset{(---)}{0.14}\ \left[(r_{t-1} - r_t^*) - (\Delta e - .8e)_{t-1}\right]$$

OLS; T = 116, 1973:1–2001:4; $\hat{\sigma} = 0.015$

$\mathsf{F}_{\mathsf{Chow}(1987:3)}(58,50)$	$= 0.458$ [0.9978]	$\mathsf{F}_{\mathsf{ar}(1-4)}(4,104)$	$= 0.553$ [0.6970]
$\mathsf{F}_{\mathsf{Chow}(1999:1)}(12,96)$	$= 0.630$ [0.8123]	$\mathsf{F}_{\mathsf{arch}(1-4)}(4,108)$	$= 0.197$ [0.9394]
$\chi^2_{\mathsf{nd}}(2)$	$= 10.125$ [0.0063]	$\mathsf{F}_{\mathsf{het}}(14,101)$	$= 0.814$ [0.6527]

Unemployment rate

$$\Delta\hat{u}_t = \underset{(0.0677)}{0.338}\ \Delta u_{t-1} - \underset{(0.017)}{0.053}\ u_{t-1} - \underset{(0.291)}{1.87}\ \Delta_4 y_t - \underset{(1.04)}{3.04}\ \Delta y^*_{t-2}$$
$$+ \underset{(0.522)}{1.22}\ \Delta(w-p)_{t-1} + \underset{(0.702)}{1.68}\ N1649AT_t$$

OLS; T = 117, 1972:4–2001:4; $\hat{\sigma} = 0.060$

$\mathsf{F}_{\mathsf{Chow}(1987:3)}(58,44)$	$= 0.787$ [0.8049]	$\mathsf{F}_{\mathsf{ar}(1-4)}(4,98)$	$= 0.300$ [0.8776]
$\mathsf{F}_{\mathsf{Chow}(1999:1)}(12,90)$	$= 0.830$ [0.6198]	$\mathsf{F}_{\mathsf{arch}(1-4)}(4,108)$	$= 0.881$ [0.4782]
$\chi^2_{\mathsf{nd}}(2)$	$= 2.574$ [0.2761]	$\mathsf{F}_{\mathsf{het}}(23,92)$	$= 1.854$ [0.0208]

Wage growth and Inflation

$$\Delta\hat{w}_t = \underset{(0.095)}{0.39}\ \Delta p_{t-1} + \underset{(0.097)}{0.37}\ \Delta p_{t-2} - \underset{(0.11)}{0.49}\ \Delta h_t - \underset{(0.012)}{0.094}\ \left[(w-p-pr)_{t-1} + 0.1u_{t-2}\right]$$

$$\Delta\hat{p}_t = \underset{(0.031)}{0.27}\ \Delta w_t + \underset{(0.021)}{0.13}\ \Delta w_{t-1} + \underset{(0.009)}{0.036}\ \Delta pm_t + \underset{(0.008)}{0.065}\ \Delta pe_t + \underset{(0.012)}{0.038}\ \Delta y_{t-1}$$
$$- \underset{(0.006)}{0.062}\ \left[p_{t-3} - 0.65\,(w_{t-2} - pr_{t-1} + \tau_{1,t-1}) - 0.35pm_{t-1} - 0.5\tau_{3,t-1}\right]$$

$FIML$; T = 117, 1972:4–2001:4; $\hat{\sigma}_{\Delta w} = 0.009$, $\hat{\sigma}_{\Delta p} = 0.004$

$\mathsf{F}_{\mathsf{ar}(1-5)}(20,198)$	$= 1.58$ [0.06]
$\chi^2_{\mathsf{nd}}(4)$	$= 4.36$ [0.36]
$\mathsf{F}_{\mathsf{het}}(135,186)$	$= 1.25$ [0.08]

Tables and figures

Table 1: Specification of simple interest rate rules

Arguments:		r_{t-1}	$\Delta_4 pu_t$	$\Delta_4 y_t$	q_t	q_{t-1}	$\Delta_4 ph_t$	$\Delta_4 s_t$
Steady states:		$\bar{\pi} + \overline{rr}$	$\bar{\pi}$	$\bar{g}_y$	$\bar{q}$	$\bar{q}$	$\bar{\pi}_{ph}$	$\bar{g}_s$
Steady state values:		0.06	0.025	0.025	0	0	0.10	0.10
Weights:		ω_r	ω_π	ω_y	ω_{q0}	ω_{q1}	ω_{ph}	ω_s
Flexible	FLX		1.5	0.5				
Smoothing	SM	0.75	1.5	0.5				
Exchange rate	MCI		1.5	0.5	0.33			
Housing prices	PH		1.5	0.5			0.20	
Equity prices	OSE		1.5	0.5				0.20
Composite rule	CMP	0.25	1.5	0.5	0.25	-0.25	0.05	0.05

