

The Financial Accelerator: Evidence using a procedure of Simultaneous Structural Model Design

Roger Hammersland and Dag Henning Jacobsen *[†]

Institute for New Economic Thinking at the Oxford Martin School,
Statistics Norway and Norges Bank

April 8, 2014

Abstract

We find empirical evidence of a financial accelerator using a new data based procedure of Simultaneous Structural Model Design. Credit to firms, asset prices and aggregate economic activity interact over the business cycle in our empirical model of a dynamic economy. Furthermore, the interdependence between credit and asset prices creates a mechanism by which the effects of shocks persist and amplify. However, while innovations to asset prices and credit do cause short run movements in production and vice versa, such innovations do not precede real economy movements in the long run. Hence, there could still be a case for the Modigliani-Miller theorem in the long run.

Keywords: Financial variables and the real economy, The Financial Accelerator, Business fluctuations, Structural vector Error Correction modeling, Identification, Cointegration.

JEL Codes: C30, C32, C50, C51, C53, E44, E51

*We are indebted to many colleagues and seminar participants. In particular we would like to thank David Hendry, Kevin D. Hoover, Grayham Mizon, Neil Ericsson, Asbjørn Rødseth and several participants at the 25th annual congress of the European Economic Association, Glasgow, for many thoughtful and insightful comments. We would also like to thank participants at internal staff seminars at Statistics Norway and Norges Bank. A special thank you goes to Terje Skjerpen for commenting on a preliminary version of this paper and to the Institute for New Economic Thinking at the Oxford Martin School for providing Roger Hammersland with the necessary support to enable us to conclude this research project. Email address of the corresponding author: Roger.Hammersland@ssb.no and Roger.Hammersland@norges-bank.no

[†]The analyses of this paper have been conducted by using PcGive 10.2 (Doornik and Hendry (2001))

1 Introduction

The idea that credit market conditions may have important effects on an economy's business cycle is today widely accepted, see e.g. Bernanke et al. (1999) and Hubbard (1998). A number of authors do in this context even talk about the existence of a financial accelerator where macro economic effects of shocks to credit conditions may be amplified at the macro economic level, see e.g Kiyotaki and Moore (1997) and Bernanke and Gertler (1989). Spurred by these theories, a growing empirical literature has provided evidence supporting the existence of a link between indicators of credit availability and macroeconomic fluctuations, suggesting that credit market conditions tend to impact significantly on measures of real activity over the business cycle.

However, from a theoretical point of view one may still ask, why credit should matter in the first place? After all, in a Modigliani and Miller (1958) world with perfect information and no credit constraints, the financial structure should both be indeterminate and irrelevant to real economic outcomes. A natural answer to such an objection would be the lack of realism in the premises of the Modigliani-Miller theory itself. Obviously, in the real world there is nothing like perfect information, and credit constraints are more or less omnipresent. However, to come to Modigliani and Miller's rescue one may plead that the standard assumption of the irrelevance of the financial structure never has had the intention of being fully realistic and that it only must be viewed as a simplification, not to be taken too literally for the short-run evolvement of the economy. In the long run, however, when frictions in financial and credit markets play a significantly more subdued role its relevance should be more compelling. To be able to test the long run relevance of the Modigliani-Miller theorem one should therefore resort to methodologies that explicitly aims at distinguishing between the short- and long-run outcome of a model.

A problem related to the existing literature applies to the empirical evidence giving support to the financial accelerator hypothesis. Most of these studies are either based on reduced form analysis not aimed at revealing the causal structural interplay among the variables, or structural specifications not necessarily given support by data in the sense of being potentially misspecified.¹As far as the second point is concerned there are several potential reasons for such kind of misspecification. For instance, in the case of estimating simultaneous equation models that have been exactly identified through e.g. imposing a priori restrictions on their contemporary causal structure and assuming a diagonal structural covariance matrix, one certainly risk ending up with models that do not adequately represent the causal structure of the data and thus to induce a simultaneity bias in estimation through imposing an improper causal structure. The reason for this is related to the fact that one never can test for the exactly identifying restrictions of a structural model and the bad habit in this context of adding the exact identifying restrictions on the part of the system that represents its intrinsic causal structure.² The case where

¹Some references in this respect are Lown and Morgan (2006), Swiston (2008), Dell'Ariccia and Garibaldi (2005), Gertler and Lown (1999) and Mody and Taylor (2004)

²When talking about structural models and shocks in the following we are not restricting our models to be derived from an explicit utility maximizing rational representative agent (RA) framework. This means that a structural model, it's constituent behavioral equations and it's shocks are given a far wider interpretation than is given to these concepts in modern micro based macro theory and refer in principle to theory-driven structural representations in general; be that structures based on more old fashioned type of macro informed models, models based on emerging macro properties or structures

the system is made up of equations that have been individually designed by a process of single equation reductions in a preliminary step – before possibly being put together as a system – bear on the other side witness to the fact that the estimated simultaneous equation model might be the outcome of a design process that is by itself plagued by an intrinsic simultaneity bias. The idea of getting rid of a potential simultaneity bias by putting individually designed equations together in a system and then to re-estimate them simultaneously – after they have found their final form – apparently suggests that the single equation design process itself must have been affected by a simultaneity bias in the first place. Otherwise, there would be no need trying to get rid of it at a later stage.

To address some of the deficiencies of earlier empirical studies and in this respect in particular to address the inherent problem of a simultaneity bias in design, this paper advocates the use of a fully simultaneous structural model design procedure, in the following occasionally referred to as the procedure of Simultaneous Structural Model Design (SSMD). In this procedure – and which hopefully should make it eligible for a claim to the status of representing a contribution to the econometric literature – the preferred simultaneous equation model not only is estimated simultaneously, but is itself the outcome of a fully simultaneous and structural reduction, or design process, where the causal structure of the data has been taken properly into account from the very onset on. It is worth noting that this amounts to an approach where all the behavioral or structural equations of a structural system are reduced and designed jointly, an exercise that differs widely from the much less involved one-equation-at-the-time general to specific approach associated with the LSE school of econometrics (see e.g. Hendry (1993, 1995) and Ericsson and Tran (1990)), or for that sake from a SVAR approach where little room is left for design beyond what is implied by the process of exact identification.

Admittedly though, the outcome of such a process of Simultaneous Structural Model Design will involve an element of arbitrariness in that it will depend on how the structural model was exactly identified in the first place. To add to the reliability of the final outcome it is therefore prudent to give credence to the identification scheme being used and in doing so, not only to the restrictions being imposed, but also to the extent that the auxiliary tools being used to exactly identify the system makes sense, in the sense of having arguably a structural or behavioral interpretation.³ However, having said this, it is in this context also important to emphasize that the procedure promoted in this paper is a fully simultaneous structural reduction process with the scope of ending up with an over-identified and parsimonious structural representation. As such, this should render the problem related to ambiguity less of an issue as it directly combines the process of exact identification to the initialization of a search process rather than to the scope of directly ending up with an a priori predetermined final structural representation. Hence, even in the case where one would have certain objections to the exact identification

based on common sense, including in this structural representations based on an explicit representative agent utility maximizing framework. A consequence of this is that the concept of being structural loses its un-ambiguity as several types of models and shocks can rightly be claimed to have a structural interpretation, though the way they are defined or interpreted as structural will differ across models. This also contributes of course to dilute the proper meaning of the world behavioral, as it makes structural relations based on relational and descriptive macro theories juxtaposed to micro based structural relations. Despite this fact we have in the text chosen to use the word behavioral throughout, keeping in mind that a more appropriate connotation perhaps would have been relational.

