ANO 2006/7

Oslo

July 6, 2006

Working Paper

Research Department

Flexible inflation targeting and financial stability: Is it enough to stabilise inflation and output?

by

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ISSN 0801-2504 (printed) 1502-8143 (online)

ISBN 82-7553-358-9 (printed), 82-7553-359-7 (online)

Flexible inflation targeting and financial stability: Is it enough to stabilize inflation and output?*

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June 26, 2007

Abstract

We investigate empirically whether a central bank can promote financial stability by stabilizing inflation and output, and whether additional stabilization of asset prices and credit growth would enhance financial stability in particular. We employ an econometric model of the Norwegian economy to investigate the performance of simple interest rate rules that allow a response to asset prices and credit growth, in addition to inflation and output. We find that output stabilization tends to improve financial stability. Additional stabilization of house prices, equity prices and/or credit growth enhances stability in both inflation and output, but has mixed effects on financial stability. In general, financial stability as measured by e.g. asset price volatility improves, while financial stability measured by indicators that depend directly on interest rates deteriorates, mainly because of higher interest rate volatility owing to a more active monetary policy.

Keywords: *Monetary policy, financial stability, asset prices, interest rate rules.*

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

*We would like to thank two anonymous referees for very useful comments. We are also grateful to Andrew Filardo, Jonathan Temple, participants at the workshop "The Architecture of Financial Stability System" in 2006 and several colleagues at Norges Bank (the central bank of Norway) for useful comments. The views expressed are those of the authors, and do not necessarily represent those of Norges Bank. Corresponding author: farooq.akram@norges-bank.no. Fax: +47 2242 4062. Address: Bankplassen 2, P.O. Box. 1179 Sentrum, 0107 Oslo, Norway.

1 Introduction

Inflation-targeting central banks are generally entrusted with the responsibility of promoting a stable financial system as well. A stable financial system facilitates a regular and efficient allocation of funds between savers and borrowers and diversification of risk. It is therefore conducive to long-term economic growth, stable movements in prices and output and an effective monetary policy. The detrimental effects of financial instability on the macroeconomy are widely acknowledged. Fisher (1933) ascribed the great depression (1929–1933) mainly to over-indebtedness and the resulting deflation due to distress selling of assets. A more recent example of such a debt-deflation phenomenon is the Japanese experience; see e.g. Mishkin (2005) and the references therein. In Norway, and the other Scandinavian countries, high credit growth and booms and busts in the real estate markets contributed to severe banking crises and recessions especially in the early 1990s; see e.g. Hoggarth *et al.* (2002) and Grung-Moe *et al.* (2004).

We investigate empirically to what extent a flexible inflation-targeting central bank can promote financial stability by stabilizing inflation and real output, or as a special case, nominal income; cf. McCallum and Nelson (1999). A flexible inflation-targeting central bank typically incorporates a concern for output stability when targeting inflation; cf. Svensson (1999). We particularly investigate whether there are gains in terms of financial stability, as well as in terms of inflation and output stability, by additionally stabilizing variables that are commonly linked to financial (in)stability, such as asset prices and credit growth; see e.g. Borio and Lowe (2002).

In the relevant literature, there is as yet no consensus as to whether inflation targeting alone or in combination with output stabilization will ensure financial stability in the normal course of monetary policy making; see e.g. Cecchetti *et al.* (2000), Bordo and Jeanne (2002), Roubini (2006), Posen (2006) and the references therein. A common argument is that stable inflation is conducive to a regular and efficient flow of funds between savers and borrowers since undue real wealth transfers between them, owing to inflation or deflation, can be largely avoided. In addition, prices can better guide consumption and investment and thereby help avoid over-investment and possible failures to service accrued debt. Stabilization of inflation also helps checking possible deflationary effects of distress selling of assets to pay off debt; cf. Fisher (1933) and Mishkin (2005). By additionally stabilizing output one can better maintain the debt-servicing capacity of borrowers and thereby avoid debt liquidation. A stable nominal income could be especially effective in maintaining the debt-servicing capacity of borrowers when nominal wages are sticky; cf. Bean (1983).

However, it has been argued that monetary policy may fail to deal timely and effectively with potential future economic instability implied by unchecked growth in credit and asset prices by just focusing on prices and/or output; see e.g. Cecchetti *et al.* (2000), Bordo and Jeanne (2002) and Borio and Lowe (2002). It has been pointed out that excessive debt accumulation and over-investment usually occurs in periods of a boom in asset prices because of their collateral effects on borrowing and lending; cf. Bernanke *et al.* (1999). Debt liquidation due to failures to service accrued debt or erosion of collateral values owing to asset price busts can lead to a credit crunch, business failures, unemployment and deflation. Furthermore, stabilization of inflation and output may not be sufficient to induce a stable growth in asset prices and credit, and thereby a stable financial sector and real economy, because asset prices are often more or less disconnected from their fundamentals. This may also contribute to disconnecting credit from its sustainable value because asset prices affect collateral values. Such behavior of asset prices and credit may therefore fuel unsustainable growth in consumption and investment and thereby contribute to macroeconomic instability, including financial fragility.

Accordingly, monetary policy can become more effective in reaching its macroeconomic objectives, including financial stability, by stabilizing asset prices and/or credit, in addition to inflation and output. The case for a monetary policy response to misalignments in asset prices such as real estate and equity prices has been made by e.g. Cecchetti *et al.* (2000), Borio and Lowe (2002) and Filardo (2004) and investigated by e.g. Filardo (2000) and Chadha *et al.* (2004). A response to misalignments in exchange rates is discussed in *inter alia* Ball (1999b).

Apparently, a tightening (easing) of monetary policy when asset prices rise above (below) sustainable levels may help to smooth fluctuations in credit growth, output and inflation. Such moves may also reduce the possibility of large asset price misalignments arising in the first place. On the other hand, asset prices are quite volatile and sustainable values of asset prices are hard to identify. The end result could therefore be an overactive monetary policy that may prove to destabilize the economy in general. Moreover, a misjudgment of the sustainable values can alternatively lead to an overly stable economy at the expense of efficient resource allocation.

Responding directly to credit growth is another option. It is possible that stable credit growth can contribute to reining in movements in asset prices as well as consumption and investment and thereby promote economic stability in general, and financial stability in particular. Experience from money growth targeting in some countries, including that of the USA in the early 1980s, is not encouraging, however. Accordingly, stabilization of credit growth can also induce excess volatility in interest rates, which may have a destabilizing effect on the real economy and the financial system. Yet, it is possible that the stabilization effect of asset prices and credit growth on inflation and output is of such magnitude that interest rates ultimately become more stable. An empirical investigation can shed light on the merits of responding directly to asset prices and/or credit growth in addition to inflation and output.

We investigate the performance of a large number of simple interest rate rules within the context of a well specified econometric model of a small economy, Norway, where exchange rates tend to play a more important role than in large economies. The model links credit growth and three classes of asset prices, i.e. house prices, equity prices and the nominal exchange rate, and the rest of the economy through several channels. The model is therefore well suited for evaluating the performance of Taylor-type interest rate rules augmented with asset prices and/or credit growth; see e.g. Taylor (1999). The model used is largely an extension of the model in Bårdsen and Nymoen (2001) and Bårdsen *et al.* (2003), and is presented in detail in an earlier version of this paper: Akram and Eitrheim (2006).[1]

In the next section we point out some key properties and mechanisms in the econometric model. We also present a stylized version of the model, to easily highlight the role of asset prices and credit growth in the model. Section 3 presents the objective function of a central bank under a flexible inflation-targeting regime, discusses several operational indicators of financial (in)stability and presents a general version of a simple interest rate rule that encompasses all of the rules evaluated, including non-linear versions of the simple rules. This section also sheds light on the key properties of the rules and mechanisms that come into play when the policy rate responds to movements in asset prices and credit. Section 4 presents our main analysis and the outcomes of sensitivity analyses, which support our main findings. Section 5 offers our main conclusions, while the appendix presents details about relevant variables and model simulations.

