A model based approach to analysing financial stability

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1. Introduction

Many countries have reported some form of banking system distress or crisis during the past 25 years or so. A recent survey by the IMF reports that banking crises typically have followed a period of financial liberalisation, and have occurred more frequently in countries with weak regulatory institutions, notably developing countries (Demirgüç-Kunt and Detragiache, 1998). Three of the Nordic countries experienced a serious banking crisis in the early 1990s (Norway, Sweden and Finland), and Englund (1999) inter alia has argued that there seem to be some common patterns in the macroeconomic developments leading up to these crises. They were initiated by the liberalisation of financial markets (deregulation), which in turn led to rapid credit expansion and booming asset prices (for example housing prices). When the asset price bubble burst and prices fell, a financial crisis developed as a result of increasing rates of non-performing loans, bankruptcies, and after a while a dramatic increase in credit losses. This pattern has also been discussed in Allen and Gale (1999), who point to two important lessons for policymakers which can be drawn from the recent experiences. The first is to prevent or at least dampen potential bubbles in asset prices, and the second to try to minimise the spillover to other parts of the economy during post-bubble banking crises. Financial crises have historically happened in a rather wide range of different circumstances. The banking crises in the Nordic countries are notably different from the recent financial crisis in Southeast Asia. According to Allen and Gale (1999), nepotism, corruption and lax banking regulations are less probable causes of the Nordic banking crises, and the authors suggest that these crises were due rather to some common market failure than to idiosyncratic causes.

This paper is organised as follows. In Section 2 we describe the macroeconomic developments in Norway over the past two decades. In Section 3 we outline the Central Bank of Norway's surveillance of financial stability, its objectives and methods, focusing on how the Central Bank of Norway's quarterly macroeconometric model RIMINI is used to help forecast trends and developments in important macroprudential indicators of financial stability.[2] Section 4 is devoted to a brief description of the model, focusing on the monetary transmission channels. In Section 5 we discuss some econometric considerations and model specification criteria, and Section 6 contains a brief presentation of some of the main submodels. In Section 7 we discuss model properties based on simulation exercises, and Section 8 focuses on the trends and developments in the macroprudential indicators. Finally, Section 9 contains a short summary.

2. Macroeconomic developments in Norway from 1980 to 2000

In the mid-1980s, the Norwegian economy experienced a very strong domestic-led expansion similar to developments in many other countries, inter alia Sweden and Finland. Monetary policy was expansionary, notably in the form of very low real after-tax interest rates, in an environment of gradual liberalisation of the credit markets and with surging asset prices in real estate markets. The bubble had to burst sooner or later, but in Norway it was punctured rather early by the fall in oil prices in 1986. Fiscal policy was tightened in order to adjust domestic absorption to the new income level, and the Norwegian krone was devalued by 9.2% in May 1986. The tightening of the structural fiscal deficit

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[2] Macroprudential indicators can be broadly defined as indicators of the health and stability of financial systems; for a comprehensive discussion, see Evans et al (2000).

amounted to 4.5% of GDP (accumulated over the years 1986, 1987 and 1988). The deep economic recession from 1987 to 1990 (mainland GDP was reduced by 1.5% during the period) contributed to an increasing stock of non-performing loans, and ultimately to a dramatic build-up in recorded financial sector losses. The expected upturn following this recession did not materialise, however. One reason may have been that the domestic economy was in deeper trouble than was generally realised. Another contributing factor was German unification, and the tighter monetary policy that followed because of Norway's ECU peg.

The upturn in the Norwegian economy was thus delayed for three crucial years, and did not materialise until 1993. In the meantime the banking sector experienced severe problems following the rapid credit expansion of the mid-1980s. The operating results for both commercial and savings banks were negative in these years, and the guarantee funds of the two bank groups, as well as the government, were subsequently led to organise rescue operations for several small and large banks. Three of the largest banks (all commercial banks) lost all their capital and could only continue to operate with the aid of new capital injected by the government.[3]

Since 1995 the Norwegian economy has experienced a period of strong growth in domestic demand, eventually causing the economy to grow above its long-run potential. At the same time there has been a rapid downturn in unemployment, and eventually wage growth has picked up along with stronger CPI inflation, despite falling import prices. Also during this period the housing market has experienced a boom with double digit price growth at the end of the century, and credit growth is showing a strong positive trend fuelled by strong domestic demand growth.

3. The Central Bank of Norway's surveillance of financial stability

3.1 Background and motivation

In Norway, the Ministry of Finance, the Banking, Insurance and Securities Commission and the Central Bank of Norway share a joint responsibility for endorsing and securing financial stability. The Ministry of Finance has the overall responsibility and ultimately provides the funds for resolving solvency crises, whereas the Banking, Insurance and Securities Commission is responsible for surveillance of individual market participants. The Central Bank of Norway's primary objective in this area is to promote robust and efficient payment systems and financial markets.[4] Accordingly, the central bank has an overall responsibility for financial stability along with the Ministry.

To motivate preventive work in this area, it is worth recalling the need to carefully analyse the three Cs of financial instability according to Mayer (1999). In his introduction to the recent special issue on Financial Instability of the *Oxford Review of Economic Policy,* Mayer (1999) assesses the Causes, Consequences and Cures of financial instability. Mayer states that prevention is much better than cure, and also that where financial crises threaten the stability of the financial system, governments and central banks should act decisively.

For obvious reasons, the central bank's responsibilities in "tranquil" periods are very different from those it faces during a financial crisis (Kaminsky, 1999). In the following we will outline some elements of the Central Bank of Norway's preventive work in this area, which is based on the experiences of the financial crisis in the early 1990s. The primary purpose of the Central Bank of Norway's effort is to identify developments that may threaten financial stability. In this work it is also important to identify mechanisms by which a local financial crisis may spread to other parts of the financial system. Several studies have made efforts to identify common features of developments which historically have led to the full outburst of financial crises. Wood (1999) and Mayer (1999) stress in this respect the need to distinguish between "pseudo" crises and "real" crises. More precisely, this means that it is necessary

[3] For a brief description of the Norwegian banking crisis in 1987-92, see Allen and Gale (1999); for further details, see, for example, Norwegian Official Reports No 30E (1992), Report to the Storting No 39 (1993-94) and Document No 17 (1997-98).

[4] A further description of The Central Bank of Norway's responsibility is given in Lund and Solheim (1999).

to understand why some initial negative asset price or terms-of-trade shocks in some situations magnify and develop into a fully-fledged financial crisis while in other situations they do not.

A typical chain of events like the boom-to-bust development discussed by Englund (1999) and Allen and Gale (1999) has already been mentioned among potential causes behind the Scandinavian banking crises in the early 1990s. Since the authors also include financial deregulation in this chain, one might argue that this is a one-time event, which should preclude it from ever playing such a role again. Although the relatively fresh memories of the Scandinavian banking crises should reduce the likelihood of a similar chain of events, some writers stress the fact that economic agents may suffer from "disaster myopia". Hence even the "crisis awareness" arising from the quite recent financial crises could soon be so heavily played down by (new) myopic agents that the repetition of previous mistakes becomes unavoidable.

Although it seems like a daunting task to develop fully appropriate tools to systematically analyse microprudential and macroprudential indicators of financial fragility, several efforts have been made in this area in recent years. The IMF (Demirgüç-Kunt and Detragiache, 1998) has developed a model for monitoring banking sector fragility, estimating a multivariate logit model for 65 countries using variables from International Financial Statistics for the period 1980-95. Kaminsky (1999) has developed an early warning model for financial crises based on simple macroeconomic indicators. The idea is simple and intuitive. Suppose we know the distribution of an indicator of financial fragility, I, based on accurately and timely measurable information and the careful monitoring of current events. We could then extract a warning signal if $I>I_\varepsilon$ where ε = *Prob* ($I<I_\varepsilon$ |"Crisis" state), ie ε is the probability of observing values of the indicator less than I_ε if a crisis occurs, hence controlling for the Type I error. If the distribution of the indicator in "tranquil" states is sufficiently shifted to the left as compared with the "crisis" state, we would expect the probability of making a Type II error to be of a negligible magnitude, ie *Prob* ($I< I_\varepsilon$ | "Tranquil" state) ≈ 1. Hence a false alarm would be very unlikely. In practice, however, it may be very difficult to extract a signal with such nice properties. The distribution of the indicator may be unknown and potentially complex, the measurement may not be sufficiently accurate or timely, and the definition of what actually distinguishes states of "crisis" or "pseudo crisis" from "tranquil" states may not be clear-cut.