Note: $r_t = \omega_r r_{t-1} + (1-\omega_r)(\bar{\pi} + \overline{rr}) + \omega_\pi(\Delta_4 pu_t - \bar{\pi}) + \omega_y(\Delta_4 y_t - \bar{g}_y)$
$+\omega_{q0}(q_t - \bar{q}) + \omega_{q1}(q_{t-1} - \bar{q}) + \omega_{ph}(\Delta_4 ph_t - \bar{\pi}) + \omega_s(\Delta_4 s_t - \bar{g}_s)$

Table 2: *Mean and relative standard deviations of key variables under different rules*

		Simulation period 1995:1–2000:4:						
		$\Delta_4 pu_t$	$\Delta_4 y_t$	Δr_t	e_t	$\Delta_4 ph_t$	$\Delta_4 s_t$	$\Delta_4(l-p)_t$
Sample	Mean	0.019	0.027	0.000	0.013	0.106	0.163	0.074
1995:1-2000:4	sdev	0.005	0.023	0.007	0.017	0.040	0.232	0.023
	Mean	0.019	0.028	-0.001	0.016	0.109	0.163	0.075
Flexible rule FLX	Rel. sdev	0.85	0.81	1.92	1.36	1.19	0.77	1.00
	Mean	0.021	0.030	-0.001	0.024	0.121	0.161	0.086
Smoothing SM	Rel. sdev	0.92	0.88	1.53♠	1.51	1.24	0.68	1.20
	Mean	0.019	0.028	0.000	0.014	0.107	0.161	0.073
Exchange rate MCI	Rel. sdev	0.87	0.84	2.18	1.19♠	1.18	0.87	0.99
	Mean	0.020	0.027	-0.001	0.015	0.108	0.156	0.076
Housing prices PH	Rel. sdev	0.80♠	0.81	1.78	1.32	0.98♠	0.77	0.89♠
	Mean	0.019	0.028	0.000	0.011	0.105	0.140	0.069
Equity prices OSE	Rel. sdev	0.85	0.77♠	1.61	1.71	1.53	0.36♠	1.06
	Mean	0.020	0.028	0.000	0.016	0.110	0.148	0.076
Composite rule CMP	Rel. sdev	0.85	0.80	1.53♠	1.38	1.22	0.60	1.01

Note: The symbol ♠ denotes the minimum value of the standard deviation (relative to the FLX rule) in a column.

Table 3: Some efficient interest rate rules without and with asset prices

Arguments:		r_{t-1}	$\Delta_4 pu_t$	$\Delta_4 y_t$	q_t	$\Delta_4 ph_t$	$\Delta_4 s_t$
Steady states:		$\bar{\pi} + \overline{rr}$	$\bar{\pi}$	$\bar{g}_y$	$\bar{q}$	$\bar{\pi}_{ph}$	$\bar{g}_s$
Steady state values:		0.06	0.025	0.025	0	0.10	0.10
Weights:		ω_r	ω_π	ω_y	ω_{q0}	ω_{ph}	ω_s
Without Asset prices:	TR1	0.25	1.5	2			
	TR2	0.00	4	0.5			
	TR3	0.3	4	0.00			
With Asset prices:	AP1	0.25	1.5	2	0	0.2	0
	AP2	0	4	0	0	0.1	0

Note: $r_t = \omega_r r_{t-1} + (1-\omega_r)(\bar{\pi} + \overline{rr}) + \omega_\pi(\Delta_4 pu_t - \bar{\pi}) + \omega_y(\Delta_4 y_t - \bar{g}_y)$
$+\omega_{q0}(q_t - \bar{q}) + \omega_{ph}(\Delta_4 ph_t - \bar{\pi}_{ph}) + \omega_s(\Delta_4 s_t - \bar{g}_s)$.

Note: The weights recorded in this table are based on model simulations. They define (some of) the efficient interest rate rules, which correspond to the points marked on the efficiency frontiers in Figure 7.