2 The model in a stylized form

The model pertains to the Norwegian mainland economy, i.e. exclusive of its petroleum sector. It explicitly takes into account several channels of interplay between asset prices, credit, output and inflation. Specifically, the model includes equations of house prices, domestic equity prices, the nominal exchange rate, credit demand, aggregate demand, unemployment, wages and domestic consumer prices. Monetary policy represented by short-term nominal interest rates has direct effects on the three asset prices including the nominal exchange rate, credit and aggregate demand, but it is neutral in the long run. The model may be considered a backward-looking model in the sense that the expectations formation process is not explicitly modeled.

The model is (log) linear and its equations are in error-correction form. They have been specified and estimated on samples of quarterly aggregate data from the period 1970–2001. The model is econometrically well specified, with apparently invariant parameters with respect to changes in monetary policy over the sample; its statistical properties are documented in Akram and Eitrheim (2006). The model characterizes a stable (economic) system where effects of transitory shocks eventually die out. A linear stable model may be considered appropriate for shedding light on the merits of incorporating concern for financial stability, considered as an observable state of affairs, in

[1] Available from http://www.norges-bank.no/upload/import/publikasjoner/arbeidsnotater/pdf/arb-2006-07.pdf

the normal course of monetary policy making than in situations of crises or near-crises. Non-linear models are required to model the latter situations.[2]

To highlight the transmission mechanism of asset prices in the Norwegian economy, we present a stylized version of the model used in equations (1)–(8), obtained by following the approach of Bårdsen (2005). Here, effects of exogenous variables such as foreign output, interest rates, oil prices and government expenditures have been suppressed. Our results, however, are based on the complete model, as presented in Akram and Eitrheim (2006), with its rich dynamics and embedded attention to institutional and structural changes in the Norwegian economy since the 1970s.

Below, all variables except nominal interest rates (r) are in natural logarithms. Δ denotes the first difference operator, and foreign variables are denoted by starred superscripts. The nominal effective 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 (log of) nominal credit demand, while pr denotes labor productivity; see the appendix for precise definitions of the variables.

$$\begin{aligned}
\text{Aggregate demand: } \Delta y_t &= 0.02\Delta(s-p)_t + 0.3\Delta q_t && (1)\\
&\quad - 0.2\left[y + (r - \Delta_4 p) - 0.5q - 0.1(ph - p)\right]_{t-1}, \\
\text{Real credit: } \Delta\left(\ell - p\right)_t &= 0.1\Delta y_t + 0.05\Delta\left(ph - p\right)_t + 0.01\Delta\left(s - p\right)_t && (2)\\
&\quad - 0.05\left[(\ell - p) - 0.5y + 3r - (ph - p)\right]_{t-1}, \\
\text{House prices: } \Delta ph_t &= 1.1\Delta p_t + 0.05\Delta s_t + 0.2\Delta y_t + 1.0\Delta\left(\ell - p\right)_t - 1.4\Delta r_t && (3)\\
&\quad - 0.1\left[(ph - p) - 0.5y - 0.25\left(\ell - p\right) + 4\left(r - \Delta p\right)\right]_{t-1}, \\
\text{Equity prices: } \left(\Delta s - r\right)_t &= 0.9(\Delta s^* - r)_t - 5\Delta r_t\ , && (4)\\
\text{Exchange rate: } \Delta e_t &= -0.5\Delta r_t - 0.1(r - r^*)_t - 0.1\left[e - (p - p^*)\right]_{t-1}, && (5)\\
\text{Unemployment: } \Delta u_t &= -0.1u_{t-1} - 2.8\Delta y_t, && (6)\\
\text{Wages: } \Delta w_t &= 0.7\Delta p_t - 0.1[w - p - pr + 0.1u]_{t-1}, && (7)\\
\text{Consumer prices: } \Delta p_t &= 0.4\Delta w_t + 0.05\Delta y_t - 0.06\left[p - 0.7\left(w - pr\right) - 0.3\left(e + p^*\right)\right]_{t-1}. && (8)
\end{aligned}$$

Aggregate demand (y_t) is characterized in equation (1). Equity prices and house prices, in particular, have wealth effects on aggregate demand; cf. Kiyotaki and Moore (1997). In addition, aggregate demand is affected by the real interest rate ($r - \Delta_4 p$) and the real exchange rate q. Thus, a change in the nominal exchange rate would also directly affect aggregate demand.[3]

[2] Another argument for using non-linear models becomes relevant if one considers financial stability as a property of a system rather than a state of affairs; see Allen and Wood (2006). Accordingly, a stable linear model would be considered unsuitable for studying financial stability in this case, since financial instability would be ruled out *a priori* by model design.

[3] We have not found any significant direct effect of oil prices on aggregate demand (of the mainland economy).

Equity prices and house prices have collateral effects on (real) credit demand; see equation (2). Credit demand also depends on income (represented by actual output (y_t)) and interest rates, as in a standard money-demand equation.

House prices in real terms are mainly determined by income, interest rates and credit; see equation (3). Equity prices have also some short-run effects on house prices. Credit affects the economy through its effects on house prices.

Nominal equity 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 relationship obtained in equation (4) suggests that excess returns on the Norwegian stock market portfolio $(\Delta s - r)_t$ move closely with excess returns on the international market portfolio. There is a strong negative relationship between changes in interest rates and excess returns on the domestic stock market. In addition, an increase in oil prices (here suppressed) has a positive effect on equity prices, and thereby on aggregate demand, credit growth and house prices; see equations (1)–(3).

The nominal exchange rate appreciates when the interest rate and/or the interest rate differential increases, ceteris paribus; see equation (5). It also reacts to correct deviations from PPP and thereby contributes to stabilizing the real exchange rate; see Akram (2006). Also, a rise in oil prices (here suppressed) tend to appreciate the nominal exchange rate in the short run. In the long run, the nominal exchange rate reflects the difference between domestic and foreign prices and any difference between domestic and foreign interest rates. Accordingly, domestic inflation becomes fully reflected in the nominal exchange rate in the long run.

The unemployment rate u_t follows output growth in the short run, as in an Okun's law relationship; see equation (6). In addition, it reverts slowly towards its equilibrium rate, which also depends on an intercept term (here suppressed).

There is a partial pass-through of consumer price inflation to nominal wage growth (Δw) in the short run; see equation (7). In each period, nominal wages adjust towards their long-run relationship where there is a full pass-through of consumer prices and productivity. However, the mark-up of wages on prices and productivity falls with the unemployment rate.[4]

In the short run, consumer price inflation varies with changes in aggregate demand and to some extent nominal wage growth; see equation (8). In addition, it adjusts to correct deviations from the long-run relationship for consumer prices. In the long run, consumer prices reflect a weighted average of domestic and imported costs, represented by unit labor costs and import

However, oil prices indirectly affect aggregate demand through their positive effects on equity prices and the nominal exchange rate; see the complete equations in Akram and Eitrheim (2006). One reason for the absence of direct oil price effects could be that the effects of oil prices are already taken into account by the government consumption variable, which is exogenous (and hence is suppressed in equation (1), but appear explicitly in the detailed documentation of the model in Akram and Eitrheim (2006)). Norwegian oil revenues are invested abroad while the return on the petroleum assets abroad is used by the government in accordance with a fiscal policy rule.

[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.

prices. The model also includes an equation for the underlying inflation rate ($\Delta_4 pu$), which is linked to consumer price inflation.

Impulse response of key variables to shocks in asset prices (equity prices, house prices and the nominal exchange rate) and short-term interest rates are helpful in understanding the results to be presented. The impulse responses (based on the complete model) reveal the following overall effects of shocks to asset prices, credit growth and short-term interest rates. First, a shock to the nominal exchange rate has stronger and more immediate effects on inflation and output growth than shocks to house prices and equity prices. This is partly because the nominal exchange directly affects inflation and aggregate demand. The initial effect of a nominal exchange rate on aggregate demand becomes modified over time, however, due to the exchange rate pass-through to inflation, whose effect is opposite to that of the nominal exchange rate on the real exchange rate. House prices and equity prices affect aggregate demand and (through that) domestic inflation with some lags. Second, house prices tend to have relatively stronger effects on credit growth than the nominal exchange rate and equity prices. And third, a shock to interest rates directly affects the asset prices, credit and aggregate demand. Asset prices respond more strongly than credit and aggregate demand to changes in interest rates.