3.2 Macroprudential surveillance in Norway

The preventive work undertaken by the Central Bank of Norway to maintain financial stability can be divided into three areas of activity:[5]

- Work to reduce the risk and improve the robustness of the payment and settlement system.
- Continuous monitoring of factors that affect financial stability.
- Assessment of the impact of monetary policy and other economic policy components on financial stability.

Promoting a safe and stable financial infrastructure

An important part of the Central Bank of Norway's work on macroprudential surveillance takes the form of promoting a safe and stable financial infrastructure. The payment and settlement system plays a pivotal role in this regard. Disturbances that may develop into a systemic problem can be transmitted through the payment and settlement system. Several measures have been introduced over the last few years to strengthen this system, reduce settlement risk and improve efficiency. It is, however, still a high-priority task of the Central Bank of Norway to identify risks and, together with the industry, contribute to more secure and effective systems.

[5] See Eklund and Gulbrandsen (2000) for a further description of the Central Bank of Norway's surveillance of financial stability.

Monitoring of factors that affect financial stability

The primary purpose of the Central Bank of Norway's monitoring is to identify developments that may threaten financial stability. It is also important to expose mechanisms that contribute to the spreading of problems from one part of the financial system to another. The analyses strive, therefore, to provide an overall picture of the situation and developments in the financial sector. The analyses focus on the different types of risk to which financial institutions are exposed through their operations. The primary focus is on the banks' financial situation and trends, with a view to providing a picture of the banks' financial strength in relation to their risk exposure. The analyses concentrate on banks because they are large and are key participants in the financial sector, and also because the central bank has a distinct role in relation to banks. In view of the Central Bank of Norway's role, developments at individual banks receive little attention. Analyses of stability in the financial system are based on a combination of quantitative and qualitative information. Extensive data are analysed with the purpose of identifying developments that can increase the vulnerability of the financial system. More qualitative information about the participants' behaviour and strategies also helps establish a general picture of potential developments.

The analyses include an assessment of the effects that any major disturbances may have on the financial sector. The consequences of substantial disturbances in the economy depend on several factors:

- Banks' exposure to different types of risk.
- Developments in underlying conditions which influence the different types of risk, such as the debt burden of households and enterprises.
- Banks' earnings and financial strength, ie how well equipped banks are to deal with any losses.
- The extent to which mechanisms exist which ensure that problems arising in one part of the system are not amplified and/or do not spread to other parts of the system.

To a certain extent the analyses also contain an assessment of the likelihood of major disturbances or marked changes in expectations, which depend on the financial system's overall risk exposure, macroeconomic conditions and conditions that have an impact on the structure of the financial system. Therefore, in addition to monitoring the institutions, it is important to monitor conditions that more generally affect financial institutions and financial markets. The combination of the likelihood of disturbances and possible consequences gives an indication of total risk exposure in the financial sector.

A major element of the Bank's work on macroprudential surveillance is the biannual Financial Stability report. The report is published after having been discussed with the Banking, Insurance and Securities Commission and the Ministry of Finance. The publication offers a comprehensive analysis of the overall situation within the financial sector, including an assessment of the outlook for the next couple of years. This assessment is based on the Bank's own macroeconomic forecasts, produced for the quarterly Inflation Report. The Bank's macroeconometric model, RIMINI, is then used to elaborate on developments in the stocks of assets and liabilities of households and enterprises and their ability to service their debt, for instance when major changes in the interest rate occur.

An important aspect of the analyses is to shed light on the effect of macroeconomic conditions on the debt servicing capacity of households and enterprises, and thereby on credit risk in banks. Major emphasis is put on the potential for losses on loans to households and enterprises. Lending to households account for approximately 40% and 70% respectively of commercial and savings banks' total loans. A major portion of banks' total credit risk will therefore be tied to households' capacity to service their debt. In addition, the interplay between the household and enterprise sectors has a significant impact. Developments in the housing sector constitute the key component of an assessment of the household sector's financial situation. Home ownership is very high in Norway. Housing is the major household asset, whereas the share of financial assets is relatively small. Hence, developments in the housing market and house prices in particular are important in an assessment of the household sector's robustness in case of major shocks.

Of particular concern in this regard is the enterprise sector, where about 85% of the bank losses in the banking crisis of the early 1990s occurred. To help assess the risk of the enterprise sector, the Bank uses the macroeconometric model RIMINI, which will be discussed in the rest of this paper, as well as a risk classification model based on data from the annual accounts of all Norwegian limited companies

(see Eklund and Gulbrandsen (2000) for a presentation of this model). The risk classification of the individual enterprise is based on three key variables: self-financing ability as a share of long term debt; equity as a share of total assets; and a liquidity measure. In addition to the accounts, the data for this model provide detailed information about the industry and geographic location as well as some information about payment history. This allows us to follow the sector as a whole as well as to monitor developments in enterprises' credit risk, divided by industry and geographic location.

Acknowledging the interdependence of financial and monetary stability

The objective of monetary stability - which in Norway means exchange rate stability and low inflation - and the objective of financial stability are interdependent. High - and thereby in practice varying - inflation and unstable exchange rates can threaten financial stability through several channels. First, it is more difficult to assess the risk of investment projects. Second, fluctuations in the inflation rate are often accompanied by interest rate variations. A sharp rise in interest rates can result in losses. Financial stability primarily contributes to price and exchange rate stability by facilitating the use of monetary policy instruments. Unstable institutions and markets constrain the use of interest rates.

3.3 The use of the macroeconometric model RIMINI

The RIMINI model is in use at the Central Bank of Norway, and the model is continuously updated and revised. The increased attention to financial stability issues arising from the Norwegian experiences with the banking crisis in 1991-92 spurred the inclusion of a set of indicators of financial fragility (see Davis (1995) for a discussion). The baseline operative version of RIMINI has since 1995 contained indicators of the debt and interest burden in the household and enterprise sectors, for example indicators of debt service to income and capital gearing ratios. Future versions of the model will be further enhanced in this area, and we plan to extend the set of indicators of financial fragility in particular of the private non-financial enterprise sector. In addition, we have extended the model with a simple submodel for financial sector losses which further enhances the model's linkages between monetary policy and macroeconomic behaviour on the one hand, and indicators of financial fragility and loan losses on the other. The following table presents the macroprudential indicators for *households* and *enterprises,* which we will focus on in this paper, and the data are plotted in Figures 1 and 2.

Households

- Interest expenses/cash income (disposable income + interest expenses)
- Gross loan debt/disposable income
- Gross loan debt/gross financial assets excluding insurance claims
- Gross loan debt/value of housing wealth

Enterprises

- Interest expenses/cash surplus (value added - wage costs + capital income)
- Cash surplus less interest expenses/gross interest bearing debt
- Gross interest bearing debt/gross interest bearing assets
- Four quarter growth in interest bearing debt/fixed capital formation

Households

Figure 1a shows that the households' debt service to income ratio peaked around 1988, following a series of increases in the nominal interest rate and the rapid credit expansion of households after the deregulation of the Norwegian housing and credit markets in the first half of the 1980s. The ratio decreased to below 10% only after the drop in the international interest rate level in 1993. The debt service to income ratio stabilised and increased in 1998, primarily due to increasing interest rates, but also to some extent since household credit growth picked up again towards the end of the 1990s.

The rapid credit expansion of the 1980s is also reflected in the dramatic increase in the debt to income ratio, which increased from around 100% to 160% in 1988 (see Figure 1b). From then on it gradually decreased during the period of "debt consolidation" from 1990 to 1995 before levelling out around 125%.