³See footnote 2 for a clarification of what we mean by structural and behavioral in this context.

scheme being promoted herein, e.g. based on fears that it in some sense or another may be weak or illegitimate, the process of reduction will necessarily contribute to enhance its strength and relevance until a strongly over-identified and parsimonious structural representation is reached. In any case, to explicitly describe how the system was identified is associated with a couple of distinct advantages; Not only does it serve to guarantee against sweeping the problem of identification under the carpet, but provides us with a test for over-identifying restrictions that later can be used to inform the structural design process and, in this respect, the imposition of causal restrictions in particular. This stands in contrast to what is common practise in e.g. the SVAR literature where a priori restrictions on the contemporary causal feedback matrix are used to exactly identify the model, often based on some perceived a priori view of delayed reaction. As there is no way to test for these exactly identifying restrictions this introduces necessarily a significant trace of arbitrariness in model design and specification, a short coming that we seek to ameliorate by resorting to a classical identification scheme rendering importance to a much wider set of identification sources, like e.g. reasonable a priori presumptions regarding the long-run feedback or lag structure of a system, not to mention the use of extrinsic information in terms of structural breaks and institutional changes as auxiliary tools of exact identification. Some might object that such a strategy is as arbitrary and dependent on the exact identifying restrictions as the procedure we aim at criticizing. However, though we are aware of the fact that there is no such thing as a free lunch when it comes to how one goes about to exactly identify a simultaneous equation model, it is nevertheless our firm belief that ignoring additional and extrinsic information, when it exists, is clearly disadvantageous to using it when it comes to exact identification of structural representations. *In particular, such a strategy will help us avoid laying the exact identifying restrictions on information laden parts of the model – like the contemporaneous feedback matrix – and to leave such kind of restrictions at the discretion of the data.*

To illustrate our proposed procedure and to study the mutual interplay between financial variables and the real economy a simultaneous structural equation model is constructed using Norwegian aggregate data.⁴ In doing so particular emphasis has been placed on investigating i) whether a financial accelerator mechanism has empirical relevance and – if so is the case – ii) whether it is possible to reconcile such a mechanism with a long run structure that renders the financial structure all but irrelevant for the real economic outcome of the model. To be able to utilize the SSMD procedure advocated herein we have in this respect been forced to keep the dimension of the model down to a minimum due to a relatively few number of observations. The model is thus necessarily simple, and our analysis should be viewed as an attempt to obtain qualitative insights based on data, rather than to provide an empirical description of real financial interactions that aims at being fully realistic. However, having said this, one must bear in mind that one of the main purposes of this analysis after all is to illustrate a new method for structural modeling and design, a fact that requires making certain sacrifices to get the

⁴We have chosen to focus on Norway, which happens to be our country of origin and thus the country we know best, both institutionally and otherwise. This choice, however, is also related to the fact that the SSMD procedure advocated in this paper is extremely cumbersome, involved, not to say downright complex, due to a complete lack of automatic structural model reduction procedures. Analyzing another country utilizing the procedure advocated herein, would therefore surely require a tremendous effort, if not a separate analysis on its own.

point across. None the less, in the case of Norway, it turns out that to illustrate the working of a financial accelerator in the setting of a fully simultaneous equation model that adequately and congruently portrays the evolvment of the real economy one can do with a surprisingly small information set.⁵ In fact, in addition to real GDP, the information set that forms the basis of our preferred structural vector error correction model comprises only stock prices, an indicator for domestic credit and oil prices.

As regards the outcome of our procedure of Simultaneous Structural Model Design the model contributes to reconcile the two opposing views of the literature. In particular we do find evidence of a financial accelerator that is amplified by a credit-asset price spiral in the short run. However, while innovations to asset prices and credit do cause short run movements in production, and while real activity spurs credit and asset prices, such innovations do not precede real economy movements in the long run. Noteworthy, this stands in contrast to what is found in Beaudry and Portier (2005, 2006) where shocks to stock prices have a lasting long run effect on the US and Japanese real economy.

The remaining sections of the paper are structured as follows. In Section 2, in addition to give some background information, we present some stylized facts related to a potential link between financial variables and the real economy. Section 3 is devoted to a critical discussion of the procedure that these days more or less has got the status of a *come-il-faut* when it comes to how to proceed when exactly identifying structural representations. This is a discussion that has clear implications for the line of approach chosen in the data based design procedure advocated in this paper. In Section 4 we then set up the empirical model framework and run through a modeling exercise with the aim of illustrating the potential of our data based structural model design procedure and to show how it can be used to shed light on the sources of economic fluctuation. Finally, Section 5 offers some concluding comments.

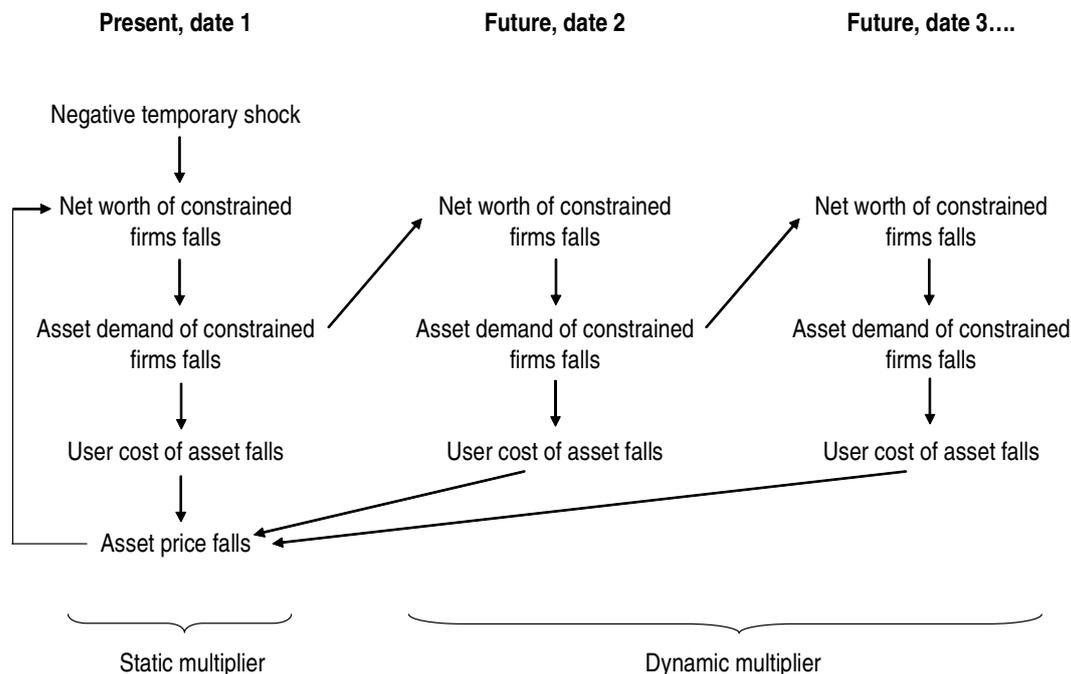
2 Background, Stylized Facts and the Data

2.1 Theoretical Background

It has long been recognized in the literature that in an environment with informational asymmetries, internal finance has a cost advantage over external finance for an entrepreneur considering undertaking a project. Hence, the Modigliani and Miller (1958) theorem does not apply, as internal funds, new debt or equity finance are not perfect substitutes. Lenders who are less informed about e.g. borrower types, borrower action or project quality, will demand a premium when providing uncollateralized loans. This external finance premium will be increasing in the size of the uncollateralized loan, causing financing costs to be higher than if the loan was fully collateralized. Since the agency problem raises the costs of external finance, it will affect wealth-constrained entrepreneurs' willingness to undertake projects. If increased borrower net worth renders possible more internal finance to the funding of the project and/or to raise collateral, then agency costs will be curbed. Thus, a positive shock to net worth will reduce the agency problem and

⁵To our knowledge this is the first analysis to confirm such a mechanism on Norwegian data using a fully simultaneous structural modeling framework (for a further discussion on this point see e.g. Hammersland and Tr e (2014)).