3 Monetary policy objectives and interest rate rules

The following version of a standard quadratic loss function can be used to represent monetary policy objectives under strict and flexible inflation-targeting regimes:

$$L(\lambda, \phi) = V(\widetilde{\pi}) + \lambda V(\widetilde{y}) + \phi V(f), \tag{9}$$

where $V(\widetilde{\pi})$ denotes the variance of price inflation relative to a fixed inflation target, $\widetilde{\pi}$, $V(\widetilde{y})$ denotes the variance of output relative to an equilibrium path, $\widetilde{y}$; while $V(f)$ is a variance term representing financial instability. The parameters λ and ϕ are the weights the monetary policy authority attaches to output and financial instability, respectively. The loss function under a flexible inflation-targeting regime with a preference for output and financial stability can be defined by $\lambda > 0$ and $\phi > 0$, while a strict inflation-targeting regime can be defined by $\lambda = \phi = 0$; cf. Svensson (1999).

The issue of interest for this study is whether an inflation-targeting central bank with a preference for output and financial stability can obtain a better performance by responding to excess movements in asset prices and/or credit than by just responding to excess fluctuations in inflation and output. Moreover, whether it can by additionally responding to asset prices or credit increase stability in inflation and output, even when financial stability is not its concern, i.e. $\phi = 0$.

3.1 Financial stability

We employ several indicators of financial stability since there does not seem to exist a widely accepted definition and (hence) indicator of financial stability; see e.g. Allen and Wood (2006) for a discussion. Nevertheless, financial instability is commonly associated with periods of booms and busts in asset prices and credit; see e.g. Borio (2005) and the references therein.

Booms and busts in asset prices can be represented by the (empirical) variances of asset prices which can be used as indicators of the state of financial stability. A low variance of asset prices can indicate that they are fluctuating largely in line with their sustainable values, while a high variance can signal that they are frequently misaligned relative to their sustainable values. A positive weight on the variance measure in the loss function also implies that the monetary policy authority wants to avoid positive as well as negative misalignments. One may therefore let the variable f be a function of asset prices. It is also common to use variance of (changes in) interest rates as an indicator of financial stability, partly because volatility in interest rates is among the main determinants of volatility in asset prices.

However, one may argue that financial instability is generally associated with fluctuations in several financial and real economic variables rather than in just asset prices. The state of financial stability may therefore be difficult to assess by merely focusing on a single or a limited set of either financial or real economic variables. Below, we consider such broad indicators.

Consequences of booms and busts in asset prices for financial stability may depend on the debt burden of borrowers relative to their carrying capacity. A stable debt burden relative to the carrying capacity therefore seems conducive to financial stability. This motivates use of measures such as the debt to income ratio: $f = L/PY$, where L is the level of nominal credit, while PY defines nominal income; P is the consumer price index, since the GDP deflator is not modeled.

In the medium run, however, defaults on loans to households and firms are usually associated with their inability to service their debt rather than to the debt level itself. This suggests defining f as the debt service to income ratio: $f = r_L L/PY$, where r_L is the nominal lending interest rate, which is a function of the short-term interest rate (r) in the model.

We also define f as the broader financial fragility indicator employed by Eitrheim and Gulbrandsen (2001).[5] This indicator depends on a number of variables that are commonly considered to be of direct relevance to financial stability. These are the debt service ratio, real interest rate, the unemployment rate and the real values of the three asset prices: house prices, equity prices and the nominal exchange rate. These variables are able to explain a substantial fraction of accrued losses in the Norwegian financial sector (mainly banks); see Eitrheim and Gulbrandsen (2001). Finally, we consider a version of this indicator net of direct interest rate effects since interest rate fluctuations themselves need not harm financial stability if the other financial and real economic

[5] See http://www.bis.org/publ/bispap01o.pdf, p. 321 for details.

variables remain stable, partly because of movements in interest rates.

3.2 Simple interest rate rules

We characterize monetary policy by different simple interest rate rules and evaluate their performance within the econometric model in terms of standard deviations of the excess inflation, output growth and the financial stability indicators; cf. Taylor (1999) and the references therein. We consider linear as well as non-linear simple interest rate rules. These rules can be obtained as special cases of the following general interest rate rule:

$$
\begin{aligned}
r_t = &(\bar{\pi} + \overline{rr}) + \omega_\pi(\Delta_4 pu_t - \bar{\pi}) + \omega_y(\Delta_4 y_t - \mu_y) \\
&+ \omega_r(r_{t-1} - (\bar{\pi} + \overline{rr})) \\
&+ \omega_{e,t}(e_t - (p - p^f)_t) + \omega_{ph,t}(\Delta_4 ph_t - \mu_{ph}) + \omega_{s,t}(\Delta_4 s_t - \mu_s) \\
&+ \omega_{\ell,t}(\Delta_4 \ell_t - \mu_\ell).
\end{aligned} \tag{10}
$$

Here, $\bar{\pi}$ represents the (constant) inflation target while $\overline{rr}$ represents an equilibrium real interest rate. Their sum, $(\bar{\pi} + \overline{rr})$, defines the neutral nominal interest rate. The μs represent steady values of the growth terms which are assumed to be constant. The ωs denote constant or time varying response coefficients associated with the different terms in the rule; subscript t indicates time variation.

The interest rate rule is specified mostly in terms of growth gaps. Such a specification turned out to improve on results obtained by using deviations from equilibrium paths, defined by the error-correction terms in the model, except for the nominal exchange rate term. In the latter case, interest rates respond to the deviation between the nominal exchange rate and its equilibrium path, i.e. the difference between domestic and foreign prices in line with the PPP hypothesis. Also, the terms entering the rule are assumed to be contemporaneous with the interest rate changes, for simplicity. A forward- or backdating of the terms did not change our conclusions.[6]

The first two lines in the rule specify a Taylor-type rule, hereafter Taylor rule, without and with interest rate smoothing, respectively; see e.g. Taylor (1999) and the contributions therein. Here, the inflation gap is specified in terms of the underlying annual inflation rate ($\Delta_4 pu_t$), in line with the monetary policy in Norway. The rule includes output growth, instead of the output gap, since it provides a better fit with the actual policy than the output gap over the simulation period.[7] Moreover, output growth usually undergoes smaller data revisions than the output gap.

[6]Our conclusions are also robust to the following alternative specification of the linear interest rate rule: $r_t = \omega_r(r_{t-1} - (\bar{\pi} + \overline{rr})) + (1 - \omega_r)[(\bar{\pi} + \overline{rr}) + \omega_\pi(\Delta_4 pu_t - \bar{\pi}) + \omega_y(\Delta_4 y_t - \mu_y) + \omega_e(e_t - (p - p^*)_t) + \omega_{ph}(\Delta_4 ph_t - \mu_{ph}) + \omega_s(\Delta_4 s_t - \mu_s) + \omega_\ell(\Delta_4 \ell_t - \mu_\ell)]$.

[7]Bernhardsen and Bårdsen (2004) show that such an output growth rule offers a better fit with the actual interest rate setting than an output gap rule. The estimated weight on output growth was found to be 0.6 in this study,

The third line in the rule specifies the response to excess fluctuations in the three asset prices, while the fourth line specifies the response to excess credit growth.

The steady-state values for the arguments in the interest rate rule are determined mostly in light of their historical values; see Table 1 for details. The exceptions are the target rate for the underlying annual inflation rate, $\bar{\pi}$, which is set equal to the official target of 2.5% per annum and the equilibrium value for the real interest rate, $\overline{rr}$, which is set at 3.5.

The simple interest rate rule (10) is linear when the response coefficients associated with asset prices and credit terms are (also) constant, i.e. $\omega_{a,t} = \omega_a$, where $a = e$, ph, s and ℓ. In the linear rule, the policy interest rate responds symmetrically to misalignments in asset prices and credit. Raising interest rates when asset prices and credit rise above their sustainable values can be seen as a preemptive act to avoid a potential bust later. That is, one counteracts booms to avoid potential busts. A response to asset prices and credit when they fall below their equilibrium values can be seen as a cure aimed at counteracting their fall or the effects of it.