The debt to financial asset ratio in Figure 1c shows broadly the same development until 1988 following the rapid credit expansion, and the gradual decline in the ratio thereafter reflects the fact that households' accumulation of financial assets (excluding insurance claims) has been stronger than their debt accumulation. Finally in Figure 1d we see that the debt to housing capital value initially increases because household loans grow faster than housing prices. Whereas housing prices reached their peak level around 1988, the debt to housing capital ratio continued to increase until 1993, first due to strong credit expansion and later on due to the fact that housing prices fell dramatically from 1989 to 1992 before the housing price growth started to pick up again from 1993. Thus, the debt to housing capital value reflects the strong cyclical movements in housing prices during this period, and while credit growth has also shown significant swings over this period, it is the housing price cycle which leads while the credit growth cycle follows with a lag.

Non-financial enterprises

Figures 2a-2d broadly reflect a similar boom-to-bust development as we have seen above for the household sector.

4. The macroeconometric model RIMINI

The macroeconometric model RIMINI[6] has been operative as a forecasting model for nearly 10 years. It is used by the policy departments to make short-term forecasts for the Norwegian economy four to eight quarters ahead, which are published in the quarterly inflation reports. Once a year the forecast horizon is extended to four-five years ahead, and these projections also underlie the Bank's published reports on financial stability. A key quality of the model is thus its capability to forecast variables like output growth and CPI inflation, but in practice policymakers will be interested in the developments of a large number of other variables. The model should therefore be able to adequately describe the behaviour of households and enterprises, as summarised by variables such as aggregate output, employment, private consumption, the current account, housing prices, housing investments and business sector fixed capital formation. In the context of the present application we could add to this list net wealth of households and enterprises as well as appropriate indicators of financial stability, which we will denote as RIMINI's macroprudential indicators.

Although the model is mainly used as a projection tool, it has become increasingly used by policymakers to analyse the effects of alternative scenarios for key exogenous variables, such as the growth in international markets and world market prices, in particular the price (in USD) of crude oil. It is also frequently used to assess the effects of changes in key monetary policy variables like short-term interest rates and exchange rates, which are both treated as exogenous variables in the baseline version of the model. It is, however, easy to supplement the model with an exchange rate equation and/or a reaction function for short-term interest rates in order to obtain a more realistic representation of monetary policy issues in the model.

RIMINI is by Norwegian standards a fairly aggregated macroeconometric model. The core model consists of some 30 stochastic equations, and there are about 100 non-trivial exogenous variables which must be projected by the forecaster. RIMINI is a fairly closed model in the sense that the most important macroeconomic variables describing the Norwegian economy are all determined by the model, whilst the model forecasts are made conditional upon "outside" variables like foreign prices and output as well as policy variables like interest rates, exchange rates, tax rates and other fiscal policy variables. The model is basically a two-sector model and distinguishes between the manufacturing and construction sectors (producers of traded goods) and services and retail trade (producers of non-traded goods), for which there exist complete submodels. The oil and shipping sectors are treated exogenously in the model, as are agriculture, forestry and fisheries and the public sector.

[6] RIMINI is an acronym for a model for the Real economy and Income accounts - a MINI-version; see Eitrheim and Nymoen (1991) for a brief documentation of a predecessor of the model.

Figure 1 *Households:* Indicators of financial fragility. Historical data 1983 Q1 - 1998 Q4

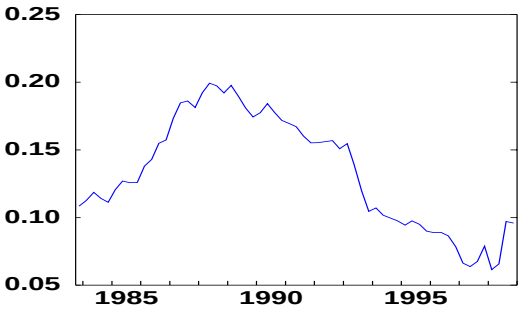


Figure 1a Interest expenses/cash income (disposable income + interest expenses)

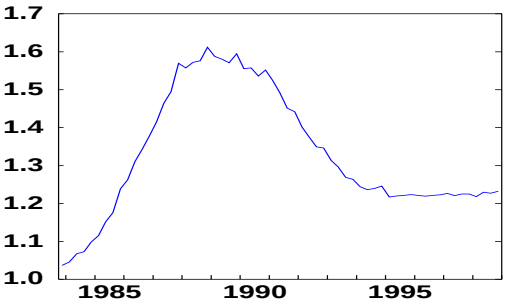


Figure 1b Gross loan debt/disposable income

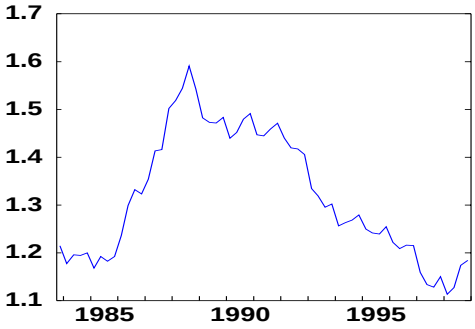


Figure 1c Gross loan debt/gross financial assets excluding insurance claims

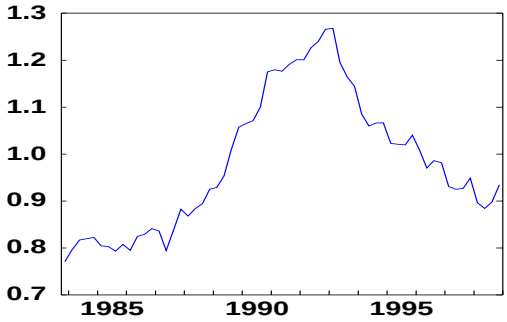


Figure 1d Gross loan debt/value of housing wealth

Figure 2 *Non-financial enterprises:* Indicators of financial fragility. Historical data 1983Q1 -1998Q4

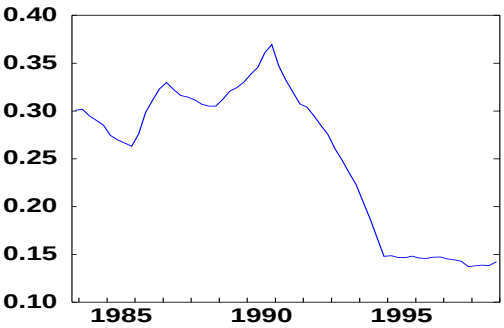


Figure 2a Interest expenses/cash surplus (value added - wage costs + capital income)

