

Master thesis for the Master of Economics degree

Monetary policy and asset prices

Interest rate rules and asset prices in Norway

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Preface

I would like to thank my supervisor Hilde C. Bjørnland for her guidance and support. This thesis was partially inspired by her lectures on Monetary Policy and Business Fluctuations during the spring of 2005 and partially on her paper "Identifying the interdependence between US monetary policy and the stock market" written with Kai Leitemo (2005).

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1. Introduction

The purpose of this thesis is to survey and investigate the role of asset prices, in particular stock prices, on monetary policy in Norway.¹ There has been a long established consensus in the literature that asset prices should not be targeted explicitly and that asset prices have a limited role on monetary policy. However, recent contributions in the literature have argued that asset prices might have a more prominent role due to their forward looking nature. This thesis will survey some of these contributions and perform an empirical investigation on interest rate rules and asset prices on Norwegian data.

Modern monetary policy, which incorporates inflation targeting, is founded on the New Keynesian literature. The New Keynesian literature assigns a role to monetary policy in the short-run due to the presence of nominal price rigidities and assumes optimizing households and firms. However, it does not fully incorporate the adverse effects of severe asset price misalignments for at least two reasons. First, household optimization implies intertemporal consumption smoothing which in turn assumes somewhat stable asset prices since they provide for a predictable store of wealth. The existence of severe asset price misalignments, which are prevalent in most asset markets, implies that households may act sub-optimally since such misalignments may significantly impact their lifetime savings. Second, the literature has generally downplayed the role of investments since adding a variable capital stock does not significantly change the overall results (see e.g. McCallum & Nelson (1999)). However, recent studies have found that variability in capital utilization may be an important prerequisite for inflation persistence (see e.g. Dotsey & King (2001) and Christiano et al. (2001)), which may suggest that asset price volatility is desirable.

There is a consensus in the literature that asset prices should not be targeted explicitly. Aside from the argument concerning capital utilization, this is due to the uncertainty surrounding the identification of asset price misalignments and the uncertain effects interventions may have on asset markets. This is not to say that there is no role for asset prices in New Keynesian models. Some of the literature has argued that asset prices may

¹ In the context of this thesis asset prices shall refer to stock prices only. Other forms of assets that serve as stores of wealth such as real estate, physical capital etc. have been ignored for simplicity although the fundamental analysis is the same. While foreign exchange deposits might be thought of as asset prices they are treated differently in the literature and this thesis will adhere to this differentiation.

contain information regarding future inflation not found elsewhere, mainly due to their forward looking nature (see e.g. Cecchetti et al. (2000)). Other reasons for why asset prices may have an important role are the existence of market frictions such as agency problems and market incompleteness. Much of the literature ascribe such frictions as the cause of severe asset price misalignments (e.g. asset price bubbles). Although the adverse effects asset price bubbles may have on the real economy have been thoroughly discussed in the literature, they have been discussed less so in the context of monetary policy.

There exist several empirical contributions on asset prices and monetary policy. Generally the literature has focused on measuring the relative efficiency of interest rate rules with asset prices using calibrated small structural (New Keynesian) models (see e.g. Bernanke & Gertler (2001)). Empirically estimated interest rate rules (reaction functions) that incorporate asset prices have received relatively little attention (one notable exception is Chadha et al. (2003)). One reason for this is the existence a simultaneity problem between asset prices and interest rates making the identification issue problematic. Another is the measurement problem associated with identifying asset price misalignments.

However, asset prices could be included in empirically estimated interest rate rules provided the simultaneity and measurement problems are appropriately addressed. To avoid the simultaneity problem I have formulated a simultaneous interest rate rule model for Norway where asset prices enter endogenously. In measuring asset price misalignments I have opted to follow the methodology used by Borio & Lowe (2002) which is based on measuring the asset price gap as the deviation in cumulative asset returns from trend. I find that this methodology is consistent with other asset price determination methodologies.

Using Norwegian data from 1993, I find that asset prices enter significantly in a simultaneous model estimated using two stage least squares (2SLS). I also find that asset prices contain more precise information on future inflation than the output gap and the growth gap, particularly in conjunction with the unemployment gap. This implies that asset prices can be viewed as an alternative real-time variable to the output gap or alike. These results are supported using more recent data from 1999. However, given limited data availability more research is needed to ascertain the relative usefulness of asset prices on monetary policy.

This paper is structured as follows. Section 2 gives an overview of monetary policy in a New Keynesian framework and discusses some of the empirical challenges associated with measuring interest rate rules. Section 3 surveys some of the literature on monetary policy and asset prices and discusses some of the empirical challenges associated with measuring interest rate rules with asset prices. Section 4 gives an overview of market frictions as the causes of asset price misalignments, and discusses measurement and potential indicators. Section 5 presents the empirical findings and Section 6 concludes.

2. Monetary policy and simple interest rate rules

It is widely accepted by most practitioners that modern monetary policy is best described in a New Keynesian framework. New Keynesian models assign a role to monetary policy in the short-run due to the presence of nominal price rigidities while building on the Real Business Cycle literature and incorporating rational expectations. This is different from traditional Keynesian models since aggregate demand only has short-term effects and long-run output is determined by the production function (supply side) of the economy.

It is generally agreed in the literature that monetary policy in a New Keynesian framework should aim to minimize the trade-off between inflation and output stability (see e.g. Clarida et al. (1999)). Such a trade-off is minimized by so-called “flexible inflation targeting”. It is also widely accepted that the interest rate is the preferred instrument choice of the central bank although this is dependent on the types of shocks the economy is exposed to (see e.g. Poole (1970)). The interest rate can either be set discretionary, according to a rule, or by a combination of the two. A policy rule can in general help avoid the time-inconsistency problem (inflation bias problem) and can therefore serve as a useful benchmark for policymaking.

In the following sections I will discuss some of these results in more detail. First, I will give an overview of monetary policy in a New Keynesian framework. Thereafter I will discuss targeting rules and instrument rules respectively, and discuss how they are related. I will also discuss why the central bank might want to use simple interest rate rules as a point of reference in practical monetary policy and that an empirical interest rate rule may be thought of as a central bank’s reaction function. Finally, I will discuss some of the empirical limitations associated with such reaction functions.

2.1 Monetary policy in a New Keynesian framework

The main implications for monetary policy in a New Keynesian setting are well summarized in e.g. Clarida et al. (1999). They find that there is a role for monetary policy in the short-run since prices are slow to react to fluctuations in aggregate demand and that there exists a trade-off between high output and low inflation, and vice-versa. In the long-run, however, monetary policy has no effect on output due to the assumption of a vertical Philips curve.

The New Keynesian framework has microeconomic foundations based on optimizing firms and households. Firms are assumed to behave in a monopolistic competitive setting and households are assumed to be utility maximizing. The optimization structure implies that the framework in its basic form can be represented by two equations where monetary policy can be viewed as affecting the real economy similarly to a traditional IS/LM model.

$$(2.1) \quad y_t = E_t y_{t+1} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1}) + u_t$$

$$(2.2) \quad \pi_t = \beta E_t \pi_{t+1} + k y_t + e_t$$

Equation (2.1) represents equilibrium aggregate demand. The difference between equation (2.1) and a traditional IS curve is that it is derived from intertemporal household utility maximisation (i.e. the Euler condition for optimal consumption). Hence, it is forward looking in the sense that it incorporates both expected output gap (y_t) and expected inflation (π_t). E is the expectations operator, σ is the intertemporal elasticity of substitution (which comes from the utility function of the household), i_t is the nominal interest rate, and u_t is a preferences (demand) shock. Equation (2.2) represents equilibrium aggregate supply through what is often dubbed a “New Keynesian Philips curve”. It incorporates price rigidities since changes in inflation are based on monopolistic competition where firms set prices discretely (i.e. inflation persistence see e.g. Fuhrer & Moore (1995)). β and k are constants and e_t is a cost shock.

It is worth noting, however, that the abovementioned equations are approximate solutions of a more general equilibrium model. Further it is a simplified version of a more elaborate model since it ignores investment, government spending, and foreign trade. Some studies

have found that the conclusions do not change significantly when altering the model to take into account more variables (see e.g. McCallum & Nelson (1999) for investments).

The key distinction, however, between the New Keynesian framework and the traditional IS/LM framework is the forward looking nature of the model. Credibility therefore plays an important role. This is important since the interest rate is endogenous and the model needs to be closed by an equation that describes monetary policy. That is, monetary policy needs to be credible.

The traditional IS/LM model is closed with the LM curve. For this purpose, an LM curve is superfluous since most of the literature generally agrees that the central bank's reaction function can be represented through a policy rule with the interest rate as the policy instrument (see e.g. Bernanke & Mihov (1998)). This is founded on the time consistency literature and the inflation bias problem (see e.g. Barro & Gordon (1983)). One of the possible solutions to the inflation bias problem is the implementation of a policy rule that dictates monetary policy over time. In general there are two types of rules: targeting rules and instrument rules. It can be shown that adhering to a rule implies that optimal policy in a theoretical framework is a linear relationship between the policy interest rate, inflation and output (see eg. Walsh (2003) or Clarida et al. (1999)). However, it is possible that given a more elaborate dynamical model that such a linear relationship may not necessarily hold. There are therefore trade-offs between applying a targeting rule or an instrument rule and these will be discussed in the following sections.

2.2 Targeting rules

A targeting rule (such as an inflation target rule) aims at changing the policy interest rate so that the target variable remains at its target level. The most common targeting rule is inflation targeting. In its strictest sense, inflation targeting can be described as aiming inflation around its target value at all times, or more formally at minimizing the following loss function.²

$$(2.3) \quad \min_{\pi_t} L_t = (\pi_t - \pi^*)^2$$

² Illustrated as a quadratic function for simplicity

where π and π^* are observed inflation and the inflation target respectively. However, in a New Keynesian framework, as pointed out by Clarida et al. (1999), there exists a short-run trade-off between inflation and output which implies that the loss function should be formulated as:

$$(2.4) \quad \min_{\pi_t, y_t} L_t = (\pi_t - \pi^*)^2 + \lambda y_t^2$$

where y and λ is the output gap and the weight put on the output gap respectively (note that $0 < \lambda < 1$). This is commonly referred to as flexible inflation targeting. However, due to interest rate smoothing the loss function is likely to be dynamic, as pointed out by Clarida et al. (1999). That is, the central bank not only minimizes the loss function in the current period, but in all future periods as well. Hence the loss function can be formulated as:

$$(2.5) \quad L_t = E_t \sum_{i=0}^{\infty} \beta^i [(\pi_{t+i} - \pi^*)^2 + \lambda y_{t+i}^2]$$

where β is the discount factor. Much of the literature uses such a dynamic loss function as a discretionary assumption.³

A targeting rule has some important advantages. First, it is optimal since it follows household optimisation and profit maximisation from the New Keynesian framework. Second, it takes into account all relevant variables in the model and represents therefore the optimal solution. Third, it is a fairly realistic assumption that central bank's aim to optimize their decision making. Unfortunately there are some major drawbacks. First, it is complicated to solve and requires the central bank to make several assumptions regarding some of the key variables, specifically β and λ . Hence, misspecification is likely. Second, it is model dependent and therefore relatively less robust than an instrument rule. Third, it will likely yield a too aggressive monetary policy unless lagged variables are included. This implies that deviations are costly which in turn reduces the optimality of the rule unless such costs are incorporated into the model. Fourth, and perhaps most importantly, it is not time-

³ This is based on the finding that equation (2.5) is a linear approximation of the optimal objective function in a New Keynesian setting (see e.g. Woodford (2001)).

consistent since the loss function is re-optimised in each time period which may give rise to an inflation bias.

2.3 Instrument rules

An alternative to deriving an optimal objective function is an instrument rule. Instrument rules incorporate simple interest rate rules (among others) where the interest rate is set according to a policy rule. As shown in Clarida et al. (1999) and Walsh (2003), adhering to a monetary policy rule implies that optimal policy in a theoretical framework is a linear relationship between the policy interest rate, inflation and output. Such a linear relationship can be shown as:

$$(2.6) \quad i_t = \beta_0 + \beta_1(\pi_t - \pi^*) + \beta_2 y_t$$

where i , $\pi - \pi^*$, and y are the policy interest rate, the inflation gap and the output gap respectively. Note that the coefficient β_0 indicates the steady state real interest rate plus the inflation target. Also, it is generally required that the nominal interest rate has to change more than the change in inflation in order to affect real interest rates (see eg. Clarida et al. (1999)). A linear relationship such as in (2.6) was initially found by Taylor (1993), hence the term ‘‘Taylor rule’’. The Taylor rule simply expresses the FED’s reaction function in the form of a simple interest rate rule using data from 1984 to 1992:⁴

$$(2.7) \quad i_t = 4 + 1,5(\pi_t - \pi^*) + 0,5 y_t$$

Although it must be emphasised that Taylor chose his coefficients using informal judgement, his findings seem to track the actual policy interest rate in the period remarkably well, despite the Federal Reserve not having adopted an inflation target. Similar results have been found for Norway albeit not without some empirical difficulties. These will be discussed in more detail in the next section.