We also consider non-linear simple interest rate rules where the interest rate response to misalignments increases with the size of a perceived misalignment. Such a size-dependent response can be motivated by uncertainty and heterogeneity of beliefs among economic agents regarding the equilibrium paths of asset prices and credit. Particularly large deviations of asset prices and credit from their estimated equilibrium paths are more likely to be considered misalignments by most economic agents than relatively small deviations; cf. Taylor *et al.* (2001). In addition, a significant response to only particularly large misalignments of asset prices can help avoid excess interest rate volatility, which may result if interest rates respond to every misalignment of asset prices.[8]

The non-linear simple interest rate rules are specified by assuming that $\omega_{a,t}$s are logistic functions of the corresponding excess growth terms, represented by $\widetilde{a}$. Specifically,

$$\omega_{a,t} = \left[-1/2 + 1/(1 + \exp\{-\gamma \widetilde{a}_t{}^2\})\right] 2\omega_a \tag{11}$$

where γ is a positive scale parameter while $a = e$, ph, s and ℓ. It follows that $\omega_{a,t} \longrightarrow \omega_a$ if $\widetilde{a}_t^2$ is sufficiently large while $\omega_{a,t} \longrightarrow 0$ if $\widetilde{a}_t^2 \longrightarrow 0$; the speed of convergence will depend on γ. Hence, the response to an asset price misalignment will increase with the size of the misalignment and even be negligible if the misalignment is not sufficiently large; see e.g. Teräsvirta (1998) for details on this class of non-linear functions.

In Subsection (3.3), we present results based on six special cases of (10). This facilitates understanding of the mechanisms that come into play when different interest rate rules are implemented

while the degree of interest rate smoothing was found to be 0.7.

[8]One can alternatively specify a sign-dependent response to asset prices and let the central bank respond asymmetrically to asset prices, e.g. neglect rising asset prices but become engaged when they start falling, especially when such a fall is perceived as endangering financial stability. However, such a response to asset price misalignments can give rise to moral hazard and excessive risk-taking, because the central bank's response could be interpreted as if it would be offering insurance against particularly large falls; see e.g. Roubini (2006) and Cecchetti *et al.* (2000).

in the model. Our main analysis is presented in Section 4.

3.3 Performance of special interest rate rules

The six special interest rate rules are presented in Table 1. We let the Taylor rule, TR, be our benchmark rule and define the other special cases of (10) by adding each of the remaining terms in turn. For example, we define the smoothing rule, SM, by just adding the second term $\omega_r(r_{t-1} - (\bar{\pi} + \overline{rr}))$ to the Taylor rule, while a rule with a response to house prices, PH, is defined by (just) adding $\omega_{ph}(\Delta_4 ph_t - \mu_{ph})$ to the Taylor rule.

Table 1: Special cases of simple interest rate rules

Arguments:		$\Delta_4 pu_t$	$\Delta_4 y_t$	r_{t-1}	e_t	$\Delta_4 ph_t$	$\Delta_4 s_t$	$\Delta_4 \ell_t$
Steady states:		$\bar{\pi}$	μ_y	$\bar{\pi} + \overline{rr}$	$\bar{e}$	μ_{ph}	μ_s	μ_ℓ
Steady-state values:		0.025	0.025	0.06	$(p - p^*)_t$	0.10	0.10	0.05
Rules:		ω_r	ω_π	ω_y	ω_e	ω_ℓ	ω_{ph}	ω_s
Taylor	TR	1.5	0.5					
Smoothing	SM	1.5	0.5	0.75				
Exchange rate	EX	1.5	0.5		0.33			
House prices	PH	1.5	0.5			0.20		
Equity prices	OSE	1.5	0.5				0.20	
Credit growth	CR	1.5	0.5					0.20

Note: $r_t = (\bar{\pi} + \overline{rr}) + \omega_\pi(\Delta_4 pu_t - \bar{\pi}) + \omega_y(\Delta_4 y_t - \mu_y) + \omega_r(r_{t-1} - (\bar{\pi} + \overline{rr}))$
$+\omega_e(e_t - \bar{e}) + \omega_{ph}(\Delta_4 ph_t - \mu_{ph}) + \omega_s(\Delta_4 s_t - \mu_s) + \omega_\ell(\Delta_4 \ell_t - \mu_\ell)$

The response coefficients are set in the light of earlier studies within the context of different models and data sets. For the Taylor rule, we use the values of 1.5 and 0.5, respectively, for the inflation gap and the output growth gap. These are kept unchanged when the remaining rules are defined by adding the different terms. This helps to bring forward potential value added in terms of improved macroeconomic performance through an additional response to e.g. asset prices. The degree of interest rate smoothing (ω_r) is set equal to 0.75, while the response coefficient associated with the exchange rate misalignment is set at 0.33 (as in Ball (1999b)). The response coefficients associated with house prices, equity prices and credit growth are set at 0.20 in the light of Chadha *et al.* (2004) and our own analysis.

The performance of all rules is examined by measuring their performance in counterfactual simulations of the model over the six-year period, 1995q1–2000q4; the conclusions have been found to be robust to the choice of the simulation period.[9]

Table 2 summarizes the vast amount of information from the simulations. For each interest rate rule, it records the standard deviations of key variables relative to those in the sample over the simulation horizon. The following observations can be made from a glance at Table 2:

First, all of the rules contribute to lower variance in (underlying) inflation and output growth relative to their observed variances over the simulation horizon. For example, under the Taylor rule

[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 (1995).

Table 2: Performance of the special simple interest rate rules

		Variables						
Interest rate rules		$\Delta_4 pu_t$	$\Delta_4 y_t$	Δr_t	e_t	$\Delta_4 ph_t$	$\Delta_4 s_t$	$\Delta_4 \ell_t$
Sample 1995:1-2000:4	sdev	0.005	0.023	0.007	0.017	0.040	0.232	0.023
Taylor TR	Rel. sdev	0.85	0.81	1.92	1.36	1.19	0.77	1.00
Smoothing SM	Rel. sdev	0.92	0.88	1.53$^\spadesuit$	1.51	1.24	0.68	1.20
Exchange rate EX	Rel. sdev	0.87	0.84	2.18	1.19$^\spadesuit$	1.18	0.87	0.99
House prices PH	Rel. sdev	0.80	0.81	1.78	1.32	0.98$^\spadesuit$	0.77	0.89$^\spadesuit$
Equity prices OSE	Rel. sdev	0.85	0.77$^\spadesuit$	1.61	1.71	1.53	0.36$^\spadesuit$	1.06
Credit growth CR	Rel. sdev	0.78$^\spadesuit$	0.80	1.94	1.38	1.17	0.72	0.93

Note: The symbol $\spadesuit$ denotes the minimum value of the relative standard deviation (Rel. sdev) in a column. The relative standard deviations are calculated relative to the standard deviation in the sample (sdev).

(TR), the standard deviations of these variables are 0.85 and 0.81, respectively, i.e. 15% and 19%, 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 house prices. The increased interest rate volatility reduces the volatility in equity prices relative to its observed value (e.g. by about 23% in the case of TR).

Second, it appears that the volatility of a variable can be substantially reduced when the interest rate rule allows a response to that variable, in addition to inflation and output growth. We note that the relative standard deviations of interest rates, exchange rates, house prices and equity prices attain their minimum values, under the rule with smoothing (SM), the exchange rate (EX), house prices (PH) and equity prices (OSE), respectively. Credit growth also becomes more stable in the credit growth rule (CR), but its relative standard deviation attains it minimum value in the case of the house price rule (PH), reflecting the importance of house price growth for credit growth. The low volatility of asset prices and credit growth *itself* contributes to stability in the other variables, but makes interest rates more volatile.