Figure 1: The dynamic and static multiplier of a negative temporary shock



may in turn lower financing costs and increase investments. This inverse relationship between net worth and agency costs of investment finance has a decisive role for many theoretical model predictions. Bernanke and Gertler (1989) develop an overlapping-generations model with costly state verification as in Townsend (1979). The asymmetry of information between lender-investors and borrower-entrepreneurs creates an agency problem where the optimal financial contract is characterized with a deadweight loss due to agency costs. A positive shock to borrower net worth reduces agency costs and increases physical investment. This induces a persistent investment upturn which is not present in the first-best perfect-information case. As a positive shock to net worth is likely to be procyclical, a financial accelerator effect emerges: The positive shock to net worth stemming from a business cycle upturn amplifies the boom. Other theoretical studies have also identified a financial accelerator mechanism where financial frictions propagate and magnify shocks to the economy. In particular, the seminal article by Kiyotaki and Moore (1997) comprises an important theoretical basis for our empirical analysis. Kiyotaki and Moore (1997) assume that lenders cannot force borrowers to repay their debts unless debts are secured. There are two types of agents in their model, both producing a nondurable commodity but with different technologies. In addition to the nondurable commodity, there is a durable asset which is land. Land comes in a fixed total supply, works as factor input for both type of agents and play a role as collateral for loans. One type of agents has identical production technologies, while the technology of the others is idiosyncratic. In case of being debtors, the latter type of agents can threaten creditors to withdraw their labor and leaving their land - the collateral - to creditors. As the durable asset is worth less without labor input from these agents, they are enabled to

renegotiate the debt down to the liquidation value of the asset. Knowing this in advance, creditors protect themselves by not allowing the size of debt to exceed the value of the collateral. The result is that agents with idiosyncratic technologies become credit constrained. Consistently, the agents with non-specific skills are not credit constrained. In equilibrium, the non-constrained firms become creditors. Kiyotaki and Moore illustrate the interdependence between asset prices and credit limits by an illuminating figure also shown here.

Referring to Figure 1, a negative shock to productivity lowers firms' net worth and accordingly reduces the borrowing capacity of the constrained firms. Hence, the constrained firms cut back on investment, that is, they reduce their demand for land. However, as land comes in a fixed supply, non-constrained firms must increase their demand in order for the land market to clear. The non-constrained firms are only willing to demand more land if the user cost of land drops. This implies that the asset price - the price of land - must fall for the market to clear. A lower asset price in turn curbs net worth even further, forcing constrained firms to reduce investment even more. Thus, the tightening of credit limits feeds back to land prices, which induces net worth and credit limits to drop further, and so it continues. At date 1, there is a static multiplier at work. However, that is not the end of the story. The constrained firms' reduced investment in the current period lowers their production also in the next period. This causes a fall in their net worth at date 2, which brings down their demand for land in the same period. For the land market to clear, a lower user cost of land at date 2 is required, and this is reflected in a lower (forward looking) asset price today. And so it continues, with lower investment fueling future declines in production and net worth, which in turn leads to subsequent falls in both the demand for and user cost of land. This effect curbs net worth and investment of constrained firms at date 1 even further, so the static multiplier is amplified. Hence, there is both a static and a dynamic multiplier operating in the model. The asset price fall reflects the user cost drop not only in the current period but all future periods. The result is that the asset price falls considerably relative to the temporary productivity shock that initiated the process in the first place, and the effect is due to the interdependence between credit limits and asset prices. What about aggregate production? At steady state in this model, the marginal product of land of the constrained firms is higher than that of the non-constrained. Kiyotaki and Moore argue that this is reasonable since the constrained firms cannot borrow and hence produce as much as they want while the non-constrained indeed can and do. As just described, the negative, transitory productivity shock redistributes land from constrained to non-constrained firms. Accordingly, the firms with highest marginal productivity cut their production while those with a lower marginal productivity produce more, the result being that aggregate production falls. The positive relation between asset prices, credit and aggregate production is evident, and highlights the financial accelerator mechanism. Bernanke et al. (1999) have developed a dynamic general equilibrium model that combines nominal rigidities with agency costs. The model illuminates how credit market imperfections affect the transmission of monetary policy. Due to costly state verification, as in Bernanke and Gertler (1989), investment depends positively on entrepreneurs' net worth. Entrepreneurs borrow to purchase capital, implying that borrowers own the capital stock in the economy and that the price of capital influences on their net worth. The model therefore incorporates the asset price effect highlighted in Kiyotaki and Moore (1997). Bernanke et al. (1999) find

that credit-market frictions amplify shocks to the economy and the financial accelerator effect helps to explain the strength of the economy's response to a monetary policy shock.

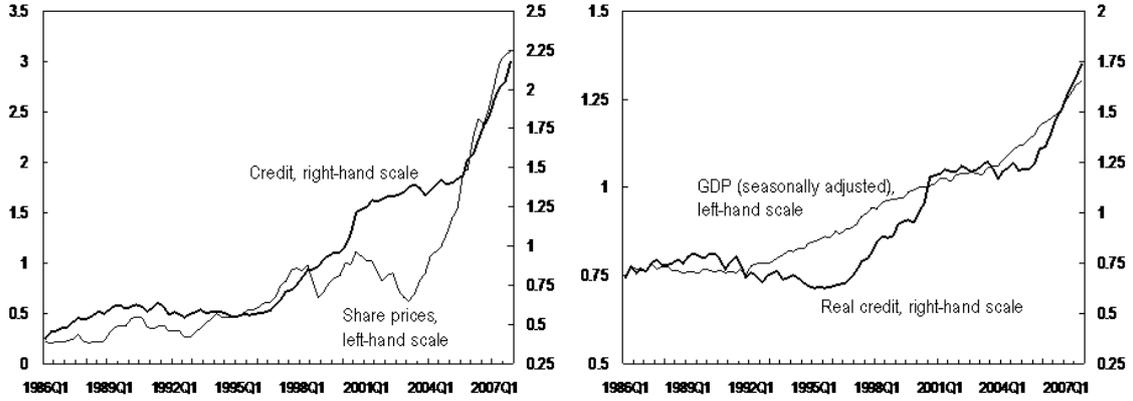
Summarizing, the models in Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and Bernanke et al. (1999) are all modified real business cycle models where a financial accelerator mechanism may cause large and persistent business cycles fluctuations. In the following, we will refer to the financial accelerator as the mutually reinforcing interaction between asset prices, credit and economic activity. We investigate whether a financial accelerator has empirical relevance, using Norwegian quarterly data for the past twenty years. More specifically, we examine the possibility of interdependence between net worth, credit and aggregate output using classical estimation methods not imposing a priori restrictions (distributional or otherwise) on the model parameters. In doing so we draw heavily on the general to-specific- principle of Hendry (1993), though the design scheme has been cast in a fully structural and simultaneous context. The variables we use are real share prices (an Oslo Stock Exchange index), total credit to non-financial firms in mainland Norway and real GDP for mainland Norway. We also include oil prices in US dollars, which are commonly seen as being particularly important for developments at the Oslo Stock Exchange. Oil prices are treated as exogenous in the empirical analysis. We search for long-term relationships within the framework of multivariate cointegration analysis, and we aim to identify a structural, dynamic Simultaneous Equations Model.

2.2 Stylized facts and the data

As already noted, the empirical analysis comprises the following variables: Credit to non-financial firms, share prices, GDP mainland Norway and oil prices. This section illuminates a few stylized facts. Figure 2, panel a, below shows developments in total credit to non-financial firms and an Oslo Stock exchange index in the period from 1986 to 2007, while Figure 2, panel b, shows the real GDP level in mainland Norway and real credit to non-financial firms in the same period. Figures 3, panel a and panel b, illustrate the corresponding variables when measured as percentage change over four quarters.

The Norwegian credit market was deregulated in the early and mid-1980's while interest rates were politically controlled at fairly low levels until end-1986. Not surprisingly, this spurred a sharp rise in credit growth and asset prices. Without discussing causal factors, the fact remains that the government had to deal with a severe banking crisis only a few years later. The banking crisis in the early 1990's coincided with a substantial downturn in the Norwegian economy. After a sharp drop in interest rates following the ERM-crisis in 1992 and breakdown of the fixed exchange rate regime, the economy started to pick up. This was also reflected in rising share prices from 1992, and after a period of economic revival, firms started to increase their debt markedly from end-1996. As the dot.com bubble burst, Norwegian stock prices fell from 2000 and credit growth stabilized. In 2003, interest rates started to decline to a very low level, and economic activity and share prices boosted. Credit to non-financial firms picked up from 2005. Overall, the figures above all indicate a positive correlation between share prices and credit to firms and between economic activity and credit. The exceptionally high credit growth in 2000, pictorial in Figure 3, is due to extremely large loan-raising by two Norwegian firms (Telenor and Norske Skog). Our preferred measure of credit to firms and GDP relates to mainland-Norway. However, the Oslo Stock Exchange index we use in the