Clarida et al. (1999) argue that the Taylor rule should be modified for two reasons. First, they argue that a simple interest rate rule should be forward looking. This is consistent with the optimal policy rule derived from combining the New Keynesian IS curve and the forward

⁴ Assuming an inflation target of 2%

looking Philips curve (as shown in equations (2.1) and (2.2)) and a simple linear response rule between inflation and output (see Walsh (2003) or Clarida et al. (1999) for a formal derivation). In addition, they argue that the rule is likely to be dynamic to incorporate that central banks tend to change interest rates gradually. So-called interest rate “smoothing” has been embraced in the theoretical literature by e.g. Brainard (1969) and Walsh (2003). Brainard (1969) argues that parameter uncertainty implies that policy makers should behave cautiously and Walsh (2003) argues that interest rate smoothing may arise from a desire to ensure financial stability.⁵

In light of this, Clarida et al. (1999) formulate an interest rate rule with expected inflation instead of current inflation and with a lagged interest rate variable to incorporate interest rate smoothing.

$$(2.8) \quad i_t = \rho i_{t-1} + (1-\rho)[\beta_0 + \beta_1(E_t \pi_{t+1} - \pi^*) + \beta_2 y_t]$$

They argue that the Taylor rule is a special case of a more general rule as formulated above, when expected inflation is unavailable and interest rate smoothing is ignored. A formulation with a lagged interest rate is also the starting point of most empirical work on interest rate rules, although there is considerable disagreement on the relative size its coefficient (i.e. ρ).

There are several advantages of applying simple interest rate rules to monetary policy. They are simple, intuitive and time consistent. They also seem to track actual monetary policy reasonably well and are in general more robust than targeting rules since they are not model dependent and may be applied under a variety of assumptions and monetary policy regimes. However, their simplicity is also their main drawback. Simple interest rate rules may not always be optimal since they do not aim at completely neutralizing demand shocks as under a targeting rule.⁶

Interest rate rules may also be inflexible to special situations. There may under certain conditions be variables relevant to policy making other than inflation and output. One

⁵ However, Rudebusch (2002) argues that interest smoothing behaviour may imply that the policy maker will act sub-optimally. Further, Lansing (2002) attributes interest smoothing as an illusion caused by real time information problems. An alternative interpretation for interest rate smoothing is that interest rates have inertia.

⁶ This is because equation (2.1) now becomes relevant for determining interest rates. See Walsh (2003) p. 549 for a formal derivation.

example of this is the exchange rate, particularly for small open economies. Another example is asset prices which in extreme circumstances may adversely affect the real economy. Both of these will be discussed further in section 3.5

Given their drawbacks, it follows that simple interest rate rules should be used with a high degree of caution and at most as reality checks in conjunction with a targeting regime. McCallum (1999) argues that a good interest rate rule is one that is robust to different modelling assumptions. Much of the econometric literature has therefore aimed at finding simple relationships that can be used in a wide spectre of situations.

2.3.1 Empirical Issues:

Unfortunately, econometric work has shown that a simple interest rate rule such as that proposed by Taylor (1993) fail to describe real time monetary policy with a reasonable degree of efficiency. There are at least two reasons for this. First, there is uncertainty related to measuring the steady state level of the output gap, and second, some of the variables are subject to significant revisions over time.

Steady state/trend:

Estimating steady state or trend output is associated with a high degree of uncertainty since most macroeconomic variables are non-stationary. Bjørnland et al. (2004) gives a good overview of how to extract non-stationary trends. In general there are two methodologies. One way is using a statistical detrending method such as a Hodrick-Prescott (HP) filter, which is the preferred methodology of Norges Bank.⁷ An HP filter allows for a discretionary weight (λ) between a stochastic and a deterministic trend and is given by the following:

$$\min_{y_t^*} \left\{ \sum_{t=1}^T (y_t - y_t^*)^2 + \lambda \sum_{t=1}^{T-1} [(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^*)]^2 \right\}$$

where y^* is potential output. A $\lambda = 0$ implies a stochastic trend and a $\lambda \rightarrow \infty$ implies a deterministic (linear) trend. The main advantage of an HP filter is that it is very simple to

⁷ See e.g. Norges Bank's Inflation Report No. 1 (2003).

use. The drawbacks are that the choice of λ is subject to discretion and that the end points of the time series are likely to yield a too stochastic trend.

Another method is to use a multivariate methodology such as a production function or a structural vector autoregression (SVAR). Regardless of methodology, the results are likely to be imperfect due to the stochastic properties of the data which gives rise to uncertainty. Although in general all models yield similar results, they may diverge significantly over shorter time periods which is a serious drawback (see Bjørnland et al. (2004) for more details).

Data revision:

Some economic time series are subject to considerable revisions over time relative to the initially published figures. In particular this is related to output data such as GDP and productivity. One possible solution to this problem has been proposed by Orphanides et al. (2000). They find that the growth gap (actual growth less steady state growth) is subject to less revision than the output gap and formulate an interest rate rule where the output gap is replaced by the growth gap. Although their results are specific for the U.S. there are reasons to expect that data revisions are of the same concern in all countries including Norway, (see Bernhardsen et al. (2004)).

On Norwegian data, Olsen et al. (2002) finds that for the period 1995-1999 mainland GDP growth was revised up by on average 1% per year, which suggests that there is considerable uncertainty related to the growth gap as well. They further argue that other variables such as the unemployment gap or the combination of the credit gap and the wage gap, can achieve better results. Bernhardsen & Bårdsen (2004), however, shows that the unemployment gap is not significant and argues that the *estimated* growth gap for the next 12 months is the most appropriate measure. However, one thing these studies have in common is the relatively low size of the coefficient of the output parameter and in some cases the relative low significance levels. Hence, despite the vast amount of empirical literature available, the real time problem for empirical interest rate rules remains unsolved.

3. Monetary policy and asset prices

The traditional view on asset prices and monetary policy in New Keynesian framework is that they play no role. This is founded on the New Keynesian literature which assumes optimizing households and firms. However, New Keynesian models do not fully incorporate the adverse effects of severe asset price misalignments for at least two reasons. First, household optimization implies intertemporal consumption smoothing which in turn assumes somewhat stable asset prices since they provide for a predictable store of wealth. The existence of severe asset price misalignments, which are prevalent in most asset markets, implies that households may act sub-optimally since such misalignments may significantly impact their lifetime savings. Second, the literature has generally downplayed the role of investments since adding a variable capital stock does not significantly change the overall results (see e.g. McCallum & Nelson (1999)). However, recent studies have found that variability in capital utilization may be an important prerequisite for inflation persistence (see e.g. Dotsey & King (2001) and Christiano et al. (2001)), which may suggest that asset price volatility is desirable. This view regarding the capital stock is supported by other New Keynesian type models such as RBC models with balance sheet effects (see e.g. Arnold (2002)).

Severe asset price misalignments are prevalent in most asset markets and much of the literature ascribes the causes of asset price misalignments to exogenous factors such as agency problems and/or behavioral reasons. Asset price bubbles are examples of this. The adverse effects asset price bubbles may have on the real economy have also been thoroughly discussed in the literature, albeit less so in the context of monetary policy. Frictions in financial markets are therefore likely to give asset prices a more prominent role in monetary policy than what the traditional view advocates. Booms and busts in asset prices are undoubtedly bad for the real economy and history is plentiful of examples. Borio et al. (1994) shows that volatile asset prices (asset bubbles) have been an important factor in explaining business cycles in both industrial and developing countries. Gerdurp (2003) show similar results for Norway.

In the following section I will discuss the inclusion of asset prices in monetary policy rules. First, I will give a brief overview of what determines asset prices how asset prices are affected by monetary policy. Second, I will discuss the impact asset prices may have on monetary policy. Third, I will discuss explicit targeting versus using asset prices as an information variable. In so doing I will discuss asset prices in a theoretical framework where I survey and discuss some of the main findings in the literature. Last, I will discuss asset prices in a practical framework in terms of interest rate rules where among other things I will discuss the simultaneity issue between asset prices and monetary policy.

3.1 Asset price determination and interest rates

The effects of monetary policy on asset prices are best illustrated using the Capital Asset Pricing Model (CAPM). Despite many shortcomings, the CAPM is the most widely used valuation tool in economics.⁸ The fundamental CAPM valuation equation is as follows:

$$(3.1) \quad P_t = \sum_{i=1}^{\infty} \left(\frac{1}{1+r_{t+i}} \right)^i E_t(d_{t+i})$$

where P is the price of the asset, r is the risk adjusted discount rate and, d is the periodic dividend payment, and E is the expectations operator. The value of an asset is the present value of all future dividends paid discounted back using risk adjusted discount rate.

It is clear from (3.1) that monetary policy affects asset prices in two ways. First, monetary policy sets interest rates and therefore influences asset prices through an interest rate channel. With lower interest rates, future dividends are discounted at a lower rate and hence asset valuation increases, and vice-versa. Second, monetary policy affects output and hence also dividends. That is, lower interest rates cause aggregate demand and future dividends to increase, and vice-versa.

It is important to note that the discount rate (r) in equation (3.1) is period specific and not a constant. That is, it varies in each period reflecting the term structure of interest rates. It follows therefore that the effect of short-term interest rates on asset valuation is likely to be modest since monetary policy is a short-term policy tool. This is also consistent with the empirical findings in section 5.

⁸ Shortcomings of the CAPM will be discussed more at length in section 4.

The long-term effect of monetary policy on asset prices can be easily illustrated if we re-write (3.1) assuming dividends grow at a constant (steady state) rate:⁹

$$(3.2) \quad P_t = \frac{E_t(d_{t+1})}{\hat{r} - g}$$

where g is the dividend growth rate and \hat{r} is the long-run expected return on the asset. This formulation however requires that both \hat{r} and g are constant and that $\hat{r} > g$. Equation (3.2) implies that short-term interest rates, and hence monetary policy, have no effect on asset valuation in the steady state. Correspondingly, if monetary policy is not aimed at affect long-term economic performance it should not affect long-term interest rates nor steady state asset valuation.

3.2 The effect of asset prices on monetary policy

In text-book macroeconomic theory (i.e. in an AD-AS framework), asset prices affect aggregate demand through consumption and investments. That is, higher asset prices lead to increased consumption and increased investments. In a traditional aggregate demand equation this can be formulated as:

$$(3.3) \quad Y = C(\overset{+}{\Omega}, \overset{+}{w}, \overset{+}{mf}, \dots) + I(\overset{+}{q}, \overset{+}{c}, \dots) + \dots$$

where Ω is household wealth, w is household wages, mf is the level of market frictions, q is the ratio indicating the replacement cost of capital (Tobin's q), and c is the amount of collateral available (+/- signs indicate the sign of the partial derivative w.r.t. their respective functions).

Consumption is affected by asset prices through three channels. First, lifetime wealth is affected by asset prices and inevitably so is consumption since wealth is the premises for consumption smoothing. Second, higher asset prices affect household expectations of future wages since firms are expected to earn higher profits, and vice-versa. Third, consumption smoothing is distorted by imperfect capital markets which makes agents more sensitive to

⁹ Sometimes referred to as the Gordon growth model, see Gordon (1962).

current events (as opposed to future events). The two former channels are incorporated into the New Keynesian framework through the assumption of household intertemporal utility maximisation. The latter channel is somewhat overlooked and implies that asset price volatility distorts household's optimising behaviour.

A key question in this connection is the elasticity of consumption with respect to asset prices. Obviously this elasticity needs to be sufficiently high for asset prices to have an effect. There have been some findings that support this, particularly for stock markets in the US, but the empirical evidence suggest that this relationship is weak in European countries (see e.g. IMF (2000)). One explanation for this may be the smaller share of stock ownership relative to financial assets in European countries and that real property prices may play a larger role.

Investments are affected by asset prices through two channels. First, changes in asset prices affect the decision to invest relative to the replacement cost of capital (Tobin's q). That is, higher asset prices means that the replacement cost is low hence firms will invest more (since there are arbitrage opportunities in the secondary market). Second, changes in asset prices affect the ability of firms to provide collateral and hence affect their cost of capital (credit channel). Similarly to the wealth effect, empirical evidence suggests that investments are more sensitive to asset prices in the US relative to Europe (see e.g. IMF (2000)). Unfortunately, no study to date has investigated the combined elasticity of the stock market and house prices on both consumption and investment and hence the relative role of asset prices in the US and Europe remains inconclusive.

3.3 Asset prices as an explicit target?

Much of the debate in the economic literature concerning asset prices is whether asset prices should be targeted explicitly or if they are only useful as an information variable for future inflation (see e.g. Chadha et al. (2003) and Bjørnland & Leitemo (2005)). Arguments in favour of targeting asset prices explicitly are primarily based on the idea that frictions in financial markets may lead to unsustainably high asset prices (e.g. asset price bubbles) which, if not addressed, may have adverse effects on the real economy (such frictions are discussed at more length in section 4). Aside from the argument concerning capital utilization, arguments against are based on the uncertainty surrounding the identification of asset price misalignments and the uncertain effects potential remedies may have on asset

markets. The consensus in the literature therefore seems to favor that asset prices should not be targeted explicitly. However, asset prices may still be a useful variable due to its forward looking nature as discussed in section 3.1. That is, asset prices may contain information regarding future inflation not found elsewhere.

The traditional theoretical view on asset prices and monetary policy is that asset prices play no role in an inflation targeting regime. Proponents of this view are Bernanke & Gertler (1999) and Bean (2003), among others. Bernanke & Gertler (1999) constitute the main theoretical argument for not including asset prices in monetary policy decision making. They argue that the central bank does not have sufficient information to correct for price misalignments in asset markets. Using a theoretical model with sticky prices, they show that as long as the central bank reacts aggressively to inflation, it also prevents asset price misalignments from occurring. Bean (2003) reviews the role of asset prices and similarly concludes that optimal policy is sufficiently embraced by flexible inflation targeting.