Table 4: Norwegian monetary policy since 1972

Exchange rate regimes	Period	Vis-a-vis	Major fluctuations
Fixed: European *snake*	1972:5–78:12	Euro. currencies	5% reval., 16 Nov., 1973
			§5% deval., 29 Aug., 1977
			§8% deval., 2 Feb., 1978
Fixed: Currency basket	1978:12–90:10	Trade weighted	12% deval., 5 May, 1986
Fixed: EMS	1990:10–92:12	ECU	6% depr., 10 Dec., 1992; temporary switch to float
Float (Managed)	1992:12–94:5	ECU	
Stable without bands	1994:5–98:12	ECU	7% appr., 1996:1–97:1; defence abandoned on 10 January, 1997. 5% appr. 5 Feb., 1997. 6% depr. 24 Aug., 1998; and defence abandoned. 14% depr. 28 Aug., 1998
Stable without bands	1999:1–01:3	Euro	
Floating with Inflation target	2001:3–	$\bar{\pi} = 2.5\%$	

Note: *Major fluctuations* are defined as exchange rate changes equal to or above 5%, relative to central parities. §Officially motivated by concerns for the external competitiveness owing to relatively high wage and price inflation. Sources: Several issues of *Economic Bulletin* published by Norges Bank.

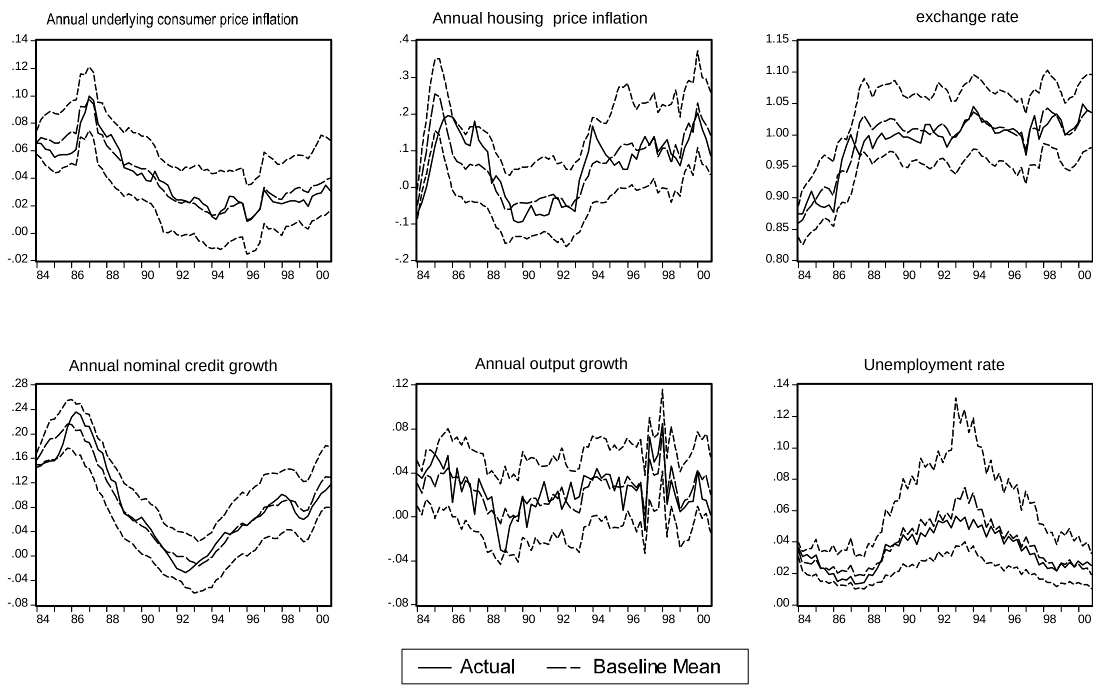

Figure 1: *Dynamic baseline simulation of the model over the period 1984:1−2001:1. Here and elsewhere in this paper dashed lines depict 95% confidence intervals. The simulations are based on dynamic simulations of the full model conditional on actual values of the exogenous variables: foreign GDP growth, oil prices and domestic and foreign money market rates.*