Third, it appears that neither overly stable nor overly volatile interest rates promote economic stability. We note that e.g. inflation and output growth are more volatile under the smoothing rule (SM) and the exchange rate rule (EX) compared with the other rules considered. Under the smoothing rule, interest rates become more stable than under the other rules considered. However, their ability to stabilize the economy becomes severely limited. Moreover, there is in general a trade-off between volatility in interest rates and credit growth. Thus, stabilization of interest rates tends to raise the volatility of credit growth, which itself contributes to making other variables more volatile, especially inflation and output. Under the exchange rate rule, the volatility of interest rates is higher than under any of the other rules considered. Thus, inflation and output growth become more volatile, despite a relatively more stable exchange rate.

Fourth, when the interest rate rule allows a response to house prices, equity prices or credit growth, inflation and output growth become more stable than under the Taylor rule (TR), and especially relative to the smoothing rule (SM). In particular, inflation is relatively more stable under the credit growth rule (CR), while output growth is more stable under the equity price rule (OSE) than under the other rules considered. These findings can be explained with reference to lags from interest rate changes to their effects on output and inflation as well as from house prices, equity prices and credit to output and inflation; see Section 2 on impulse responses. By responding to excess growth in house prices, equity prices and credit, monetary policy gets a "head start" relative to the Taylor rule and becomes able to counteract the effects of these asset prices and credit on inflation and output almost when they are realized. In contrast, the Taylor rule starts responding to asset prices and credit only when their effects on inflation and output are realized. Thus, because of lags from interest rate changes to output and inflation, it becomes less effective in stabilizing inflation and output.

However, a response to the nominal exchange rate turns out to make inflation and output growth more volatile than under the Taylor rule. This is mainly because the exchange rate rule contributes to making interest rates quite volatile, as noted above. In addition, a response to the nominal exchange rate would be as if one raised the response coefficients associated with excess inflation and output growth. This is because the nominal exchange rate has stronger and immediate effects on inflation and output in contrast with those of the other asset prices and credit, as noted in Section 2. Thus, in terms of stabilizing inflation and output, raising their own response coefficients would prove more effective than by responding to the nominal exchange rate.

Finally, interest rates do not become more volatile (than under the Taylor rule) when they respond to movements in house prices and equity prices. In the case of the credit growth rule, their volatility increases only slightly relative to the Taylor rule. The explanation is that the contributions of house prices, equity prices and credit growth to volatility in interest rates is counteracted by the contributions of more stable inflation and output growth. Credit growth becomes more volatile in the case of the equity price rule, but turns out to be especially low under the house price rule, and under the credit growth rule.

Next, we examine the performance of special cases of the interest rate rule 10 when the response coefficients are selected among a large set of possible coefficient values through model simulations.

4 Performance of efficient interest rate rules

We have examined the performance of a large number of linear interest rate rules defined by varying the response coefficients (ωs). Different combinations of the response coefficients within plausible ranges were used to define an equally large number of interest rate rules, up to 57,000. The steady-state values (μs) were kept fixed at the same values as in Table 1. And as above, the performance of all rules was recorded in counterfactual simulations of the model over the six-year period, 1995q1–2000q4; see Appendix B for details.

We will only present and focus on outcomes of a subset of the rules examined, namely those of efficient interest rate rules; cf. Ball (1999a). Such rules define efficiency frontiers that depict trade-offs between stability of inflation and output, also known as Taylor curves. Accordingly, it should not be possible to reduce inflation volatility without inducing higher output volatility by altering the response coefficients in a rule; cf. McCaw and Morka (2004) and Appendix B.

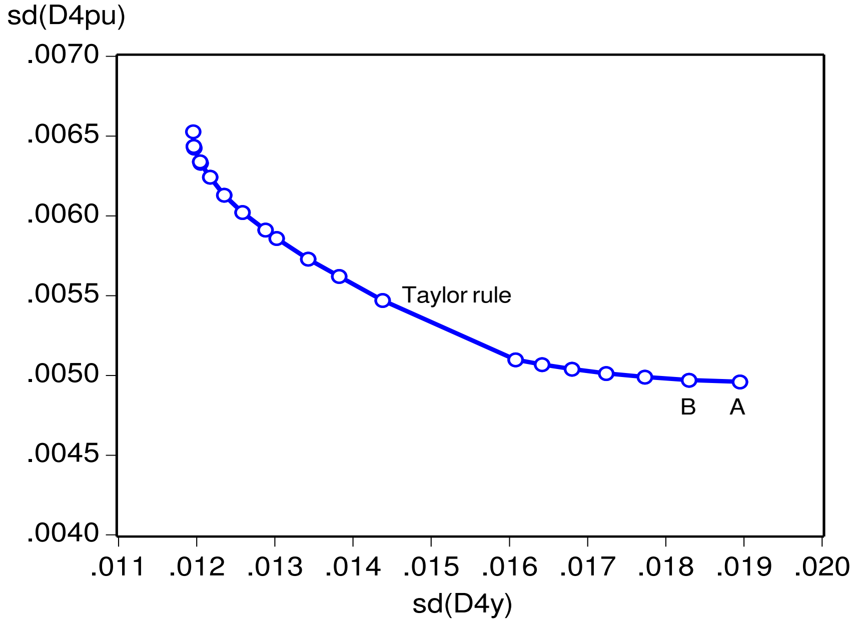

Figure 1: *An efficiency frontier for efficient interest rate rules without response to asset prices and credit. Precisely, "Taylor rule" indicates that the associated efficiency frontier is based on interest rate rules that only allow a response to inflation, output growth and/or the lagged interest rate. The response coefficients defining the rules are selected on the basis of 891 model simulations. sd(D4pu) and sd(D4y) denote the standard deviations of the annual (underlying) inflation rate and that of annual output growth, respectively.*

Figures 1–3 present our benchmark results based on the efficient rules specified as the Taylor rule with smoothing (SM). Precisely, the interest rate rule allows only responses to inflation and output growth and lagged interest rates, as in SM, except that values of the response coefficients ω_π, ω_y and ω_r are selected through model simulations.

Figure 1 presents the outcomes of model simulations under these rules in terms of an efficiency frontier of inflation and output growth. This suggests a trade-off between stability in inflation and output growth. A similar trade-off curve can be shown between stability in inflation and the output gap, since output growth is closely related to the output gap in the model; cf. equation (1). Each point on the efficiency frontier can be associated with a specific combination of the three response coefficients.[10]

Figures 2–3 depict the outcomes under the efficient rules in terms of financial stability at

[10]Conditional on a given specification of the interest rate rule, the optimal values of the response coefficients, and thereby the optimal interest rate rule, can be derived in the light of a central bank's loss function.

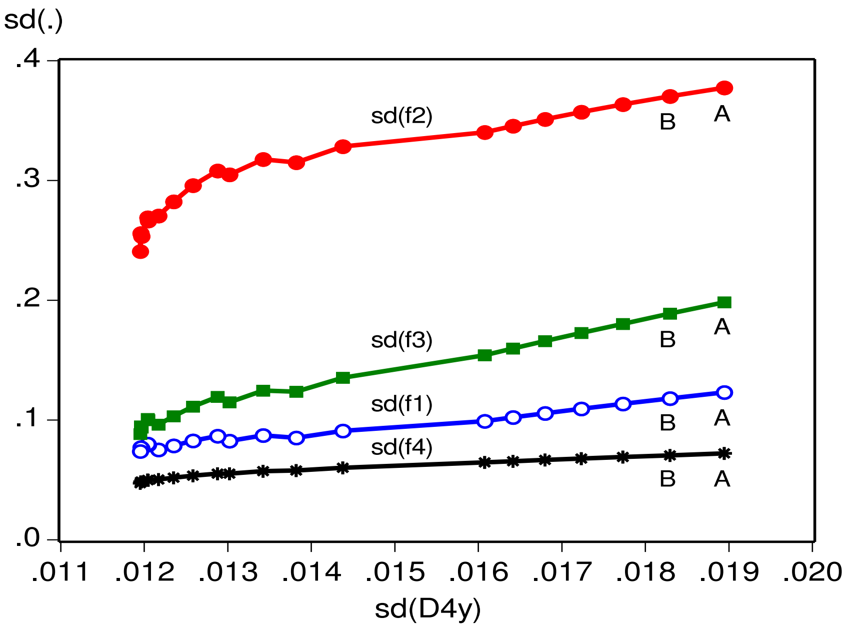

Figure 2: *Financial stability curves based on different financial stability indicators: f1–f4. Where, f1 = debt to income ratio; f2 = debt service to income ratio; f3 = the broad financial stability indicator; and f4 is f3 adjusted for direct interest rate effects. The vertical axis measures the standard deviations of the financial stability indicators corresponding to different levels of sd(D4y), obtained under the efficient interest rate rules specified as the Taylor rule (with smoothing); see Figure 1. Financial stability and inflation and output growth volatility at e.g. points A and B are the outcomes of the same Taylor rules; see Figure 1.*