Some objections need to be made. First, central banks rarely react aggressively to inflation. This is advocated by so-called “flexible inflation targeting” which implies that central bank adjusts their policy interest rate gradually (or more formally have a flexible time horizon). Second, it is not obvious that central banks do not have sufficient information to react to asset price misalignments. Cecchetti et al. (2000) argue that identifying asset price misalignments is not fundamentally different from identifying the output gap or the equilibrium real interest rate. In that respect, since the central bank must make an assessment of the output gap by making a qualified “guess” of what constitutes potential output, there is no reason why they could not do the same with asset prices.

There is an abundance of theory based literature that advocates the use of asset prices in monetary policy, all of which focus on the presence of frictions in asset markets. Most notable are the works by Borio & Lowe (2002), Carlstrom & Fuerst (2001) and Cecchetti et al. (2000). Borio & Lowe (2002) argue that financial distress can build up in an inflation targeting regime for two reasons. First, an adverse selection problem may arise since stable interest rates will likely lead to easier access to credit and hence poor lending decisions are more likely. Second, if the central bank is credible, prices will be more sticky and hence investors will take higher risks. They suggest that the central bank should react to such imbalances when appropriate.

Calstrom & Fuerst (2001) develops a theoretical model similar to that of Bernanke & Gertler (1999), but assumes that prices are perfectly flexible (which may not be realistic). They show that there is a role for asset prices in monetary policy when there is imperfect information and exogenous asset price shocks. Furthermore, their findings illustrate the model dependency of the results since their results are the exact opposite of that of Bernanke & Gertler (1999).

Cecchetti et al. (2000) also argue that optimal policy should take asset prices into account. They argue that inflation forecasts depend on an assumption regarding asset prices hence asset price misalignments may play a significant role. Although they develop no formal model, they show econometrically that asset prices have a strong effect on future inflation. They also argue that attempting to reduce asset price misalignments will reduce the likelihood of asset price misalignments in the future. They do, however, acknowledge that asset prices should not be targeted per se, only that asset prices should be used as an indicator of future inflation.

From a practical view, the answer to whether asset prices should be targeted may be more obvious. As argued by Bjørnland (2005a) fighting asset inflation or asset price misalignments through explicit targeting may do more harm than good. That is, increasing the policy interest rate due to asset price misalignments may have overly negative effects on output through a stronger exchange rate and lower inflation. This is also supported by the link between asset prices, investments and capacity utilisation may imply that volatile asset prices are a prerequisite for inflation persistence (as argued by Dotsey & King (2001) and Christiano et al. (2001)). It might therefore be that asset prices should not be targeted at all, at least during normal circumstances when asset valuations are not unduly exuberant.

The view that asset prices can be viewed as an information variable is based on the forward looking nature of asset prices since as discussed in section 3.1. Asset prices are forward looking since they contain information about future dividend growth, future interest rate levels and future risk premia. In the strictest sense, there is therefore no causal relationship between asset prices and monetary policy (see e.g. IMF (2000)) provided the central bank is at no informational disadvantage (see e.g. Bjørnland & Leitemo (2005)) and if there is no

policy regime change. That is, if the central bank has the same information set as that of the asset market then information provided by the asset market is irrelevant.

One key assumption here is that the asset market is priced correctly based on aggregate expectations and that fluctuations in asset markets reflect changing expectations and fundamental reasons only. However, it is not at all obvious that all fluctuations in asset markets reflect changing expectations and fundamental reasons only, nor is it obvious that markets are efficient, and there is an abundance of theoretical and empirical evidence to support this (see e.g. Allen & Gale (1999, 2000a, 2000b) and Shiller (2003)). Frictions in financial markets, particularly those related to agency theory, allow for price misalignments in asset markets which may “cloud” the information extracted from asset markets, or at least make it sufficiently different from the information set of the central bank. Asset prices may therefore provide a good benchmark for economy wide expectations (which is what really matters).

3.4 Asset prices and simple interest rate rules

Although asset prices may have a role in monetary policy due to their informational content, there is much disagreement in the literature whether they may have a role in simple interest rate rules. Bernanke & Gertler (2001) rejects the use of simple interest rate rules with asset prices altogether. They use simulation to compare various interest rates rules, with and without asset prices, and measure how their models respond to various types of shocks. They find that a policy rule that only takes into account inflation and output is the most efficient. However, one problem with their methodology is that a simulation framework does not aim to measure the central bank’s reaction function, but aims at measuring relative efficiency. Another is that their model is highly simplified and does not take into account other explanatory variables that may impact interest rates such as interest rate smoothing.

Simulation studies, or “new normative macroeconomic research” as dubbed by Taylor (2001), are highly model dependent. This is well illustrated by the findings of Akram et al. (2005) who finds that adding asset prices to an interest rate rule may improve macroeconomic performance, which is the exact opposite of Bernanke & Gertler (2001). They use Norwegian data from 1984-2000 and simulate macroeconomic performance when adding asset price shocks. They find that variability in output and inflation decreases when asset prices are included in the central bank’s reaction function.

Chadha et al. (2003) estimates empirical interest rate rules with asset prices using a GMM methodology on data from the US, UK and Japan from 1979-2003. They argue that asset prices should be used as an information variable concerning future inflation and that central banks should use the policy interest rate to offset price misalignments in asset markets. They find that asset prices are relevant when misalignments in asset markets are relatively large implying that asset prices may enter into the central banks' reaction functions. However, they concede that asset prices may enter the reaction function non-linearly which suggests that estimating interest rate rules with asset prices may be difficult.

Bordo & Jeanne (2002) argue along the same line, suggesting that adding asset prices to the central bank's reaction function may be optimal but that such a rule is unlikely to be linear. They use two historical examples of when reacting to asset prices bubbles have gone awoul. They argue that a contractionary monetary policy following the 1929 crash and Japanese real estate bubble in the 1980s were sub-optimal since higher interest rates worsened the effects on the real economy (see also Bordo et al. (2001)).

This illustrates well the dilemma when considering asset prices in monetary policy. If interest rates are used as a tool to burst an asset bubble, the central bank may risk initiating a financial crisis. Allen & Gale (1999, 2000a,b) argues that if a financial crisis occurs, the central banks primary role should be to provide liquidity for ailing banks. This in turn implies that interest rates should be lowered which may explain the non-linearity of the central banks reaction function. However, so long as no financial crisis occurs, there are no a priori reasons to expect that the central bank's reaction function should be non-linear.

3.5 Empirical issues related to interest rate rules and asset prices

The interest rate and possible explanatory variables will in general be mutually dependent. That is, one or more of the explanatory variables might be endogenous. Failing to account for such endogeneity issues will yield inconsistent estimators. The inclusion of exchange rates in interest rate rules for small open economies is a good example. The exchange rate has a simultaneous relationship with interest rates. That is, higher interest rates generally imply an appreciation of the exchange rate. A stronger currency generally implies higher imports which in turn imply lower interest rates. It follows therefore that estimating an

interest rate rule with the exchange rate as an explanatory variable will yield inconsistent estimates since the exchange rate is not exogenous. It may therefore be appropriate to estimate the impact of the exchange rate using a simultaneous model where the exchange rate is treated endogenously.

Much of the empirical work related to exchange rates is based on calibrated structural macroeconomic models where various interest rate rules are tested based on different types of shocks. Obstfeld & Rogoff (1995), Ball (1999) and Svensson (2000) all find that simulated interest rate rules that include the exchange rate perform better than those without. Taylor (2001) on the other hand argues that these improvements are relatively small and that the exchange rate should not be targeted at all, even for small open economies. He argues that there exists an indirect effect of the exchange rate on inflation and output, assuming a rational expectations model of the term structure of interest rates and that the policy rule will be used consistently over time. It has also been common to use simultaneous models to account for the endogeneity of the exchange rate. One such example is Bernhardson & Bårdsen (2004) who estimates an interest rate rule with the exchange rate using Norwegian data from 1999-2005 where they find that the effect of the exchange rate is significant.¹⁰ One objection to such a methodology is that it somewhat defeats the purpose of a “simple” interest rate rule since the rule will be more model dependent and hence less robust.

Due to simultaneity, there are reasons to believe that asset prices may behave in a similar fashion as the exchange rate. As discussed in section 3.1, asset prices are affected by monetary policy since interest rates affect asset valuations through the discount rate. Conversely, as discussed in section 3.2, asset prices affect monetary policy through variation in aggregate demand which in turn affect interest rates.

This is supported by the empirical literature where the effect of monetary policy on asset prices has been studied extensively. Traditional studies have largely found these effects to be modest, although they point in the right direction. That is, higher interest rates lead to lower asset prices (and vice-versa) and higher asset prices lead to higher interest rates (and vice-versa). Event studies have tried to find the immediate effects between asset prices and monetary policy; e.g. Bernanke & Kuttner (2004) finds that an unexpected rate increase of

¹⁰ Due to data limitations however, they estimate an interest rate rule with the foreign interest rate as an instrumental variable for the exchange rate under the assumption of interest parity.

25 basis points reduces asset values by 1 percent primarily due to lower equity risk premiums. Rigobon & Sack (2004) have found similar results. However, event studies fail to account for long-term simultaneity effects between asset prices and monetary policy although Rigobon & Sack (2003) shows that increased asset prices increases the likelihood of higher interest rates. Newer studies using structural vector autoregression (SVAR) models find that the simultaneity effect is much stronger. Bjørnland & Leitemo (2005) find a high degree of interdependence between asset prices and monetary policy. They show with US data that a 10 basis point interest rate increase decreases asset valuations by 1,5% and that an increase in asset valuations of 1% leads to 5 basis point interest rate increase. Asset prices and monetary policy are therefore interdependent and should be modelled simultaneously with both interest rates and asset prices as endogenous variables.

4. Price misalignments in asset markets

It is generally agreed that asset markets are not perfectly efficient (see e.g. Shiller (2003) and Malkiel (2003) for an overview). Asset markets are subject to considerable noise which may be persistent in the sense that valuation in asset markets can deviate from its fundamental value over longer periods of time. Asset price bubbles are examples of this. There are at least three factors that may cause asset markets to deviate from their fundamental value. First, frictions in asset markets, particularly those related to principal-to-agent related issues, signify that asset markets may be incorrectly priced. Second, there may be behavioural or psychological effects that cause asset prices to have short-term momentum (see e.g. Shiller (2003)). Third, asset prices may be subject to noise like any other economic variable simply because there will be pricing disagreements among agents.

Frictions in financial markets have been widely studied, particularly those related to principal-to-agent related issues. Such frictions may include liquidity rationing, risk shifting, and convex incentive schemes of intermediaries, among others. These will be discussed in more detail in the next section. Thereafter, in section 4.2, I will discuss some methodologies for identifying price misalignments. I will also attempt to find a reliable indicator for price misalignments in the Norwegian stock market that can be used for empirical purposes.

4.1 Frictions in asset markets and asset price bubbles

Traditionally, macroeconomic modelling has assumed complete markets, or markets without the existence of frictions. The principal-agent literature, however, identifies several “frictions” which may give rise to incomplete markets. The literature concerning asset price bubbles and financial crises has ascribed the existence of incomplete markets as an important contributing factor to the existence of asset price misalignments. Deviations in asset values from their fundamental values can therefore be ascribed to market incompleteness.

Since information is costly, financial intermediaries have a prominent role in the functioning of financial markets. That is, there is asymmetric information between principals and agents. The presence of information asymmetries gives rise to the two most commonly noted market

frictions; the moral hazard problem and adverse selection problem. A moral hazard problem arises when the interests of the principal and the agent are misaligned. An adverse selection problem exists when there are information asymmetries between principals and agents and the principal is forced to make a sub-optimal choice. Note that these frictions give rise to even more financial intermediaries since moral hazard and adverse selection give rise to monitoring (see e.g. Diamond (1991)), credit rationing (see e.g. Stiglitz & Weiss (1981)) and increased quantity of money (see e.g. Bernanke & Blinder (1988)), among others.

Price misalignments due to frictions in asset markets are much discussed in the literature concerning asset price bubbles and financial crises. Allen & Gale (2000a) define a positive (negative) asset price bubble as an event where asset prices are above (or below) their fundamental value.¹¹ Little of the literature has focused on the sources of asset price bubbles in isolation but has instead focused on explaining their occurrence jointly with financial crises. Allen & Gale (1999) describe the development of a typical financial crisis in three phases:

1. Financial liberalisation or a conscious decision to increase lending bids up asset prices due to agency problems and risk shifting.¹² As asset prices increase, more collateral becomes available to fund new loans and the bubble fuels itself.
2. The bubble bursts due to an exogenous real shock or exogenous financial shock.
3. A financial crisis develops since asset prices have collapsed and can no longer serve as collateral for inflated credit levels.

Allen & Gale argue that financial liberalisation or a conscious decision to increase lending bids up asset prices. In this respect they treat financial liberalisation as an exogenous event. However, Shiller (2003) argues that much of the fluctuation in asset price markets may be for behavioural (i.e. psychological) reasons. It is therefore plausible that if asset prices increase sufficiently (for behavioural reasons) access to credit may in fact increase (since bank officers may suffer from the same behavioural dysfunctions as the market) and the bubble may initiate itself.

¹¹ Although it may seem obvious that a small price misalignment is not necessarily a “bubble”, I will treat them as the same thing for the purposes of this discussion.