Figure 2: Credit to non-financial firms, GDP and share prices in levels

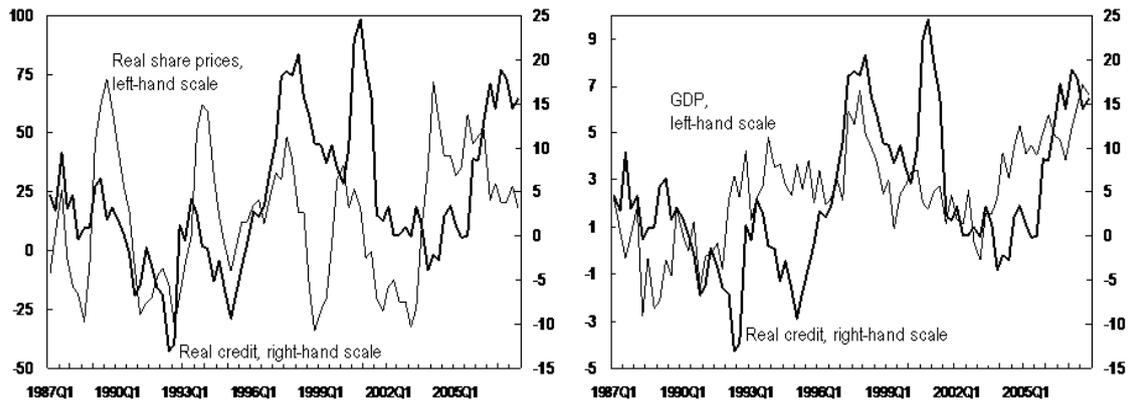


(a) Real share prices and credit to firms.

(b) GDP mainland Norway and real credit to firms.

Indices, 2000Q1=1. 1986Q1-2007Q4.

Figure 3: Credit to non-financial firms, GDP and share prices as percentage change over four quarters

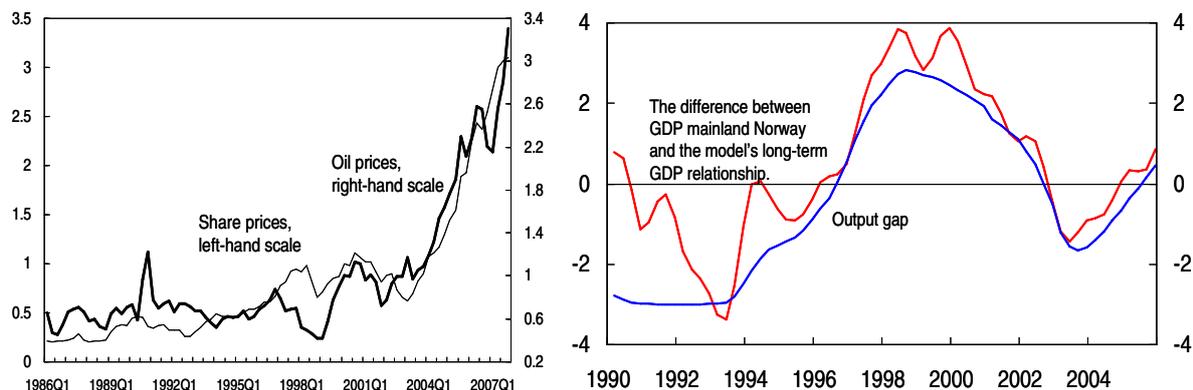


(a) Real share prices and credit to firms.

(b) GDP mainland Norway and real credit to firms.

Annual growth. Per cent. 1987Q1-2007Q4.

Figure 4: Share prices and oil prices, in levels, and an output gap comparison



(a) Real share prices and oil prices in USD. (b) Output gap from Inflation Report 1/06 (IR) and the difference between GDP mainland Norway and the model's long-term GDP relationship of the model of this paper (SEM). Per cent. 1990Q1 - 2005Q4

a) Indices, 2000Q1=1. 1986Q1-2007Q4. b) GDP mainland Norway has been adjusted for seasonality and irregular components. Sources: Norges Bank and Statistics Norway.

empirical analysis also includes offshore activities. Due to the structure of the Norwegian economy, oil prices are commonly seen to have a significant bearing on developments at the Oslo Stock Exchange and we therefore include oil prices denominated in US dollars as an exogenous variable. Figure 4a shows oil prices measured in USD and the share price index. The figure displays a clear and positive correlation between the two series.⁶

3 The role of data vs. a priori information in structural model design

These days a priori information has more or less completely got the upper hand on data in the process of structural model identification and design. For instance, in the structural vector autoregressive (SVAR) and simultaneous equation (SEM) model literature it has been, and still is, common to exactly identify the system by combining the imposition

⁶In this context it's also worth mentioning that in the run-up to this paper a number of models were estimated on information sets that, in addition to the variables mentioned in the text, included short- and long-term interest rates and their differentials. However, none of these modeling attempts turned out to be successful, in the sense of producing a well specified interpretable simultaneous model with good statistical properties. There are a couple of potential explanations for this. First, according to the Tobins-Q theory the so-called Q, that is the ratio of the market value of capital to its replacement costs, should intercept all that is relevant for the investment decision, interest rate movements included. To the extent that movements in share prices are good at intercepting the movements in the underlying theoretical Q variable itself, separate interest rate effects should thus not be expected. Second, the model is based on a reduced form equation for aggregate credit to firms. As credit probably is highly correlated with the trajectory of interest rates, including credit as an endogenous variable in the information set together with share prices, probably contributes to render the identification of separate interest effects even more difficult.

of a diagonal structural form covariance matrix of the errors with either (non-testable) a priori restrictions on the contemporaneous feedback matrix or analogous restrictions on the matrix of parameters that characterizes the long run solution of the system.⁷ Often these kind of restrictions imply a lower or upper block triangular contemporaneous feedback matrix which gives importance to the ordering of the variables in the block diagonal part of the system in that the short run responses implied by the lower or upper triangularity should be in accordance with some perceived a priori view of "delayed" reaction.⁸ In general little attention is paid in this literature to the issue of model design beyond what is implied by this process of identification. That is, when the model is exactly identified it has also more or less found its final form.

The inherent problem of structural model design is that there is no way to test for the exact identifying restrictions of a structural or simultaneous equation model. As long as the exact identifying restrictions reflect subjective a priori information of substantial interest and consequence for the properties of the model, this introduces necessarily a significant trace of arbitrariness in model design and specification. In fact, in some cases one might even speak of design where the outcome is more or less fully driven by the researcher's a priori subjective belief or wishful thinking.

Moreover, though imposing the covariance matrix of the structural model's disturbances to be diagonal is theoretically substantiated, the matter presents itself quite differently when constructing empirical models on real data as there is little to suggest that the empirical covariance matrix of an estimated structural form model should inherit the stochastic properties of its theoretical counterpart. This follows both as a consequence of utilizing empirical proxies for theoretical variable constructs and due to the fact that empirical models in most cases are linear approximations of non-linear theoretical equivalents. Add to this the inherent problem of omitted variables and the fact that theories, after all, are revised in light of ongoing scientific theory, there should be no lack of reasons to substantiate why one should be careful with laying the identifying restrictions on the covariance matrix of the disturbances of an empirical model. When all comes to all such a practise only contributes to impair the possibility of developing a data congruent model as it contributes to make the model less elastic when confronted with data. In particular the price paid for securing a structural interpretation of shocks ex ante in this respect could be unduly high in terms of miss-specification and lack of congruency.

To reduce the degree of arbitrariness inherent in structural modeling the procedure advocated in this paper strikes a blow for classical identification techniques aimed at giving more emphasis to data in the process of structural model specification and design. The strategy is based on the idea of making the models "more elastic" when confronted with data and thus to avoid laying the exact identifying restrictions on information laden

⁷There is a huge and growing literature in this area and to render justice to all of its contributors is clearly outside the scope of this paper. However, not to mention Sims (1980) seminal paper where he introduces the idea of exact identification through recursive identification would indisputably have to be characterized as an oblivion. Papers that deserve mention for the introduction of restrictions on the systems long run properties are, respectively, Blanchard and Quah (1989), Shapiro and Watson (1988) and Gali (1992).