different levels of output growth volatility, $sd(D4y)$. Hereafter, we refer to these relationships as "financial stability curves". For example, point A on the efficiency frontier for inflation and output in Figure 1 and those on the "financial stability curves" in Figures 2–3 are the outcomes of the same interest rate rule, defined by a specific combination of the three response coefficients. In Figure 2, financial stability is represented by the standard deviations of the debt to income ratio, $f1$, debt service to income ratio, $f2$, the broad financial fragility indicator of Eitrheim and Gulbrandsen (2001), $f3$, and a version of $f3$ adjusted for direct interest rate effects, f_4. In Figure 3, financial stability is represented by the standard deviation of changes in the short-term interest rates and an equally weighted sum of the standard deviations of the three asset prices; alternative weights led to comparable results.

While there is a trade-off between stability in inflation and output under the (efficient) Taylor rules with smoothing, there seems to be a positive relationship between financial stability and output stability, except when output stability is relatively high; see Figures 2–3. In the latter case, a reduction in output (growth) volatility (and simultaneously, an increase in inflation volatility) has ambiguous effects on financial stability. We note that all indicators of financial stability in Figure 2 suggest an improvement, i.e. a reduction in the standard deviations of $f1$–$f4$, when output volatility is reduced from high levels. Financial stability as measured by asset price and

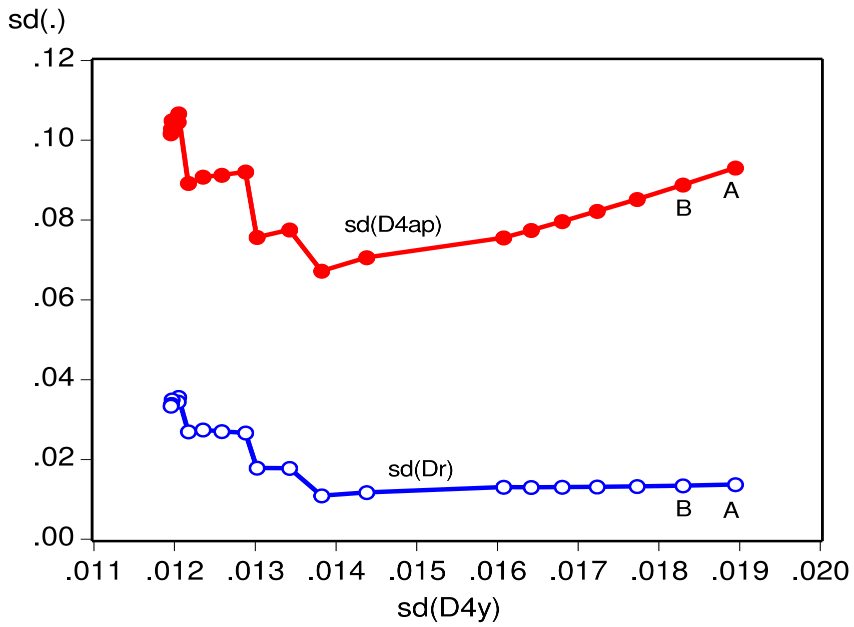

Figure 3: *Financial stability curves based on measures of volatility in asset prices and interest rates. The vertical axis measures the standard deviations of these financial stability indicators corresponding to different levels of sd(D4y), obtained under the efficient interest rate rules specified as the Taylor rule (with smoothing); see Figure 1. sd(D4ap) denotes an equally weighted sum of the standard deviations of the three asset prices: house prices, equity prices and the nominal exchange rate, while sd(Dr) denotes the standard deviation of quarterly changes in interest rates. Financial stability and inflation and output growth volatility at e.g. points A and B are the outcomes of the same Taylor rules; see Figures 1–2.*

interest rate volatility decreases, however, at relatively low levels of output volatility; see Figure 3. This is mainly because the corresponding relatively high volatility in inflation induces high volatility in nominal interest rates and thereby high volatility in asset prices. Figure 3 shows that asset price volatility largely behaves as interest rate volatility at different levels of output growth volatility.

Below, we investigate whether an additional interest rate response to asset prices and credit would reduce volatility of inflation, output and the financial stability indicators. If there are such gains, the efficiency frontiers should move inwards, while the financial stability curves should move downwards at the different levels of output volatility, relative to the cases under the efficient Taylor rules with smoothing presented in Figures 1–3.

Figure 4 presents the efficiency frontiers associated with extended simple interest rate rules that allow a response to asset prices and credit growth, in addition to inflation, output growth and lagged interest rates. The solid crossed line represents the efficiency frontier associated with the interest rate rules that allow a response to asset prices, inflation and output growth, but not to credit growth. The boxed line represents the efficiency frontier when a response to credit growth is also allowed. For comparison, we have also pasted in the efficiency frontier from Figure 1, circled line, which is implied by rules that do not allow a response to asset prices or credit growth. In

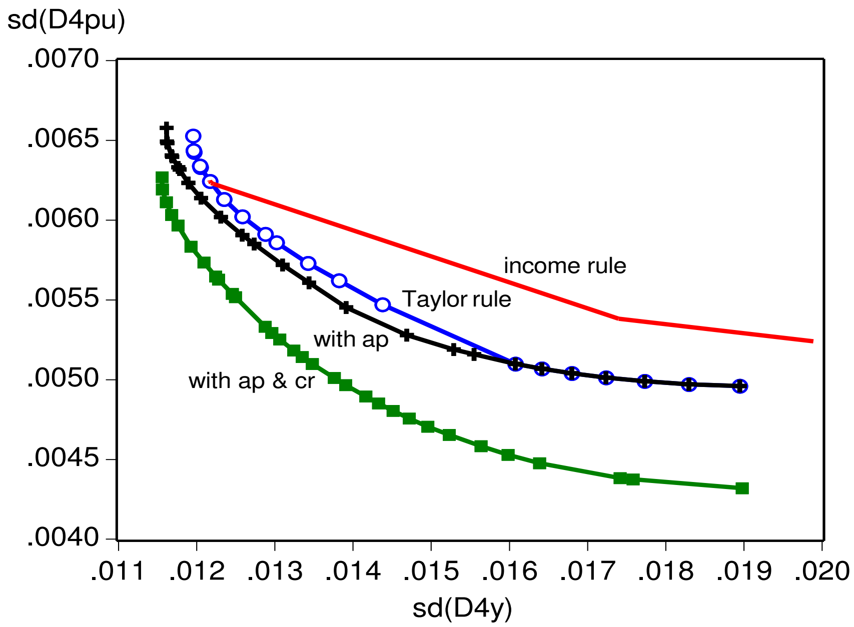

Figure 4: *Efficiency frontiers for (efficient) interest rate rules without and with response to asset prices and credit. Solid circled line represents the outcomes under efficient Taylor rule (with smoothing), as in Figure 1. The solid line represents the outcomes under a nominal income (targeting) rule. The solid crossed line represents the outcomes under efficient Taylor rules that allow response to the three asset prices: house prices, equity prices and nominal exchange rate. Finally, the solid boxed line represents the outcomes under efficient Taylor rules that allow response to excess growth in the three asset prices and credit. The response coefficients defining each of the rules are selected on the basis of about 57,000 model simulations.*

addition, we have also pasted in a solid line representing an efficiency frontier based on simple interest rate rules where the interest rate responds to nominal income growth and the real output growth; cf. McCallum and Nelson (1999).

