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Staff Memo

The financial accelerator and the real economy: A small macroeconometric model for Norway with financial frictions

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The financial accelerator and the real economy

A small macroeconometric model for Norway with financial frictions

by
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Abstract

This paper studies the salient features of a core macroeconometric model that allows for self-reinforcing co-movements between credit, asset prices and real economic activity. In contrast to the economic literature that cultivates highly stylized model representations aimed at illustrating the workings and the implications of such features, the model of this paper integrates no less than two mutually reinforcing financial accelerator mechanisms in a full-fledged core macroeconomic model framework. Noteworthy, the impulse responses of such a model turns out to be very much in line with the ones one would have expected using a typical SVAR/DSGE model, though the amplitude of shocks is in most cases stronger than the ones pertaining to these kinds of models. This is due to the workings of the financial accelerators that contribute to the magnification of the effects of shocks to the economy. Furthermore, a forecast comparison undertaken between our model and an alternative macroeconometric model without a financial block, suggests that financial feedback mechanisms may improve the forecasting properties of theory-informed macroeconometric models.

Keywords: The Financial Accelerator, Structural Vector Error Correction Modelling, Impulse response analysis, Forecasting

JEL classifications: E1, E32, E44

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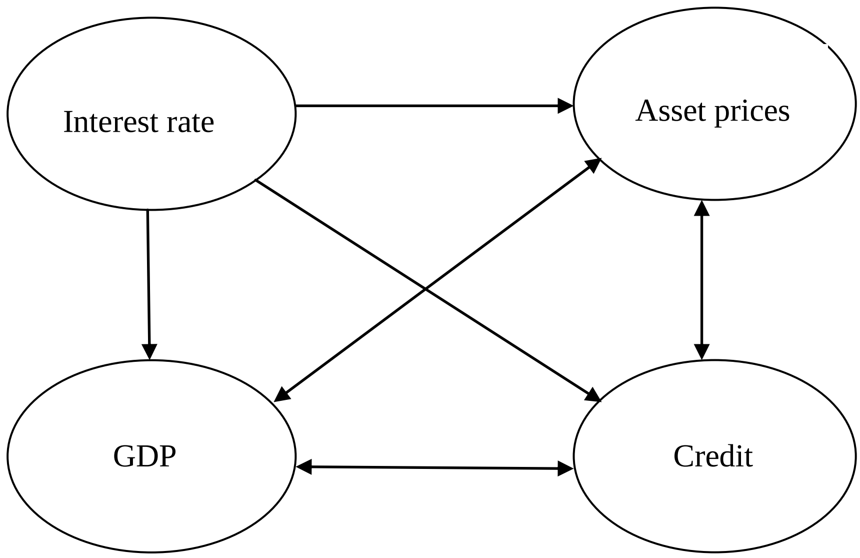
Introduction

There is much to indicate that financial frictions could have an important bearing on the transmission mechanism of shocks. This paper presents a small macroeconometric model, called Small Macro Model (SMM), which is designed to incorporate self-reinforcing co-movements between credit, asset prices and real economic activity.

As a case in point, the effects of a shock to the monetary policy rule governing the key policy rate could be reinforced through several channels in the presence of frictions. Such a contingency can be illustrated by spelling out the transmission mechanism of a monetary policy shock in the presence of self-reinforcing feedback loops between credit, asset prices and real economic activity. An interest rate hike would through affecting the propensity to save on the part of households, lowering real investments and reducing net trade – the latter as a consequence of an appreciating real exchange rate − lead to a drop in activity that could potentially be reinforced by a procyclical correction to asset prices. Such kind of a self-reinforcing feedback mechanism is given support by standard theory. For instance in the case of Tobin's Q (Tobin (1969)), lower asset prices lead to a drop in the ratio of the market value of capital to its replacement cost and thus reduced investment. The permanent income hypothesis (Friedman (1957)) can likewise argue for a similar mechanism based on a negative wealth effect on consumption. However, in the presence of financial frictions this is only part of the story. Lower asset prices that affect net worth of firms and household wealth would also have a negative effect on the value of collateral. In the presence of asymmetric information that raises the cost of external finance relative to the cost of internal finance, this would affect the borrowing capacity of wealth constrained entrepreneurs and households and thus reduce investments. Through the working of a credit-asset price spiral where lower asset prices spur lower credit and lower credit in turn leads to a reduction in investment − and thus further reductions in asset prices due to their procyclicality − this amounts to a mechanism that in the end will lead to a self-reinforced procyclical drop in domestic absorption and output, asset prices and credit. Such a mechanism is often referred to as a financial accelerator in the literature (See e.g. Kiyotaki and Moore (1997) and Bernanke, Gertler and Gilchrist (1999)). Figure I.1 presents a simplified flow diagram of the financial accelerator mechanism referred to in the text.[4]

[4] In Section 2, we present a more comprehensive flow diagram that spells out the whole transmission mechanism of a monetary policy shock in relation to the small macroeconomic model developed in this paper.

Figure I.1- The Financial Accelerator



In contrast to highly stylized model representations aimed at illustrating the workings of a financial accelerator, the SMM model integrates such mechanisms in a full-fledged macroeconomic structural model. The model is used by the financial stability wing of Norges Bank, for the purpose of forecasting, constructing risk scenarios and to illustrate the relative importance of different transmission channels (see also Andersen et al. (2008)). The model presented herein is based on an augmented and revised version of the model documented in Bårdsen and Nymoen (2009), and implies a model for the real economy that includes a financial block. The role of the financial block is to take account of the co-movements and procyclicality of credit, asset prices and real economic activity that typically characterises a financial accelerator. The model differs from optimizing representative agent models in several respects, the main reason for this being a wider and less stringent theoretical framework, and the fact that data is given a more central role in the shaping of the long- and short-run structure of the model.[5] This notwithstanding, the impulse response pattern of this model turns out to be in line with the ones from a typical SVAR/DSGE model, though the amplitude of shocks is in most cases stronger than the ones pertaining to the latter kinds of models. This is due to the working of the financial accelerators that contribute to magnify the effects of shocks to the economy. Furthermore, a forecast comparison undertaken between our

[5]To be more explicit this means that data in this framework has played the role of distinguishing between admissible structures lying in a hypothetical extended possibility set. This is a possibility set that in addition to span an exhaustive catalogue of theory-admissible subject matter structures also is intended to cover relationships with a less solid theoretical foundation, like relationships regarded to be admissible only because they make sense. For a more comprehensive account of such an approach, the reader is referred to Section 1.2 and the discussion therein.

model and an alternative macroeconometric model without a financial block, suggests that financial feedback mechanisms may improve the forecasting properties of theory informed macroeconometric models.

In the following, we start with a presentation of the model and its methodological foundation in section 1. That is, Subsection 1.1 starts out with a brief account of the principles behind the construction of our data-based model. In Subsection 1.2, this is followed by a more extended account of the methodology used in design and estimation. Particular emphasis is in this respect given to a discussion of a pragmatic and non-dogmatic approach to model design. Subsection 1.3 ends the section with a more comprehensive account of the model's main features, including a full account of all the model's behavioural equations. In Section 2 we present the model's transmission mechanism to a monetary policy shock. Special emphasis has in this respect been placed on describing the role of the financial accelerators. In Section 3, we proceed to a description of the model's long- and short-run responses to a wide range of different shocks.[6] In this section, particular importance has been attached to describing the dynamic transmission mechanism of shocks. Section 4 addresses the model's forecast properties, comparing the model's forecasts to forecasts of simple autoregressive and vector autoregressive models and an alternative econometric model designed and estimated on Norwegian data. Finally, Section 5 offers some concluding remarks.

[6]A structural shock is often taken to mean a shock with a clear structural interpretation, in the sense of referring to shocks to structural model representations derived from an explicit utility maximizing rational representative agent (RA) framework. However, in this case, a shock is given a wider interpretation, and refers to shocks to theory-driven structural representations in general, be that structures based on more old fashioned type of macro informed models, so-called emergent models or structural representations based on an explicit representative agent utility maximizing framework. A consequence of this is that the concept of "a structural shock" loses its un-ambiguity as several types of shocks can rightly be claimed to have a structural interpretation, though the way they are defined or interpreted as structural will differ across models. In spite of this, Section 3 reveals a great degree of conformity between our impulse responses and those following from a typical SVAR or DSGE framework.

1 The model and its construction

1.1 The construction of the model: Design and estimation

The SMM model is an estimated equilibrium-correction model with in general backward-looking rather than forward-looking rational expectations and a credit channel for monetary policy (see Bårdsen and Nymoen (2009)). At Norges Bank the model is mainly used for constructing risk scenarios related to low-probability events. A model with backward-looking expectations and on estimated reduced-form has proved to be useful for this purpose so far (see e.g. Bårdsen et al. (2006)). Economic policy enters the model through public expenditures as an exogenous variable in a reduced form GDP equation, as well as through an estimated Taylor-type rule for money market interest rates. The model uses quarterly data from 1978 to date. However, some equations are estimated over a shorter time period due to lack of data or difficulties in finding stable relationships over periods with shifts in policy regimes.

The model's variables can be decomposed into fully model endogenous variables, and weakly and strongly exogenous variables. The weakly exogenous variables are not only a function of variables characterized as strongly exogenous, but depend also on lagged variables classified as model endogenous. The strongly exogenous variables consist of non-modelled variables and policy variables, and include domestic tax rates, world market prices, real foreign demand and government expenditures.

As far as the specification of the possibility set is concerned, the approach is closely related to − and compatible with − the design strategy proposed by the general to specific strategy of Hendry (1993), though it clearly is more restrictive than indicated by a completely a-theoretical modelling strategy. Thus, as a backdrop for model design we have sought to start out with the most general specification given support by what we a priori perceive to be a sensible possibility set[7], and then to simplify such a point of departure down to a parsimonious representation. Ideally, this process of reduction should have taken place within the framework of a simultaneous structural system setup. However, a general lack of degrees of freedom due to short time series makes such a strategy unfeasible and restricts us to follow a mixture of strategies. One of these involves splitting the model up into blocks perceived to be sufficiently autonomous to be treated separately from the rest of the system without

[7] Proper account taken to subject matter theory.

invalidating the outcome of a modelling exercise. Another strategy implies to resort to individual equation model design procedures, proper account taken to the fact that some of the explanatory variables might be characterized as endogenous.

In designing and estimating the model of this paper, a variety of strategies has thus been utilized. In estimating the wage, price and productivity block of the model we have used full information maximum likelihood in estimating the final structural specification, while the final structure itself is the outcome of a general to specific reduction process on the block's individual equations separately. A potential bias in design due to simultaneity – and as indicated by proper tests of exogeneity – has in this context been taken into account by utilising appropriate instruments. Moreover, an automatic general-to-specific modelling algorithm called Autometrics (Doornik (2009)) has been used extensively as a device for controlling for a potential path dependence in the chosen simplification scheme (crosschecking). As far as the simultaneous system consisting of asset prices and corporate credit is concerned, this block has been designed and estimated jointly with real activity, utilising a fully simultaneous procedure of Simultaneous Structural Model Design.[8] In this procedure, the whole structure[9] of the subsystem has been designed and estimated jointly by full information maximum likelihood procedures, based on an exactly identified point of departure utilizing structural dummies. Noteworthy, and as distinct from the other equations of the model, this sequence of reductions has entirely been undertaken manually due to the lack of an automatic general-to-specific modelling algorithm for structural systems. Other equations of the model, like the equations for the nominal exchange rate, household credit, interest rates and import- and house prices, have on the other hand all been designed by utilising ordinary least squares in an ordinary general to specific sequence of simplifications, proper account taken to alleviating the threat of a simultaneity bias in design by proper testing and utilising instruments if deemed necessary. As was the case for the single equation general-to-specific scheme followed to arrive at the final wage-, productivity- and price-system, potential path dependence in the chosen simplification scheme has here been controlled for by using Autometrics.

[8] See Hammersland and Jacobsen (2008) for a more detailed account of such a procedure.

[9] That is all the equations of the structural model.

1.2 Methodology

Quantitative information about macroeconomic variables and the state of the economy can only come from macroeconomic data.[10] Hence, an empirical macro model has to be a model of macroeconomic data. Second, and only to the extent that it does not compromise being a model of data, it should also aim at being a model of the economic mechanism that generated the data in the first place. Given the premise of data congruency, the latter is more difficult to achieve the more restricted ones view is of what is meant by a macro model being a model of the data generating mechanism.

The model of this paper has been designed and estimated according to what we have chosen to call a pragmatic view. Thus, we have neither adopted a pure top-down approach where data is allowed to determine the outcome of the modelling process all alone, nor a pure bottom-up approach where the structure is imposed by micro based macro theory without taking proper account of data. Instead we undertake something in between, where theory and data is set to play "harmoniously" together in an attempt of identifying the economic structure best at reconciling the information contained in the two sources of model design. Theory by contributing to put up an extended theoretical possibility set, and data by playing a role in choosing among the alternatives spanned by this possibility set.