⁸Notably there are authors that have tried to avoid the recursive identification scheme, see e.g. Bernanke (1986) and Blanchard and Watson (1986) among others who introduced non-recursive restrictions on the contemporaneous interactions among variables for identification. For sign restrictions see e.g. Paustian (2007) and Uhlig (2005).

parts of the model and on parts that would make it harder to come up with an admissible and congruent deterministic structure, like the covariance matrix. The advantage of such a strategy should be obvious as after the system is exactly identified tests for over-identifying restrictions are at ones disposal and one can enter into a design process where the data are allowed to speak, i.e. a process where both the ordering of the variables and the contemporaneous structure of the model is the outcome of a testable dialog with the data and not a priori information. As regards the covariance matrix, this advocates a strategy where the structural shock restrictions are tested for and potentially imposed ex post, i.e. after the deterministic part of the model has found its final structural form.

Ruling out the use of the contemporaneous feedback matrix and the covariance matrix of the disturbances as sources of exact identification limits the set of ways to exactly identify the system. However, it is important to point out that several alternatives still remain at our disposal. A classical approach to the problem would for instance imply that one puts to use exogenous information and information about structural breaks. In addition one might utilize information – inferential or otherwise – regarding the long run feedback structure of a model. A priori assumptions related to the lag structure of the structural model is another option (Hammersland (2008)). As regards the first of these alternatives – and to help us with the exact identification part of the model building process in this paper – we have in particular chosen to utilize additional and exogenous information with only a minor qualification; that this information should be structural, in the sense of having a ”behavioral” information content or interpretation.⁹ To legitimate this being the case one often has to resort to some ad hoc reasoning, a fact that clearly illustrates that there are no such thing as a free lunch when it comes to exact identification. Whether one combines the imposition of a diagonal covariance matrix with SVAR-like restrictions on the contemporaneous feedback matrix or utilizes exogenous information in the form of structural breaks one will never be able to fully free oneself from the curse of arbitrariness. However, to ignore using identification promoting exogenous information when it exists, is clearly not optimal in this respect as it would represent a huge disservice to the aim of constructing models informed by data. In particular, such kind of extrinsic information would enable us to avoid laying the exact identifying restrictions on information laden parts of the model, and to leave such kind of restrictions at the discretion of the data.

4 Simultaneous Structural Model Design and the Results

To save space we will in this part seek to illustrate the potential of our so-called data based Simultaneous Structural Model Design procedure by running through an explicit modeling exercise, aimed at revealing the structural interplay between real and financial variables. However, before starting on this we will first give a rough outline of the steps involved.

⁹Again see footnote 2 for a clarification of what is meant by behavioral in this context. See also footnote 10 for a more precise statement of the meaning of the term ”a structural dummy” in this paper.

4.1 The procedural steps

The first step of the procedure starts out with the specification of a congruent reduced form VAR model of all model endogenous variables. To help with the transformation of the reduced form model to a simultaneous equation model or structural form representation later on, so-called structural dummies, that is dummies that are supposed to have a behavioral information content and origin, are here included in the information set.¹⁰ The next step of the procedure then consists of reducing this general reduced form representation down to a parsimonious model and then to use this to identify and estimate the long-run structure of the model. Given this long run structure the reduced form version of the model is then transformed into an exactly identified simultaneous structural equation version thereof, more precisely a Structural Vector Equilibrium Correction Model (SVECM), utilizing the structural dummies included in the first step as instruments of exact identification, possibly in combination with restrictions on the feedback matrix related to long run equilibrium imbalances and/or restrictions on the system's lag structure.

In the last step this exactly identified SVECM is so used as the point of departure for what we believe to be a new design procedure. That is, a kind of simultaneous structural general to specific design process where the entire structural model is reduced down to a parsimonious and over-identified structural specification within a fully simultaneous and structural set-up. As distinct from one-equation-at-the-time model design procedures this final process of reduction takes on a fully simultaneous and structural perspective where all the structural equations are reduced and designed jointly, a corollary of this implying a constant search for uncovering whether identified reduced form relationships are due to separate and independent structural/behavioural causal links or the consequence of effects feeding through via contemporaneous causal links between the endogenous variables. Naturally, in such a context, a restriction imposed on a parameter belonging to one of the behavioral equations in the system would potentially spill over and have consequences for parameters belonging to all or some of the other behavioral equations in the system. In the process of model design this kind of simultaneous interdependence therefore involves a substantial degree of trial and error, a feature that contributes to make the process of model design time consuming as well as involved, not least due to the fact that it has been undertaken by hand.¹¹

¹⁰Whether a dummy can be characterized as a carrier of structural information is related to whether the information on which it is based can be regarded as something that is intrinsic to the structural equation of which it is intended to inform, a corollary of this being that a structural dummy can only inform one and only one of the equations of a structural form model. Though not stated explicitly in the above, a defining characteristic of a structural dummy is also that the information on which it is based comes from sources outside the system under consideration. A structural dummy should thus in principle neither be caused by any of the model endogenous variables nor be correlated with the structural error of the equation it is intended to structurally inform, the last requirement hinting at an additional absence of so-called nonsense correlations due to omitted variables, like e.g. variables intercepting anticipatory movements (for a discussion of how to get rid of a potential potential bias in estimation due to endogenous and anticipatory movements in single equation conditional models see e.g. Romer and Romer (2004) and Romer and Romer (2010)).

¹¹The fact that this procedure of reduction is highly informed by theory and a desire of ending up with a model with good interpretable properties is what makes it difficult to automatize. As one reduction imposed early on in the process might turn out to have dire consequences for the possibility of ending

4.2 Structural Model Design: an illustrative example

As regards our illustrative example the point of departure is the error correction version of the vector autoregressive model written in reduced form. In the general case this can be given the following representation:

$$\Delta X_t = \Pi Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \epsilon_t, \quad (1)$$

where X_t represents a $p \times 1$ vector of endogenous variables, $Y_t = (X_t', Z_t')'$ a $(p+q) \times 1$, vector where Z_t is a $q \times 1$ vector of exogenous variables and k the order of the VAR. D_t is a vector composed of contemporaneous and lagged differences of the model exogenous variables, Z_t , deterministic variables like dummies, a trend and a constant. ϵ_t is a Gaussian white noise term with covariance matrix Ω . The rank of the Π matrix gives us information about the cointegration properties of the model, and in the case the rank, r , is less than full, i.e. less than p , the Π matrix may be written as the product of a $p \times r$ matrix, α , and a $(p+q) \times r$ matrix, β , with full column rank equal to $r < p$. The level term in equation (1) can then be written as $\Pi Y_{t-1} = \alpha \beta' Y_{t-1}$ where $\beta' Y_{t-1}$ represents the r cointegrating linear combinations of the variables while the α matrix has got the interpretation of a coefficient matrix with error correction coefficients or loadings. The cointegration analysis in connection with the preparation of the SVECM¹² is based on a three dimensional conditional VAR of order 2,¹³ where all the variables are specified as logarithms of the original level series and a trend restricted to lie in the space spanned by the α matrix.¹⁴ Since we are utilizing unadjusted data centered seasonal dummies were specified to enter unrestrictedly together with a constant and dummies for certain important historical events. As will be evident from the subsequent discussion, some

up with a model with the desired properties, the process of design will necessarily imply a lot of back and forth searching with theory and interpretation as the rule of conduct. Also as we in the process of reduction have given priority to theory and interpretation, we have occasionally had to resort to brute force, in the sense of accepting partial reductions that would otherwise have been *marginally* rejected if one exclusively gave priority to the outcome of tests or information criteria. This further complicates the use of automatic reduction procedures as it involves a great deal of ad hoc judgement as to whether the end justifies the means in the individual steps considered in the reduction process.

¹²To distinguish the type of structural model developed in this paper from the SVAR model type we have chosen to use the term Structural Vector Equilibrium Correction Model interchangeably with the statistical concepts of a structural form and a simultaneous equation model (SEM).

¹³The VAR of order 2 amounts to a valid reduction of a data congruent VAR of order 6. In this VAR(2) none of the individual equation hypotheses for normality or absence of autocorrelation and heteroscedasticity are rejected at conventional significance levels. The system diagnostics of the VAR(2) model, given below, where the figures in parentheses are the respective tests' significance probabilities, do neither give rise to any concern.