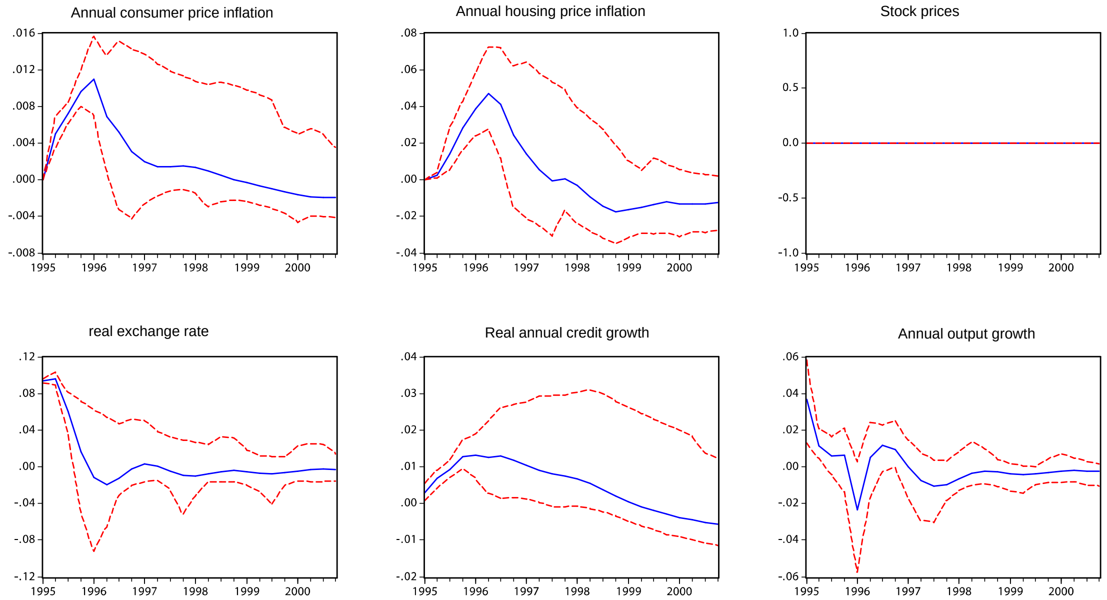

Figure 2: *Responses to a transitory shock in 1995:1 that induces a 10% depreciation of the nominal exchange rate. Solid lines depict deviations from the baseline simulations.*

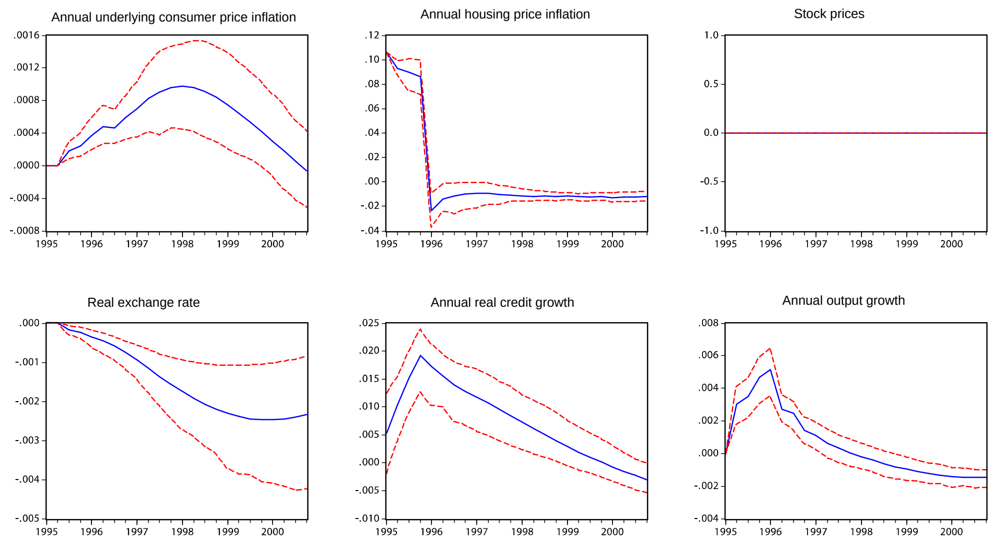

Figure 3: *Responses to a transitory shock that increases housing prices by 10% in 1995:1*