¹² Risk-shifting occurs when providers of funds are unable to observe the risk level of the ultimate investments.

Asset prices are further inflated due to agency problems. These may include risk-shifting, convex incentive schemes,¹³ increased liquidity and limited liability.¹⁴ However, the existence of agency problems only means that there is an upward-bias in asset valuation. I would argue that this is somewhat overlooked in the literature. It is not agency problems that cause bubbles although their existence may have multiplicative effects. In that sense, agency related problems and other market frictions might give higher persistence to noise in asset markets.

Eventually the bubble will burst due to an exogenous real or financial shock. Allan & Gale use the financial crisis in Norway (1988-92) and the oil shock in 1986 as an example of this. However, Mankiw (1986) shows that in a theoretical framework financial collapse can occur when asset price markets are in disequilibrium (i.e. in a bubble state) and that such a collapse occurs due to adverse selection. Furthermore, I would argue that the behavioural reasons mentioned earlier may serve in the opposite direction to end the bubble. Since future credit growth is already “priced-in” in asset prices, any deviation from expectations may cause the bubble to burst. Whether the burst is due to a real or financial exogenous shock, or due to systemic imbalances is not that important. The main thing to notice is that the bubble will burst sooner or later since credit is limited in supply.

Borio & Lowe (2002) argue that “other common signs [of asset price bubbles] include rapid credit expansion and often, above-average capital accumulation” (p. 1). This is supported by Allen & Gale (1999, 2000b) who develop a theoretical model which shows that the two most important factors that influence the size of an asset price bubble is the amount of credit available (and the expected amount of credit available in the future) and the degree of uncertainty. That is, the higher the uncertainty and the higher the availability of credit, the greater the potential price misalignment. Hence it is the combination of high credit growth and asset prices in a bubble state that gives rise for concern since asset valuations serve as collateral for bank credit.

It is also often argued that real estate prices play an important role in the formation of asset price bubbles. Real estate assets are subject to the same bubble tendencies as equity markets since they are both affected by the availability of credit. Further, real estate is arguably a

¹³ That is, financial intermediaries have unlimited upside in revenues but limited downside.

¹⁴ Investors can only lose as much as they have invested which gives rise to an asymmetric payoff profile.

more important source of household savings in some countries, particularly for Norway (see e.g. IMF (2000)) and Hansen (2003) attributes real estate prices to be a predictor of bankruptcies and therefore an indicator of macroeconomic imbalances. Following Borio & Lowe (2002)'s argument, a rapid increase in credit, real estate prices, and or equity markets in isolation pose little threat to financial stability, but jointly they increase the likelihood of a financial crisis.

Borio & Lowe (2002) argues therefore that a combined index of credit growth, real estate prices and equity markets could be a useful indicator for policy makers. Using cross country annual data from 1960-1999 on a sample of OECD countries, they find that equity markets and credit growth are in combination a reliable indicator of historical financial crises. Although they recognize the importance of real estate prices, they are forced to ignore them due to data limitations. Despite of this, their results are remarkably robust, hence I have opted not to focus on real estate prices in analysis in the succeeding section, but noting that real estate prices may in fact play an important role.

The main problem associated with asset price bubbles is the high probability of an ensuing financial crisis. As Allan & Gale (1999) argue, "financial crises are often associated with a significant fall in output or at least a reduction in the rate of output" (p.6). Why this is the case is fairly obvious: if asset prices decline rapidly and asset prices serve as a source of financial cash flow and as collateral for bank debt, borrowers will have a lower probability of paying interest and repaying their loans. Hence there will be a higher default frequency. This will in turn force banks to write-off bad loans and/or risk having a portfolio of bad loans that is larger than their associated collateral. This may also force banks into insolvency. Jointly this series of events may have adverse effects on the real economy for a number of reasons. First, a banking crisis and/or a bank run may occur. Second, access to credit will be severely constrained since banks will not be able to raise new capital which is likely to lead to a lower investment rate. Third, households will be reluctant to save which may affect their willingness to smooth consumption over time. Allen & Gale (1999) further point out that for small economies this may put serious strain on the economy's currency since the central bank may be forced to lower interest rates to prevent banks from becoming insolvent. This may have particular relevance for Norway. Additionally, there is strong

empirical evidence of a link between financial crisis and a drop in output (or a reduction in growth), see e.g. Bernanke & Gertler (1989) and Gerdrup (2003) for Norway.¹⁵

It is clear therefore that asset price misalignments may undoubtedly be bad for the real economy. The question then arises how policy makers should respond to such misalignments. There are at least three approaches, depending on how far the bubble has developed. First, policy makers can impose regulation and institutional structures such that financial crises are unlikely to occur (see e.g. Bernanke & Gertler (1999)). Second, policy makers can proactively try to prevent them by intervening when appropriate by e.g. raising interest rates to reduce asset valuations and reduce the availability of credit. Third, policy makers can reduce the impact of financial crises after they have occurred by e.g. lowering the interest rate to provide more credit to ailing banks (see e.g. Allen & Gale (2000a)). Since the appropriate response depends somewhat on how far the bubble has developed, it is likely that the response function of policy makers with respect to asset prices is non-linear, similarly to some of the findings in section 3.4.

4.2 Price misalignments in the Norwegian stock market

There is much disagreement in the literature whether identifying asset price bubbles are at all possible. Gurkaynak (2005) argues that there are several econometric problems with identifying asset price bubbles using the CAPM. In light of this, many economists dismisses the idea of asset prices in monetary policy outright (see e.g. Bernanke & Gertler (1999)). However, as Cecchetti et al. (2000) points out, the difficulties associated with measuring asset price misalignments are not substantially different from those associated with measuring the output gap. I will therefore assume that asset price bubble identification is possible.

To identify asset price misalignments one needs to make an assessment about what constitutes fundamental value. There are at least three methodologies on how to evaluate the fundamental value of aggregate asset markets. First there is the CAPM approach which has already been discussed somewhat in section 3.1. Second, there is the Tobin's q approach which uses the ratio of observed asset values relative to their replacement cost. Third, there

¹⁵ In particular he finds reduced output following the financial crises of 1899-1905, 1920-28, and 1988-92.

is a much simpler but nonetheless effective approach of measuring the deviation in asset returns from their long-run trend.

All three methodologies are based on the same economic principle: that there exists a steady state valuation level since long-run corporate profits cannot grow faster than the economy as a whole. In the short-run, however, there might be more variables affecting asset valuations such as risk shifting or behavioural reasons as pointed out in the previous section. Such frictions imply that evaluating short-run asset valuations is not an exact science and there might be considerable room for disagreement, which of course is the reason why asset markets are so volatile. Other variables affecting short-term valuations, such as access to natural resources, will for the purposes of this paper be ignored since they are unlikely to affect short-term policy decisions.

4.2.1 The CAPM approach:

The CAPM says that the periodic return on any asset is the periodic risk free rate plus a risk premium that reflects the risk level of the asset:

$$(4.1) \quad E_t(r_{i,t}) = r_{f,t} + \beta_i(r_m - r_{f,t})$$

where $r_{i,t}$ is the return on asset i in period t , $r_{f,t}$ is the risk free return in period t , r_m is the return on the market portfolio, β_i is the risk coefficient of asset i relative to the market and E is the expectations operator. However, it is worth noting that the formulations in (4.1) is related to individual assets. When valuing the aggregate asset market (4.1) can be written as:

$$(4.2) \quad E_t(r_{i,t}) = r_m$$

since the β of the aggregate asset market must be 1. This is important since it implies in the long run asset valuations are determined by economy wide characteristics only. It is plausible, however, that the expected return may fluctuate in somewhat in the long-run reflecting e.g. the level of competition (see e.g. Smithers & Wright (2000)).

The CAPM has many shortcomings. The most important is probably that pointed out by Shiller (2003) which is that the CAPM cannot explain much of the volatility in asset

markets. Most economists therefore agree that the CAPM only serves as a long-term valuation guideline and that short-term asset prices are subject to considerable noise. It may appear therefore that the traditional CAPM methodology may be incorrectly specified, that it fails to account for important variables, or at least that it only serves as a representation for a steady state solution.

There has been much debate in the literature on the validity of the CAPM, most of which has been centred on whether the CAPM is at all testable. The untestability of the CAPM is well summarized in Roll (1977). Roll ascribes the untestability of the CAPM to the identification problem of the true market portfolio and that the only valid conclusion one can draw from testing the CAPM is that there is insufficient data available. Other problems with the CAPM are mostly related to its assumptions and how the model is applied. The CAPM is founded on some fairly unrealistic assumptions which are sometimes overlooked. First, the CAPM defines risk as the covariance of future returns with other asset markets in general. This is a fairly narrow definition which ignores risks such as default risk and the fact that risk is heavily right-skewed due to market frictions. Second, for practical purposes there is no such thing as a truly risk-free interest rate since there is no guarantee that central banks cannot go bankrupt. Third, there is ample empirical evidence that asset markets are not perfectly efficient (see e.g. Shiller (2003) for an overview).

Despite its weaknesses the CAPM is widely used in financial markets and is the most frequently used model to identify asset price misalignments. Gurkaynak (2005) adds an error term to the standard CAPM valuation equation to allow for noise in asset markets, similarly to that of Shiller (2003):¹⁶

$$(4.3) \quad P_t = \sum_{i=1}^{\infty} \left(\frac{1}{1+r} \right)^i E_t(d_{t+i}) + B_t$$

where B_t is an error term that can be interpreted as a bubble component that gives rise to price misalignments. Shiller (2003) shows that equation (4.3) applied on dividends paid on the S&P500 from 1871-2001 tracks actual returns remarkably well. However, as Gurkaynak (2005) points out, the purpose of Shiller's study was not to identify price misalignments, but

¹⁶ This can be shown under certain conditions of the Consumption CAPM (CCAPM) which is derived from a household optimisation problem.

to test for market efficiency. Despite this, many researchers have adopted Shiller (2003)'s methodology to test for asset price misalignments with limited success (see Gurkaynak (2005) for an overview).

There are however some differences in assumptions between the standard CAPM and the formulation in equation (4.3). First, equation (4.3) explicitly assumes risk neutrality and that marginal utility is constant. This is different from the standard CAPM which assumes at least some level of risk aversion. Second, as pointed out by Gurkaynak (2005), equation (4.3) assumes a constant discount rate and a constant dividend growth rate. However, the standard CAPM does not require the discount rate nor the growth rate to be constant (except in the steady state). This is noteworthy since a variable discount rate allows asset prices to exhibit much higher volatility as shown in Shiller (2003). Third, equation (4.3) does not allow for persistent price misalignments since the error term is identically distributed with a mean of zero, which is a clear drawback. Fourth, and perhaps more importantly, neither the standard CAPM nor the formulation in (4.3) assume information asymmetries.

Given these limitations it is not at all obvious that the CAPM is a realistic nor an appropriate methodology for valuing aggregate equity markets. The CAPM is primarily a tool for valuing individual assets that are not exposed to specific frictions such as those discussed in the previous section. Further, some fairly unrealistic assumptions and ambiguity around the correct specification of the model makes the model less robust.

However, the biggest obstacle to identifying asset price bubbles in Norway is the availability of long and consistent time series data. Unfortunately, for the CAPM methodology little readily available time series data exists prior to 1996. In light of this and the abovementioned associated problems with using the CAPM to identify asset price misalignments I have not used the CAPM methodology in the ensuing analysis.

4.2.2 *The Tobin's q approach:*

The idea of valuing aggregate asset markets as a whole goes back to Tobin (1969). His idea was that asset markets are mean reverting in the sense that observed market value over time must converge to its replacement cost of capital. It follows therefore that asset markets are “overvalued” when the observed market values are higher than its replacement costs, and vice versa. This relationship is often referred to as the Tobin's q ratio.

Smithers & Wright (2000) argue that the Tobin's q principle is more appropriate than the CAPM methodology when valuing asset markets in aggregate. They argue that the Tobin's q principle says that in aggregate asset markets there are supply and demand forces at work just as in any other market. Hence, if the aggregate valuation of all companies is too low, more companies will enter the market and hence drive up aggregate value. The same applies when aggregate valuation is too high where companies will be sold at inflated prices. They do not rule out the possibility that some companies may be earning above- or below-average profits in which case a CAPM valuation approach would be appropriate. They only assert that the aggregate asset market can only be affected by business cycles, not by company specific events such as bankruptcies. They assert that profits matter only when valuing one company, not when valuing all of them since companies individually are small relative to the economy but in aggregate produce the bulk of all economic output. The same applies for growth; individual companies can grow faster or slower than the economy as a whole over longer periods of time but companies in aggregate cannot. It follows therefore that the valuation of companies in general should follow the business cycles of the economy as a whole.

Another notable curiosity about Tobin's q is that although it is widely used in text-book macroeconomics, it has received relatively little empirical attention. The most obvious reason for this is lack of data available, at least for Norway. Only recently have economists found enough data to assess the usefulness of Tobin's q. Robertson & Wright (2002a,b) have found that Tobin's q data in the US possess mean reverting properties and coincide well with most of the asset price bubbles of the 20th century. Although it lacks predictive power for overall levels of investments, the authors show that the predictive power for Tobin's q on asset returns is strong, although not overwhelming. Unfortunately no such

study has been performed on Norwegian data but there are no a priori reasons to expect that they would yield significantly different results.