To summarize, the model in this paper has been designed and estimated by drawing extensively on the general-to-specific principle of Hendry (1993) and using classical estimation methods not imposing a priori restrictions (distributional or otherwise) on the model parameters. In this sense the model can thus be said to be the outcome of a process where data has been allowed to "speak", not only in the sense of estimation, but also in the broader sense of trying to get at how the most data compatible structural representation might look like. For a model to be compatible in this respect involves the statistical concept of

[10]As should be clear after having read this section, this does not imply that we advocate measurement without theory. On the contrary, we strongly believe that numbers can only make sense within some economic structure, theoretical framework or mindset. However, that said, we also think it is contra-productive restricting a model to lie in the space of a possibility set spanned by an overly specific, simplistic and restrictive theoretical understanding of how the economy works and looks like. The world − as we view it − is complex, if not downright constituting a complex system. To rely completely on economic theories not taking properly into account the possibility of interaction and interdependencies between agents and disregarding the fact that economies after all are embedded in a social, cultural, judicial and political context − would potentially pose a huge disservice to the goal of developing realistic models with support in data. In this, we fully agree with Colander (1993) who writes: "Some economic mindset is a prerequisite for extraction and interpretation of information from macroeconomic data. However, we do not believe that strictly economic and formalized macroeconomic theories deduced from microeconomic first principles by the aid of representative agents provide the one and only sensible mindset."

congruence by which a model is deemed to be a good representation of the data generating process based on the outcome of proper statistical testing. However, as this kind of testing is an integral part of the general-to-specific strategy utilised in model construction,[11] the equations and sub-systems of our model would necessarily fulfil most requirements for such an entitlement by design. In this respect, suffice to mention that all equations and sub-systems of the model of this paper are designed to pass a number of tests for non-spherical noise, for example tests for autocorrelation, heteroskedasticity and non-normality. Moreover, recursive testing shows that the sub-systems as well as the individual equations of the model are stable and not subject to structural breaks. This should constitute sufficient evidence to counter the Lucas critique.

1.3 Main features

The main equations of the SMM model are given in Appendix 2 and belong to one of two main blocks, respectively a real economy block and a financial block.

1.3.1 The real economy

The model for the real economy is based on the model presented by Bårdsen and Nymoen (2009). The reduced form aggregate demand equation has been extended to include effects from several financial variables. In this equation, output (y) is determined by real public consumption expenditures (g), real credit to households $(cr^h - p)$, the real exchange rate $(v + p - p^*)$ and the real interest rate $(RL - \pi)$ in the long run.[12] In the short run there are significant effects of changes to real public expenditures, real house prices $(ph - p)$ and real credit (both households $(cr^h - p)$ and enterprises $(cr^e - p)$). As regards credit, the short-run effect is interpreted as reflecting frictions in the credit market, while the long-run effect points towards a form of rationing of the household sector.

The long-run property of the model's exchange rate equation, (2), is based upon the theory of purchasing power parity (PPP) and implies a full pass-through of changes in relative prices $(p^* - p)$ to the nominal exchange rate (v). In the long run, the equation further implies that the real exchange rate $(v + p^* - p)$ appreciates in the wake of changes to the spread between

[11] In the sense of constituting compulsory design criteria.

[12] In the following, small letters denote the logarithm of a variable, a notable exception being the letter (π) that stands for the rate of inflation. For a comprehensive variable list containing all the model's variables the reader is referred to Appendix 1.

domestic and foreign real short-term interest rates $(R-\pi)-(R^{*}-\pi^{*})$ and to a change in the real oil price in Norwegian kroner $(po+usd-p)$. Beyond reacting to deviations from its long- run structure, the equation only includes effects of changes to foreign and domestic short -term interest rates and the oil price in US dollars.[13] An increase in the spread between domestic and foreign short-term interest rates or an increase in oil prices will lead to an instantaneous appreciation of the krone exchange rate. As this feature is also present in the long run with a pass through of almost the same magnitude, there is little scope for a substantial overshooting in the short run.

Import prices (3) are modelled in accordance with a pricing- to- market model, where the degree to which foreign competitors adjust their prices to the prevailing domestic prices depends also on domestic factors, such as the degree of competitiveness in domestic markets. Thus, in the long run, the ratio of Norwegian import prices (pi) to foreign producer prices denoted in Norwegian kroner $(v+pi^{*})$ is a function of domestic market conditions, represented by the real exchange rate. Given the real exchange rate, the effect of an increase in either the foreign export price or the nominal exchange rate will thus be fully reflected in the import price index in the long run. If the real exchange rate on the other hand appreciates and foreign producer prices (denoted in Norwegian kroner) stay the same, pricing- to- market will lead to increased import prices.

Another important equation is the unemployment equation (4). The first thing to notice is that there are no non-linear effects that can transform transitory shocks into permanent effects on the rate of unemployment. However, unemployment (u) is a function of GDP growth (Δy), and not the level of GDP (y), implying that the level of unemployment cannot be permanently influenced by fiscal or monetary policy. Hence, although the wage-price part of the system does not imply a NAIRU, the equilibrium rate of unemployment implied by the full model, is independent of the level of aggregate demand. Instead, it is determined by real wages and the growth rates of the domestic economy.

In the wage, price and productivity block, equations (5)-(7), workers do not maintain their buying-power in the short run, as there is no contemporaneous short-run effect of prices on wages. In the long run, however, the outcome is as predicted by the battle of mark-ups

[13] For an account of the oil price effect, see e.g. Akram (2004).

model of Layard et al. (1994) where the wage share is a function of an indicator for the tightness in the labour market. Unemployment is the typical indicator of this labour market tightness. Prices (p) obey the price-setting rule of an open economy monopolistic competitor; price equal to a weighted mark-up over unit labour costs $(w-z)$ and import prices (pi).

Accordingly, there is a limited short-run pass-through of consumer price inflation (Δp) to nominal wage growth (Δw) in the wage equation (5). However, in each period, nominal wages adjust towards their long-run relationship. This is a relationship where there is a full pass-through of changes to consumer prices (p) and productivity (z), and the mark-up of wages on prices and productivity is inversely related to the unemployment rate (u).[14]

As regards the consumer price, (6), these vary in the short run with changes in aggregate demand (Δy), and to some extent with changes in nominal wage growth (Δw). In addition, they adjust to deviations from their long-run relationship. In this long-run relationship, the consumer price (p) reflects a weighted average of domestic and imported costs, represented, respectively, by unit labour costs $(w-z)$ and import prices (pi). It follows that the initial effect of a change in the nominal exchange rate on aggregate demand would become modified over time due to the exchange rate pass-through to inflation, which would have an effect opposite to that of the nominal exchange rate on the real exchange rate. The model also includes an equation for the underlying, i.e. core inflation rate (π^c) not shown here, which is linked to consumer price inflation.

In addition, according to the wage, price and productivity block, and due to a two-way contemporaneous link between wages and productivity, shocks to productivity and wages give rise to a self-reinforcing productivity wage cycle. In fact, a shock to wages that generates

[14] Note that the lack of a short-run price effect on wages implies that the wage-price block of the model is even further away than in Bårdsen et al. (2005) from tying down the equilibrium rate of unemployment, as it makes wages homogeneous of degree zero in producer prices. Thus, as before, the wage-price block does not pin down a NAIRU and given stability of the wage-price sub-model, the implied steady state inflation rate, conditional on any given rate of unemployment, is given by: $\Delta p_t = \Delta pi_t = \Delta v_t + \Delta pi_t^*$

Where pi stands for import prices in Norwegian kroner and pi^* import prices in foreign currency. v stands for the nominal exchange rate, i.e. the number of kroner per foreign currency unit, and a delta symbolizes the relative rate of change of each variable.

a contemporaneous increase in productivity of 0.12 percent is in the long run amplified to 0.5 per cent via this process. As regards the productivity equation, productivity is mainly driven by the equilibrium-correction term based on a relationship where the productivity gap is explained positively by developments in real wages and unemployment.

1.3.2 Financial stability block

So far, our discussion has been confined to the real part of the model. However, as alluded to in the introduction of this paper, the SMM model also contains a financial block where interactions between the real and financial sphere are taken into account. As we do know from the preceding discussion, interest rates, house prices and credit (to both households and firms), all have real effects. As a point of departure, it is therefore natural to focus on the equations for these variables when commenting on the financial block in the following.

As regards interest rates, the money market interest rate of the model follows a Taylor rule where the long-term equilibrium real interest rate − the Wicksell rate − is calibrated at approximately 3 per cent and the coefficients of the inflation and output gaps are estimated to respectively 1.3 and 0.7.

Lending rates, on the other hand (see Equation (9)), is in the model a function of money market interest rates and an exogenous lending margin (μ_{RLM}), defined as the difference between the lending rate and the money market rate. While there is full pass-through of changes to the money market interest rate in the long run, the short run pass-through is in this equation 0.8. The coefficients of this equation are calibrated and not estimated.

The relationship explaining movements in household debt in Equation (10), builds on the work by Jacobsen and Naug (2004). In the short run, growth in real household debt $(cr^h - p)$ reacts positively to growth in real income $(inc - p)$ and real housing prices $(ph - p)$ and decreases with higher interest rates on loans (RL). As activity is affected by household credit and household credit spurs house prices in the long run, this contributes to reinforce the presence of a financial accelerator in the model. In steady state, household debt is a function of real house prices, the loan rate and real income. More precisely in this respect, a one per cent increase in real house prices and real income is estimated to increase household debt by, respectively, 0.9 and 0.4 per cent, while a one percentage point increase in the interest rate is estimated to reduce household debt by 0.03 percent.

The model of house prices (ph) in Equation (11) is based on Jacobsen and Naug (2005). The nominal house price growth (Δph) is in the short run explained by growth in nominal income (Δinc), household expectations regarding economic prospects from survey data (h^e), as well as interest rate changes (ΔRL) and deviations from steady state. As activity (see Equation (1)) is affected by house prices, this introduces a mechanism where demand shocks are reinforced through affecting house prices via a real income channel. In steady state, real house prices $(ph - p)$ are mainly determined by income (inc), housing capital[15] (hs) and the interest rate (RL). In addition there are effects from changes in unemployment (u) and household credit (cr^h). As house prices contribute to explain the level of activity also in the long run through affecting household debt (see comment below), the financial accelerator is a persistent characteristic of the model.

The equation for gross fixed housing investments (12) is based on Jacobsen, Solberg-Johansen and Haugland (2007). According to this equation, growth in gross fixed housing investments (Δj) depends solely on the lag structure of changes to real lending rates $(RL - \pi)$ in the short run. However, the long run steady state relationship is based on Tobin's Q- theory as the ratio of real housing prices $(ph - p)$ to the costs of building a new house is affecting housing investments, where real investment costs $(pj - p)$ are a proxy for building costs. In steady state, gross fixed investments also depend on the level of housing capital (hs) – due to replacement investments – households' real wage income $(w - p)$ – as a proxy for land costs – and the real lending rate $(RL - \pi)$.

According to Equation (13), growth in non-financial enterprise debt $(\Delta(cr^e - p))$ is in the short run affected by growth in real activity (Δy). Accordingly, a shock to demand that momentarily leads to higher activity growth will feed into a contemporaneous increase in credit growth. As growth in non-financial enterprise credit according to Equation (1) spurs output, the model incorporates a financial accelerator with a firm side origin, see also Hammersland and Jacobsen (2008). Noteworthy, this is a mechanism that in the model comes in addition to the one documented for the households. Furthermore, in Equation (13), growth

[15] The housing stock and wage income are strongly correlated when adjustment is made for seasonal variation. The effects of the housing stock and wage income are therefore imprecisely estimated if we allow the variables to be included with separate coefficients. We have therefore chosen to impose the condition that income and the housing stock shall have the same long-term effect with opposite signs, see also Jacobsen and Naug (2005).

in real domestic credit to firms is contemporaneously affected by asset price growth (Δpa). As asset prices in turn are affected contemporaneously by credit growth, Equation (14), this gives rise to a dynamic interaction between credit and asset prices that turns out to create a transmission mechanism by which the effects of real shocks could persist and amplify. This feature is fully in accordance with Kiyotaki and Moore (1997), where a financial accelerator mechanism is reinforced by a credit- asset price spiral. As regards the long-run structure of our model, there is a link between household debt and output. However, according to Equation (1) there is no such link between enterprise debt and activity. Hence, while innovations to asset prices and firm credit do cause short run movements in production, and while real activity spurs credit of firms, such innovations do not precede real economy movements in the long run. Otherwise, according to Equation (13), higher oil prices (po) affect credit negatively in the short run, only mitigated partially by its positive effect on asset prices. Such an effect of higher oil prices on credit is interpreted to represent a cost effect. In the long-run, however, the effect of higher oil prices on credit comes exclusively via its effect on asset prices and is strongly positive. In fact a one percent rise in oil prices is estimated to increase credit in the long run by approximately 0.26 percent, the same effect that an oil price hike is estimated to have on asset prices in the long run.

The equations of default[16] by households and firms in (15) and (16), respectively, are based on Berge and Boye (2007). Households' default rate $(d^h - c^h)$, i.e., default as a share of total household bank debt, depends on households' real income $(inc - p)$, unemployment (u), the real interest rate $(RL - \pi)$ and real house prices $(ph - p)$. As regards firms' default, there is no homogeneity between default and debt in the short run, only in the long run. Firms' default, measured in real terms $(d^e - p)$ depends on the level of debt $(cr^e - p)$, the real interest rate $(RL - \pi)$, domestic demand, proxied by the unemployment rate (u), the real exchange rate $(v + p^* - p)$ as a measure of competitiveness and the real oil price $(po + usd - p)$. The latter variable captures that the level of activity and investments in the oil sector affect other industries.