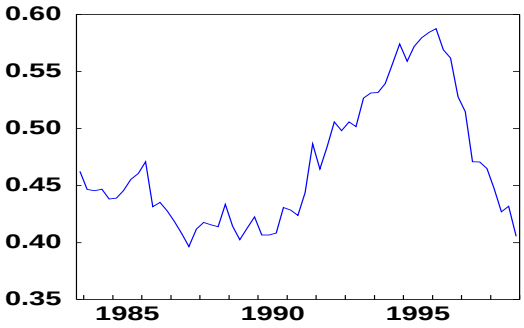


Figure 2b Cash surplus less interest expenses/gross interest bearing debt

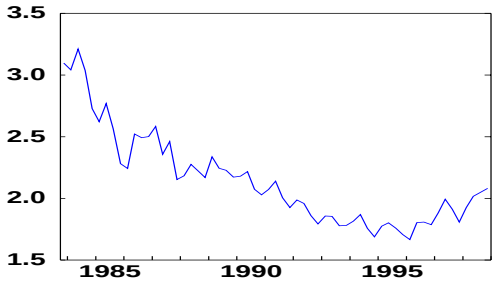


Figure 2c Gross interest bearing debt/gross interest bearing assets

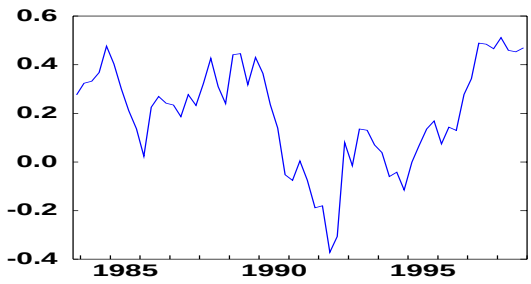
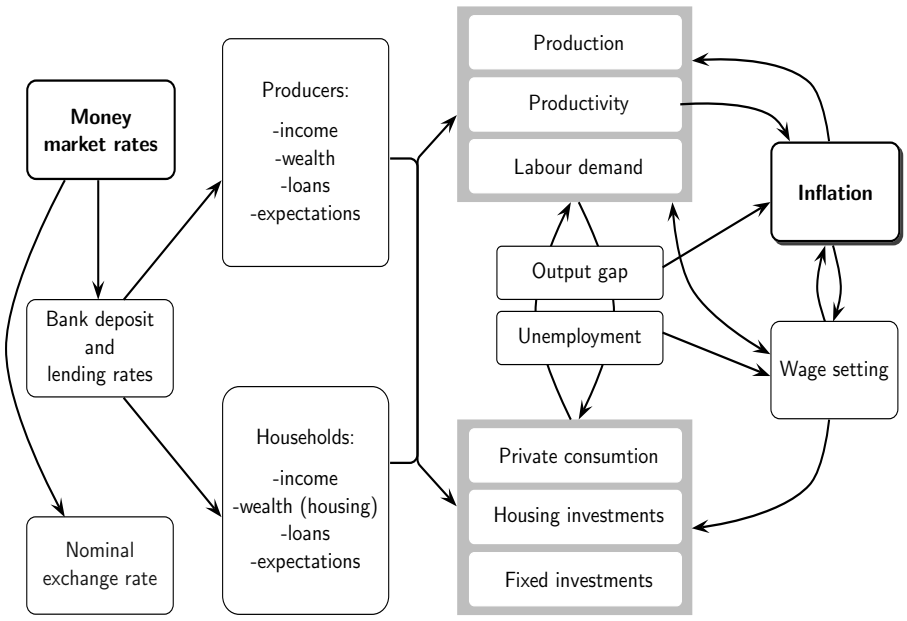


Figure 2d Four quarter growth in interest bearing debt/fixed capital formation

4.1 Monetary transmission channels in RIMINI

In RIMINI there are two main channels through which monetary policy instruments affect employment, output and prices - the interest rate channel and the exchange rate channel. Figure 3a below outlines the interest rate channel, highlighting the submodels for households and enterprises, and shows also the main interaction between the demand side (lower shaded box) and supply side (upper shaded box).

Figure 3a Interest rate channels in RIMINI. Given constant exchange rates



Assuming fixed exchange rates, a change in the central bank interest rate (the signal rate) immediately affects the money market interest rate, which in turn affects the banks' borrowing and lending rates with a lag. Aggregate demand is affected through several mechanisms, as shown in Figure 3a. There is a negative effect on housing prices which (for a given stock of housing capital) causes real household wealth to decline, thus suppressing total consumer expenditure. Also, there are negative direct and indirect effects on fixed capital formation in the traded and non-traded sectors, and on housing investments.

The main submodels for households are discussed in Eitrheim and Gulbrandsen (2001), where we focus on the interaction between asset price inflation in the housing market (see also Eitrheim, 1994) and the submodels for household loans, private consumer expenditures (see Brodin and Nymoen, 1992) and housing investments, and point to some important linkages with the indicators of financial fragility presented above. Compared with the household sector, the current version of RIMINI contains fewer submodels for non-financial enterprise behaviour. We find it reasonable, however, to assume that asset price inflation, for example, in the stock market and/or real estate markets, interacts with investment behaviour as well as the loan behaviour of the enterprise sector.

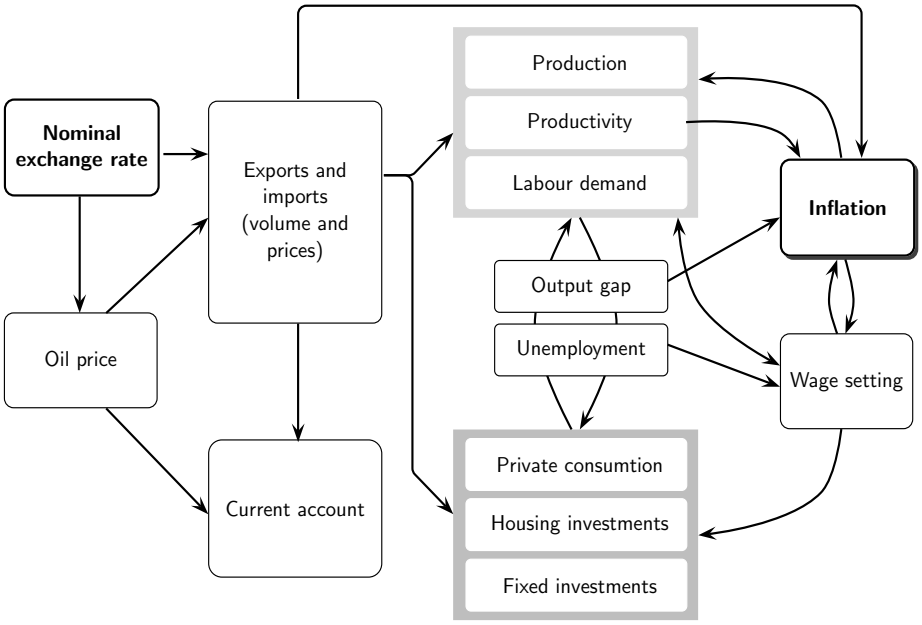
CPI inflation is reduced after a lag, mainly as a result of the effects of changes in aggregate demand on aggregate output and employment, but also as a result of changes in unit labour costs. Due to labour hoarding effects, the initial productivity response in the model is countercyclical. The core model for wages and prices is consistent with a conflict model of inflation where inflation plays the role of an arbiter between mutually inconsistent real wage claims for trade unions and firms in a small open economy; see Kolsrud and Nymoen (1998) and Baardsen et al (1998).[7] An updated version of this wage and price model has recently been documented in Baardsen, et al (1999), who find strong

[7] The role of inflation as an arbiter of conflicting claims was brought out in Haavelmo's conflict model of inflation; see Qvigstad (1975).

support for the steady state properties of the wage and price relationships, and Eitrheim (1998) showed that a similar model of CPI inflation was found to be robust when exposed to a series of tests against potentially neglected monetary effects on inflation.

An appreciation of the krone has a more direct effect on CPI inflation than an interest rate change. As illustrated by the first box in Figure 3b, it works mainly through reduced import prices with a lagged response, but such that there is complete pass-through in import and export prices after about two years. The model specification allows for a non-constant mark-up factor on unit labour costs in import and export prices in the short run. Furthermore, a currency appreciation has a weak negative effect on demand for traded goods. In addition to small relative price elasticities in the export equations, export prices (in local currency) adjust with a lag and tend to restore relative prices.

Figure 3b Exchange rate channels in RIMINI. Given constant interest rates



5. Model specification criteria and econometric considerations

As is clear from the outline above, the RIMINI model is too big and complex to be modelled simultaneously. Thus, we need to deal with the submodels for the different sectors in the model in turn and finally graft them into the complete model. Jansen (2000) discusses how this approach implies that we impose simplifying restrictions on the model through sequential factorisation of the joint density function of all observable variables in the model. He also points to the risk that by putting together subsystems modelled separately, one may ignore influences across different subsystems, which could potentially lead to inefficient statistical estimation and inference.

The aim of our modelling approach is, however, straightforward and clear, ideally we would want the model to be a congruent representation of all salient features of the data generating process (Hendry, 1995). Modern econometric methods are well suited to meet this end, and we apply dynamic model specification and cointegration analysis to represent the non-stationary (trending) nature inherent in many macroeconomic time series. Cointegration and equilibrium correcting models, VEqCMs, are useful since they quite often facilitate the economic interpretation of the model's properties, and their long-run (steady state) properties can in many cases be associated with equilibria derived from economic theory.

The different issues which arise in the context of the specification of a macroeconometric model which is designed to satisfy the objectives discussed above are summarised in the following list (see Jansen (2000) for a more detailed discussion):

- **Data admissability** (adequate representation of the trending properties of data. Model residuals should ideally be innovations):

  well specified dynamic equations, assuming difference stationarity;

  cointegration/EqCMs (equilibrium correcting models);

  acceptable model design criteria;

  encompassing results from rival models.

- **Theory coherency** (sensible theoretical properties):

  identifiable structure, imposed on the long-run (steady state) relationships;

  reasonable interim multipliers.