Vector AR 1-5 test:	$F(45, 128)$	=	0.7020[0.9128]
Vector Normality test:	$\chi^2(6)$	=	6.9778[0.3229]
Vector Heterosc. test:	$F(96, 222)$	=	0.7550[0.9417]
Vector Heterosc-X test:	$F(264, 68)$	=	0.4018[1.0000]

The F-test statistic for the elimination of all lags greater than 2 from the model is $F(48, 113) = 0.67113[0.9396]$, where the figure in parenthesis is the test's significance probability. Nor where any of the partial reductions of the model reduction scheme rejected.

¹⁴The VAR is conditional in that the model is contingent on the US dollar price of oil being exogenous

of these dummies can arguably be considered as carriers of structural information in the sense of informing one and only one of the behavioral equations.¹⁵ This is what motivates their role as auxiliary tools of exact identification in the following. The VAR was then estimated by full maximum likelihood.¹⁶

As regards the historically motivated dummies, several of these turns out to have a potential structural interpretation in the sense of being related structurally to one of the behavioral equations. For instance if we look at the "behavioral" credit equation, the dummy, D2000Q3, is fairly straight-forward in this respect as it represents the influence on the full amount of credit provided to firms of two extraordinary big corporate credit expansions in the third quarter of 2000 (see Section 2 for the details). Accordingly, it takes the value of one in 2000Q3 and zero otherwise.¹⁷ As regards the behavioral equation of real activity, we have chosen to look at two candidate dummies, mainly to be able to test the robustness of the identification scheme related to using only one of them as an auxiliary tool of exact identification. The reason for this is a rather unclear understanding of the two dummies' structural status. The first of these, D1986Q2, represents a dummy for the devaluation of the Norwegian krone in may 1986 while the second one, D1997Q2, is a dummy for the krone appreciation that followed in the eve of the emerging market crisis in 1997-1998, mainly as a result of high oil prices and a wide interest rate differential against Germany. As regards the first of these, history tells us that when the devaluation finally came back in 1986 it had been highly expected several months in advance, suggesting that most of the devaluation already was fully priced in in the forward looking asset price market when it came in the second quarter of that year. Assuming that the devaluation either had a leading or delayed effect on credit to firms this might be used to argue for the dummy playing a structural role in the behavioral DGP equation of our system. To argue for a structural interpretation in the case of the 1997 appreciation we will have to resort to a story of delayed reaction, as the appreciation came in the first quarter while the dummy is one in the second quarter of 1997 and zero otherwise. However, the idea that the stock market reacts before the real economy in the wake of exchange rate realignments seems to us a rather low price to pay in this respect, not least taken into consideration that it contributes to provide us with a way to test for the robustness of alternative identification schemes. Incidentally, it is also in accordance with the line of reasoning used to argue for the imposition of a lower or upper diagonal contemporaneous feedback matrix in the SVAR literature. In the case of the asset price equation things are less problematic as there is much to indicate that the stock market crash in the fourth

¹⁵Again see footnote 10 for a more precise statement of what we mean by a structural dummy in this context

¹⁶In this context it is, as pointed out by Johansen (2006), worth noting that there is a price paid by using maximum likelihood in estimating VARs. Namely that the model must fit the data in the sense of constituting a congruent representation of the data generating process (DGP). However, in light of Footnote 13, this requirement does not seem to represent any cause for concern in our case.

¹⁷In this paper we have not tried to identify separate equations for credit supply and demand, the main reason for that being a lack of specific aggregate supply and demand data. Admittedly we could have circumvented this problem by utilizing the procedure advocated in this paper on the sub structure related to the provision of aggregate credit. However, as this - not least due to a limited number of observations - would have complicated matters considerably without necessarily leading to new insights as far as the relevance of the financial accelerator is concerned, we have deliberately left this for future research. As a consequence we cannot tell whether the dummy, D2000Q3, has a structural interpretation in the sense of being related either to the supply or demand of credit. It could be related to both.

quarter of 1987 had a pure structural asset price origin. As a default option we therefore use a dummy that is one in the fourth quarter in 1987 and zero otherwise to help us with the exact identification part of the modeling exercise. However, to be able to test the robustness of such a proposition we also here operate with an alternative identification tool; the dummy D1992Q3. This dummy represents the collapse of the ERM exchange rate system in the fourth quarter of 1992 and is 1 in the third quarter of 1992 and zero otherwise, the one period lead reflecting the forward looking nature of the asset price market. It is our claim that the dummies' one period lead on when the devaluation actually took place contributes to enhance its appropriateness as an auxiliary tool of exact identification.

As regards the line of reasoning being used to legitimize whether a dummy is to be considered as a carrier of structural information we have no problem admitting that it in a couple of the instances referred to above, is rather ad hoc. We therefore want to stress the importance of looking at the possibility of supplementing – or even substituting – the use of extrinsic information in terms of structural dummies with other kind of identification promoting restrictions, like e.g. restrictions regarding the long run feedback- or lag structure of the system. After all – and a point we implicitly seek to convey in this paper – one should in our opinion never on a priori grounds rule out any kind of information, extrinsic or otherwise, relevant for the exact identification of a system. Rather, as long it does not directly interfere with or directly impede the ability of coming up with an unbiased analysis, one should seek to throw as much information there is at the problem of resolving the issue of exact identification. In any case, in the presence of a perceived threat to the validity of the outcome of the analysis this stresses the importance of testing for the robustness of the identification scheme being used, be it whether one uses structural dummies or not.¹⁸

Compared to alternative approaches, it is important to be aware of the fact that the exact identification procedure advocated in this paper comes with an advantage. That is, it renders possible formal tests of causal restrictions without resorting to the imposition of incredible restrictions on either the structural empirical covariance matrix or the contemporaneous feedback matrix. Put differently, by resorting to what amounts to no less than a purely classical identification scheme utilizing various kinds of extrinsic information, we have been able to move the act of exact identification to a higher level in the design process, rendering possible data informed testing and design of the models contemporaneous causal structure without resorting to untestable restrictions on information laden parts of the model.

Based on the discussion used to legitimate the appropriateness of the auxiliary tools used to exactly identify the structural representation of this paper, we therefore move on to a structural analysis, feeling rather confident that the identification scheme being proposed would represent a contribution to the goal of revealing important aspects of the true underlying causal structure. However, before doing so, we will first return to the

¹⁸However, having said this, it is at the same time important to realize that the implicit critique used to argue against using structural dummies above does not differ substantially from the arguments being put forward to argue for whether the contemporaneous feedback matrix is lower or upper triangular in the case of SVAR modeling. In any case, resorting to structural dummies should be highly preferable to the practise being used in single equation model design where the issue of exact identification is more or less swept under the carpet altogether.

Table 1: **Johansen’s test for the number of cointegrating vectors**

VAR order: 2, constant and trend restricted to lie in the α space, unrestricted centered seasonal dummies. Estimation period: 1986 Q2 to 2006 Q3.

Trace Eigenvalue test:		
H_0	H_1	Values of test statistics
$r=0$	$r \leq 3$	84.200[0.000]**
$r \leq 1$	$r \leq 3$	35.400[0.002]**
$r \leq 2$	$r \leq 3$	14.089[0.025]*

1) The values in parentheses are the respective tests’ significance probabilities.

2) * and ** signify that the test is significant at a level of 5 and 1%, respectively.

reduced form analysis and the identification of the model’s long-run structure.

The results of the reduced form cointegration analysis is given in Table 1 and Table 2 and give unambiguous support for the existence of three cointegrating vectors. Moreover, the F-test for the number of overidentifying restrictions in Table 2, shows that the identified system, consisting of three cointegrating relationships, constitutes a valid restriction of a corresponding exactly identified long run structure.¹⁹ The first of the structural long-run relationships implies that GDP mainland Norway is a trend stationary variable with a yearly growth rate of approximately 2.9%. In this respect it is worth noting that the output gap, as estimated in this way, is fairly similar to that presented in Norges Bank (2006) from 1996 and onwards (See Figure 4b).²⁰ It is also almost identical to the output gap relationship estimated in Hammersland (2008), using a slightly different information set.