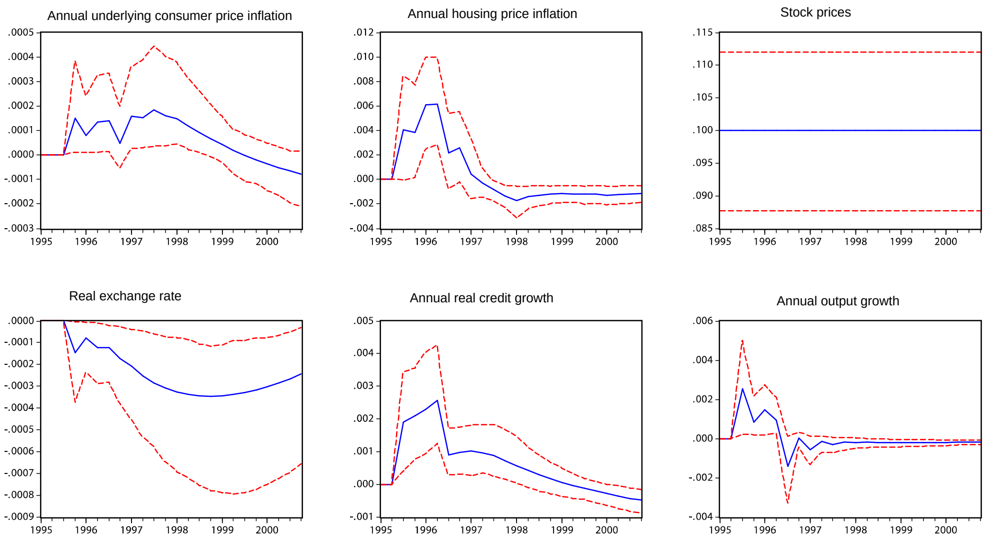

Figure 4: *Responses to a transitory shock that increases equity prices by 10% in 1995:1*