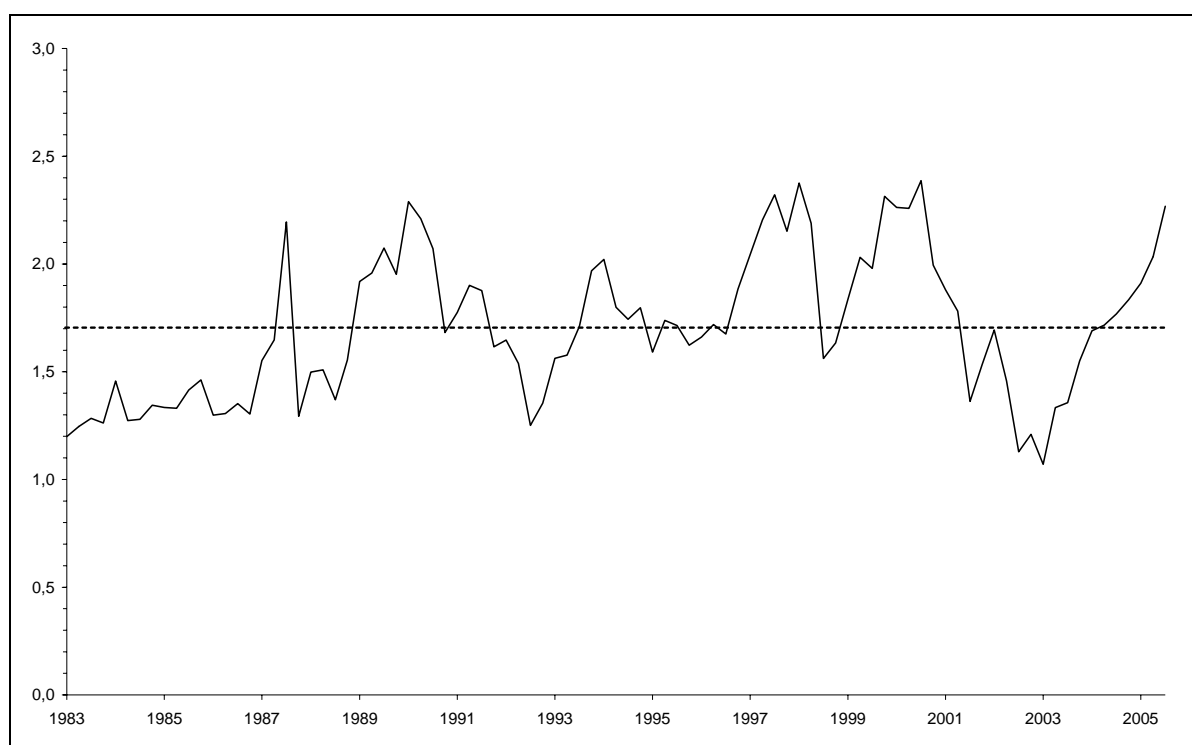
There are however, some objections to some of these findings. The lack of empirical evidence between investment and Tobin's q is well documented in Chirinko (1993) and is a puzzle from a macroeconomic perspective. The consistency between asset returns and Tobin's q is encouraging but it does not provide a definitive answer. Some economists have attributed the lack of predictive power of Tobin's q on the overall level of investment on market frictions and agency problems (see e.g. Hubbard (1998)), and miss-measurement of capital (see e.g. Hall (2000)), among others.

Despite some differences, the best available time series data for Tobin's q in Norway is a price-to-book ratio time series from 1983. It is worth noting that the price-to-book ratio is only a proxy for Tobin's q since for one thing it does not include debt figures. Further, there are differences with regards to depreciation and treatment of goodwill. In that respect, a price to book ratio will be systematically biased. However, for the purposes of assessing relative value this may not be a problem if the systematic bias is somewhat stable over time.

Figure 4.1 shows the price-to-book ratio for all non-shipping and financial companies listed on the Oslo Stock Exchange from 1983-2005.¹⁷ The data series has been adjusted to account for changes in accounting and dividend payout regimes, and adjusted for unpaid dividends to avoid double counting. The data series seems to be able to at least identify some of the main peaks and troughs in the Norwegian asset markets over the last 20 years including the stock bubble of the late 1980s, the recession of 1991-92, the bubble of the late 1990s, the recession of 2003 and arguably the exuberant behaviour in today's stock market environment.

¹⁷ Data series has been provided by First Securities ASA.

Figure 4.1: Price-to-book ratio Oslo Stock Exchange (1983-2005), quarterly*



Source: First Securities ASA.

*Excludes shipping and financial sectors. The series has been adjusted for changes in accounting and dividend payout regimes. The dotted line represents the period average price-to-book ratio of 1.7x.

4.2.3 Deviation in asset returns from their long-term trend:

There is no logical inconsistency between a Tobin's q approach to valuing the aggregate asset market and the CAPM approach. Nor is there any logical inconsistency with an alternative methodology proposed by Kaminsky & Reinhart (1999) and Borio & Lowe (2002). They argue that one can identify asset price bubbles as deviations in asset return from a non-stationary trend, although Borio & Lowe (2002)'s methodology emphasises cumulative effects rather than period imbalances. Both implicitly assume that asset returns have a "trend level" which reflect investor expectations. This is not all that different from the CAPM approach and the Tobin's q approach as all three methodologies implicitly assume that asset returns will be fairly stable over time and that deviations are likely to be reversed since profits cannot grow faster than the economy as a whole in the steady state.

Borio & Lowe (2002) investigates whether above average growth in asset prices and credit can serve as a useful indicator of financial crises. They use a Hodrick-Prescott filter on asset returns and credit growth to estimate an "asset price-gap" and a "credit-gap". Using

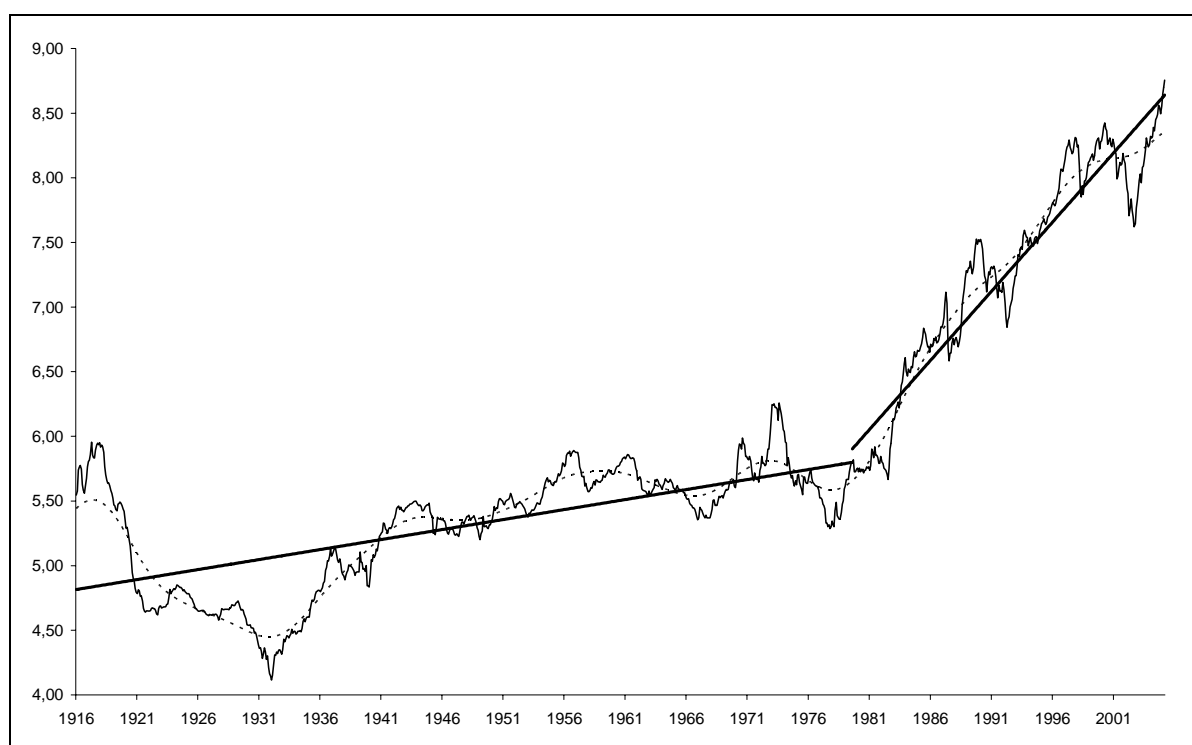
cross country annual data from 1960-1999 on a sample of OECD countries they find that when using an asset return threshold of a cumulative increase of 40% above trend in conjunction with a 4% credit growth gap, they can ex-ante predict all financial crisis identified by Bordo et al. (2001). Their findings are remarkably robust despite failing to account for real estate prices due to data limitations. Interestingly they find that investments and the “investment gap” does not serve as a good predictor of financial crisis.

As argued by Allen & Gale (1999) financial distress usually succeeds asset price bubbles. It is therefore reasonable to assume that an asset price bubble can occur when asset prices are sufficiently higher than their long term trend. The size of this threshold is obviously open to debate but one can get a general idea by using Borio & Lowe (2002)’s 40% threshold as a starting point and examining empirical data for Norway.

Identifying financial crises in Norway is therefore a good place to start. Gerdrup (2003) identifies three financial crises since end of the 19th century: 1899-1905, 1920-28 and 1988-92. Gerdrup finds that the common denominators for these three periods of financial crisis were significant bank expansion and banking competition, considerable asset price inflation and increased indebtedness, and that they were followed by severe economic downturns. Unfortunately, for the purposes of this analysis reliable asset return data only encompass the financial crises in 1988-92.

The longest time series data on asset returns available in Norway is the Historical Stock Price Indexes 1914-2001 from Norges Bank, as shown in figure 4.2. Unfortunately, it is incomplete and hence not comparable over time for at least two reasons. First, prices are nominal and second, and perhaps more importantly, dividends are ignored. Since dividends payout regimes may vary over time this is a serious drawback and hence the time series shown in figure 4.2 is clearly second best. However, I have included it for illustration purposes as it illustrates well that the trend in asset returns varies somewhat over time.

Figure 4.2: Log monthly nominal returns (ex. dividends) Oslo Stock Exchange (1914-2005)*



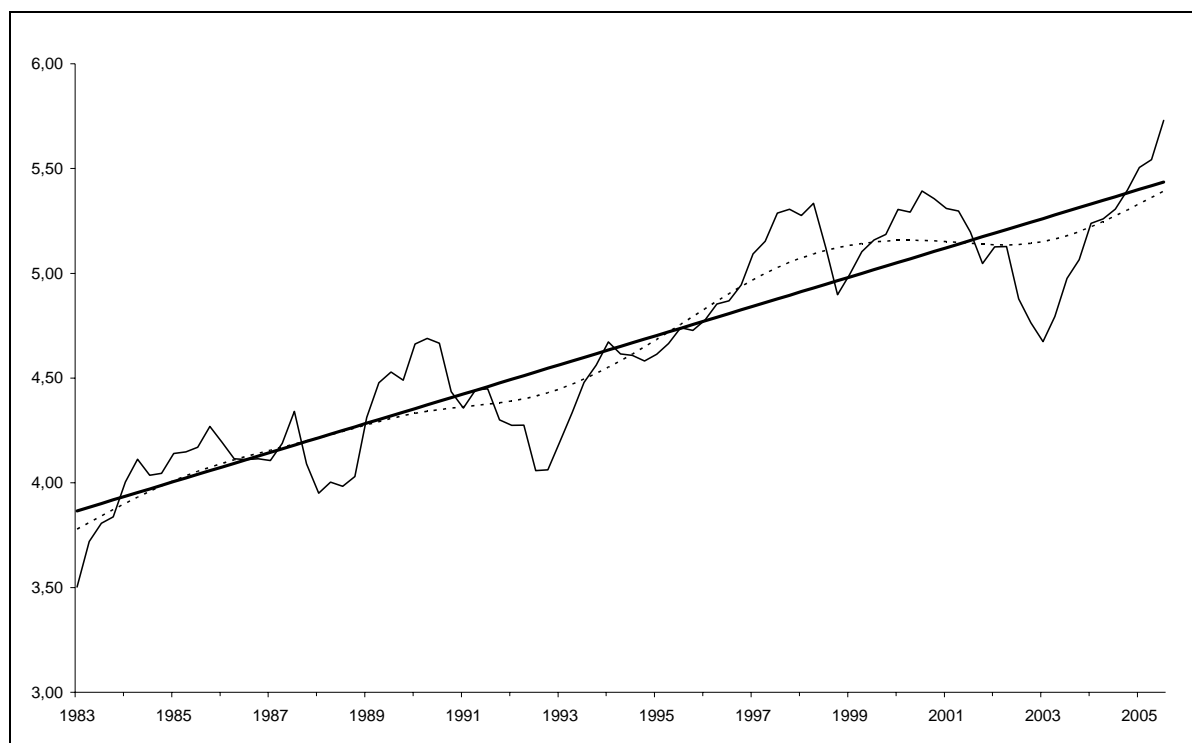
Source: 1914-2001: Norges Bank, 2001-2005: Oslo Stock Exchange (OSEBX Index).

*The two solid black lines are linear regressions from 1914-1980 and 1980-2005 and have slopes of 1,5% and 10,7% p.a. respectively. The dotted line is a stochastic trend using a Hodrick-Prescott filter with $\lambda = 250,000$.