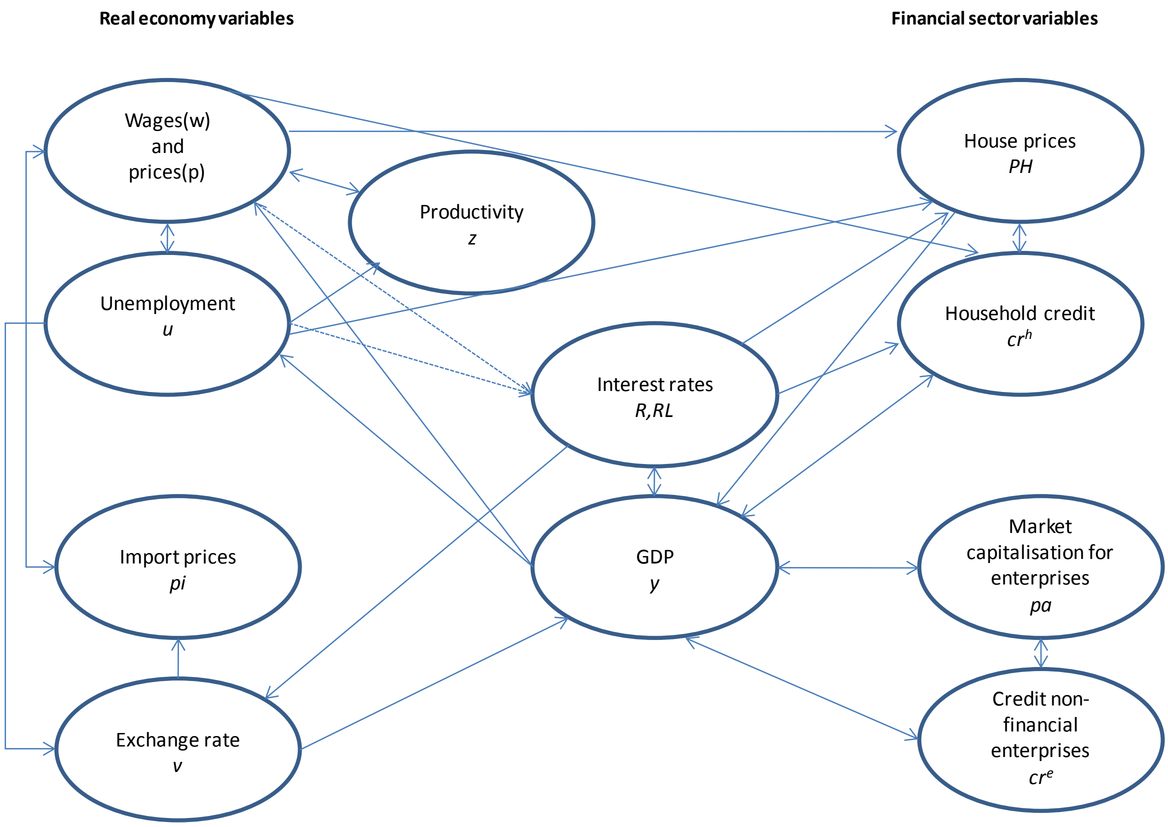
[16] Our data on defaults include both defaults and loans with a very high probability of default as reported by the banks (problem loans). These are all loans where banks have made write offs. The actual recorded losses by the banks are then denoted as a fraction alpha of these problem loans.

In addition to the equations commented on above comes a technical relation for the determination of the consumer price index adjusted for energy and taxes (p^c) and a set of identities defining various transformations of the model variables.

2 The Transmission Mechanism

As commented on above the SMM model includes financial accelerators for both firms and households, see Figure 2.1; where procyclical fluctuations in house- and asset-prices affect borrowing capacity of, respectively, households and non-financial enterprises and hence real activity through an increase in both real and housing investments. As far as both accelerators are concerned, this feedback mechanism is reinforced by an asset- price credit spiral where higher asset prices chases more credit and vice versa. As will be shown in Section 3 on impulse responses, these feedback effects are significant in both the short- and long-run.

Figure 2.1 - The transmission mechanisms of the SMM model



Through the mechanisms outlined in Figure 2.1, the SMM model is able to represent procyclical co-movements between asset prices, credit growth and the real economy. House prices and credit to both households and firms directly affect GDP growth. Corporate and household credit affect GDP in the short run, possibly reflecting frictions in the credit market, while the long-run effect of household credit points towards some form of persistent rationing of the household sector. The house price effect can be interpreted as a wealth effect. As GDP growth spurs house prices and credit, in both the short and long run, a financial accelerator emerges that contributes to the amplification of shocks through a credit asset price spiral enhanced feedback mechanism between output, credit and house prices.

To get a sounder grasp on the transmission mechanism of the model, and to facilitate the identification of the models' chain of causation, we will take a closer look at the transmission mechanism of the monetary policy shock alluded to in the introduction and trace the entire dynamic response of a monetary policy shock in the model. A negative monetary policy shock in terms of a positive shock to the rule governing the policy rate, will lead to a decline in activity through several channels. First, given that a positive shock to the policy rule will lead to a jump in the money market interest rates (long- and short-term), bank lending rates will to a varying degree follow suit. In the model, this will lead to a downward credit, house and asset price spiral. Combined with an enhanced propensity to save on part of households, lower real investments and reduced net trade – the latter as a result of a stronger real exchange rate − this will initiate a feedback mechanism that in the end leads to a self-reinforcing procyclical drop in domestic absorption and output, asset prices and credit. As output declines (relative to a baseline scenario) unemployment will also increase. In the model, this will dampen the pressure in the labour market and lead to a restrain in wage and consumer price inflation. Combined with a negative output gap this will result in a reversal of the central bank's monetary policy stance and thus to lower interest rates. Lower interest rates on the other hand will contribute positively to household credit and house prices. Together with lower domestic inflation and a weakening of the exchange rate this will lead to a significant slowing down of the feedback mechanism initiated by the monetary policy shock in the first place. Eventually, this course of progress will in the model partially reverse the decline in employment. However, before this happens, wage and price inflation have already reached their turning point as a consequence of productivity gains related to the high level of unemployment. Lower unemployment on the other hand will eventually contribute to the amplification of this process of higher wage and price inflation and we enter a new period of policy tightening on part of the central bank. This tightening will so initiate a new round of cyclical oscillations to take place and so it continues until the oscillations in the long run gradually die out.

3 Impulse Responses

In this section, we illustrate the model's short- and long-run properties by adding a series of shocks. The shocks are considered one at a time, entered as shocks to a baseline scenario of the model. Noteworthy is the fact that the impulse response patterns overall are very much in line with the ones one would have expected using a representative agent (RA) modelling framework, though the amplitude of the responses in most cases is stronger and the responses are more volatile than the ones in for instance the Dynamic Stochastic General Equilibrium Models of the Euro area (SW) and Norway (NEMO) (see respectively Smets and Wouters (2003) and Brubakk et al. (2006)). The stronger amplitude is mainly due to the working of the financial accelerators that contribute to magnify the effects of shocks to the economy. The more volatile pattern comes as a consequence of utilizing unadjusted data, a richer dynamic structural model specification and a policy rule with an interest rate persistence that differs somewhat from the ones present in SW and NEMO.

A shock to interest rates

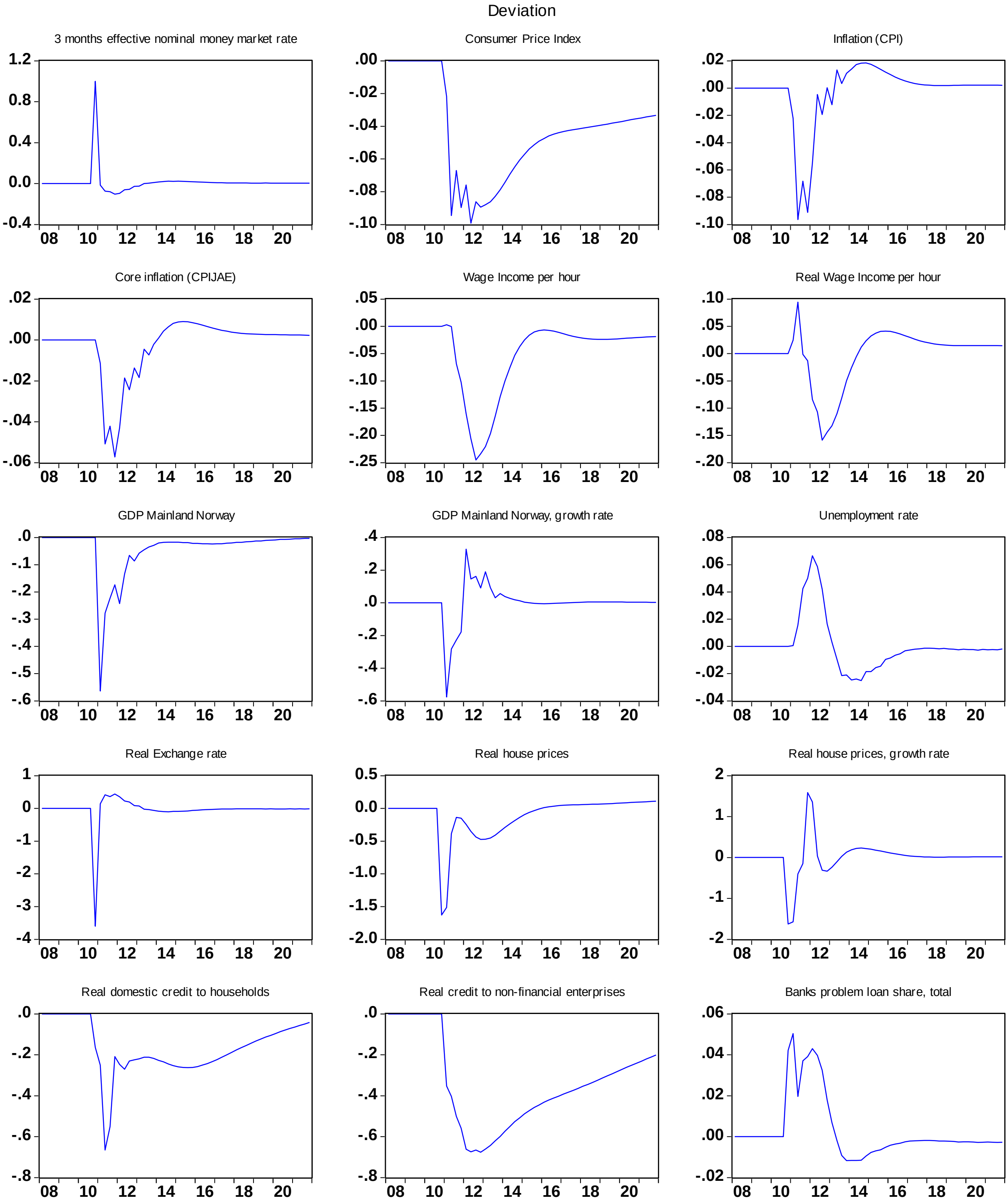
Figure 3.1 shows the responses to a shock to the equation governing the money market interest rate, calibrated such that the money market interest rate increases by 1 percentage point in 2010q4, and letting the full system play out freely after the shock. The impulse responses are based upon the monetary policy reaction function of a Taylor-type rule, see Equation (8) in Appendix 2.[17]

The interest rate increase is channelled to the real economy through an increase in the banks' lending rates, as well as through a currency appreciation, both having a contractionary effect on activity and employment, amplified by the financial accelerators. As a consequence, consumer price inflation and wage inflation are reduced. Credit demand and house price growth falls. In the quarters following the shock, the interest rate gradually reduces to its previous level, and at the same time the exchange rate depreciates. GDP growth strengthens, with inflation and credit growth also picking up again. The effect diminishes in the course of the 20 quarters covered by the graph, indicating that the system is stable (For a more comprehensive account of the transmission mechanism, see the last part of the previous section).

[17] See appendix 4 for an alternative impulse response analysis based upon an augmented Taylor rule with interest rate smoothing.

In contrast to the impulse responses of a monetary policy shock in a typical DSGE model, the real quantitative consequences of the shock are amplified while real prices including the real wage are less affected by the interest hike. For instance, in SW a 1 percentage point increase in the sight deposit rate is estimated to reduce output by approximately 0.4 per cent after about 4 quarters. The impulse responses of a corresponding monetary policy shock using NEMO imply a less pronounced fall in GDP of 0.25 per cent and the output- response is somewhat quicker than in SW. In the case of the SMM model, the same type of shock is simulated to reduce output by almost 0.6 percent already after a couple of quarters. However, a prompt policy response contributes to quickly reverse the drop in output such that output is back on trend already after 6-8 quarters. Unemployment on the other hand shows a more protracted course of progress as the effect does not reach its maximum of almost 0.07 percentage points − corresponding to an increase of about 2 ½ per cent − before after 4-5 quarters. However, as regards real wages these are in SW simulated to be reduced by approximately 0.25 per cent after about 8 periods, while the SMM model predicts a more modest drop of about 0.15 per cent in a slightly shorter time span (6-7 quarters). Noteworthy, real wages in the SMM model initially rise in the wake of a monetary policy shock. This is due to nominal prices being more flexible than nominal wages in the short run. Overall, though, the pattern is largely the same as in both SW and NEMO, with hump shaped responses to output, prices and wages.