- **Acceptable ex post and ex ante forecasting properties**

- **Invariance of model parameters:**

  to extensions of the information set;

  to shocks in exogenous variables.

6. Econometric specification of main submodels

Outline of the household sector model

This section outlines the household sector model in RIMINI. We present some of the decompositions we have made into conditional and marginal submodels, and for each submodel we indicate some of its main variables. See Jansen (2000) for a more comprehensive discussion of different econometric issues which arise in the context of modelling subsectors of the economy. Details on the econometric results can be found in Eitrheim and Gulbrandsen (2001).

Total consumer expenditure, ch_t, is modelled as a function of real disposable income, yh_t, and real total household wealth, wh_t. Small letters denote variables in logarithms. Total wealth consists of the real value of the stock of housing capital plus total net financial wealth. The stock of housing capital is denoted H_t and the real housing price is PH_t / P_t. Net real financial wealth is the difference between real gross financial assets and real loans $M_t - L_t$, hence

$$wh_t = \ln[(PH_t / P_t)H_{t-1} + M_{t-1} - L_{t-1}]$$

- Conditional submodel for total real consumer expenditures, ch_t, (Brodin and Nymoen, 1992)

$$D_{c|yw}(ch_t \mid yh_t, wh_t; \lambda_c)$$

RIMINI also contains submodels which allow the joint forecasting of all the individual components which determine real household wealth, wh_t, above, such as housing prices, ph_t, nominal household loans, $(p+l)_t$, net additions to the housing capital stock, Δh_t, and the price on new housing capital, phn_t. RL_t denotes the interest rate on bank loans. The long-run (steady state) consumption function estimated on quarterly data for the period from 1986Q1 to 1998Q4 can be written as follows (leaving out the intercept). Standard errors are reported in parentheses.

$$ch_t = \underset{(0.23)}{0.70}\, yh_t + \underset{(0.10)}{0.18}\, wh_t$$

The model for aggregate consumption satisfies the criteria listed above. The formulation is consistent with the broad implications of the life cycle and the permanent income hypotheses, but see the discussion of rival hypotheses in Eitrheim et al (2000), where the relative merits of consumption functions of the type presented above and well known Euler equation models are compared. The inclusion of wealth in the consumption function allows a similar interpretation as offered in Hendry and von Ungern-Sternberg (1981), ie that consumers seek to attain long-run proportionality between consumption and real disposable income as well as between consumption and real wealth respectively.

- Conditional submodel for housing prices, ph_t, (Eitrheim, 1994) and real household loans, l_t

$$D_{w|y}(ph_t, l_t \mid RL_t, yh_t, h_{t-1}; \lambda_w)$$

Real housing prices and household loans are jointly determined, and there may be substantial feedback effects in the dynamic models describing the housing and credit market behaviour, noting that the housing capital is used as collateral in typical household mortgage loan contracts. In the long run, real housing prices are determined as a function of real disposable income, yh_t, the level of housing capital, h_t, and the real after-tax loan interest rate, $RL_t(1-TM_t)-\Delta_4 p_t$. Household loans are negatively affected by changes in the rate of unemployment, reflecting uncertainty about the future income and debt servicing capacity of private households, and in the long run nominal loans, $(p+l)_t$, are determined by the value of the housing capital, $(ph+h)_t$, with a long-run elasticity of 0.80. The estimated joint long-run system for real housing prices, $(ph-p)_t$, and real loans, l_t, can be rewritten as:

$$(ph-p)_t = 0.83yh_t + 0.67h_t - 0.17p_t - 3.33\left(RL_t(1-TM_t)-\Delta_4 p_t\right)$$
$$l_t = 0.67yh_t + 1.33h_t - 0.33p_t - 2.67\left(RL_t(1-TM_t)-\Delta_4 p_t\right)$$

- Conditional submodel for recorded financial sector losses

We link the financial sector losses to the developments and trends in some of the indicators of financial stability using household sector indicators as proxy variables for determinants of losses arising in the non-financial enterprise sector. Losses are assumed to depend on the debtor's ability to service the debt as well as on the value of the collateral in loan contracts and the level of unemployment. Recorded financial sector losses have been scaled by the level of private sector debt, and we have modelled this ratio, TAN_t, (as a percentage) as a function of the debt service to income ratio of households, $FFRU50_t$, (debt service ability), the real after-tax loan interest rate, $RL_t(1-TM_t)-\Delta_4 p_t$, and the unemployment rate, $UAKU_t$, (uncertainty about future income and debt servicing ability). The submodel for financial sector losses is inspired by empirical studies of UK household and enterprise sectors in Davis (1995) and earlier work on models with bankruptcy costs; see, for example Wadhwani (1986). We refer to Eitrheim and Gulbrandsen (2001) for estimation results and discussion.

$$TAN_t = \underset{(0.22)}{4.09}FFRU50_t + \underset{(0.58)}{1.08}\left(RL_t(1-TM_t)-\Delta_4 p_t\right) + \underset{(0.86)}{3.81}\left(\textstyle\sum_{i=0}^{3} UAKU_{t-i}\right)/4 + \underset{(0.02)}{0.30}CRISIS91_t$$

The dummy variable $CRISIS91_t$ captures the bulk of recorded losses which were recorded in 1991 and the first quarter of 1992, primarily in commercial banks. Eitrheim and Gulbrandsen (2001) discuss some alternative interpretations of this dummy variable in the equation for recorded financial sector losses.

7. RIMINI simulations

In this section we compare ex post forecasts over the period 1990Q1 to 1998Q4 based on stochastic simulations of the RIMINI model. In the following figures we report observed values (solid line) and the estimated mean from 1,000 replications of stochastic simulations of the model (dashed line) for a subset of the variables determined in the model. To illustrate the prediction uncertainty, we have plotted the boundaries of 50% (dotted lines) and 95% (dashed lines) prediction intervals for each of the reported variables. The RIMINI model is simulated "as is", and we have made no intercept corrections beyond those embedded in the estimated coefficients of the model in terms of impulse- and step-dummy variables.

As explained above, RIMINI can be viewed as a system of equilibrium correcting relationships, EqCMs, in which variables in differences are combined with linear combinations of variables in levels (cointegrating relationships). An alternative class of models which are widely used are formulated in terms of differences in the data only, ie without equilibrium correction terms, such as dVAR models (VAR models in differences), univariate models in differences (DV), or double differences (DDV). Clements and Hendry (1999) have provided analytical results on the relative merits of the forecasting properties of these models, Eitrheim et al (1999) compare forecast error biases across five corresponding forecasting models for the Norwegian economy over different forecasting horizons, and Eitrheim et al (2001) focus on inflation models' forecast accuracy. The latter paper also provides a comparison of forecasting uncertainty as represented by an estimated 95% prediction interval around the models' forecast over different horizons.

Ex post historical tracking

Figure 4a shows the simulated growth in mainland GDP. The model underpredicts domestic growth in 1994-95 and 1997, but the model's overall ability to track many real economic variables seems to be quite good, in particular viewed against the background of considerable cyclical variation during the 1990s. The household savings rate provides one example; we see in Figure 4b that the savings rate is somewhat overpredicted towards the end of the simulation period, but there is no indication of a forecast failure in the sense of Clements and Hendry (1999). Turning to headline CPI inflation, we see from Figure 4e that the annual rate of inflation is somewhat overpredicted in 1991-92, underpredicted in 1994-95 and, again, somewhat overpredicted towards the end of the simulation period. The trajectory for inflation can, at least to some degree, be explained by the model's tendency to underpredict unemployment in the beginning of the simulation period and overpredict unemployment towards the end; see Figure 4f. Likewise, there have been changes in indirect taxes in 1994-95, only partly reflected in the price/wage model, and, similarly, there have been shocks in energy prices (electricity, oil and gasoline), which may explain some of the deviations of simulated from actual CPI inflation towards the end of the simulation period. This lends some support to the interpretation in Eitrheim and Wulfsberg (1999) that the inflation forecasts from a model like RIMINI, which seems to be quite successful in picking up the underlying trends and developments in annual CPI inflation, can be interpreted as forecasts of underlying or "core" inflation. Again, we can find no sign of any serious forecast failure for the annual rate of inflation in Figure 4e. The simulated development in the real after-tax rate of interest mainly reflects the forecast properties of CPI inflation; see, Figure 4c. Finally, we see that housing price growth, despite considerable prediction uncertainty, is simulated quite accurately across a period with substantial variation; see Figure 4g. Likewise, the growth in household loans is fairly well on track, although we see some tendency in Figure 4h for the simulated growth path to "cut through" the actual development, such that the model does not quite capture the decline in household loans in the early 1990s, and also to underpredict the rather strong growth in household loans towards the end of the simulation period.