The average return in the whole time period is 3,5% but there is much variation. There is a clear break in the data around 1980 where asset returns seem to have increased. From 1980-2005 asset returns were on average 10,7% vs. 1,5% in the period 1914-1980, which may imply that asset returns are non-stationary although this conclusion is weak due to the low quality of the data. However, it does seem that asset returns are deterministic at least over shorter time periods.

Available data for total return (i.e. including dividends) only goes back to 1983 which is illustrated in figure 4.3. I have for illustration purposes included a linear trend based on an average return of 6.9% and a stochastic trends based on a Hodrick-Prescott filter with a $\lambda = 1600$, partially reflecting the fact that asset returns are deterministic in the short-run but are allowed to vary somewhat in the long-run. It is clear from figure 4.3 that the choice of trend is somewhat arbitrary although it should be noted that the choice of starting point when extracting a trend can seriously affect the size of the trend.

Figure 4.3: Log real quarterly average returns (including dividends) Oslo Stock Exchange (1983-2005)*

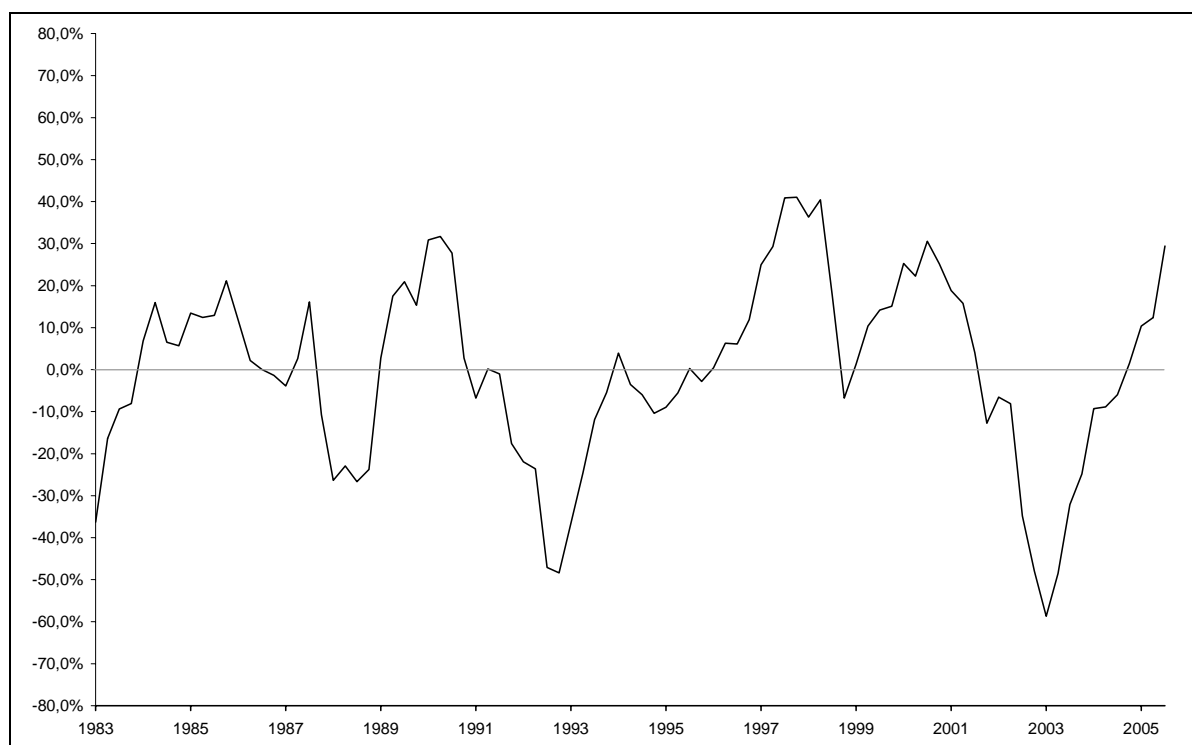


Source: Oslo Stock Exchange (OSEBX and TOTX Index) and Statistics Norway.

* The solid black line represents a linear trend based on an average return of 6.9% and the dotted line is a stochastic trend using a Hodrick-Prescott filter with $\lambda = 1,600$.

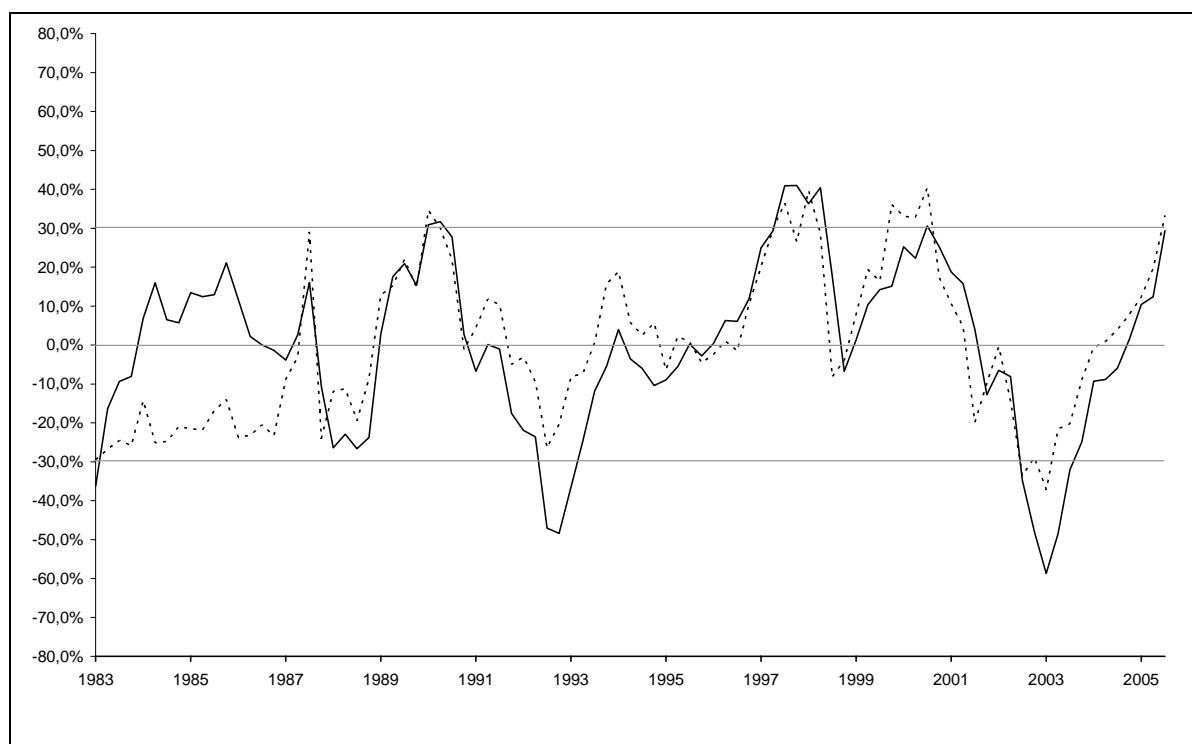
Following Borio & Lowe (2002) I define the “asset price gap” as the difference between the observed asset price level and the trend asset price level. For simplicity I have chosen to use a linear trend when deriving the asset price gap. An asset price gap based on a linear trend is shown in figure 4.4. It is clear from figure 4.4, however, that the results are very similar to that of the price-to-book ratio in figure 4.1 hence they are shown together in a standardized framework in figure 4.5.

Figure 4.4: Asset price gap Oslo Stock Exchange (1983-2005)*



* Based on the percentage difference between the log of real returns and a linear trend.

Figure 4.5: Asset price gaps compared: deviation from trend vs. price-to-book ratio*



* The solid line is the asset price gap based on a linear trend and the dotted line is the percentage deviation in the price-to-book ratio standardized to 1 around its periodic average of 1.70x.

From figure 4.5 we can clearly see that the asset gaps derived using the two methodologies follow each other closely, with the exception of the period 1983-1987. From mid-1987 the correlation between the two is 0,86. However, it should be noted that the deviation from trend methodology is based on quarterly averages whereas as the price-to-book ratio is based on end of quarter values. With that in mind, the deviation from trend methodology is the preferred indicator for the purposes of the empirical analysis in the next section but with regards to identifying price misalignments the choice of methodology appears to be somewhat arbitrary.

Knowing that a financial crisis occurred in the period 1988-1992, as discussed by Gerdrup (2003) and Allen & Gale (1999), it appears that Borio & Lowe (2002)'s definition of an asset price bubble of a 40% deviation from trend may be too strict considering that asset prices peaked at 34% in the period 1988-1992.^{18 19} Using instead a threshold of 30% implies that there have been 3-4 positive asset price bubbles since 1983, depending on parameter choice. Positive asset price bubbles have occurred in 1990, 1997-98, 1999-2000 and in 2005. Negative asset price bubbles have occurred in 1992-93 and in 2003.

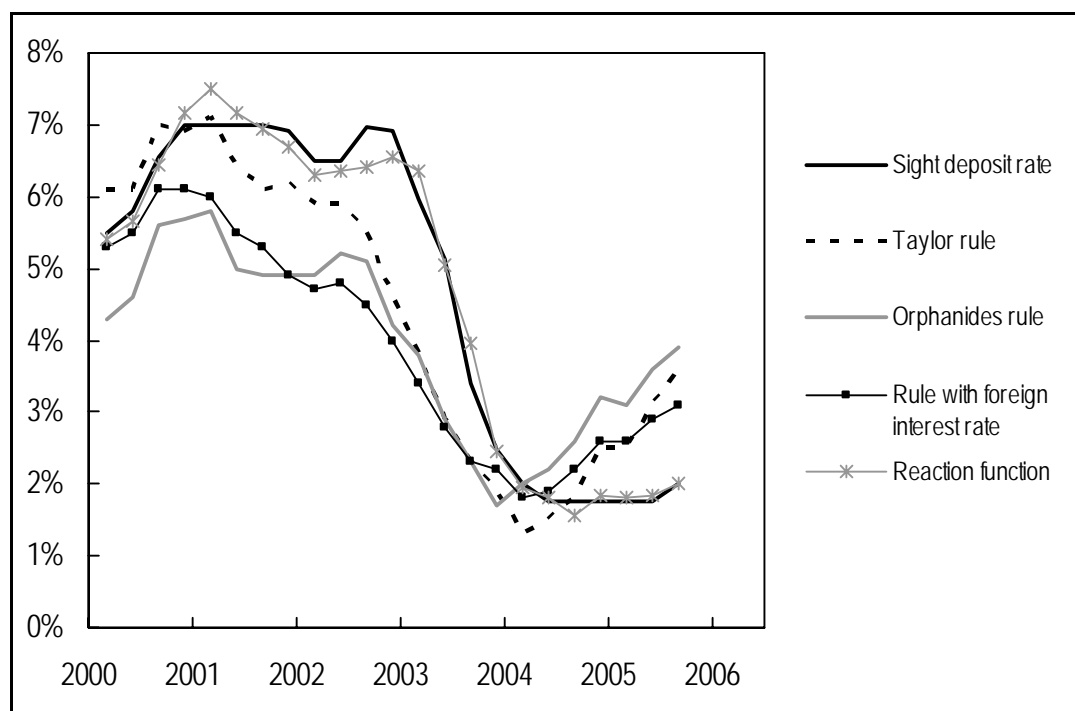
¹⁸ Although Riiser (2005) argues that gap thresholds for Norwegian data ought to be higher than those argued by Borio & Lowe (2002). Further she argues that such thresholds may not necessarily be stable over time.

¹⁹ It should be emphasised that I am using quarterly averages whereas as Borio & Lowe (2002) used monthly data.

5. Empirical results

There have been relatively few studies on empirical interest rate rules on Norwegian data. Arguably this is because Norges Bank has only pursued an inflation targeting policy since 2001 which limits data availability. Recent empirical literature on interest rate rules in Norway includes Bernhardsen & Bårdsen (2004), Olsen et al. (2002) and Akram et al. (2005). In addition, Norges Bank publishes various interest rate rules each quarter including a standard Taylor rule, an Orphanides rule (see section 2.3), a weighted Taylor rule with foreign interest rates and an estimated reaction function.²⁰ These are shown relative to actual interest rate setting in figure 5.1.

Figure 5.1: Interest rate rules versus actual interest rate (sight deposit rate)



Source: Norges Bank Inflation Report No. 3, 2005.

In the next section I will first review some of the previous empirical evidence on interest rate rules in Norway. Thereafter I will perform an empirical analysis on two different samples. The first sample is from 1993 and the second is from 1999. The latter has been used as a robustness check as it represents a different monetary policy regime and includes more

²⁰ Based on the findings of Bernhardsen & Bårdsen (2004). See Norges Bank Inflation Report No. 3, 2004.

variables that are not available from 1993. The choice of sample is based on a trade-off between the availability of a reasonably long time series and the presence of a reasonably stable monetary policy regime. Although Norges Bank did not formally adopt an inflation targeting policy until 2001, Bernhardsen & Bårdsen (2004) have estimated interest rate rules from 1999 (when Norges Bank informally adopted an inflation targeting policy). However, Olsen et al. (2002) argues that monetary policy can be viewed as adhering to a Taylor rule from as early as 1993. The two samples therefore provide insight into interest setting behaviour in what can be viewed as two different monetary policy regimes.