Figure 3.1 – A rise in the money market interest rate[1]

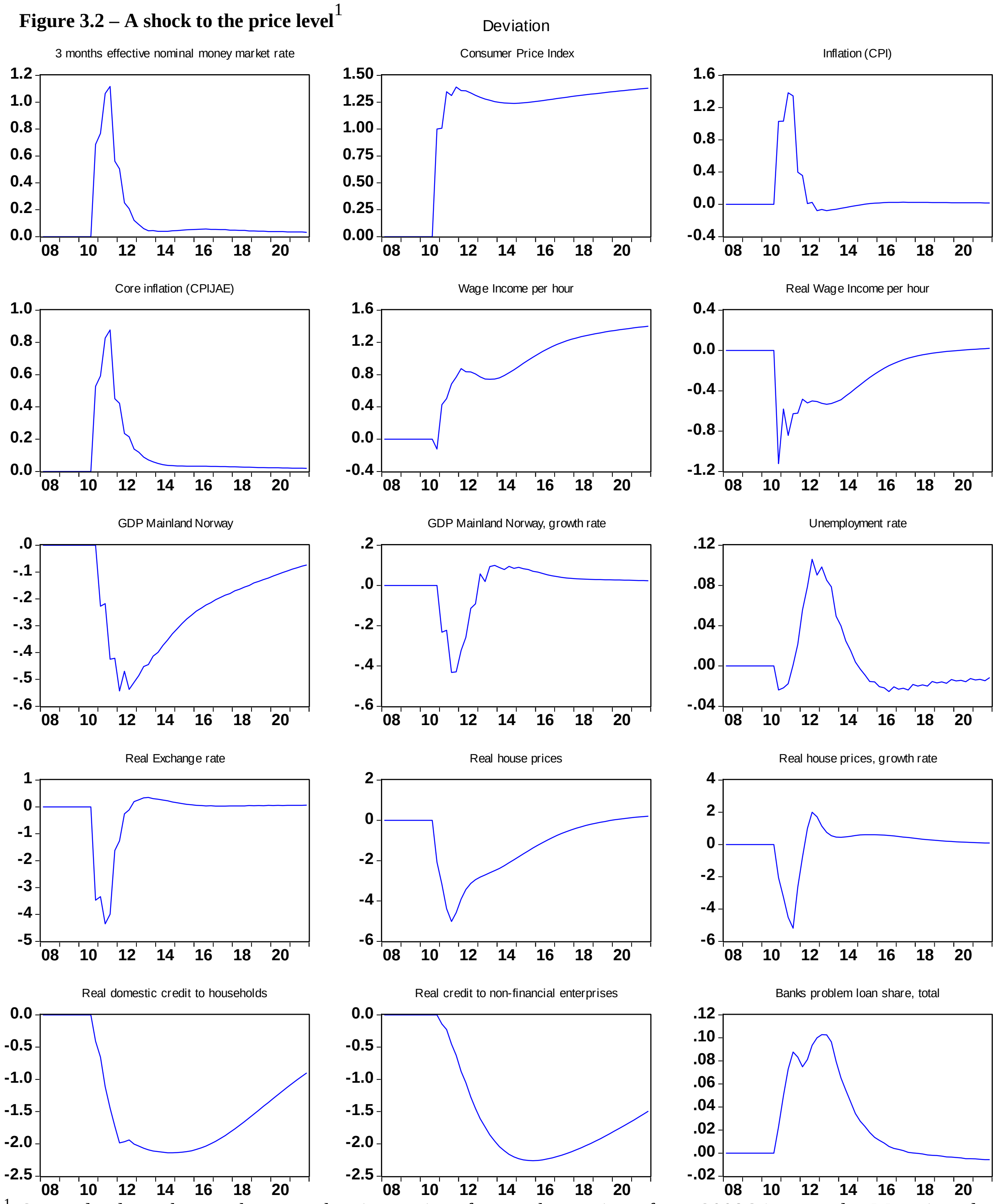


[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.

A price shock

Figure 3.2 below, shows the response to a permanent shock to the equation governing consumer prices, calibrated such that the CPI index increases by 1 percent in 2010q4, and letting the full system play out freely after the shock. The impulse responses are based upon using a Taylor rule, Equation (8) in Appendix 2. Again the similarities to the responses in SW are striking.

Figure 3.2 – A shock to the price level[1]



[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.

A price-shock in the SMM model will lead to an instantaneous appreciation of the real exchange rate, and via the Taylor rule, to higher real money market interest rates. Higher real interest rates and a stronger real exchange rate will on the other hand contribute to reducing the level of real activity in the economy, as a result of both lower consumption, investments and a drop in net exports. As a result, the rate of unemployment will start to increase. Together with reduced real income, these effects combined will spur a financial accelerator where lower credit (both among households and firms), reduced activity and increased unemployment contribute to mutually reinforcing each other. As far as both sectors are concerned this financial accelerator is boosted by a credit- asset price spiral, where falling asset prices and credit mutually contribute to reinforce each other. Gradually, the level of unemployment will have increased so much that the pressure on wages and prices starts to abate. Together with a lingering nominal depreciation and an expansionary monetary policy, there will be a gradual pick-up in activity and employment. As with the decline, this process will be characterized by the credit asset price spiral enhanced financial accelerator where asset prices, credit and activity contribute to mutually reinforce each other according to the mechanism described above, only that this time the process will be put in reverse. When activity and inflation have recovered sufficiently, time has come for a new bout of interest rate increases and real exchange appreciations. In other words, we have started on a new cycle exactly like the one we have just described, the only difference being that the amplitude this time is smaller. In accordance with Figure 3.2, this process of subsequent cycles will continue until the cycles become so small that they eventually die out (In the figure this does not seem to happen before after the end of the simulation period).

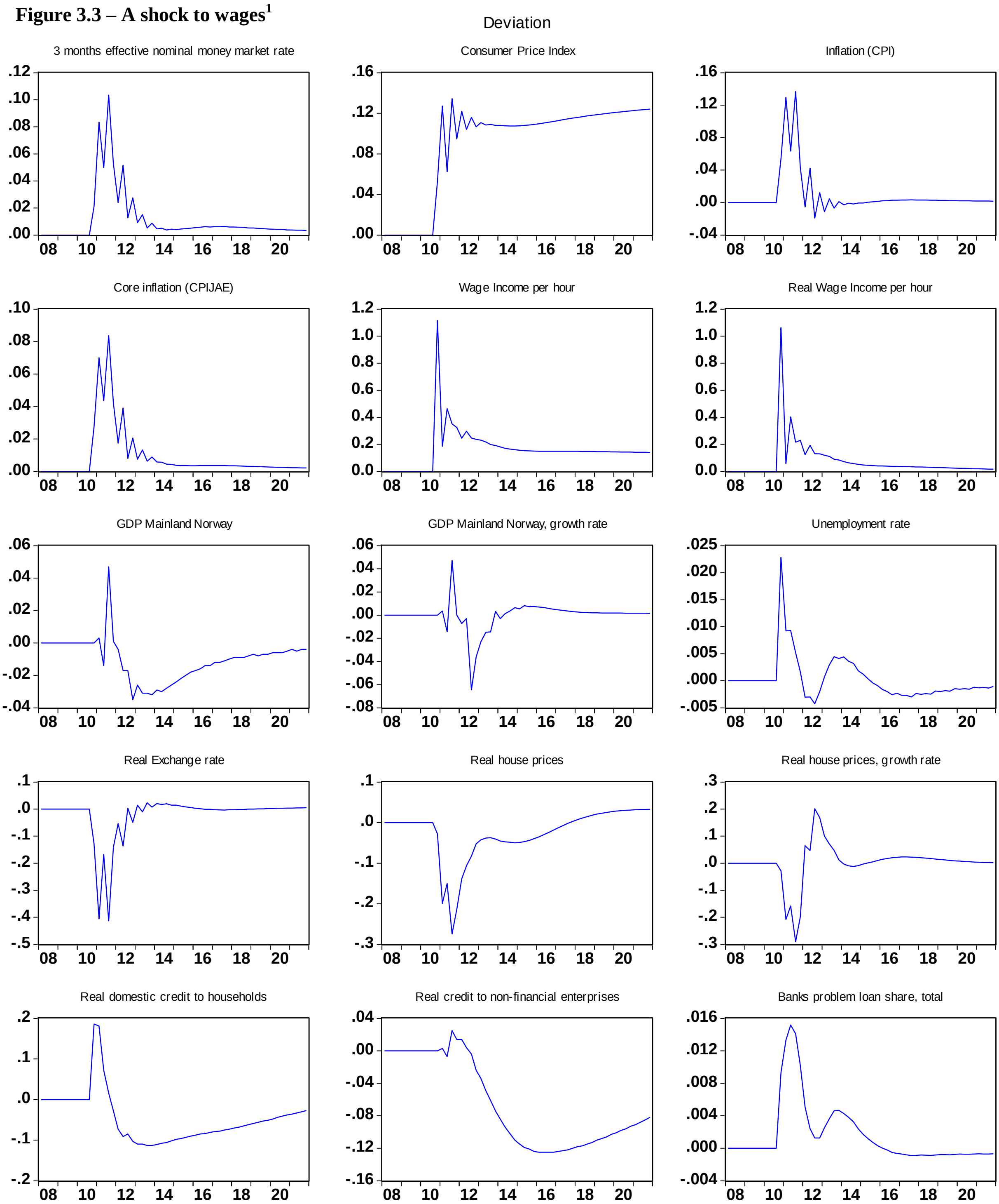
In contrast to the impulse responses in SW, the real volume effects of a shock to the price mark-up are all amplified due to the working of the financial accelerators. For instance, a one-period shock that is calibrated to lead to an instantaneous rise in consumer prices of one per cent is in SW estimated to reduce output by approximately 0.12 per cent after 4-5 periods. A similar exercise using the SMM model on the other hand would, according to Figure 3.2, lead to a reduction in the order of magnitude of 0.5 per cent after 5-6 quarters. As was the case with a monetary policy shock the unemployment response of the SMM model is protracted and does not reach its maximum increase of about 0.1 percentage points − corresponding to a increase in unemployment of about 3.5 percent − before after about 8 quarters time. As regards wages, we see that the pass-through of the price shock is rather slow and protracted in the SMM model leading to an instantaneous drop in real wages of almost the same order of magnitude as the shock to inflation itself. Compared to an instantaneous drop of approximately 0.2 percent in SW this illustrates the comparable high degree of nominal wage stickiness in the SMM model. However, Figure 3.2 shows that the real wage gradually rises towards its equilibrium level – given by its level in the baseline scenario − in the long run. Noteworthy, this is a characteristic that SMM shares with the impulse responses in SW. Another feature that SMM seems to share with the impulse responses of a price shock in SW is the relatively protracted and slow adjustment of real output as neither in SW nor in the SMM, output seems to have reached its long- run equilibrium level within the simulation period. While SW though clearly demonstrates that output converges to its baseline level in the long run this is more unclear in the case of the SMM model. In fact, an extension of the simulation period shows that output in the case of the SMM model remains below its baseline level for a considerable time. Figure 3.2 and Equation (1) in the appendix suggest that this comes mainly as a consequence of a persistent drop in household and firm credit. Otherwise, we do again see that the impulse response pattern is largely the same as in SW, with hump shaped responses to output, prices and wages.

A wage shock

Figure 3.3 shows the response to a permanent shock to the equation governing the wage rate, calibrated such that wages increase by one percent in 2010q4, and letting the full system play out freely after the shock. The impulse responses are based upon using the Taylor rule, Equation (8), in Appendix 2.

A wage-shock will in the model feed into higher inflation. Higher inflation in turn will lead to an instantaneous appreciation of the real exchange rate and via the Taylor rule, higher real interest rates. Higher real interest rates and a stronger real exchange rate will on the other hand contribute to reducing the level of real activity in the economy, as a result of both lower consumption, investment and a drop in net exports. As a result, the rate of unemployment will start to increase. Together with reduced income these effects combined will ignite the financial accelerators of the model where lower credit (both among households as among firms), reduced activity and increased unemployment contribute to mutually reinforce each other. As for both sectors this financial accelerator is boosted by a credit asset price spiral, where falling asset prices and falling credit mutually contribute to a reinforce each other. Gradually, the level of unemployment will have increased so much that the pressure on wages and prices starts to abate. Together with a lingering nominal depreciation and a monetary policy put in reverse, this will in turn lead to a gradual pick-up in activity and employment.

Figure 3.3 – A shock to wages[1]



[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.

As with the decline, this process will be characterized by the financial accelerators ,where asset prices, credit and activity contribute to mutually reinforce each other according to the mechanism described in earlier sections, only that this time the process will be put in reverse.

When activity and inflation have recovered sufficiently, there will be interest rate increases and real exchange appreciations. In other words, a new cycle exactly like the one we have just described will start again, the only difference being that the amplitude this time is smaller. In accordance with Figure 3.3, this process of subsequent cycles will continue until the cycles become so small that they eventually die out (In the figure this does not seem to happen before after the end of the simulation period).

Based on the impulse response of a shock given to the wage mark-up documented in Smets and Wouters (2003) it is difficult to state exactly how big the shock is in percentage terms. We have therefore chosen to waive a direct comparison of the volume effects of a wage mark-up shock between the two models in this case. However, comparing the impulse response trajectories of the two models reveals a much faster real output response in the case of the SMM model compared to the SW model. In fact, while it takes slightly more than 12 periods before the drop in output reaches its maximum in the case of the SW model in the wake of a wage mark-up shock, the drop seems to have run its course already after 8 quarters in the case of the SMM model and the subsequent return to a new equilibrium seems to happen much faster. As was the case with a price shock, though, Figure 3.3 indicates the possibility of a permanent reduction in real activity. However, as distinct from what was the case in the wake of a price shock this seems to be a feature that could be shared with the SW model, despite the fact that this feature in the case of the SMM seems to be driven by a persistent drop in credit, a variable that is all but non-existent in the case of the SW model. Otherwise, we do again see that the impulse response pattern is largely the same as in SW, with hump shaped responses to output, prices and wages.