Figure 4 RIMINI simulations of key macroeconomic variables. Stochastic simulation over 1990 Q1 - 1998 Q4 (mean, 50% and 95% prediction intervals)

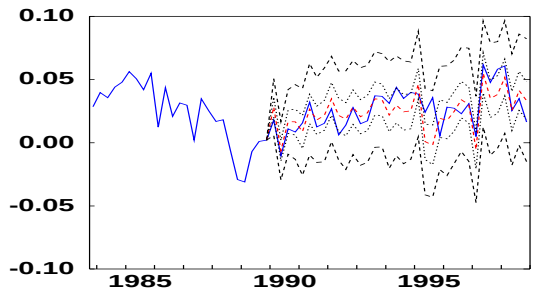


Figure 4a Annual mainland GDP growth

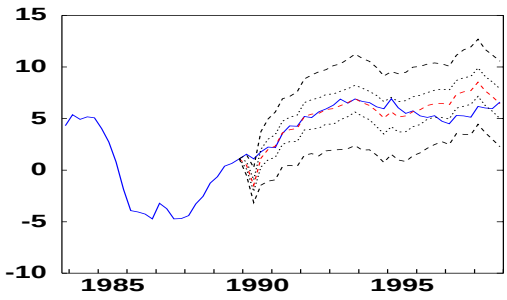


Figure 4b Household savings rate

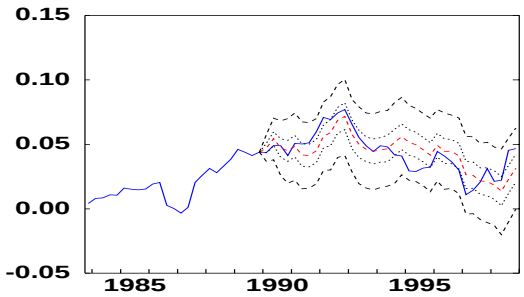


Figure 4c Real after-tax bank loan interest rate

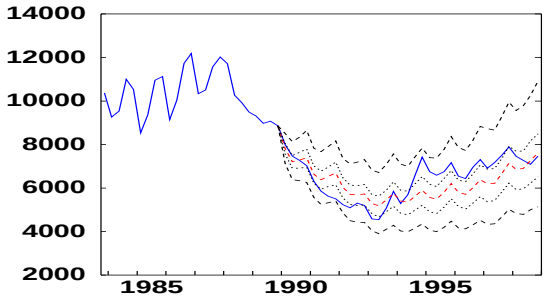


Figure 4d Housing investments

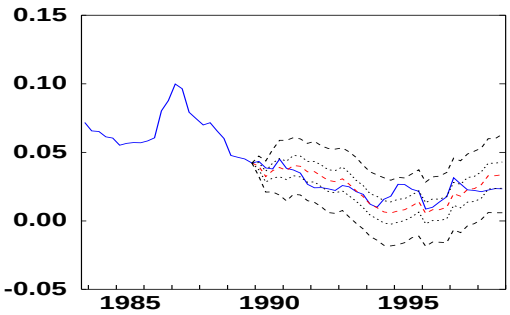


Figure 4e Annual CPI inflation

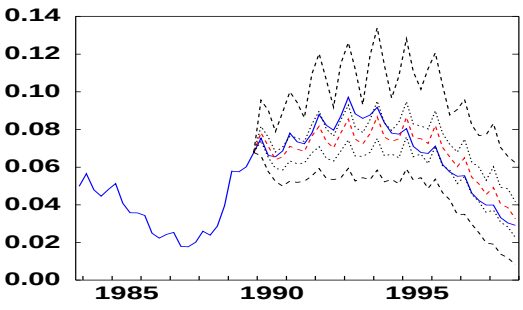


Figure 4f Total unemployment rate

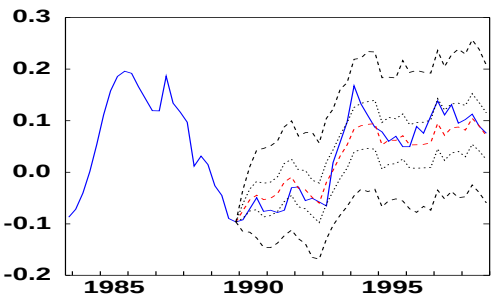


Figure 4g Annual housing price growth

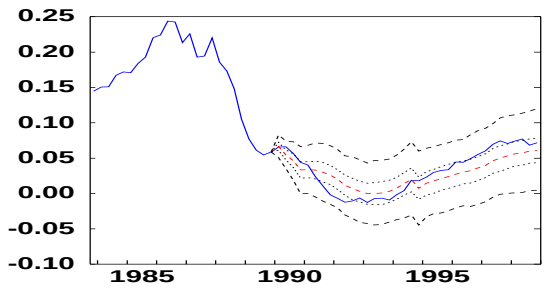


Figure 4h Annual growth in household loans

8. Simulated indicators of financial fragility

Ex post historical tracking

Figures 5 and 6 show the development in the indicators of financial fragility for households and non-financial enterprises over the period 1990Q1 to 1998Q4 as described by the Central Bank of Norway's macroeconometric model RIMINI. We see that the developments in the four selected ratios are all fairly well described by the model. Conditional on the (exogenous) development in the money market interest rate level, the debt service to income ratio falls as shown in 5a. We have seen above that the model's tracking performance for the annual growth in housing prices and household loans is quite good, and that this also seems to hold for the household savings rate. These are important determinants for all the indicators of financial fragility for the household sector, and it is therefore not unreasonable to find that the selected set of indicators of financial fragility also seems to track reasonably well; see Figures 5a-5d.

Figure 5 *Households:* Indicators of financial fragility. Stochastic stimulation over 1990 Q1 - 1998 Q4 (mean, 50% and 95% prediction intervals)

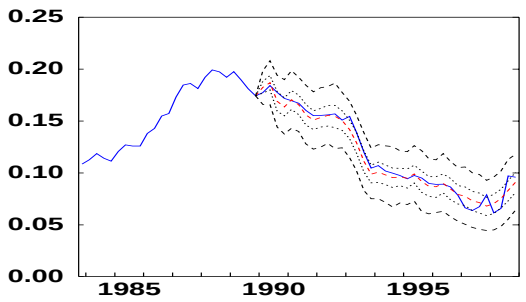


Figure 5a Interest expenses/cash income (disposable income + interest expenses)

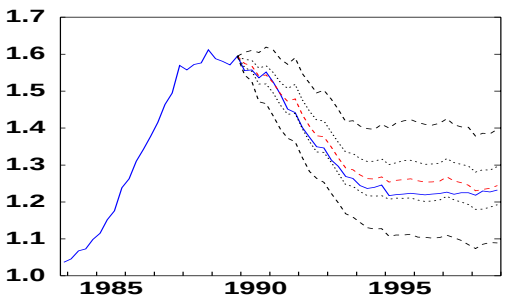


Figure 5b Gross loan debt/disposable income

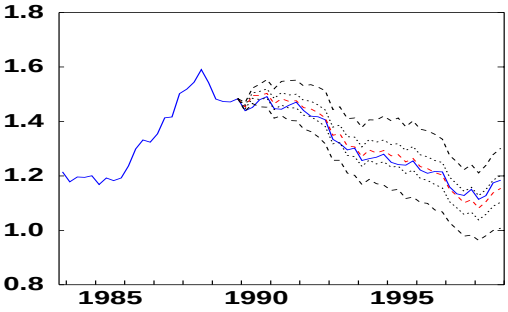


Figure 5c Gross loan debt/gross financial assets excluding insurance claims

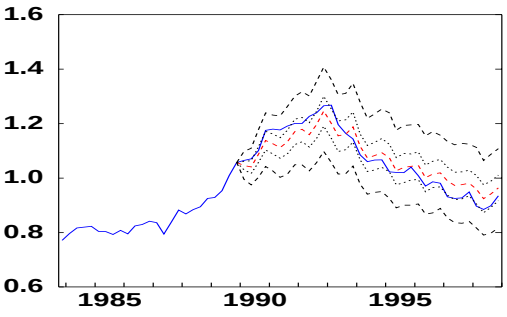


Figure 5d Gross loan debt/value of housing wealth

Figure 6 *Non-financial enterprises:* Indicators of financial fragility. Stochastic simulation over 1990 Q1 - 1998 Q4 (mean, 50% and 95% prediction intervals)