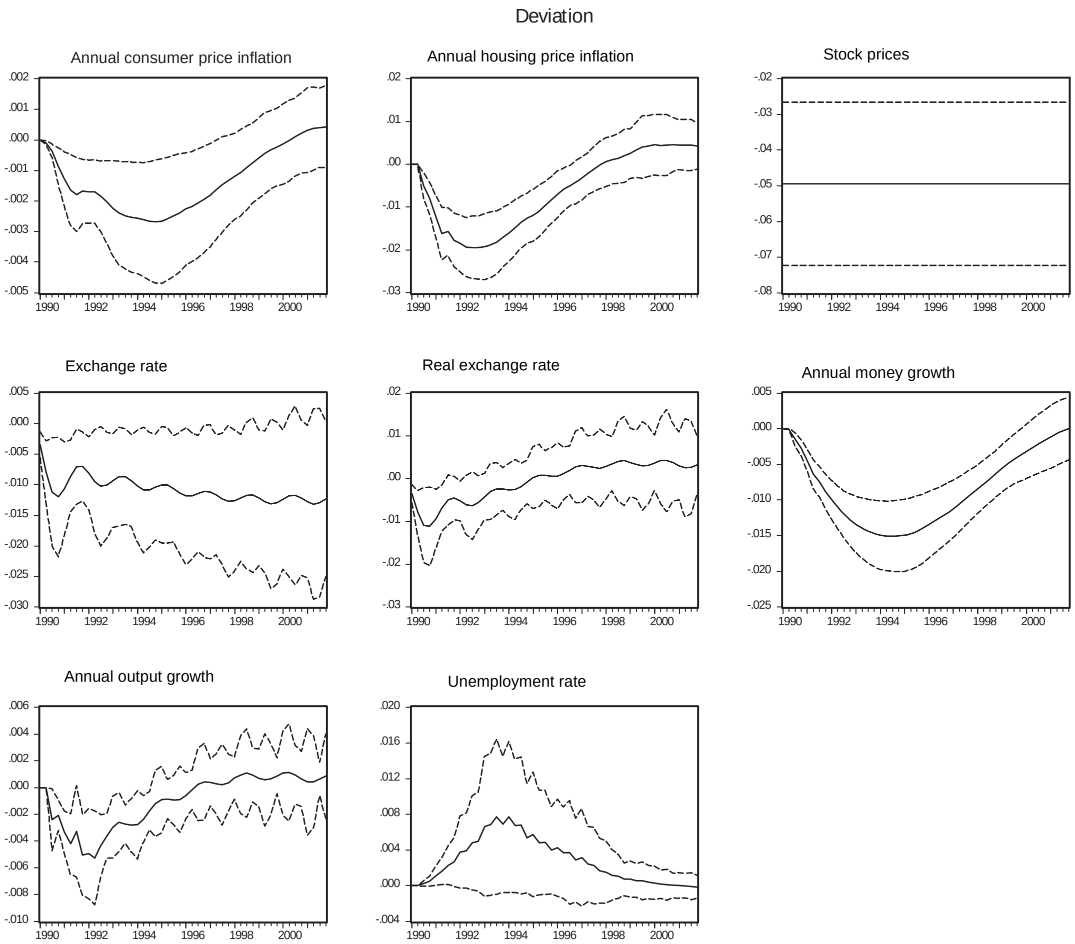

Figure 5: *Responses to a percentage point rise in short-term interest rates*

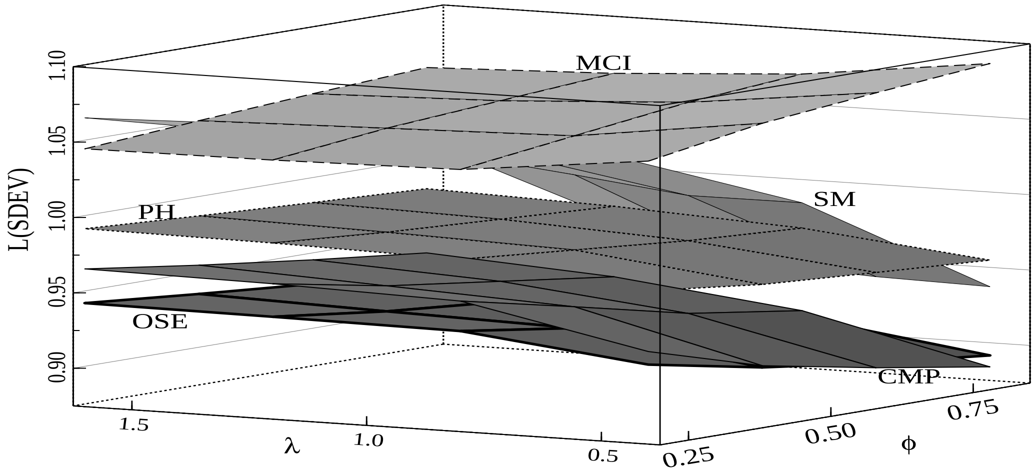

Figure 6: Loss function evaluation based on relative variances (to the FLX rule) $\pounds(\lambda, \theta) = V[\Delta_4 pu_t] + \lambda V[\Delta_4 y_t] + \phi V[\Delta r_t]$ for $\lambda \in (0, 0.5, 1, 2)$, $\phi \in (0, 0.1, 0.5, 1)$.

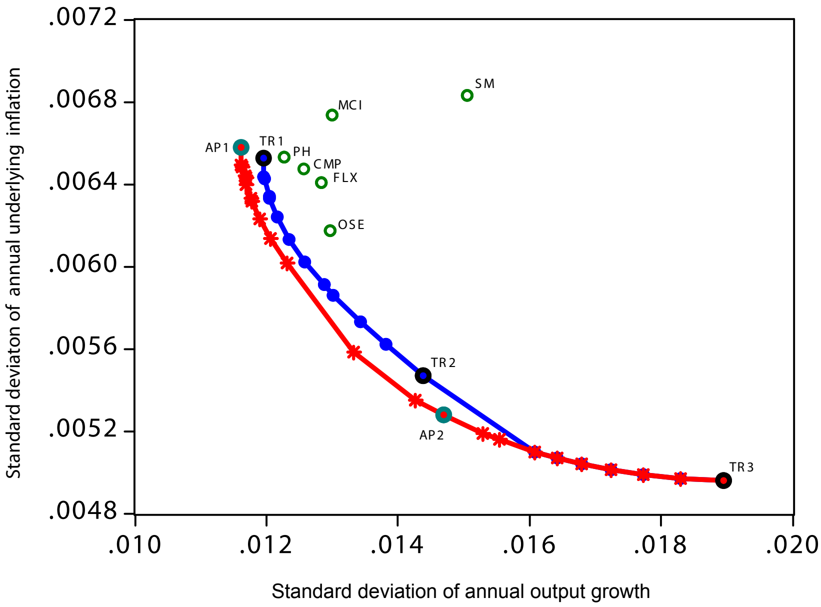

Figure 7: *Efficiency frontiers for efficient interest rate rules without (including TR1–TR3) and with response to asset prices (including AP1 and AP2). We also mark the outcomes of the simple interest rate rules defined in Table 1.*