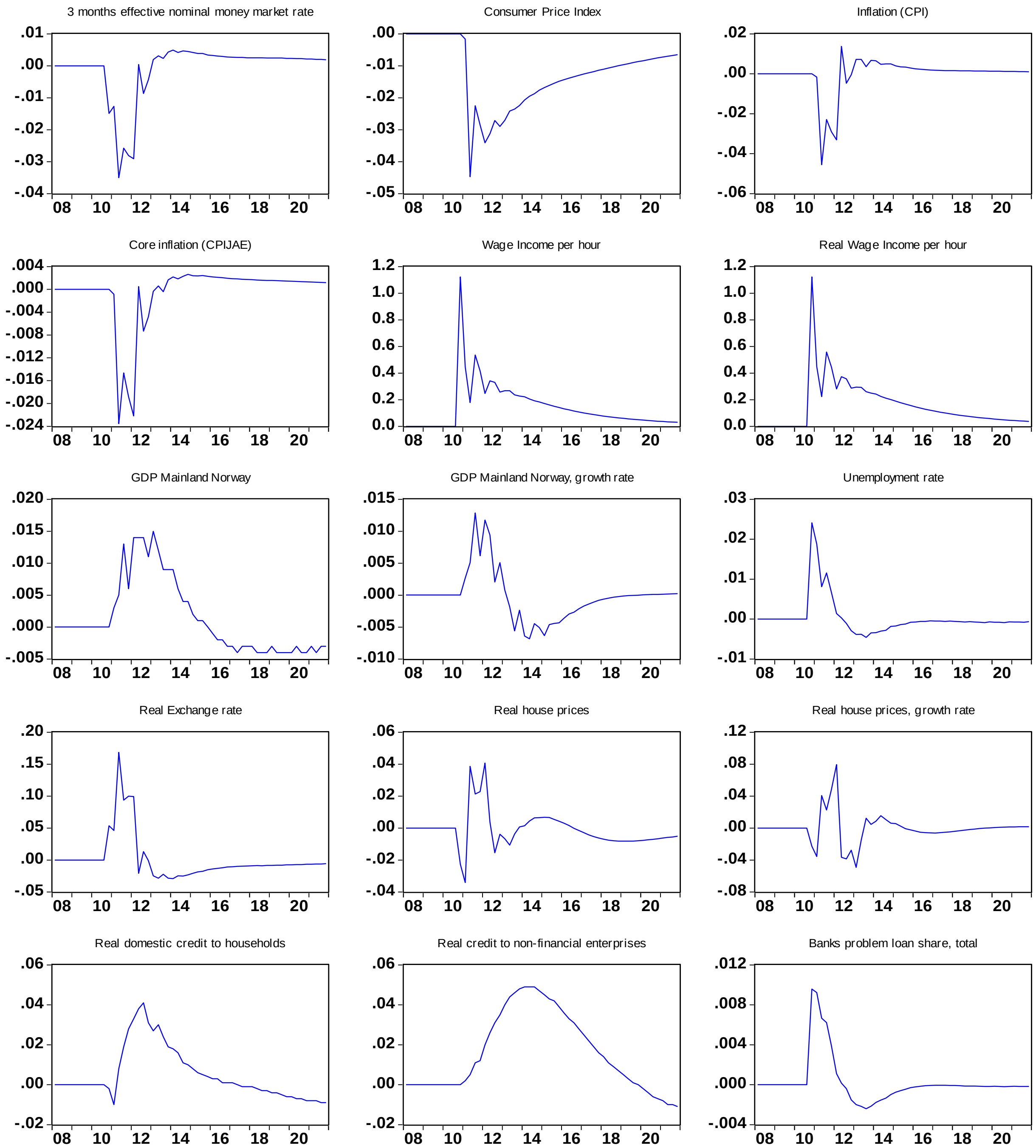
A shock to productivity

Figure 3.4 shows the response to a permanent shock to the equation governing productivity, calibrated such that productivity increases by 1 percent in 2010q4, and letting the full system play out freely after the shock. The impulse responses are based upon using the Taylor rule, Equation (8), in Appendix 2.

Basically, a positive productivity shock will in the model lead to an instantaneous increase in nominal wages and through lowering unit labour costs, bring about a momentary drop in consumer prices and inflation as well. Higher wages and lower consumer prices in turn leads to higher real wages and thus higher unemployment. Together with reduced inflation, this will trigger a change to the monetary policy stance and interest rates will decrease, giving a boost to output both directly via higher investments, reduced saving and increased net exports and indirectly by actuating the financial accelerators of the model. A weaker nominal exchange rate and higher activity combined with a lingering reduction in unemployment, will then contribute to a gradual rise in inflation. Through the pursuit of the Taylor rule, this will in turn lead to a change in the monetary policy stance and a stronger real exchange rate. As a consequence, output growth will abate though the persistent nature of the rate of unemployment contributes to delay the inflation response. Eventually though inflation is pushed towards the trajectory of its base line scenario as unemployment falls back.

Figure 3.4 A shock to productivity[1]

Deviation



[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.

The instantaneous rise in output combined with lower employment is a characteristic trait of the impulse responses following a positive productivity shock in the literature. This applies also to the initial fall in inflation, mainly as a result of a decline in marginal costs. However, due to the strong short-run productivity response of wages in the SMM model the trajectory of the real wages in Figure 3.4 becomes hump-shaped, a characteristic that deviates significantly from the gradual real wage rise following a positive productivity shock in both NEMO and SW.

Shock to consumer confidence

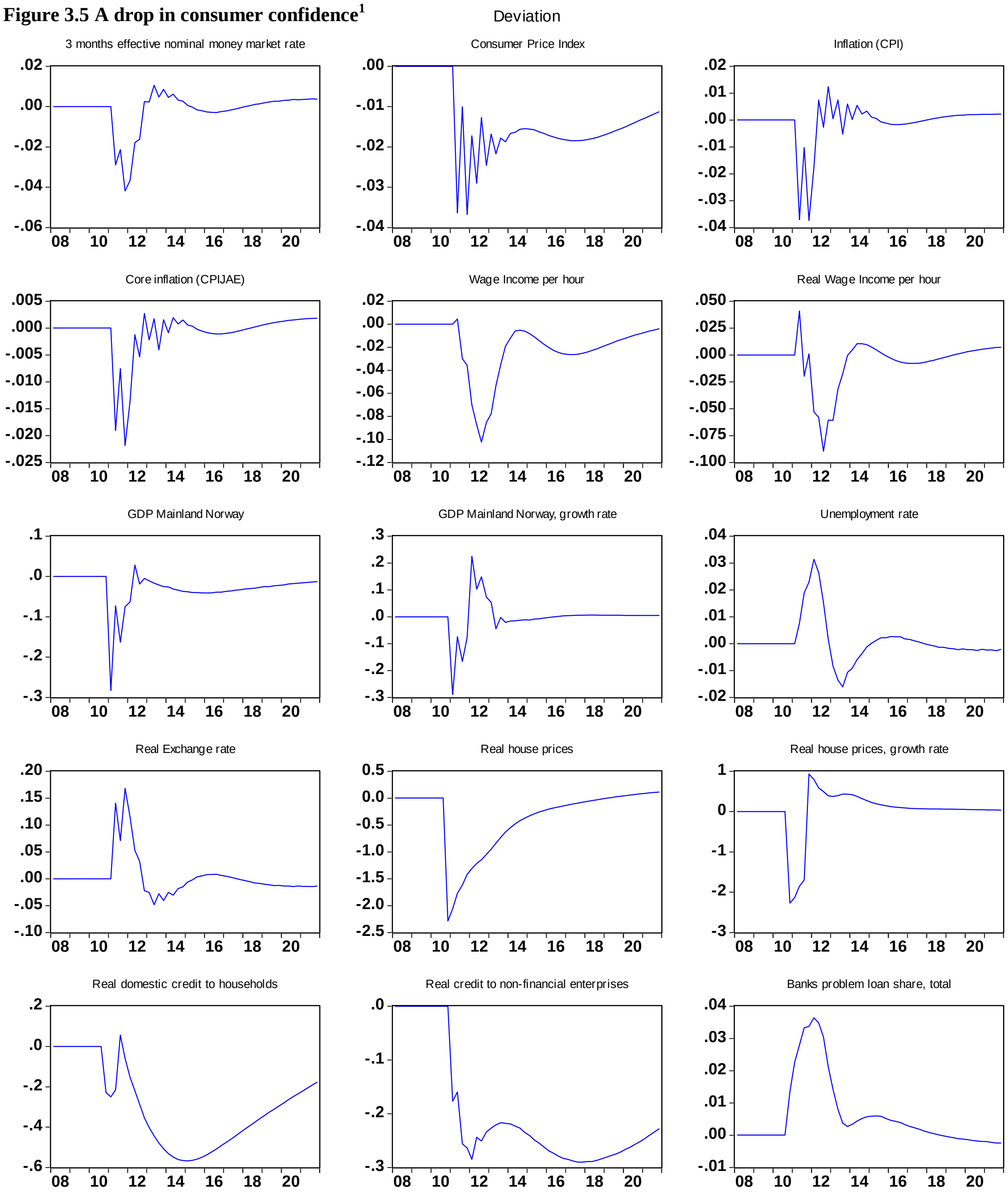
Figure 3.5 shows the response to a drop in consumer confidence[18] in 2010 Q4.

A one period shock to consumer confidence will in the model lead to an instant fall in housing prices. As household domestic credit depends on house prices, and house prices depend on households domestic credit, this will trigger a credit- asset price spiral where lower credit spurs further reductions in housing prices, and so on. As reduced household credit spurs lower real activity and vice versa, this will initiate a process where the drop in output is amplified through a financial accelerator put in reverse. However, this is only a part of the story. The drop in real activity will also precipitate a drop in the amount of credit supplied to firms. Through the working of a financial accelerator mechanism similar in kind to the one just described for the household sector, where lower firm credit growth spurs lower real activity growth and vice versa, this will contribute to further aggravate the real consequences of the shock to consumer confidence. However, lower activity and higher unemployment also mean less wage and price pressure. Through the pursuit of the Taylor like monetary policy rule, this will eventually lead to a lowering of market interest rates and to a weakening of the real exchange rate, both features leading to a gradual pick-up in activity and employment. As with the decline this process will be characterised by the working of credit asset price spiral-enforced financial accelerators, where asset prices, credit and activity contribute to mutually reinforce each other. Eventually, this recovery will be sufficiently strong for the Taylor rule to produce a change in the monetary policy stance and interest rates start to rise. Combined with a strengthening real exchange rate this will contribute to dampen growth and inflation through the same kind of negative feedback mechanisms that amplified the downturn in the first place. When activity and inflation eventually have come down sufficiently for the Taylor rule to produce a new change in the monetary policy stance, time has come for a new turn of interest

[18] We add a shock to the consumer confidence indicator, such that the value of the indicator corresponds to the value in 2008 Q4.

rate decreases and real exchange depreciations. In other words, we have started on a new cycle exactly like the one we have just described, the only difference being that the amplitude this time is smaller. In accordance with Figure 3.5, this process of subsequent cycles will continue until the cycles become so small that they eventually die out.

Figure 3.5 A drop in consumer confidence[1]



[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.

4 Forecast Properties

In this section, the forecast properties of the SMM model are evaluated against simple time series models, autoregressive (AR) and vector autoregressive models (VAR), and an alternative macroeconometric model. As far as the alternative macroeconometric model is concerned it has a lot in common with the model presented in this paper. Its equations are both on error-correction form and several of the mechanisms, such as the supply side being modeled through wages, prices and productivity, are common features shared with the model of this paper. However, an important difference is that the alternative econometric model has not been furnished with a financial block and thus does not include a financial accelerator mechanism. This renders possible a direct identification of the role played by financial accelerators in econometric modeling and forecasting. The evaluation is undertaken by comparing the accurateness of the different models on forecast horizons of respectively, 4, 8 and 12 quarters. Below follows a list of the variables that form the bases of the forecasting exercise together with a closer account of the different models made object to the comparison.

4.1 Variables

The forecast comparisons have been made for the following variables:

1. Inflation (π^c)
2. Wage inflation $(\Delta_4 w)$
3. Growth in GDP mainland Norway $(\Delta_4 y)$
4. The registered rate of unemployment (u)
5. The short-term interest rate (R)
6. Banks' lending rate (RL)
7. The nominal effective exchange rate (v)
8. The real effective exchange rate $(v + p^* - p)$
9. Growth in house prices $(\Delta_4 ph)$

4.2 Models

The following alternative models have been developed:

- AR models for all of the above mentioned variables. All models are assumed to have four lags. The models are estimated from the first available observation and throughout 2007Q4, as several of the equations of the SMM model have been estimated on data to this date.
- A VAR model with 4 lags for the following six variables: π^c, $\Delta_4 y$, u, RL, $\Delta_4 w$ and $(v + p^* - p)$. This model has also been estimated over the period 1990Q4-2007Q4. Due to the number of degrees of freedom we have only included 6 variables in the VAR model.
- An econometric model, called EMod, which also has been estimated on data mainly to 2007Q4. The EMod version used here has previously been included in Norges Bank's system for short-term forecasting.

4.3 Evaluation of forecast properties

We have calculated the Root Mean Square forecast Errors (RMSE) for every forecast round based on prediction errors for each variable over a chosen forecast horizon. Thereafter we have taken the average of the RMSE-values for the individual variable. Finally, these average values based on a given model for each variable, are compared with corresponding average RMSE-values based on the SMM model.

For instance, if inflation is forecasted 4 quarters onwards with forecasts starting every 4th quarter, that is 2001Q1, 2002Q1,…,2009Q1, that will produce 9 RMSE-values. We have therefore taken the average of these 9 RMSE-values. The average values of RMSEs for inflation based on the SMM are subsequently evaluated against the corresponding average RMSE of inflation from each of the alternative models.

The RMSE-values are calculated for three different horizons: 4, 8 and 12 quarters. The forecasts are in addition undertaken with forecasts starting both each quarter and every 4 quarter, in both cases reaching the same kind of conclusions. In the SMM version of this evaluation, an estimated version of the short-term interest rate equation in Appendix 4 is employed.

4.4 Results

Detailed results of the forecast comparisons are presented in respectively, Table 1 for the forecasts starting each quarter, and Table 2 for the forecasts starting every 4th quarter. The figures in the respective cells show variable-specific RMSE-values for SMM compared to corresponding values for an indicated model. Numerical values larger than 1 indicate higher RMSE-values and thus poorer accurateness for SMM. Missing values due to non-comparable variables or missing variables in the VAR or EMod model are indicated by a "-". The forecasts are worked out for 4, 8 and 12 quarters over the period 2001Q1 to 2009Q4 and the start period has been advanced, respectively, one and 4 quarters.[19]

One can draw the following conclusions based on the forecast comparisons of these tables:

- The accuracy of SMM is better than AR and VAR for forecasting wage inflation and GDP growth on all horizons.
- However, for forecasting core inflation, the rate of unemployment, the lending rate and the real exchange rate, the VAR model is the best on all horizons.
- For forecasting core inflation, GDP growth, the rate of unemployment, short-term interest rates and the nominal exchange rate, the SMM model is better than the corresponding forecasts of the EMod model on all but the 4 quarter horizon, where the core inflation forecast of the EMod model does a slightly better job than the SMM model. However, for wage inflation the EMod model makes it clearly better than the SMM model.
- The relative advantage of the SMM model seems to increase with the forecast horizon.