Figure 4 shows that allowance for additional responses to asset prices, i.e. house prices and equity prices, and particularly credit growth, contributes to a shift in the efficiency frontier towards origin, and hence provides lower variability in both inflation and output growth. In our simulations, the response coefficient of the exchange rate turned out to be zero, as a positive response tended to increase the variability in both inflation and output and thus led to a shift outwards from the origin. Thus, the different points on the solid circled and boxed efficiency frontiers refer only to different combinations of response coefficients for all the other variables except the exchange rate.[11] It also appears that the performance of the nominal income targeting rule in terms of inflation and output stability is inferior to that of the Taylor rule with smoothing, mainly because it behaves as a restricted version of this rule. Thus, we leave it out in the further discussion.

The response to asset prices and credit growth has mixed effects on financial stability, however; see Figures 5–6. When financial stability is measured by volatility in the debt service to income

[11]The points where two of the efficiency frontiers merge with each other include combinations of weights where the response coefficient of output growth becomes zero.

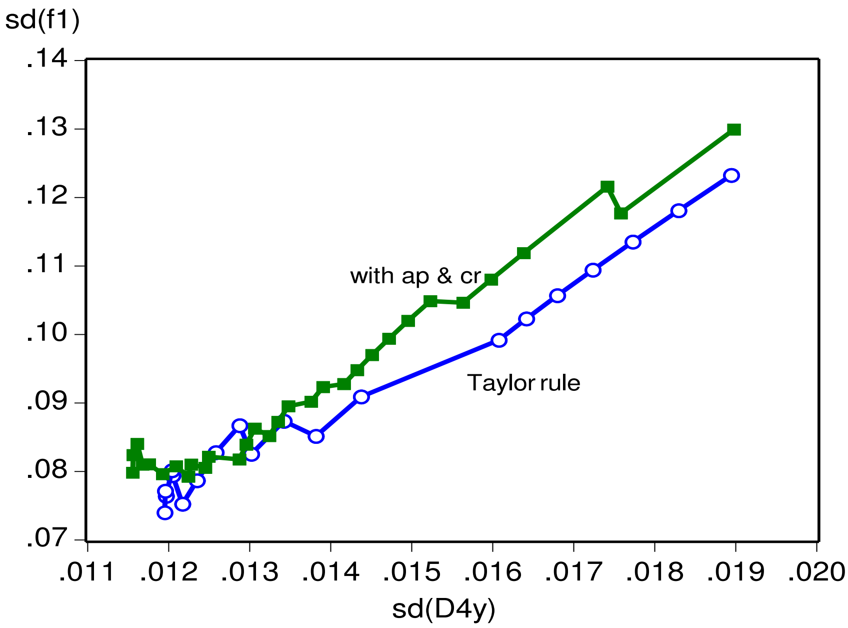

Figure 5: *Financial stability curves based on debt to income ratio (f1) under efficient Taylor rules (with smoothing) and with additional allowance for a response to asset prices and credit; cf. Figure 2.*

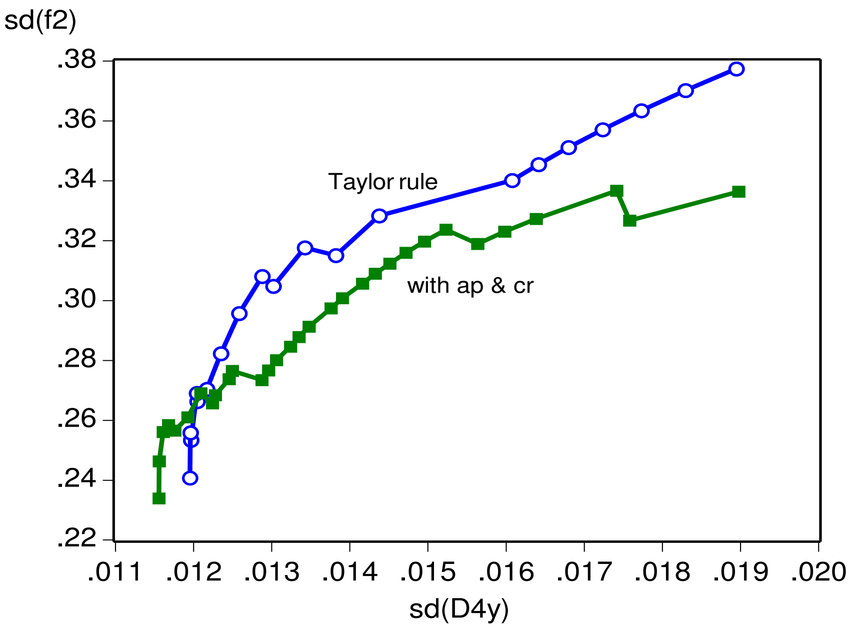

Figure 6: *Financial stability curves based on debt service to income ratio (f2) under efficient Taylor rules (with smoothing) and with additional allowance for a response to asset prices and credit; cf. Figure 2.*

ratio ($f2$) and the broad indicators ($f3$ and $f4$), the financial stability curves move slightly upward, relative to the benchmark cases based on efficient Taylor rules (with smoothing), indicating a deterioration in financial stability at different levels of output growth volatility; see e.g. Figure 5. The explanation is that allowing a response to asset prices and particularly credit growth tends to

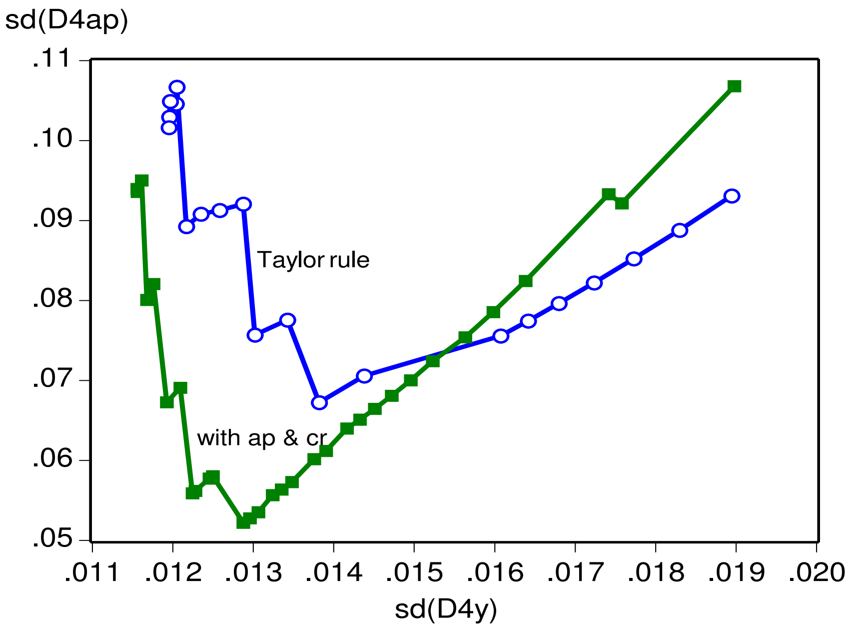

Figure 7: *Financial stability curves based on asset price volatility and interest rate volatility under efficient Taylor rules (with smoothing) and with additional allowance for a response to asset prices and credit; see Figure 3 for details.*

stabilize these variables, but at the expense of relatively higher interest rate volatility. This effect dominates the effect on the debt service to income ratio of relatively more stable credit growth, inflation and output growth. Consequently, financial stability indicators depending directly on interest rate movements tend to display more variation than in the other cases. However, financial stability improves when measured by volatility in the debt to income ratio and asset prices. We note that the corresponding financial stability curves shift downwards at the different level of output growth volatility; see Figures 6–7.

4.1 Sensitivity analyses

We have undertaken a number of sensitivity analyses to examine the robustness of our results regarding gains from responding to asset prices and/or credit. We obtained results comparable to those presented in Figures 4–7 when we altered the interest rate rule (10) in the following ways and undertook simulations to derive efficiency frontiers and financial stability curves.[12]

In the first (sensitivity) analysis, we replaced the underlying inflation rate ($\Delta_4 pu$) in the different rules with the inflation rate ($\Delta_4 p$), and obtained comparable results.