Since a long time series may in general provide more robust results, I will first estimate an empirical interest rate rule with data going back to 1993 and compare the results with the previous empirical evidence. Second, with the same sample I will estimate a simultaneous model with asset prices and see how asset prices can improve the empirical results. Third, I will perform the same analysis on data from 1999 as a check for robustness.

5.1 Previous empirical evidence

Bernhardsen & Bårdsen (2004) find that the empirical interest rate rule that best describe the interest rate setting of Norges Bank in the period 1999-2004 is a variant of the Orphanides rule with the estimated growth gap (for the following 12 months) instead of the actual growth gap. In addition, they use expected inflation similar to the findings of Clarida et al. (1999) and add the wage growth gap and the foreign interest rate to increase the explanatory power of the model. They use the latter as an instrumental variable for exchange rate effects to avoid the simultaneity problem. I have updated their analysis through Q3 2005 and found the following results (t-values in parenthesis):²¹

$$(5.1) \quad i_t = 0,8 i_{t-1} + 0,2[1,5 E_t \pi_{t+1} + 1,0 E_t g_{t+1} + 1,0 ui_t + 0,9 w_t]$$

(10,29) (2,13) (2,80) (1,47) (2,84)

where i is the sight deposit rate, $E_t \pi_{t+1}$ is expected inflation, $E_t g_{t+1}$ is estimated 12 month GDP growth rate, ui is the foreign interest rate and w is wage growth. The model is constrained to have a coefficient equal to zero since all variables are measured as deviations from their steady state (see Appendix 1 for a complete description of all the variables). That is, when all explanatory variables are in their steady states (i.e. all gaps are equal to zero) the

²¹ The original findings by Bernhardsen & Bårdsen (2004) are largely the same.

interest rate gap is also zero, which in this case implies a steady state nominal interest rate of 5,5%.

The results have some interesting implications. First the coefficient on the lagged interest rate is high relative to the other explanatory variables. In isolation this is not problematic since the lagged interest rate is included to emulate interest rate smoothing. However, one cannot rule out that other explanatory variables can have been omitted. Second, all variables are significant under traditional standards and enter the rule with the correct sign, except the foreign interest rate gap. The inclusion of the latter reflects an emphasis on a priori expectations and limited data availability.

Olsen et al. (2002) attempts at finding other real time variables that can substitute for the output gap or the growth gap. They find that the unemployment gap or the wage gap in combination with the credit growth may yield satisfactory explanatory results.²² Their study is also based on a longer time series than Bernhardsen & Bårdsen as they find that interest rate setting in Norway follows a Taylor rule from as early as 1995 despite Norges Bank not having adopted a formal inflation target until 2001. In that respect their findings can be viewed as more robust than those of Bernhardsen & Bårdsen.

Akram et al. (2005) does not attempt at estimating empirical interest rate rules, but instead simulates relative economic performance of a large general equilibrium model under various policy rules. Similarly to Taylor (2001) they find that adding exchange rates to a simple policy rule actually does more harm than good as output variability increases. However, they find that adding asset prices as an explanatory variable may be beneficial as it reduces output variability. Although this particular study is based on simulation and does not attempt at measuring the behavioural pattern of Norges Bank, their findings provide a justification for adding asset prices to an interest rate rule following many of the arguments in section 3.

²² However, Bernhardsen & Bårdsen (2004) finds that the unemployment gap is not significant on Norwegian data, although only in conjunction with other measures of relative economic performance.

5.2 Data and methodology

In estimating empirical interest rate rules for Norges Bank (with or without asset prices) I have opted to follow Bernhardsen & Bårdsen (2004) in the sense that I have focused mainly on a priori expectations of the signs of the coefficients and less so on the level of significance. This is mainly due to a limited sample size although I have opted to use data from 1993 which increases the sample. Olsen et al. (2002) estimates interest rate rules from 1995 arguing that interest setting from 1995 follows closely to a Taylor rule. Bjørnland (2005b) uses a similar argument with data going back to 1993, with the exception of the period from the fourth quarter of 1996 through the first quarter of 1998 (i.e. 6 observations) when Norges Bank clearly was preoccupied with defending the Norwegian krone. I have used a dummy variable to exclude this time period. Nevertheless, the sample size is still relatively small and a priori expectations should still be emphasised. A complete description of the dataset is provided in Appendix 1. Unit root tests (see Appendix 1) confirm that all variables are non-stationary in the levels, thereby motivating me to take differences or analysing the variables as deviations from trend (gap). For some variables like the (domestic and foreign) interest rate and inflation, the variables are close to rejecting the unit root hypothesis. Due to the low power of the unit root test in small samples, I have decided to treat these variables as stationary, modelling them in the levels.

Two points about model specification has to be made. First, I have constrained all models to have an intercept equal to zero by measuring all variables as deviations from their steady states. This is possible since all non-stationary variables have been detrended using a Hodrick-Prescot filter. Second, I have added an interest rate lag variable in all models to emulate interest rate “smoothing” similar to the forward looking rule from Clarida et al. (1999) (see equation (2.8)). Both of these points are important for interpretation. Avoiding an intercept term is advantageous for three reasons. First, model misspecification and exclusion of potentially important variables will show up in the coefficient for the interest smoothing parameter. All things equal, one would prefer a policy rule with a low coefficient over one with a high coefficient on the lagged interest rate. Second, avoiding an intercept term makes it easier to allow for a time-varying inflation target since, as mentioned in section 2.3, the intercept can be interpreted as the steady state real interest rate plus the

inflation target.²³ Third, it makes it easier to include an asset price gap as a deviation from fundamental value (more on this will be discussed in section 5.4).

5.3 Interest rate rules in Norway from 1993

With data from 1993, I do not have access to all the variables used by Bernhardsen & Bårdsen (2004). However, I can estimate more traditional interest rate rules similar to those of Taylor (1993) and Orphanides (2000). In general, however, Taylor rules and Orphanides rules from 1993 and from 1999 generate equally unsatisfactory results. That is, neither output nor growth are significant in the empirical interest rate rule. The following OLS results for an empirical Taylor rule and empirical Orphanides rule with data from 1993 illustrates this:²⁴

$$(5.2) \quad i_t = 0,68 i_{t-1} + 0,32 [2,04 \pi_t + 0,21 y_t]$$

(11,41)
(5,75)
(0,80)

$$i_t = 0,67 i_{t-1} + 0,33 [2,09 \pi_t + 0,04 g_t]$$

(10,77)
(6,89)
(0,24)

Note that y is the output gap and g is the ex-post growth gap (as defined in Appendix 1). It should also be noted that the above equations use actual inflation as opposed to expected inflation as argued by Clarida et al. (1999).

The lack of significance of the output gap and the growth gap may explain some of the motivation by Bernhardsen & Bårdsen (2004) for using the expected growth gap instead of the ex-post growth gap as in (5.2). The coefficient on the lagged interest rate is fairly high albeit lower than in (5.1), which in isolation is a good thing. In that sense, it may appear that interest rate smoothing is less important with longer time series, which is consistent with the empirical findings in the U.S. (see e.g. Taylor (1993)).

However, the relatively low t-values for the output gap and the growth gap indicate that an empirical interest rate rule is best described with inflation as the only explanatory variable. However, there are theoretical problems with such a formulation since, as discussed in section 2.1, monetary policy is a trade-off between inflation and output stabilisation. Hence, a priori expectations tell us that an interest rate rule with inflation as the only explanatory

²³ This follows Bernhardsen & Bårdsen (2004) whom have used a 2% inflation target up to Q1 2001.

²⁴ Dummy variable for regime change is excluded for presentation purposes.

variable is an insufficient description of Norges Bank's reaction function since it ignores output stabilisation.

One alternative solution could be to add the unemployment gap as an alternative real time variable, as argued by Olsen et al. (2002). Adding the unemployment gap (instead of the growth gap) to the Orphanides rule in (5.2) yields the following results:

$$(5.3) \quad i_t = 0,68i_{t-1} + 0,32[1,95\pi_t - 0,51u_t]$$

(13,56) (6,37) (-2,37)

Here the unemployment gap enters the rule with the correct sign (since unemployment is counter cyclical) and is significant under traditional standards.²⁵ Hence the best available empirical interest rate rule from 1993 is an interest rate rule with inflation and unemployment as the explanatory variables. This is in line with the findings of Olsen et al. (2002), but clearly ignores some potentially important variables as shown by Bernhardsen & Bårdsen (2004). Equation (5.3) is, however, a reasonable starting point for a simultaneous model with asset prices.²⁶

5.4 Asset prices in a simultaneous model from 1993

Adding asset prices outright to equation (5.3) will yield inconsistent estimators of the coefficients since asset prices may be an endogenous variable. A Wu-Hausman test for endogeneity confirms that this in fact is the case as shown in Appendix 1. Instead, as argued section 3, it might be plausible to formulate an interest rate rule with asset prices in a simultaneous model:

$$(5.4) \quad i_t = \beta_1 i_{t-1} + \beta_2 \pi_t + \beta_3 u_t + \beta_6 a_t + \varepsilon_{1,t}$$

$$(5.5) \quad a_t = \alpha_1 a_{t-1} + \alpha_2 i_t + \varepsilon_{2,t}$$

Equation (5.4) follows the findings from section 5.3 where a is the asset price gap, and ε_1 is an error term. Equation (5.5) explains the endogenous behaviour of the asset price gap using lags and interest rates only (ε_2 is an error term). Although equation (5.5) could be more elaborate I have attempted at leaving it as simple as possible to avoid complicating the

²⁵ Similar results are found by adding the unemployment gap to the Taylor rule in (5.2).

²⁶ Note however that I have not included the foreign interest rate gap as argued by Bernhardsen & Bårdsen (2004) mainly due to simplicity (but also due to its limited marginal effect).

problem further. That is, I am not ruling out that there may be other potentially important explanatory variables for the behaviour of asset prices but these will be included in the lagged endogenous variable.

I would expect all the coefficients in equation (5.4) to be positive and that $0 < \beta_1 < 1$. This implies that high asset prices in isolation imply high interest rates and vice versa. A coefficient of β_1 less than unity is important to ensure stability of the model. The same applies to equation (5.5) where $0 < \alpha_1 < 1$ to maintain stability. Further, I would expect $\alpha_2 < 0$ since higher interest rates in isolation would lead to lower asset prices and vice versa.

I have used two stage least squares (2SLS) to estimate the model above. There are three reasons for this. First, it is a fairly simple and intuitive methodology which is easily interpretable. Second, an instrumental variable approach can be ruled out due to lack of readily available and good instrumental variables. Third, indirect least squares is not applicable since the system is over-identified.²⁷ In addition, 2SLS is generally thought of as possessing better small sample properties than other similar estimators.

Applying 2SLS on equations (5.4) and (5.5) yield the following results:

$$(5.6) \quad \hat{i}_t = 0,79 i_{t-1} + 0,21 [1,97 \pi_t - 0,56 u_t + 0,06 \hat{a}_t]$$

(10,88) (2,94) (-1,74) (2,04)

$$(5.7) \quad \hat{a}_t = 0,90 a_{t-1} - 2,15 \hat{i}_t$$

(15,85) (-3,00)

where \hat{a} is the estimated asset price gap and \hat{i} is the estimated interest rate gap found by estimating the reduced form equations of the model. The asset price gap enters the model with the correct sign and is significantly different from zero under traditional standards. This may suggest that the asset price gap has important explanatory effects on the interest rate setting behaviour of Norges Bank.

²⁷ The system is overidentified since there are fewer exogenous variables in equation (5.5) (i.e. 1) than there are endogenous variables in the system (i.e. 2).

The same applies to inflation as its partial effect remains virtually unchanged. The unemployment gap, however, is not significant by traditional standards but is kept in the model due to a priori expectations.

The data from 1993 seems therefore to confirm the hypothesis that asset prices may be useful as an information variable. A 1% overvaluation in asset prices increases interest rates by 6 basis points and conversely a 1% increase in interest rates reduces asset prices by 2,15%, based on quarterly averages. This is qualitatively consistent with the findings by Bjørnland & Leitemo (2005), although not quantitatively (since I measure effects on quarterly averages and do not attempt to differentiate between short and long-term effects). Moreover, the results indicate that the asset price gap is a more useful indicator for future inflation than the ex-post growth gap and the ex-post output gap. However, more analysis is needed to make similar conclusions about other potentially important variables that are available in the 1999 sample.

5.5 Robustness check with data from 1999

The sample from 1999 is based on a different monetary regime than the sample from 1993. Hence performing the same analysis as in section 5.3 and 5.4 on data from 1999 will give an indication of the robustness of the results from the previous section. Furthermore, with the results of Bernhardsen & Bårdsen (2004) in mind, it is clear that the results in section 5.3 omit some important explanatory variables such as expected inflation, the expected growth gap, the foreign interest rate level and the wage growth gap. It would therefore be interesting to check whether the methodology used in section 5.4 applied on data from 1999 will yield similar results.

I have formulated a model similarly to equations (5.6) and (5.7) but substituted (5.6) with the results of Bernhardsen & Bårdsen in equation (5.1) and added the asset price gap. The results using 2SLS are as follows:

$$(5.8) \quad \hat{i}_t = 0,90 i_{t-1} + 0,10 [2,09 E_t \pi_{t+1} + 2,66 E_t g_{t+1} + 0,99 u_t + 1,77 w_t + 0,05 \hat{a}_t]$$

(6,06) (1,03) (2,56) (0,53) (2,84) (0,81)

$$(5.9) \quad \hat{a}_t = 1,00 a_{t-1} - 2,69 \hat{i}_t$$

(13,14) (-3,20)

It is clear that all the variables enter the interest rate rule with the correct sign. Some of the variables are not significantly different from zero, at least according to traditional standards. The asset price gap has a coefficient of 0,05 which is relatively low regardless of whether it is significantly different from zero or not, and is the variable with the least effect on interest rates. Nevertheless, the asset price gap is clearly not significantly different from zero but I will leave it in the model due to a priori expectations.