[19] Noteworthy, only part of these forecasts can be characterized as true “out-of-sample” forecasts, as all the models have used data up to and including 2007Q4 in their design. The forecasts made for the period after 2007Q4 though could be classified as close to true “out-of-sample” forecasts.

Table 1: SMM's forecast properties when forecasts are made each quarter. Relative RMSE.

Horizon	4q			8q			12q		
Model	AR	VAR	EMod	AR	VAR	EMod	AR	VAR	EMod
π^c	1.19	1.77	1.20	1.00	1.77	**0.69**	**0.95**	1.81	**0.58**
$\Delta_4 w$	**0.78**	**0.99**	2.25	**0.78**	**0.89**	1.68	**0.78**	**0.86**	1.58
$\Delta_4 y$	**0.58**	**0.67**	**0.84**	**0.56**	**0.63**	**0.79**	**0.59**	**0.64**	**0.75**
u	**0.66**	1.50	**0.92**	**0.66**	1.53	**0.76**	**0.63**	1.62	**0.76**
R	**0.76**	-	**0.86**	**0.73**	-	**0.74**	**0.66**	-	**0.51**
RL	**0.97**	1.10	–	**0.89**	1.13	–	**0.80**	1.09	-
v	**0.94**	-	**0.39**	1.14	-	**0.48**	1.12	-	**0.46**
$v+p^*-p$	**0.98**	1.36	-	1.24	1.72	-	1.20	1.80	-
$\Delta_4 ph$	**0.70**	-	-	**0.75**	-	-	**0.82**	-	-
Success ratio	8/9	2/6	4/6	6/9	2/6	5/6	7/9	2/6	5/6

Table 2: SMM's forecast properties when forecasts are made every 4 quarter. Relative RMSE.

Horizon	4q			8q			12q		
Model	AR	VAR	EMod	AR	VAR	EMod	AR	VAR	EMod
π^c	1.16	1.75	1.07	**0.90**	1.61	**0.63**	**0.97**	1.96	**0.56**
$\Delta_4 w$	**0.76**	**0.99**	1.96	**0.81**	**0.92**	1.76	**0.79**	**0.88**	1.58
$\Delta_4 y$	**0.57**	**0.69**	**0.89**	**0.58**	**0.65**	**0.83**	**0.62**	**0.68**	**0.75**
u	**0.51**	1.09	**0.92**	**0.59**	1.39	**0.71**	**0.60**	1.76	**0.76**
R	**0.77**	-	**0.87**	**0.74**	-	**0.79**	**0.61**	-	**0.51**
RL	**0.92**	1.07	-	**0.84**	1.22	-	**0.72**	1.08	-
v	**0.90**	-	**0.41**	1.05	-	**0.47**	1.05	-	**0.46**
$v+p^*-p$	**0.95**	1.38	-	1.11	1.62	-	1.08	1.60	-
$\Delta_4 ph$	**0.80**	-	-	**0.79**	-	-	**0.91**	-	-
Success ratio	8/9	2/6	4/6	7/9	2/6	5/6	7/9	2/6	5/6

5 Conclusions

In this paper, we have studied a small macroeconomic model that allows for self-reinforcing co-movements between credit, asset prices and real economic activity, often denominated a financial accelerator in the literature. The model considered in this paper has tried to integrate a financial accelerator mechanism in a full-fledged macroeconomic model framework. New in this context, is the fact that the model presented in this paper contains no less than two interdependent financial accelerator mechanisms; i) one with a firm side origin where asset prices affect borrowing capacity and hence real activity through an increase in real investments, and ii) another based on a similar procyclical feedback mechanism between household credit, house prices and housing investment.

Noteworthy, the impulse response patterns overall are very much in line with the ones based on a typical SVAR/DSGE model, though the amplitude of shocks are in most cases stronger than in the latter models. This is mainly due to the working of the financial accelerators that contribute to magnify the effects of shocks to the economy. Taken at face value this suggests that the absence of an explicit financial accelerator can lead to underestimation of effects of shocks in a macroeconomic model.

As regards the forecast properties of the model, the model clearly outperforms simple univariate autoregressive time series models. It also outperforms an alternative econometric model designed on Norwegian data without a financial block. As far as the last finding is concerned this suggests that the incorporation of financial accelerators can improve forecasting properties of a macroeconomic model. For some variables, though, a multivariate data driven VAR seems to be preferable to our model when it comes to forecasting. However, the relative advantage of the SMM model seems to increase with the forecast horizon.

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Appendix 1 – Variable descriptions and data sources

cr_t^e	Credit to non-financial enterprises, mainland Norway. Source: Statistics Norway
p_t	Consumer Price Index (CPI). Source: Statistics Norway
p_t^c	Consumer Price Index Adjusted for Taxes and Energy Prices (CPI-ATE). Sources: Statistics Norway and Norges Bank
v_t	Nominal Exchange Rate, import-weighted 44 countries (I-44). Sources: Statistics Norway and Norges Bank
p_t*	Consumer Price Index Trading Partners (25 countries). Sources: Statistics Norway and Norges Bank
pi_t	Imports, deflator
H^e	Household expectations (Norsk Trendindikator). Source: TNS Gallup
cr_t^h	Domestic credit to households (C2). Source: Statistics Norway
π_t	CPI inflation. $\pi = 100\frac{\Delta_4 P_t}{P_{t-4}}$
π_t^c	Core inflation (CPI-ATE)
π_t^*	CPI inflation trading partners
g_t	Public consumption. Source: Statistics Norway
z_t	Productivity. GDP divided by hours worked. Source: Statistics Norway
pe_t	CPI Electricity Component. Source: Statistics Norway
μ_{RLM}	Long-run lending margins at banks (calibrated)
ph_t	House prices. Thousand NOK per square meter. Sources: NEF, NFF, Finn.no, Econ Pöyry
inc_t	Wage income households. Source: Statistics Norway
hs_t	Value of households housing stock. Source: Statistics Norway
j_t	Gross investment housing. Source: Statistics Norway
pj_t	Deflator housing investment. Source: Statistics Norway
pa_t	Price shares Oslo Stock Exchange (OSEAX). Source: Ecowin and Statistics Norway
d_t^h	Banks' problem loans, households. Sources: Statistics Norway and Norges Bank
d_t^e	Banks' problem loans, non-financial enterprises. Sources: Statistics Norway and Norges Bank

usd_t	Nominal spot exchange rate NOK/USD. Source: Norges Bank
RL_t	Average spot interest rate on bank loans (total). Sources: Statistics Norway and Norges Bank
R_t	3 months effective nominal money market rate. (NIBOR). Source: Norges Bank
R_t^*	3 months effective nominal money market rate, euro area. (EURIBOR). Source: Norges Bank
po_t	Oil prices Brent Blend USD per barrell. Source: Norges Bank
u_t	Registered unemployment rate. Number of unemployed people registered at NAV. Source: Statistics Norway
pi_t^*	Producer Price Index, Norway's 25 largest Trading Partners. Source: Norges Bank
w_t	Wage Income per hour Mainland Norway. Source: Statistics Norway
y_t	Gross domestic product Mainland Norway. Measured in million NOK at fixed market value prices. Source: Statistics Norway
φ	Dummy for inflation targeting. Equals one starting from 2001Q2
μ_i	The mean of the steady-state relationship for equation i

Appendix 2 – The main equations of SMM

Variables in small letters denote the natural logarithm of the variable. Δ_j denotes the *j*-period difference operator, and foreign variables are denoted with starred superscripts. Standard errors are reported in brackets. The estimation method, which is either ordinary least squares (OLS), or full information maximum likelihood (FIML) is indicated below each equation, along with the sample size ,T. Intercept terms, dummies and seasonal dummies are omitted due to space considerations. Identities are not reported.

Real economy block

Aggregate demand

$$\begin{aligned}\Delta y_t = &\underset{(0.05)}{-0.2}[(y_{t-2} - 0.8g_{t-2} - 0.1(v+p^* - p)_{t-1} - 0.1(cr^h - p)_{t-4} + 0.01(RL-\pi)_{t-1}] \\ &\underset{(0.1)}{-0.6}\Delta y_{t-1} + \underset{(0.06)}{0.7}\Delta g_t + \underset{(0.1)}{0.4}\Delta g_{t-1} + \underset{(0.04)}{0.1}\Delta(ph-p)_{t-1} + \underset{(0.04)}{0.1}\Delta(cr^e - p)_{t-1} + \underset{(0.08)}{0.2}\Delta(cr^h - p)_{t-3}\end{aligned} \tag{1}$$

Estimated by OLS, T=64. Estimation period 1991Q1-2006Q4

Exchange rate

$$\begin{aligned}\Delta v_t = &\underset{(0.04)}{-0.1}[(v+p^* - p)_{t-1} + 0.03((R-\pi)_{t-1} - (R^* - \pi^*)_{t-1}) + 0.1(po + usd - p)_{t-1} - \mu_v] \\ &+\varphi(\underset{(0.01)}{-0.04}\Delta R_t + \underset{(0.01)}{0.05}\Delta R^*{}_t - \underset{(0.02)}{0.1}\Delta po_t)\end{aligned} \tag{2}$$

Estimated by OLS, T=63. Estimation period 1994Q2-2009Q4

Import prices

$$\begin{aligned}\Delta pi_t = &\underset{(0.1)}{-0.4}[(pi - pi^* - v)_{t-1} - 0.6(p - p^* - v)_{t-1}] \\ &+\underset{(0.08)}{0.4}\Delta v_t + \underset{(0.2)}{0.8}\Delta pi^*{}_t\end{aligned} \tag{3}$$

Estimated by OLS, T=70. Estimation period 1990Q1-2007Q2

Unemployment

$$\begin{aligned}\Delta u_t = &\underset{(0.01)}{-0.03}[u_{t-2} - 11.1\Delta(w-p)_t - \mu_u] \\ &+ \underset{(0.08)}{0.4}\Delta u_{t-1} \underset{(0.33)}{-1.5}(\Delta_4 \frac{1}{2}\sum_{j=1}^{2} y_{t-j} - mean(\Delta_4 \frac{1}{2}\sum_{j=1}^{2} y_{t-j})\end{aligned} \tag{4}$$

Estimated by OLS, T=119. Estimation period 1979Q3-2009Q1

Wages, prices and productivity

Wages

$$\Delta w_t = \underset{(0.05)}{-0.4}[w_{t-2} - p_{t-1} - z_{t-2} + 0.1u_{t-1} - \mu_w]$$
$$\underset{(0.09)}{-0.8}\Delta(w_{t-1} - z_{t-1}) + \Delta z_t \qquad (5)$$

Consumer prices

$$\Delta p_t = \underset{(0.01)}{-0.05}[p_{t-3} - 0.7(w_{t-3} - z_{t-2}) - 0.3pi_{t-1} - \mu_p]$$
$$+ \underset{(0.06)}{0.3}\Delta p_{t-2} + \underset{(0.04)}{0.1}\Delta y_{t-1} + \underset{(0.04)}{0.1}\Delta_2(w_t - z_t) + \underset{(0.009)}{0.1}\Delta pe_t \qquad (6)$$

Productivity

$$\Delta z_t = \underset{(0.08)}{-0.5}\Delta_2 z_{t-1} - \underset{(0.1)}{0.15}[z_{t-3} - 0.52(w_{t-3} - p_{t-3}) - 0.0004u_{t-2} - 0.0025T - \mu_z]$$
$$\underset{(0.07)}{+0.12}\ \ \Delta w_t - \Delta p_t \qquad (7)$$

Estimated by FIML, T=117. Estimation period 1978Q4-2007Q4

Financial sector block

Money market interest-rate[21]

$$R_t = \underset{(0.2)}{1.3}(\pi_t^c - 2.5) - \underset{(0.3)}{0.7}(u_t - 3) + 5.5 \qquad (8)$$

Estimated by OLS, T=43. Estimation period 1999Q1-2009Q1

Banks' lending rate

$$\Delta RL_t = 0.8\Delta R_t + 0.2\Delta R_{t-1} - 0.35[\ RL_{t-1} - R_{t-1}\ \ - \mu_{RLM}] \qquad (9)$$

Calibrated

[20] In the forecasting version of this equation, 8 b) the terms for foreign money market interest rates and interest rate differentials are included.