In the second analysis, we replaced the excess output growth term, ($\Delta_4 y - \mu_y$), in the rules with the error-correction term in the aggregate demand equation, (1), representing deviation from trend output, without observing much difference in the results. We have also examined the sensitivity of the results by replacing the excess output growth term with an unemployment gap term defined

[12]The results are available upon request to the authors.

as deviation between actual and equilibrium unemployment rate set at 4%; A change of this to 3% or 5% did not alter the ranking of the rules in terms of their stabilization properties.

In the third analysis, we checked the sensitivity of our results to several alternative values for the steady-state values of the growth terms (μs). We observed gains from responding to asset prices and credit in most of the cases except when the steady-state values were set at particularly high values relative to the corresponding in-sample estimates of their mean values, as presented in Table 1. In such cases, monetary policy responded to the growth in house prices, equity prices and credit by lowering interest rates and thereby fueled their growth in most of the simulation period. In these exercises, the steady-state growth value of house prices (μ_{ph}) was shifted in the range 7–13%, that of equity prices (μ_s) was shifted in the range -10%–30%, while that of credit growth (μ_ℓ) was changed in the range 5–10%. We also let the steady-state value of output growth (μ_y) take on different values within the range 1.5–4%.

In the fourth analysis, we investigated the sensitivity of our conclusions to allowance for a size-dependent response to excess growth in asset prices and credit. Such a response was modeled by letting their response coefficients in the interest rate rule be zero unless excess growth in house prices, equity prices and credit moved outside the ranges specified above (in the third sensitivity analysis); see equation (11). Values of the response coefficients when asset prices and credit moved outside the ranges were determined by model simulations such that they defined efficiency frontiers. The steady-state values (μs) were maintained at their reference values provided in Table 1, while γ was set at a large value to obtain (almost) no response to excess growth within the specified ranges.

The efficiency curves under such non-linear rules also suggested gains from responding to asset prices and credit in terms of inflation and output stability, but mixed effects on financial stability, as above. As one would expect, the relevant curves were found to lie between those of the Taylor rule and the (linear) rules extended with asset prices and credit in Figures 4–7. This is because, for movements close to the steady-state values, the interest rate response to excess growth in asset prices and credit was quite weak and hence the outcomes of the rules were close to those of the Taylor rule. In the case of particularly large growth in asset prices and/or credit, however, the interest rate response was close to that in the linear rules with asset prices and credit. Given that the non-linear rules responded to fewer misalignments, the performance of such rules in terms of the efficiency curves was found to be inferior to that of the corresponding linear rule, but superior to that of the Taylor rule.

Finally, it is comforting that our conclusions seem fairly robust to model choice. A number of recent studies have obtained comparable results regarding gains from responding to asset prices and credit using alternative empirical models for other countries. This is in contrast with e.g. Bernanke and Gertler (1999) who reported no gains from responding to equity prices within the context of a closed economy model. In particular, Cecchetti *et al.* (2000), contradicting this finding, point out gains from responding to misalignments in asset prices within the context of a comparable closed economy model. Romaniuk (2006) using a small reduced form model of the US economy also finds significant gains from responding to equity prices. Also, Kontonikas and Ioannidis (2005) using a small rational expectation model for the UK point out gains from responding to house prices and equity prices.

5 Conclusions

Our results suggest that monetary policy faces a trade-off between inflation and output stability, while financial stability can be improved together with output stability, unless the latter is pushed towards relatively high levels. At such levels, inflation becomes quite volatile leading to high interest rate volatility, making financial stability decrease when measured by interest rate-sensitive indicators of financial stability, especially asset prices (including the nominal exchange rate).

We also find that an additional interest rate response to excess growth in house prices, equity prices and credit raises stability in inflation and output. Such a response has mixed effects on financial stability, however. Financial stability indicators that are directly affected by these variables such as volatility in asset prices and the debt to income ratio tend to suggest higher financial stability at different levels of output stability. However, the additional response to excess growth in house prices, equity prices and credit contributes to relatively high interest rate volatility. Thus, particularly interest rate-sensitive indicators of financial stability, such as the debt service to income ratio, tend to suggest lower financial stability at different levels of output volatility.

However, when interest rates respond to a misalignment in the nominal exchange rate, the increased interest rates volatility outweighs the stabilizing effect of the exchange rate on inflation and output. Thus, through an additional response to the exchange rate misalignment, inflation and output turn out to be less stable than when interest rates only respond to inflation and output gaps and lagged interest rates.

Our results have appeared quite robust to alternative specifications of the interest rate rule, use of alternative indicators for terms entering the interest rate rules, and alternative values for key parameters representing steady-state values of growth in asset prices and credit. In addition, we have obtained comparable results using several alternative indicators of output stability and financial stability. Some recent studies using alternative models for other countries also support our findings.

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A Appendix: Data definitions

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

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

H Standard working hours per week. [NH]

L Nominal credit volume. Mill. NOK. [K1M]. ℓ is log of nominal credit volume. L is a domestic credit indicator, including loans to the non-financial private sector and municipalities from all domestic financial institutions as well as bonds and loan certificates issued by some sectors.

$OILP$ 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].

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

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

PU Underlying consumer price index: CPI adjusted for indirect taxes, electricity and fuel prices. [KPIJAE].

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

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

S^* Morgan Stanley World Index (MSCI).

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].

B Appendix: Model simulations

To obtain the results in Table 2, we implemented the different rules as specified in Table 1 in the complete macroeconometric model, as presented in Akram and Eitrheim (2006). The model was then simulated over the six-year period: 1995q1–2000q4. We have checked the sensitivity of our conclusions by selecting different periods for the counterfactual simulations, in which the economy experienced different disturbances. Our main conclusions appeared robust to the choice of the simulation period, mainly because the model is linear.

The efficiency frontiers presented in Figure 1 have been obtained by implementing interest rate rules whose response coefficients ωs were selected through a grid search over different ranges. Specifically, we let each of the response coefficients for the three coefficients ω_π, ω_y and ω_r take on (positive) values within reasonable ranges. The number of possible combinations of the coefficient values in this case was 891, defining an equally number of possible simple interest rate rules with three terms. The model was then simulated over the same six-year period, as above. The outcome of each simulation in terms of standard deviations of inflation and output growth, calculated over the simulation period, was thereafter depicted in a two-dimensional diagram, with standard deviations of the inflation gap and the output growth gap on the axes, each of the simulations resulting in a single point in the diagram. The 891 points were then enveloped from below to define the efficiency frontiers; see e.g. McCaw and Morka (2004).

The financial stability curves in Figures 2–3 have been obtained by depicting the standard deviations of output growth against the standard deviations of the different financial stability indicators under the rules (or combinations of response coefficients) defining the efficiency frontier in Figure 1.

The efficiency frontiers in Figure 4 were derived as in Figure 1. Specifically, for interest rate rule with response to asset prices, we implemented 57,024 possible combinations of the six response coefficients ω_π, ω_y, ω_r, ω_{ph}, ω_s, and ω_e, defining an equal number of possible simple interest rate rules. Given that none of the combinations of the response coefficients defining the corresponding efficiency frontier included value of $\omega_e > 0$, we set $\omega_e = 0$ when implementing interest rate rule with response to asset prices and credit. In this case, we also implemented 57,024 possible combinations of the six response coefficients ω_π, ω_y, ω_r, ω_{ph}, ω_s, and ω_ℓ. In the case of the nominal income rule, we imposed the restriction $\omega_\pi = \omega_y$ and added an additional output-gap term, defined by the equilibrium correction term in the aggregate demand equation as precisely defined in the complete model, to the interest rate rule (10). Thus, to define the efficiency frontier under the nominal income rule, we implemented 891 different combinations of the three coefficients ω_π, ω_r and $\omega_{output\ gap}$.

The financial stability curves in Figures 5–7 were derived as in Figures 2–3.

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