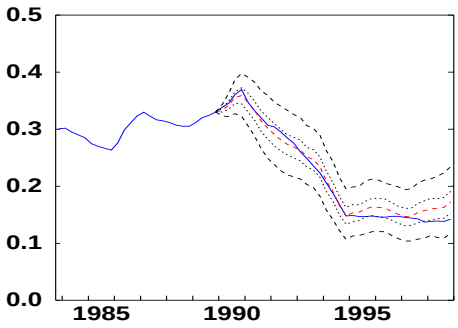


Figure 6a Interest expenses/cash surplus (value added - wage costs + capital income)

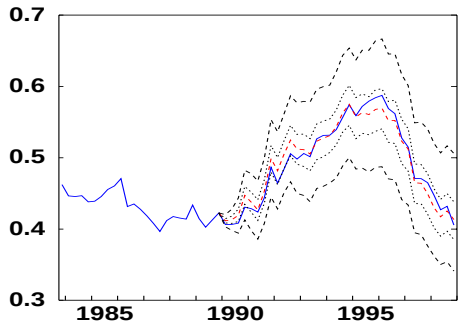


Figure 6b Cash surplus less interest expenses/gross interest bearing debt

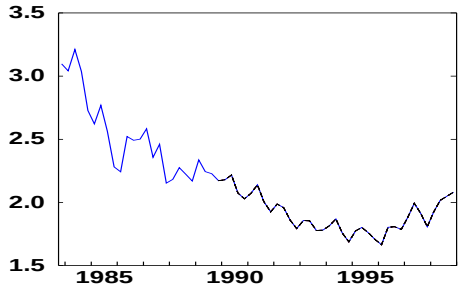


Figure 6c Gross interest bearing debt/gross interest bearing assets

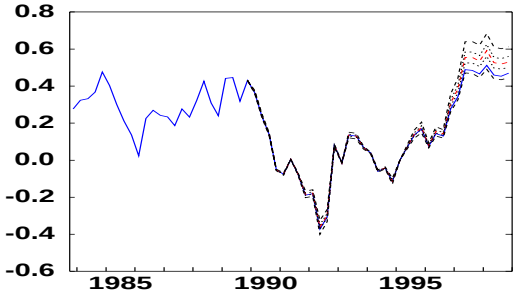


Figure 6d Four quarter growth in interest bearing debt/fixed capital formation

Simulated effects of a temporary and permanent increase in the money market interest rate

Here we investigate the effects of a temporary and permanent increase in the money market interest rate. The debt service to income ratio in Figure 7a shows that we obtain a corresponding temporary or permanent shift in the debt service to income ratio. Both debt and income are negatively affected by a negative demand shock, but due to the immediate negative shock in housing prices which spills over into a corresponding negative effect on household loans, the negative effect on the numerator of the debt to income ratio dominates that of the denominator; see Figure 7b. The ratio of debt to income drops correspondingly, but gradually at a slower rate since the effect on the activity level, employment level and wage level picks up, but also because the effects on household loans after a while start to fade out. A similar effect can be seen on the debt to asset ratio, which is negatively affected by both a permanent and a temporary increase in short-run interest rates; see Figure 7c. Finally, the ratio of debt to housing capital value shows an inital increase following the shock, since the negative housing price effect affecting the denominator dominates the negative debt effect in the numerator; hence the ratio increases until the housing price effect gradually becomes smaller and dies out as the debt effect eventually dominates before gradually fading out as well. It is, however, important to realise that the combined effects on housing prices and household loans contribute to quite substantial persistence in the shock to the debt to housing capital ratio, as a response to a permanent increase in the interest rate level; see Figure 7d.

Figure 7 *Households:* Indicators of financial fragility. Effects of a 100 bp permanent shift in short-term interest rates and a corresponding temporary shift (two years)

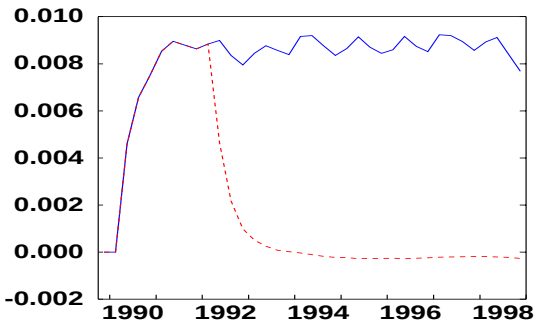


Figure 7a Interest expenses/cash income (disposable income + interest expenses)

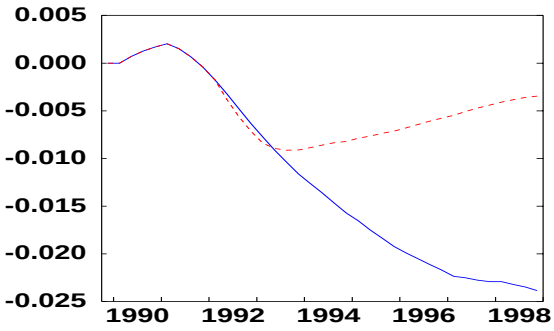


Figure 7b Gross loan debt/disposable income

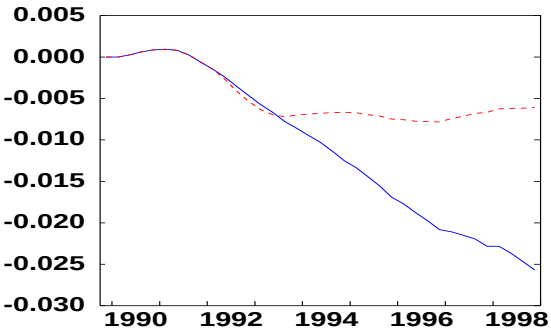


Figure 7c Gross loan debt/gross financial assets excluding insurance claims

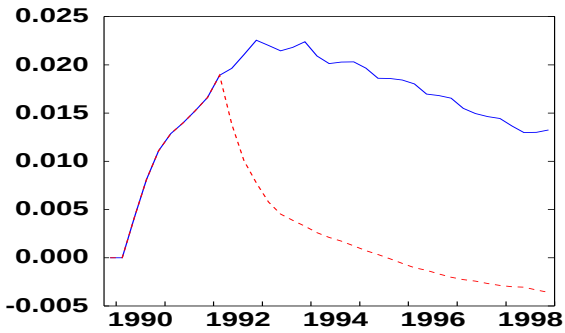


Figure 7d Gross loan debt/value of housing wealth

Figure 8 *Non-financial enterprises:* Indicators of financial fragility. Effects of a 100 bp permanent shift in short-term interest rates and a corresponding temporary shift (two years)

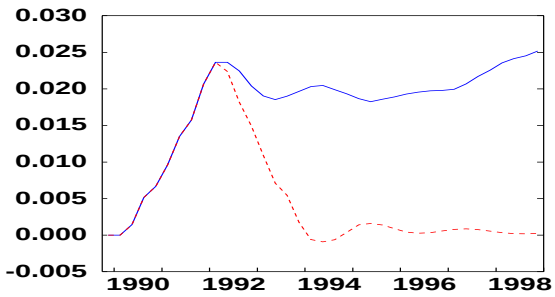


Figure 8a Interest expenses/cash surplus (value added - wage costs + capital income)