Household debt

$$\Delta(cr^h - p_t) = \underset{(0.01)}{-0.06}[(cr^h - p)_{t-1} - 0.9(ph-p)_{t-4} + 0.03RL_{t-4} - 0.4(inc-p)_{t-2}]$$
$$\underset{(0.001)}{-0.006}\Delta_2 RL_{t-2} + \underset{(0.05)}{0.2}\Delta_2(inc-p) + \underset{(0.02)}{0.1}(\Delta(ph-p)_t - \Delta(ph-p)_{t-3}) \tag{10}$$

Estimated by OLS, T=73. Estimation period 1991Q1-2009Q1

House prices

$$\Delta ph_t = \underset{(0.03)}{-0.1}[ph_{t-1} + 0.07RL_{t-1} + 0.4u_t - 1.1(inc-hs)_{t-1} - 0.2cr^h_{t-1}]$$
$$\underset{(0.2)}{+0.1}\Delta inc_t \underset{(0.006)}{-0.02}\Delta RL_t \underset{(0.005)}{-0.01}\Delta RL_{t-1} + \underset{(0.02)}{0.07}H^e_t \tag{11}$$

Estimated by OLS, T=75. Estimation period 1990Q2-2009Q1

Housing investments

$$\Delta j_t = \underset{(0.08)}{-0.2}[(j_{t-1} - hs_{t-10}) - (ph-p)_{t-4} - (inc-p)_{t-1} + (pj-p)_{t-4}]$$
$$\underset{(0.006)}{-0.01}\Delta(RL-\pi\ )_t \underset{(0.005)}{-0.02}(RL-\pi\ )_{t-4} \tag{12}$$

Estimated by OLS, T=73. Estimation period 1991Q1-2009Q1

Non-financial enterprise debt and asset prices

Non-financial enterprise debt

$$\Delta(cr^e - p) = \underset{(0.08)}{0.38}(y - 0.007Trend)_{t-1} \underset{(0.01)}{-0.04}[(cr^e - p) - pa]_{t-1}$$
$$\underset{(0.17)}{+0.58}\Delta y_t + \underset{(0.035)}{0.075}\Delta pa_t \underset{(0.02)}{-0.047}\Delta po_t \underset{(0.09)}{-0.15}\Delta(cr^e - p)_{t-1} \tag{13}$$

Asset prices

$$\Delta pa_t = \underset{(0.04)}{-0.2}(pa - 0.25po - 0.01Trend)_{t-1} + \underset{(0.09)}{0.46}\Delta pa_{t-1}$$
$$\underset{(0.33)}{+}\Delta(cr^e - p)_t + \underset{(0.26)}{0.44}\Delta(cr^e - p)_{t-1} + \underset{(0.06)}{0.16}\Delta po_t + \underset{(0.21)}{0.75}\Delta y_{t-1} \tag{14}$$

Estimated by FIML[22], T=82. Estimation period 1986Q2-2006Q3

[21] With GDP mainland Norway as an endogenous variable in the estimation, see Hammersland and Jacobsen (2008) for details.

Household default rate

$$\Delta(d^h - cr^h) = \underset{(0.1)}{-0.3}[(d^h - cr^h)_{t-4} - 0.3u_{t-3} - 0.08(RL-\pi)_{t-4} - 1.6(inc-p)_{t-1} + 2.45(ph-p)_{t-4}]$$
$$\underset{(0.1)}{-0.2}\Delta_3(d^h - cr^h)_{t-1} \underset{(0.005)}{+0.02}\Delta_2(RL-\pi)_t \underset{(0.005)}{+0.01}\Delta_2(RL-\pi)_{t-2} \underset{(0.2)}{-0.9}\Delta_4(ph-p) \qquad (15)$$

Estimated by OLS, T=65. Estimation period 1993Q1-2009Q1

Firm default

$$\Delta(d^e - p)_t = \underset{(0.1)}{-0.4}[(d^e - p)_{t-3} - (cr^e - p)_{t-4} - 0.05(RL-\pi)_{t-3}$$
$$-1.7u_{t-2} + 0.7(v + p^* - p)_{t-3} + 0.5(po + usd - p)_t]$$
$$\underset{(0.09)}{-0.2}\Delta_2(d^e - p)_{t-1} \underset{(0.01)}{+0.03}\Delta_2(RL-\pi)_t \underset{(0.2)}{+1.1}\Delta u_t \underset{(0.2)}{+0.7}\Delta u_{t-1} \underset{(0.3)}{+1.6}\Delta(cr^e - p)_{t-3} \qquad (16)$$
$$\underset{(0.1)}{-0.4}\Delta(po + usd - p)_t$$

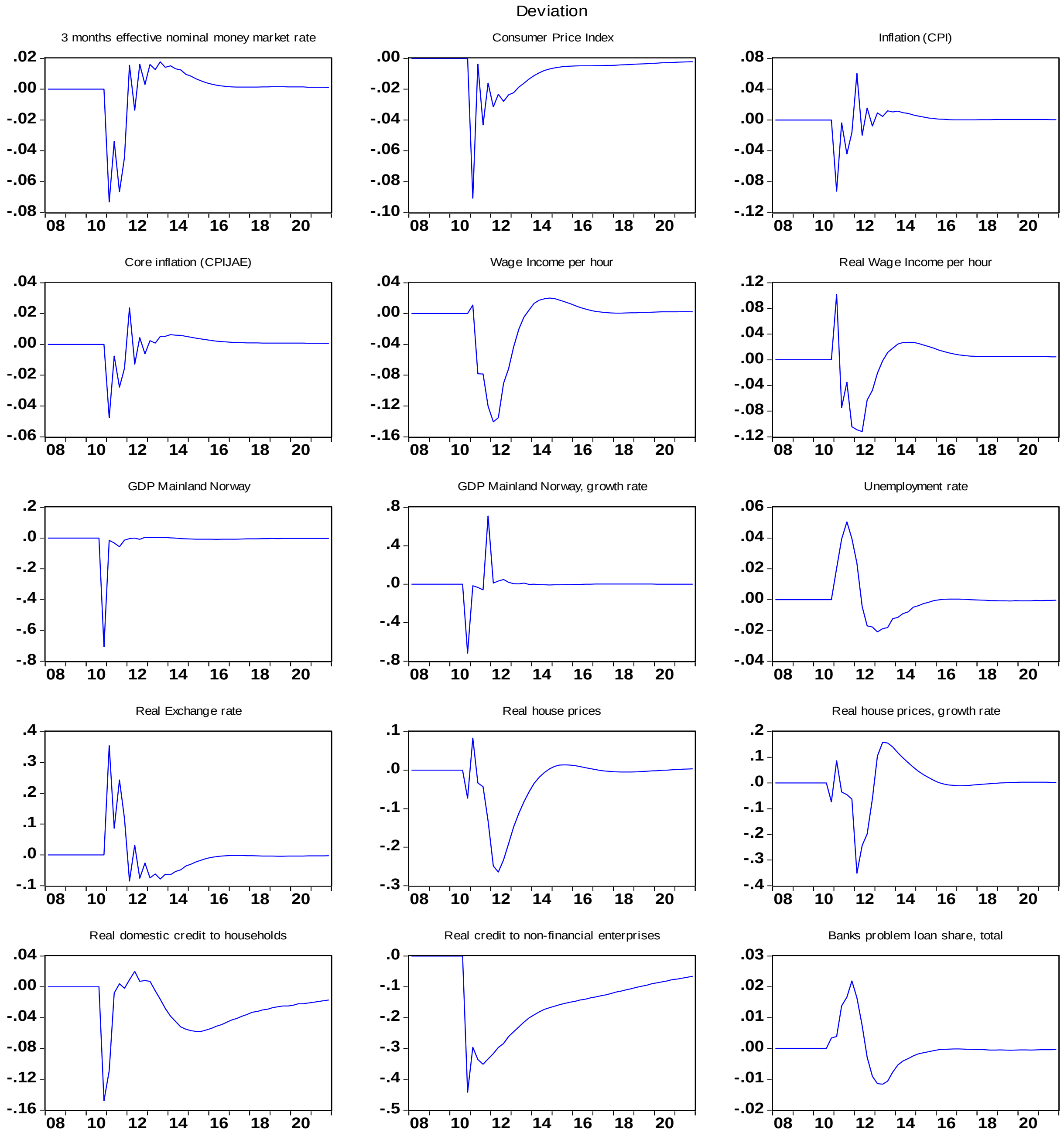
Estimated by OLS, T=65. Estimation period 1992Q1-2009Q1

Appendix 3 – Some additional impulse responses

A shock to government expenditure

Figure A3.1 shows the response to a permanent shock to government expenditure of 1 percent in 2010 Q4, and letting the full system play out freely after the shock. The impulse responses are based upon using the monetary policy reaction function of Equation (8) in Appendix 2.

Figure A3.1 A negative shock to government expenditure[1]



[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.

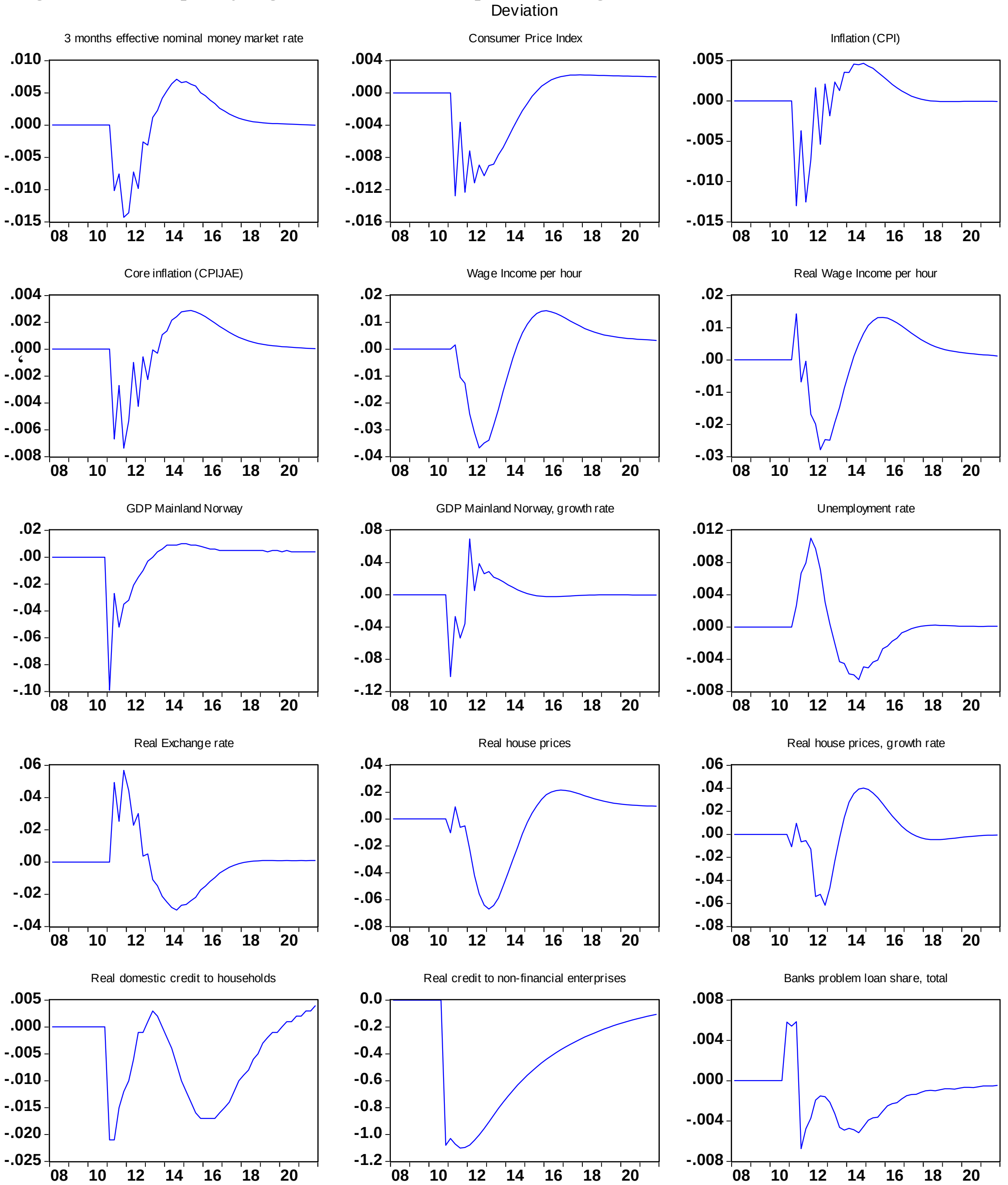
Basically, a negative shock to government expenditures will lead to an instantaneous fall in production and higher unemployment, as well as to a decline in wages and prices, though the real wage initially will increase due to the sticky nature of nominal wages. As a consequence, aggregate real income in the economy will tend to fall. Combined with higher unemployment this will lead to lower asset prices and credit and thus clear the way for further drops in activity through the working of the model's financial accelerators. However, in the model the combination of lower inflation and activity leads quickly to lower real market interest rates and a weakening of the krone real exchange rate, the first of these effects being mainly due to the fact that money market interest rates in the model follow a Taylor rule. As a consequence, growth goes relatively fast from being negative to positive and unemployment starts eventually to decrease. The drop in unemployment results quickly in enhanced wage and price inflation, and aggregate real income starts to increase. Combined with lower interest rates this leads to an increase in credit and asset price growth. However, again the financial accelerator is attenuated by the policy response that follows in the wake of the business cycle turnaround as both higher interest rates and a stronger real exchange rate contribute to rein in growth in activity, and credit and asset price growth starts to abate again. However, the decrease in the rate of unemployment continues to linger on for a while after the turnaround, mainly as a consequence of growth being too strong to spur a fast change to the worse in the labour market. Eventually, however, lower activity and inflation will trigger a new period of lower interest rates and the economy starts on a new cycle similar to the one we have just accounted for, this time though with an amplitude that dies out quickly.

Temporary shock to real credit growth for enterprises

Figure A3.2 demonstrates the effects of a permanent negative shock to the equation governing credit, calibrated such that it reduces credit by 1 percent in 2010 Q4, and letting the full system play out freely after the shock.

A negative shock to enterprise credit growth will put the corporate financial accelerator in reverse, and initiate a self-reinforcing negative process of procyclical interaction between activity, corporate credit and asset prices. As output starts to decline, income will eventually yield and thus contribute to aggravate the situation by setting in motion also the household part of the financial accelerator. Lower activity will eventually lead to higher unemployment and thus to lower wage and price inflation due to a weakening of the labour market pressure.