Another interesting observation is that inflation is no longer significant, which may suggest that asset prices may contain information about future inflation. It may therefore be interesting to repeat the analysis without the inflation gap. The results are as follows.

$$(5.10) \quad \hat{i}_t = 1,03 \underset{(14,85)}{i_{t-1}} + 0,33 \underset{(5,05)}{E_t g_{t+1}} + 0,12 \underset{(0,64)}{u_i} + 0,14 \underset{(2,52)}{w_t} + 0,01 \underset{(1,78)}{\hat{a}_t}$$

$$(5.11) \quad \hat{a}_t = 1,00 \underset{(13,20)}{a_{t-1}} - 2,72 \underset{(-3,24)}{\hat{i}_t}$$

The asset price gap again enters with the correct sign and has a reasonably high significance level, at least for the purposes of this analysis. Hence equation (5.10) describes interest rate setting in Norway fairly well and indicates that asset prices contains information about future inflation not found elsewhere. However, (5.10) has one major fault. The coefficient on the lagged interest rate is higher than unity, which contradicts much of the empirical work on interest rate rules. The coefficient on the lagged asset price gap in equation (5.11) is also higher than unity although it has not changed much from (5.9). There are at least two possible explanations for the high coefficient on the lagged variables. Either the explanatory variables are in fact not very relevant or the endogenous variables are non-stationary. As shown in Appendix 1 this may be the case for the lagged interest rate but certainly not the case the asset price gap which clearly does not have a unit root. A more probable conclusion is that the exogenous variables are not relevant enough due to the relatively small sample size.

When comparing these results with those from section 5.4, one can draw at least four conclusions. First, the results confirm in many ways the results from the sample from 1993. The data from 1999 indicate that the asset price gap may be significant but that the marginal effect on interest rates is small. Third, with data from 1999 and excluding inflation, equation

(5.10) indicates that asset prices contain information about future inflation not found elsewhere. It should be noted, however, that the same dataset also confirms that there might have been a misspecification problem in equation (5.6) since some potentially important variables may have been omitted.

6. Conclusion

The purpose of this thesis has been to survey and investigate the role of asset prices, in particular stock prices, on monetary policy in Norway. I have found that although there has been a long established consensus in the literature that asset prices should not be targeted explicitly, recent literary contributions have argued that asset prices may contain information regarding future inflation not found elsewhere, mainly due to their forward looking nature. Other reasons include the existence of imperfect asset markets and severe asset price misalignments (e.g. asset price bubbles), among others.

There exist several empirical contributions on asset prices and monetary policy. Generally the literature has focused on measuring the relative efficiency of interest rate rules with asset prices using calibrated small structural (New Keynesian) models (see e.g. Bernanke & Gertler (2001)). Empirically estimated interest rate rules (reaction functions) that incorporate asset prices have received relatively little attention (one notable exception is Chadha et al. (2003)). One reason for this is the existence a simultaneity problem between asset prices and interest rates making the identification issue problematic. Another is the measurement problem associated with identifying asset price misalignments.

However, asset prices could be included in empirically estimated interest rate rules provided the simultaneity and measurement problems are appropriately addressed. To avoid the simultaneity problem I have formulated a simultaneous interest rate rule model where asset prices enter endogenously. In measuring asset price misalignments I have opted to follow the methodology used by Borio & Lowe (2002) which is based on measuring the asset price gap as the deviation in cumulative asset returns from trend. I find that this methodology is consistent with other asset price determination methodologies.

Using Norwegian data from 1993, I find that asset prices enter significantly in a simultaneous model estimated using two stage least squares (2SLS). I also find that asset prices contain more precise information on future inflation than the output gap and the growth gap, particularly in conjunction with the unemployment gap. This implies that asset

prices can be viewed as an alternative real-time variable to the output gap or alike. These results are supported using more recent data from 1999.

It is worth mentioning, however, that the modeling framework I have used does not incorporate the short and long-term effects of asset price misalignments (as opposed to the SVAR approach by Bjørnland & Leitimo (2005)). It follows therefore that the qualitative results of the analysis in this paper may be correct but that the quantitative results may differ. Furthermore, given the limited data available and relatively short time horizon of the analysis, more research is needed to ascertain the relative usefulness of asset prices in monetary policy.

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Appendix 1: Data description and unit root tests

I have used two data samples to test for the significance of asset prices in interest rate rules. The first sample is from 1993 and the second is from 1999. The latter has been used as a robustness check as it represents a different monetary policy regime and includes more variables that are not available from 1993.* The data variables are as follows:

- i* Sight deposit rate less its steady state level. The steady state nominal interest rate is assumed to be 5,5%.* The data is calculated as quarterly averages based on daily data from Q1 1991 to Q3 2005. Source: Norges Bank
- π Inflation measured by KPI-JAE less the inflation target. The inflation target is assumed to be 2% prior to Q2 2001 and 2.5% thereafter.* The series is calculated from Q1 1993. Source: Statistics Norway
- y* Output gap as measured by seasonally adjusted quarterly mainland GDP less potential output. Potential output is estimated using a Hodrick-Prescott filter with $\lambda = 1600$ based on data from Q1 1978 to Q2 2005. Source: Statistics Norway
- g* The growth gap as measured by actual growth in mainland GDP less steady state growth. Steady state growth is assumed to be 2.5% throughout the period.*
- u* Unemployment gap as measured by seasonally adjusted unemployment less its steady state level. The steady state unemployment level is assumed to be 4,5% throughout the sample period (based on the period average). The data series is based on data from Q1 1989 to Q3 2005. Source: Statistics Norway
- a* Asset price gap as measured by the deviation in cumulative asset returns from a linear trend calculated using quarterly averages. The data series is based on the OSEBX and TOTX indexes from Q1 1983 to Q3 2005. Source: Oslo Stock Exchange.
- pb* Weighted average price-to-book ratio for all non-financial and non-shipping companies on the Oslo Stock Exchange. The data series is based on end of quarter data from Q1 1983 to Q2 2005. Source: First Securities ASA

* See Bernhardsen & Bårdsen (2004).

- $E_t \pi_{t+1}$ Estimated inflation for the next 12 months less the inflation target. The inflation target is assumed to be 2% prior to Q2 2001 and 2.5% thereafter.* The data series is based on data from Q1 1999 to Q3 2005. Source: Norges Bank.
- $E_t g_{t+1}$ Estimated growth gap for the next 12 months. Steady state growth is assumed to be 2,5%.* The data series is based on data from Q1 1999 to Q3 2005. Source: Norges Bank.
- ui Foreign interest rate gap (trading partner weighted). Steady state foreign interest rate is assumed to be 3,5%.* The data series is based on data from Q1 1999 to Q3 2005. Source: Norges Bank.
- w Wage growth gap. Steady state wage growth is assumed to be 4,75%.* The data series is based on data from Q1 1999 to Q3 2005. Source: Norges Bank.

Unit root tests results using the Augmented Dickey Fuller test for the data set are as follows:

Table A1.1: Augmented Dickey Fuller test results (based on level variable where appropriate)

Variable	Data period	t-ADF			
		Lags: 1	Lags: 2	Lags: 3	Lags: 4
i	Q2:1992 - Q3:2005	-3,00	-2,59	-2,75	-2,48
π	Q2:1994 - Q3:2005	-1,72	-2,17	-2,02	-1,40
\bar{y}^{-1}	Q2:1979 - Q2:2005	-1,28	-1,44	-1,56	-1,94
\bar{u}^{-1}	Q2:1990 - Q3:2005	-0,49	-0,75	-1,08	-1,10
a	Q1:1983 - Q3:2005	-3,15 ²	-2,77	-3,52 ²	-3,25 ²
$E_t \pi_{t+1}$	Q1:1999 - Q3:2005	-1,89	-2,52	-2,78	-1,90
ui	Q1:1999 - Q3:2005	-2,65	-2,87	-3,24	-2,78
w	Q1:1999 - Q3:2005	-2,96	-3,01	-2,78	-2,02

1. Based on the level variable (i.e. not first differences or gaps)

2. Indicates that the t-ADF value is greater than the relevant critical value with 5% significance.

With a 5% significance level only the asset price gap shows signs of not having a unit root.

* See Bernhardsen & Bårdsen (2004).

Appendix 2: Endogeneity test for asset prices

To test for the endogeneity of the asset price gap in an interest rate rule framework I have used a Wu-Hausman test using data from 1993.

The structural form equations of the model are:

$$(5.12) \quad i_t = \beta_1 i_{t-1} + \beta_2 \pi_t + \beta_3 u_t + \beta_4 a_t + v_t$$

$$(5.13) \quad a_t = \alpha_1 a_{t-1} + \alpha_2 i_t + w_t$$

In reduced form:

$$(5.14) \quad i_t = \Pi_{11} i_{t-1} + \Pi_{12} \pi_t + \Pi_{13} u_t + \Pi_{14} a_{t-1} + \varepsilon_{1,t}$$

$$(5.15) \quad a_t = \Pi_{21} i_{t-1} + \Pi_{22} \pi_t + \Pi_{23} u_t + \Pi_{24} a_{t-1} + \varepsilon_{2,t}$$

Assume that there is a linear relationship between v_t and $\varepsilon_{2,t}$ given by:

$$(5.16) \quad v_t = \rho \varepsilon_{2,t} + e_t$$

This is plausible since $\varepsilon_{2,t}$ is given by:

$$\varepsilon_{2,t} = \frac{\alpha_2 v_t + w_t}{1 - \alpha_2 \beta_4} \quad \Leftrightarrow \quad v_t = \underbrace{\frac{1 - \alpha_2 \beta_4}{\alpha_2}}_{\rho} \varepsilon_{2,t} + \underbrace{\frac{1}{\alpha_2}}_{e_t} (-w_t)$$

Combining (5.12) and (5.16) gives:

$$(5.17) \quad i_t = \beta_1 i_{t-1} + \beta_2 \pi_t + \beta_3 u_t + \beta_4 a_t + \rho \varepsilon_{2,t} + e_t$$

If $\rho \neq 0$ then a is endogenous.

OLS results on (5.17) are:

$$(5.18) \quad \hat{i}_t = 0,79 i_{t-1} + 0,41 \pi_t - 0,12 u_t + 0,01 a_t - 0,04 \varepsilon_{2,t}$$

(15,04)
(4,07)
(-2,41)
(2,82)
(-6,80)

Since the t-value for the coefficient of ε_2 is -6,80 one can conclude that ρ is significantly different from zero and that a_t is endogenous. More formally, we reject the null hypothesis of exogeneity. Further, since $\rho < 0$, the coefficient on asset prices in a one equation interest rate rule will be underestimated.

This result is confirmed using data from 1999 and using the interest rate rule formulation by Bernhardsen & Bårdsen (2004) as a starting point. The structural form equations can be written as:

$$(5.19) \quad i_t = \beta_1 i_{t-1} + \beta_2 \pi_t + \beta_3 E_t g_{t+1} + \beta_4 u_i + \beta_5 w_t + \beta_6 a_t + v_t$$

$$(5.20) \quad a_t = \alpha_1 a_{t-1} + \alpha_2 i_t + w_t$$

In reduced form:

$$(5.21) \quad i_t = \Pi_{11} i_{t-1} + \Pi_{12} \pi_t + \Pi_{13} E_t g_{t+1} + \Pi_{14} u_i + \Pi_{15} w_t + \Pi_{16} a_{t-1} + \varepsilon_{1,t}$$

$$(5.22) \quad a_t = \Pi_{21} i_{t-1} + \Pi_{22} \pi_t + \Pi_{23} E_t g_{t+1} + \Pi_{24} u_i + \Pi_{25} w_t + \Pi_{26} a_{t-1} + \varepsilon_{2,t}$$

Similarly as before, I assume that there is a linear relationship between v_t and $\varepsilon_{2,t}$ given by:

$$(5.23) \quad v_t = \rho \varepsilon_{2,t} + e_t$$

and that combining (5.21) and (5.22) gives:

$$(5.24) \quad i_t = \beta_1 i_{t-1} + \beta_2 \pi_t + \beta_3 E_t g_{t+1} + \beta_4 u_i + \beta_5 w_t + \beta_6 a_t + \rho \varepsilon_{2,t} + e_t$$

OLS results on (5.24) are:

$$(5.25) \quad \hat{i}_t = \underset{(6,40)}{0,901} i_{t-1} + \underset{(1,09)}{0,20} E_t \pi_{t+1} + \underset{(2,70)}{0,26} E_t g_{t+1} + \underset{(0,56)}{0,10} u_i + \underset{(3,00)}{0,17} w_t + \underset{(0,85)}{0,01} a_t - \underset{(-1,93)}{0,02} \varepsilon_{2,t}$$

By traditional standards ρ is not significantly different from zero and a_t is exogenous. More formally, we do not reject the null hypothesis of exogeneity. However, due to a priori expectations, the relatively high t-value and the results from 1993, one can conclude that a_t is endogenous. Given the relatively small sample size and the results from the sample from 1993, this conclusion becomes more probable.