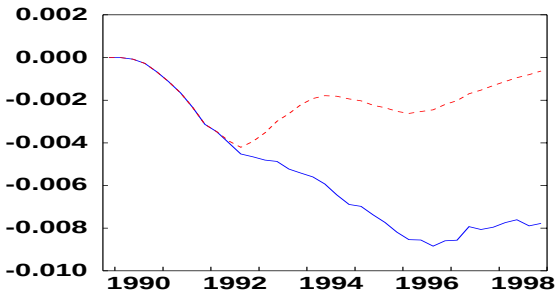


Figure 8b Cash surplus less interest expenses/gross interest bearing debt

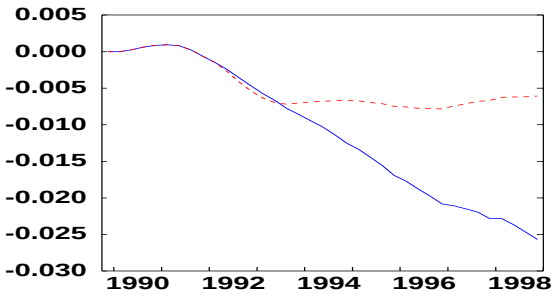


Figure 8c Gross interest bearing debt/gross interest bearing assets

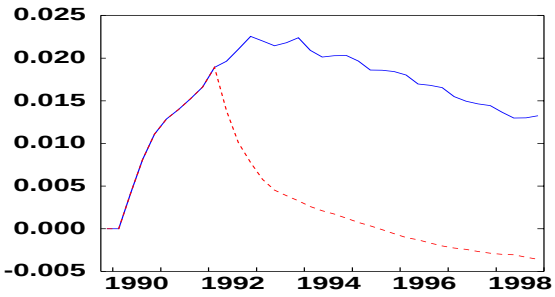


Figure 8d Four quarter growth in interest bearing debt/fixed capital formation

Figure 9 *Banks*: Indicators of financial fragility. Left column: Stochastic simulation over 1990 Q1 - 1998 Q4 (mean, 50% and 95% prediction intervals). Right column: Effects of a 100 bp permanent shift in short-term interest rates and a corresponding temporary shift (two years)

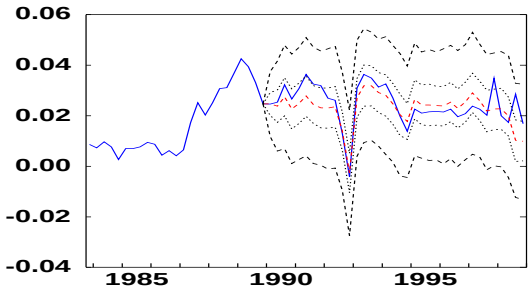


Figure 9a Bank loan interest rate margin

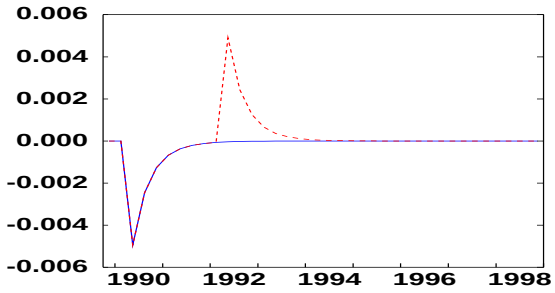


Figure 9b Bank loan interest rate margin

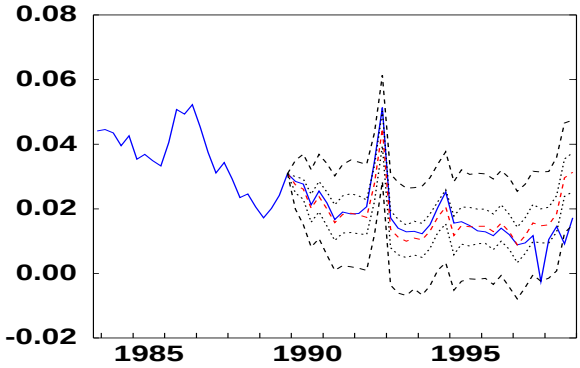


Figure 9c Bank deposit interest rate margin

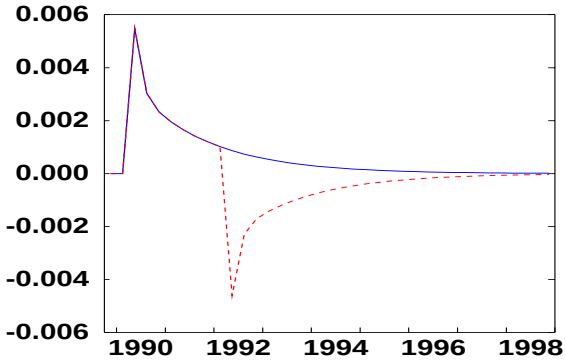


Figure 9d Bank deposit interest rate margin

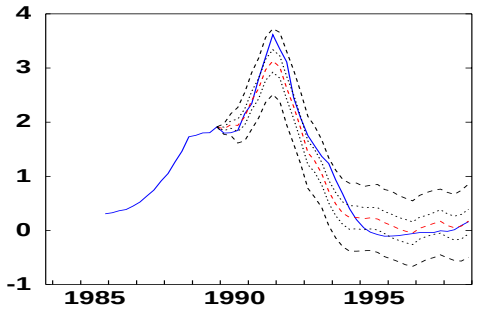


Figure 9e Ratio of financial sector losses to total bank loans

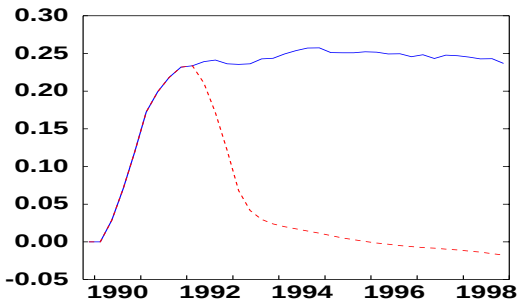


Figure 9f Ratio of financial sector losses to total bank loans

Figures 9a and 9c show the simulated interest rate margin for banks' average loan interest rate and average deposit interest rate respectively. The tracking performance of the banks' deposit rate is quite bad at the end of the simulation period, and the model misses the upswing in the deposit rate in 1998. It is, however, interesting to see that financial sector losses measured as a fraction of the banks' total volume of loans seem to track the actual development reasonably well (Figure 9e) although some intercept corrections during the banking crisis in 1991 are strongly required. Without these corrections the model would have substantially underpredicted the recorded losses during the peak year of the Norwegian banking crisis. Some corrections were also necessary towards the end of the simulation period, ie from 1997 to the end of 1998.

9. Concluding remarks

The main contribution of this paper is perhaps basically a methodological one: we have discussed the potential usefulness of macroeconometric models in the analysis of macroprudential indicators of financial stability, using as an example the recent version of the Central Bank of Norway macroeconometric model RIMINI. We have stressed the need for a *congruent* model representation, and the overall forecasting properties of the model seem to be quite satisfactory. This enables us to simulate the selected set of macroprudential indicators with reasonable accuracy. The simulated prediction intervals provide information about the level of expected forecast accuracy of the model, and are useful in detecting sources of forecast failure. It is important from a policy perspective to establish the invariance of the key submodels to different types of shocks to the system, such as policy shocks, terms-of-trade shocks and asset price shocks, which may heavily influence the macroprudential indicators.

We have shown that shocks to the system, for example in the form of permanent or temporary interest rate changes, may cause quite persistent effects on macroprudential indicators like debt service to income ratios and capital gearing ratios. It is important to identify such properties, which are useful in the process of monitoring the macroprudential dimension of financial stability. Obviously, the transmission mechanism lies at the heart of this matter, and it is vital that a model is able to adequately represent the key channels of transmission from interest rates. In particular, we have demonstrated that it is important to assess the effect shocks may have on asset prices, either affecting exchange rates or through the effects on domestic real estate and stock markets. The link through the stock market has not yet been explored empirically in the RIMINI model, and further work is required, in particular to improve the submodel for non-financial enterprises. On the other hand, the links between housing prices and household loans play an important role in the submodel for household behaviour, and provide the key links to the set of macroprudential indicators considered, and notably to the submodel for recorded financial sector losses.

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