Figure A3.2 A temporary negative shock to real corporate credit growth[1]



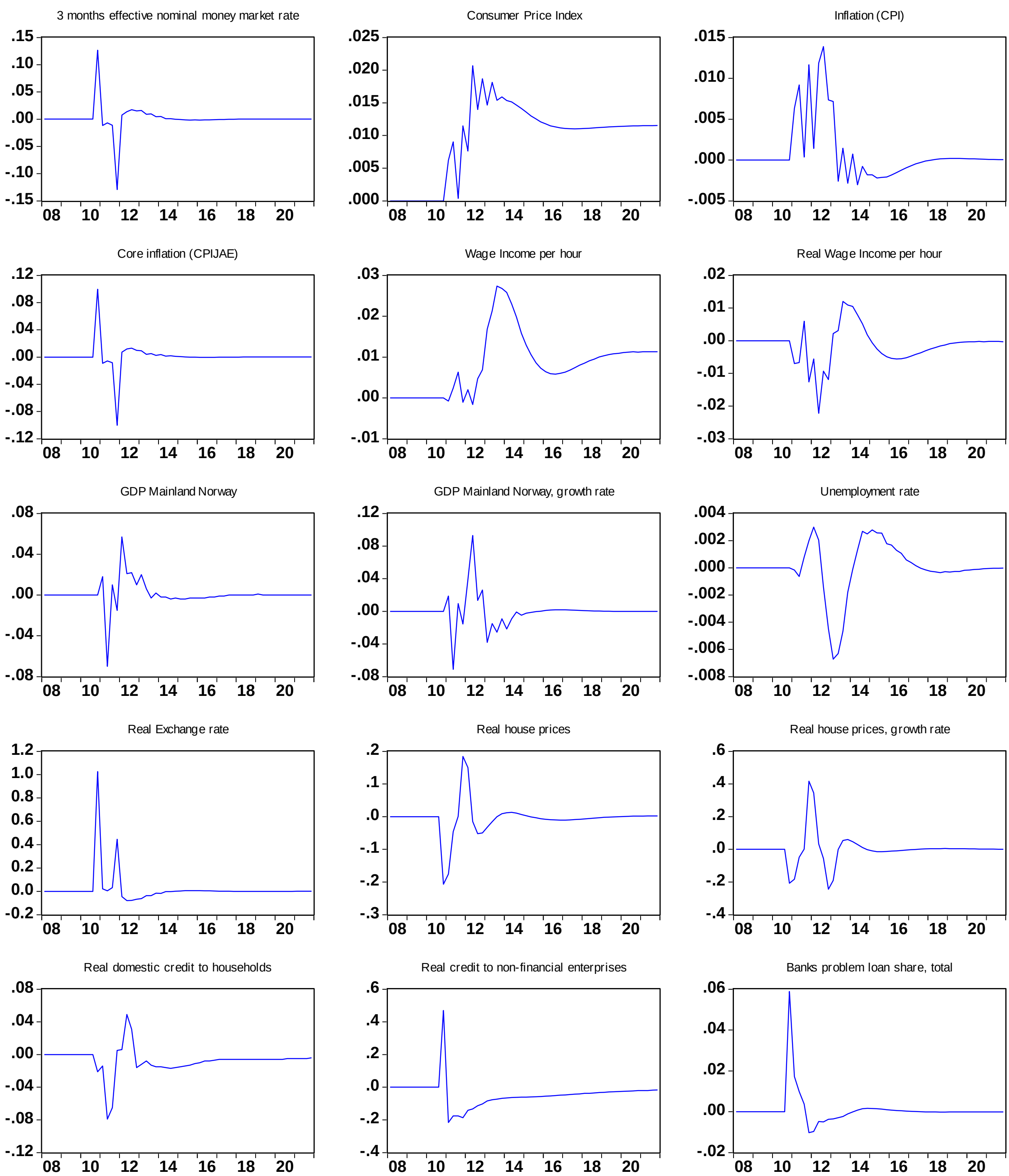
[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.

The combination of lower prices and output in turn leads to a change in the monetary policy stance and a period of declining money market and bank lending interest rates will follow. Lower interest rates will give a direct and indirect push to output through lower saving, higher investment and a rise in net trade, the last as a consequence of the real exchange rate depreciation that comes as a result of the interest rate cut in the first place. Furthermore, this process of rebound will be reinforced by the presence of the financial accelerators as the combination of lower interest rates and higher output will contribute to spur credit of both households and firms. Higher output in turn will add to the pressure in the labour market and lead to a rebound in wage and price inflation. Eventually this will also spur a reversion of the former monetary policy stance and interest rates (both money market rates and bank lending rates) start to increase. This will initiate a new cycle of financial accelerator amplified contraction and rebound (amplified by the financial accelerator) and so it continues until the cycles eventually dies out in the course of time.

Oil price shock

Figure A3.3 shows the response to a drop in the oil price of $10 in 2010 Q4. A negative shock to oil prices will in the model instantly lead to a depreciation of the nominal and real krone exchange rate. There will also be a temporary increase in cooperate credit due to reduced costs. The depreciation will in turn instantly feed into higher consumer price inflation, and together with the tentative pick up in credit, this will lead to an almost negligible and short-lived pick-up in real activity. Due to the Taylor rule this will lead to an instant hike in the money market interest rates. The change in the monetary policy stance, in turn, will create a drag on activity both through a direct saving effect and through a negative investment effect. At the same time, the working of a financial accelerator will be present, where a negative spiral of declining house prices and household credit interact with an increasingly weaker real economy through a mutually reinforcing relationship between housing prices, credit and activity. However, this is only a part of the story as the drop in activity coupled with lower asset prices, also will take its toll on corporate credit growth. As corporate credit affects activity and vice versa this will constitute a financial accelerator mechanism that will further contribute to aggravate the downturn. When price inflation eventually comes down this will then trigger a new change in the monetary policy stance and interest rates will start to decline. By discouraging saving behavior and stimulating investment, exports (through a real exchange rate depreciation) and credit expansion (both household and corporate credit) this will lead to a rise in real activity that is spurred by the same type of financial accelerator mechanisms that contributed to the preceding economic downturn in the first place. Higher real activity and lower unemployment combined with a weaker krone exchange rate will eventually lead to higher wage and price inflation. Through the pursuit of a Taylor policy rule this will then trigger a new hike in interest rates and we have started on a new cycle of output and inflation changes and subsequent policy responses. As with the other impulse responses the amplitude of the cycles abates in the course of time.

Figure A3.3 A temporary drop in the oil price[1]



[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.

Appendix 4 – A shock to interest rates, alternative monetary policy rule

The monetary policy rule is, as one would expect, of great importance for the amplitude and dynamics of the model's impulse responses to shocks. Often it is assumed a more sluggish adjustment of the monetary policy rate, by including a lagged term for the interest rate. The Taylor rule is simple compared to the actual information set central banks consider. Furthermore, data is often available with a lag, and can be subject to revisions. It can also be argued that by changing policy rates gradually, interest rate smoothing can ease the communication of policy to financial markets (see for example Goodfriend(1991)). Moreover, for example Goodhart (1999) argues that policymakers would move interest rates more slowly in order to avoid the need for frequent policy reversals.

In the following, we look at the impulse responses based upon a Taylor rule augmented with a partial adjustment process for the key policy rate[22]:

$$\Delta R_t = -0.25(R_{t-1} - 1.5(\pi_t^c - 2.5) + 0.7(u_t - 3) - 5.5) + 0.3\Delta_2 R_t^* + 0.1\Delta\ R_{t-1}$$

We also include foreign interest rates in this rule. This term can be thought of as a proxy for exchange rate effects. When foreign interest rates are included, we can also take contagion effects from increased money market risk premiums abroad into account.

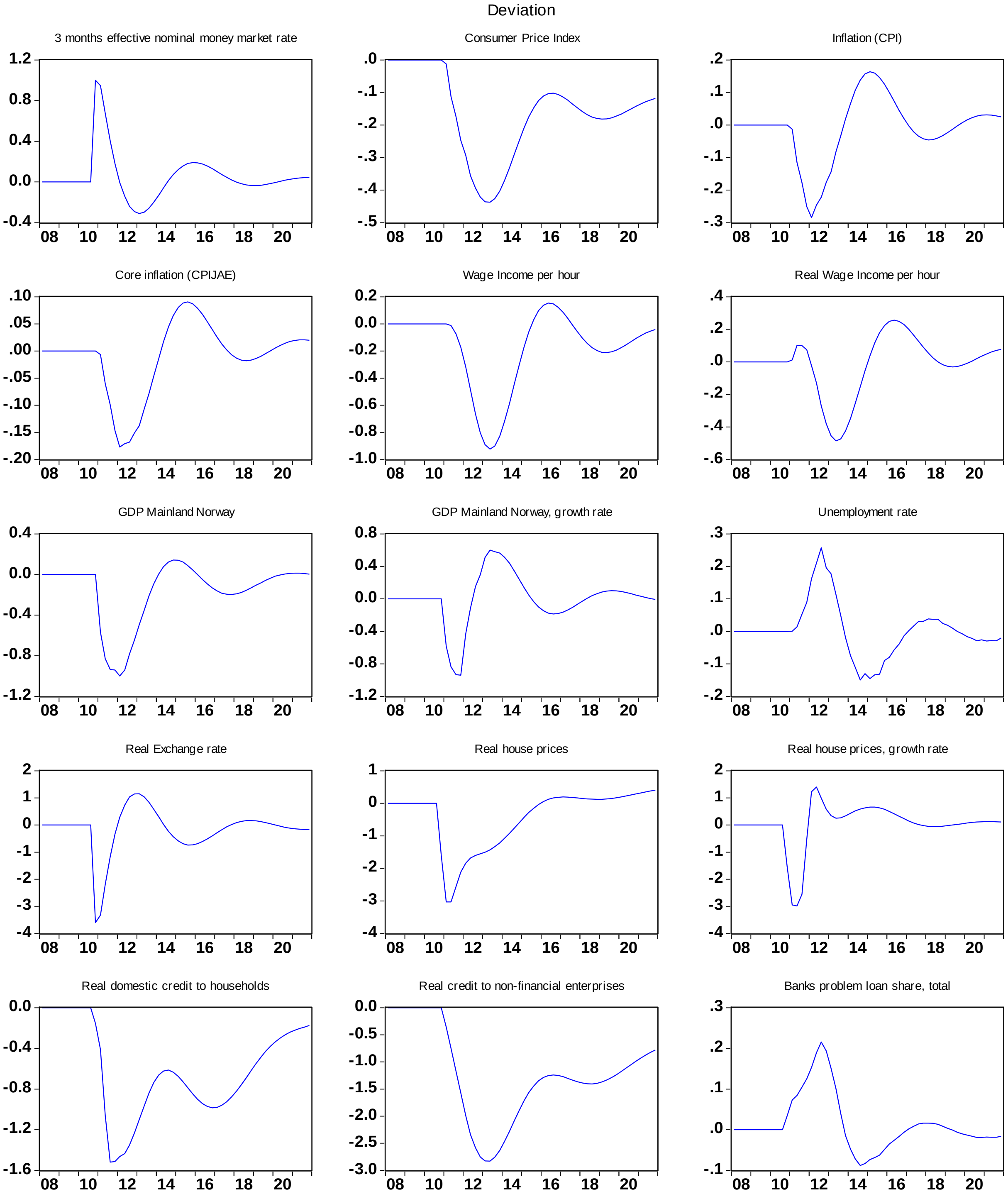
Figure A4.1 shows the impulse responses of a permanent shock to the equation governing the money market interest rate, calibrated such that the money market interest rate increases by 1 percentage point in 2010q4, and letting the full system play out freely after the shock. As was the case when using the Taylor rule, the interest rate increase is again channelled to the real economy through an increase in the bank lending rate, as well as through a currency appreciation, both channels leading to a contraction in real output and employment. As a consequence, consumer price inflation and wage inflation are also this time reduced and credit demand and house price growth fall. In the quarters following the shock, the interest rate gradually falls back to its previous level, and at the same time the exchange rate depreciates. GDP growth strengthens, with inflation and credit growth also picking up again. As was the case using the policy rule of Equation (8), the effect diminishes in the course of the 20

[22] We have calibrated the smoothing coefficient and the remainder of the long-term relationship in brackets. The short-run effects are estimated over the time period 1999Q1 to 2007Q4. The chosen smoothing coefficient in levels is broadly in line with the results of Bernhardsen and Bårdsen (2004) for Norway. The coefficient is also in line with what eg. Kuttner (2004) finds for Sweden, US, UK and New Zealand (0.75-0.95).

quarters covered by the graph, indicating that the system is stable (For a more comprehensive account of the transmission mechanism, see the previous section).

However, in contrast to the impulse responses of a monetary policy shock in a typical DSGE model, real effects of the shock are this time both strongly amplified. As we have commented on earlier, a 1 percentage point increase in the sight deposit rate is in SW estimated to reduce output by approximately 0.4 per cent after approximately 4 quarters. Furthermore, a similar experiment using NEMO, leads to a less pronounced fall in real activity of 0.25 per cent over a slightly shorter time span. Noteworthy, and which should be evident by looking at Figure A4.1, a similar experiment using a version of the SMM model were the Taylor rule has been replaced by an augmented policy rule with interest smoothing, leads to a considerably stronger drop in activity of almost 1 per cent. As was the case with a Taylor rule, the policy response contributes to reverse the drop in output, though output this time is not back on trend before after about 4 year’s time. Unemployment also shows a relatively protracted increase as the effect does not reach its maximum of about 0.3 percentage points − corresponding to an increase of close to 10 per cent − before after about 6-8 quarters. Also, as regards real wages these are in SW simulated to be reduced by approximately 0.25 after about 8 periods, while the SMM model predicts a larger fall of about 0.5 per cent over a somewhat longer time span (about 10 quarters). Interestingly, as was the case using the Taylor rule, real wages in the SMM model initially rises in the wake of a monetary policy shock. This is due to nominal wages being less flexible than prices in the short run. Overall, though, the pattern is largely the same as in both SW and NEMO, with hump shaped responses to output, prices and wages.

Figure A4.1 – A rise in the money market interest rate, augmented Taylor rule[1]



[1] Quarterly data, the numbers on the time axis refer to observations from 2008Q1 onwards. Most impulse responses for the variables in levels are displayed as deviations from the baseline in percent. Interest rates, the rate of unemployment and the problem loan share are displayed as deviations in percentage points from the baseline scenario. Moreover, growth rate responses are all displayed as deviations in percentage points from the baseline scenario.