The second cointegrating relationship implies on the other hand that the ratio of domestic credit of enterprises to equity prices is constant over time, which due to the logarithmic specification and a small abuse of terminology amounts to saying that a percentage increase in the equity price feeds into an equivalent increase in domestic credit of enterprises in the long run.²¹ To substantiate what was here hinted at, namely

¹⁹By making the process of exact identification implicit we are here admittedly making the same kind of mistake as some of the people we aim at criticizing. Namely to sweep the problem of exact identification under the carpet. However, as there are few guidelines of how to proceed in this case – an idea being to restrict some of the structural dummy coefficients to lie in the α -space –, we have on purpose chosen to leave this part of the problem for future research. However, this does not imply that the identified long-run structure of this paper is the outcome of some arbitrary way of exactly identifying it. Quite the contrary, the preferred long-run structure of this paper is the result of an extensive search procedure where in principle an exhaustive set of exactly and over identifying restrictions has been tried out and tested for. Thus, when we in Table 2 are not able to find support for a hypothesis where real activity shares a common trend with one of the financial variables, this is a robust finding in the sense that no such structure seems to lie in a reasonable and interpretable possibility set.

²⁰See Inflation Report 1/06 on <http://www.norges-bank.no/>.

²¹A similar relationship was identified in Hammersland (2008) using a different credit aggregate. As

Table 2: **The identified system of cointegrating linear combinations given $r=3$, the loading matrix and a test of overidentifying restrictions** ¹⁾

The identified long run structure given 3 cointegrating relations:

$$\begin{pmatrix} \beta_{11} & \beta_{21} & \beta_{31} & \beta_{41} & \beta_{51} \\ \beta_{12} & \beta_{22} & \beta_{32} & \beta_{42} & \beta_{52} \\ \beta_{13} & \beta_{23} & \beta_{33} & \beta_{43} & \beta_{53} \end{pmatrix} \begin{pmatrix} gdp_t \\ c_t \\ s_t \\ poil_t \\ TREND_t \end{pmatrix} = \begin{pmatrix} gdp_t - 0.0073 \text{ TREND} \\ (0.00016) \\ c_t - s_t \\ s_t - 0.26 \text{ poil}_t - 0.01 \text{ TREND} \\ (0.09) \quad (0.002) \end{pmatrix}$$

Error correction coefficient matrix:

$$\begin{matrix} \Delta gdp \\ \Delta c \\ \Delta s \end{matrix} : \begin{pmatrix} \alpha_{11} & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & \alpha_{22} & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & \alpha_{33} \end{pmatrix} = \begin{pmatrix} - & 0.13 & - & 0.0163 & - & 0.003 \\ (0.064) & & (0.0134) & & (0.0187) \\ 0.434 & - & 0.077 & - & 0.061 \\ (0.104) & & (0.022) & & (0.03) \\ 0.532 & - & 0.176 & - & 0.357 \\ (0.34) & & (0.071) & & (0.099) \end{pmatrix}$$

LR-test of overidentifying restrictions: $\chi^2(3) = 0.8386[0.8402]$

¹⁾ The value in parenthesis under each coefficient is the estimated coefficient's standard error while the value in parenthesis following the test of over-identifying restrictions is the test's significance probability. The variables gdp_t , c_t , s_t , and $poil_t$ stand for, respectively, real mainland GDP, real domestic credit to enterprises, real equity prices and the price of oil in US dollars, lower case letters indicating that all the quantities are logarithmic transformations of the original variables referred to in the text.

that the causal link between credit and equity prices goes from equity prices to credit, requires a full-fledged structural analysis. However, before starting on such a task one may get some idea as to how the causal structure might look like by taking a closer look at the error correction coefficient matrix, α , of the reduced form. We will return to this immediately after having discussed the third long-run cointegrating relationship.

Finally, the third cointegrating relationship is a long-run relationship between asset prices, the US dollar oil price and a trend, where the trend implies a long run asset price growth of approximately 4 percent for given oil prices. A one percent increase in oil prices is on the other hand estimated to feed into a quarter of a percentage increase in asset prices. Given the significant role played by oil in the Norwegian economy, the fact that oil price fluctuations contribute significantly to explain the evolvement of asset prices should hardly be surprising.

As regards the loading matrix, most of its entries are significantly estimated. This contributes to hamper its usefulness as a device to come up with qualified guesses as to the shaping of the contemporaneous feedback matrix of the model's structural form. However, the absence of the third error correction term in the real activity equation of the reduced form could be taken to indicate that if there is a contemporaneous structural form relationship between real activity and asset prices, the direction of causality should go from activity towards asset prices and not vice versa. Otherwise we do observe that the first error correction term enters significantly with positive coefficients in the reduced form equations of both credit and asset prices, the positive coefficient clearly indicating that the output gap could be playing an independent behavioral role in both equations, another alternative being that it only enters in one of the behavioral equations and feeds into the other variable's reduced form equation through a contemporaneous causal link. As regards the causal link between credit and real activity, the fact that the ratio of credit to asset prices does not enter significantly in the reduced form GDP equation could be taken to indicate a one-way causal structural interaction going from GDP to credit. However, due to the fact that it's coefficient is negatively estimated with a t-value slightly higher than 1.2 and the fact that the output gap enters significantly in the credit equation, we have chosen to uphold the possibility of a two-way causal structural link between these two quantities in the shaping of our structural model. Notably, this runs counter to the kind of causal structure hinted at when interpreting the long run cointegrating relationship between asset prices and credit earlier on. Finally, looking at the loading matrix there is nothing to indicate a simple one way causal structure between asset prices and credit. The asset price related error correction term enters as significantly in the reduced form credit equation as the ratio of credit to asset prices does in the reduced form asset price equation.

The model that so far has been analyzed is a reduced form representation of the variables in our information set. To be able to explicitly address the topic of dynamic contemporary causality and to construct a model that is more in accordance with the idea of economic systems by nature being simultaneous and structural, we will now move on and, on the basis of the reduced form analysis, develop a simultaneous structural equation model for our three variables. However, before presenting the results of this modeling

the estimated output gap of that paper is almost identical to the one estimated in Table 2, this means that the two-equation long-run structure in Hammersland (2008) is encompassed by the long run structure of this paper.

exercise we will first turn to a brief discussion of the scheme being used to exactly identify the behavioral system.

The structural form or SEM representation of the reduced form is obtained by multiplying (1) by a contemporary response matrix B . This results in the simultaneous equation system:

$$B\Delta X_t = B\Pi Y_{t-1} + \sum_{i=1}^{k-1} B\Gamma_i \Delta X_{t-i} + B\Phi D_t + B\epsilon_t,$$

or after having set $B\Pi = B\alpha\beta' = \alpha^*\beta'$, $B\Gamma_i = \Gamma_i^*$, $B\Phi = \Phi^*$ and $B\epsilon_t = u_t$

$$B\Delta X_t = \alpha^*\beta' Y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i^* \Delta X_{t-i} + \Phi^* D_t + u_t \quad (2)$$

Given the three previously estimated long run relationships and the fact that the cointegration analysis was undertaken on a VAR(2), (2) will have the following representation in our particular example:

$$\begin{aligned} & \begin{pmatrix} 1 & b_{12} & b_{13} \\ b_{21} & 1 & b_{23} \\ b_{31} & b_{32} & 1 \end{pmatrix} \begin{pmatrix} \Delta gdp_t \\ \Delta c_t \\ \Delta s_t \end{pmatrix} = \begin{pmatrix} \alpha_{11}^* & \alpha_{12}^* & \alpha_{13}^* \\ \alpha_{21}^* & \alpha_{22}^* & \alpha_{23}^* \\ \alpha_{31}^* & \alpha_{32}^* & \alpha_{33}^* \end{pmatrix} \begin{pmatrix} gdp & - & 0.0073 \text{ TREND} \\ c & - & s \\ s & - & 0.26 \text{ poil} & - & 0.01 \text{ TREND} \end{pmatrix}_{t-1} \\ & + \begin{pmatrix} \gamma_{11}^* & \gamma_{12}^* & \gamma_{13}^* \\ \gamma_{21}^* & \gamma_{22}^* & \gamma_{23}^* \\ \gamma_{31}^* & \gamma_{32}^* & \gamma_{33}^* \end{pmatrix} \begin{pmatrix} \Delta gdp_{t-1} \\ \Delta c_{t-1} \\ \Delta s_{t-1} \end{pmatrix} + \begin{pmatrix} \lambda_{11}^* & \lambda_{12}^* & \lambda_{13}^* & \lambda_{14}^* & \lambda_{15}^* \\ \lambda_{21}^* & \lambda_{22}^* & \lambda_{23}^* & \lambda_{24}^* & \lambda_{25}^* \\ \lambda_{31}^* & \lambda_{32}^* & \lambda_{33}^* & \lambda_{34}^* & \lambda_{35}^* \end{pmatrix} \begin{pmatrix} D1986Q2 \\ D2000Q3 \\ D1987Q4 \\ D1992Q3 \\ D1997Q2 \end{pmatrix} \quad (3) \\ & + \begin{pmatrix} \phi_{11}^* & \phi_{12}^* & \phi_{13}^* & \phi_{14}^* & \phi_{15}^* & \phi_{16}^* & \phi_{17}^* & \phi_{18}^* \\ \phi_{21}^* & \phi_{22}^* & \phi_{23}^* & \phi_{24}^* & \phi_{25}^* & \phi_{26}^* & \phi_{27}^* & \phi_{28}^* \\ \phi_{31}^* & \phi_{32}^* & \phi_{33}^* & \phi_{34}^* & \phi_{35}^* & \phi_{36}^* & \phi_{37}^* & \phi_{38}^* \end{pmatrix} \begin{pmatrix} \Delta \text{poil}_t \\ \Delta \text{poil}_{t-1} \\ 1 \\ S1 \\ S2 \\ S3 \\ D1991Q4 \\ D1992Q4 \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{pmatrix}, \end{aligned}$$

where we have normalized the contemporary response- or feedback matrix such that the coefficients along the main diagonal is equal to one. Furthermore, in (3) we have split the exogenous variable vector, D_t , into two parts. One containing exclusively the dummies used to exactly identify our structural model and another one containing contemporaneous and lagged differences of the exogenous oil price variable, as well as a constant, seasonal dummies and a couple of non-structural historic dummies.²² As regards the two

²²In the continuation we will refer to the matrix $\begin{pmatrix} \lambda_{11}^* & \lambda_{12}^* & \lambda_{13}^* & \lambda_{14}^* & \lambda_{15}^* \\ \lambda_{21}^* & \lambda_{22}^* & \lambda_{23}^* & \lambda_{24}^* & \lambda_{25}^* \\ \lambda_{31}^* & \lambda_{32}^* & \lambda_{33}^* & \lambda_{34}^* & \lambda_{35}^* \end{pmatrix}$ in (3) as the Λ matrix.

non-structural historical dummies these are, respectively, D1991Q4 and D1992Q4, the first one representing a dummy for the Norwegian Banking crisis while the second one represents the collapse of the ERM exchange rate system in the fourth quarter of 1992. As distinct from the dummy used as an identification tool, D1992Q3, this dummy takes the value 1 in the quarter when the crisis actually took place.

However, as regards estimation of (2) and (3), there evidently is a puzzle to resolve as neither of the two representations are identified – in the sense of representing a one-to-one mapping of the corresponding reduced form – without imposing further restrictions.²³ In the SVAR literature this problem is solved by assuming: i) a lower or upper triangular response matrix and ii) a diagonal empirical structural covariance matrix. However, as already mentioned in Section 3, there is an inherent and insuperable problem associated with imposing exactly identifying restrictions on a structural form in this way as the exactly identifying restrictions never can be tested for. Thus, one evidently runs the risk of imposing a dynamic contemporary structure that is not supported by data. This advocates a strategy where one leaves the parts of the system perceived to be of minor importance for the purpose of exact identification and then to consider over-identifying restrictions to test for restrictions on more information laden parts of the model and parts that would make it harder to come up with an admissible and congruent deterministic structure, like, respectively, the feedback- and the covariance matrix.

To help out with the exact identifying part of the modeling building process this paper resorts to classical identification techniques where additional and extrinsic information in the form of structural breaks – possibly coupled with restrictions on the long-run feedback and lag structure of the system – plays the role as auxiliary tools of exact identification. By initially limiting ourselves to look at the case where we only resort to structural breaks this means that restrictions are exclusively placed on the coefficients of the Λ matrix in (3) and in such a way that the dummies only affect the behavioral equation of which they are intended to inform structurally. Given the set of five structural dummies specified in (3) and the fact that we have chosen to stick to the 2000Q3 dummy being genuinely structural, this gives us four different ways to exactly identify our SVECM; One, and the one we have chosen to call our default, using the first three-tuple of dummies, (D1986Q2, D2000Q3, D1987Q4), where each of the dummies is related to one and only one of the behavioral equations according to the rationale given for the dummies earlier on; Another where the first of the dummies in this three-tuple is changed for D1997Q2; Then one where the last dummy of the same three-tuple is changed for the dummy D1992Q3; And finally one where both the first and last element of the original three-tuple are changed for respectively, D1997Q2 and D1992Q3.²⁴ In line with such an identification scheme and using the first three-tuple of dummies, an exactly identified SEM representation is given

²³Note that if we multiply (2) with an arbitrary non-singular F-matrix the corresponding reduced form will still be equal to (1). This illustrates that there in general does not exist a one-to-one mapping between the reduced form and a SEM or structural form representation. Only in the case where the only admissible transformation matrix, F, is equal to a diagonal matrix, or in the case of (3) where we have normalized the coefficients along the main diagonal of the feedback matrix to be equal to one, the identity matrix, will the simultaneous equation system be identified.

²⁴The three alternative ways to exactly identify the system using structural dummies, beyond the one used as a default in (4) would have given Λ matrixes equal to, respectively, $\begin{pmatrix} \lambda_{11}^* & 0 & 0 & \lambda_{14}^* & \lambda_{15}^* \\ \lambda_{12}^* & \lambda_{22}^* & 0 & \lambda_{24}^* & 0 \\ \lambda_{13}^* & 0 & \lambda_{33}^* & \lambda_{34}^* & 0 \end{pmatrix}$,

by:²⁵

$$\begin{aligned}
& \begin{pmatrix} 1 & b_{12} & b_{13} \\ b_{21} & 1 & b_{23} \\ b_{31} & b_{32} & 1 \end{pmatrix} \begin{pmatrix} \Delta gdp_t \\ \Delta c_t \\ \Delta s_t \end{pmatrix} = \begin{pmatrix} \alpha_{11}^* & \alpha_{12}^* & \alpha_{13}^* \\ \alpha_{21}^* & \alpha_{22}^* & \alpha_{23}^* \\ \alpha_{31}^* & \alpha_{32}^* & \alpha_{33}^* \end{pmatrix} \begin{pmatrix} gdp - 0.0073 \text{ TREND} \\ c - s \\ s - 0.26 \text{ poil} - 0.01 \text{ TREND} \end{pmatrix}_{t-1} \\
& + \begin{pmatrix} \gamma_{11}^* & \gamma_{12}^* & \gamma_{13}^* \\ \gamma_{21}^* & \gamma_{22}^* & \gamma_{23}^* \\ \gamma_{31}^* & \gamma_{32}^* & \gamma_{33}^* \end{pmatrix} \begin{pmatrix} \Delta gdp_{t-1} \\ \Delta c_{t-1} \\ \Delta s_{t-1} \end{pmatrix} + \begin{pmatrix} \lambda_{11}^* & 0 & 0 & \lambda_{14}^* & \lambda_{15}^* \\ 0 & \lambda_{22}^* & 0 & \lambda_{24}^* & \lambda_{25}^* \\ 0 & 0 & \lambda_{33}^* & \lambda_{34}^* & \lambda_{35}^* \end{pmatrix} \begin{pmatrix} D1986Q2 \\ D2000Q3 \\ D1987Q4 \\ D1992Q3 \\ D1997Q2 \end{pmatrix} \quad (4) \\
& + \begin{pmatrix} \phi_{11}^* & \phi_{12}^* & \phi_{13}^* & \phi_{14}^* & \phi_{15}^* & \phi_{16}^* & \phi_{17}^* & \phi_{18}^* \\ \phi_{21}^* & \phi_{22}^* & \phi_{23}^* & \phi_{24}^* & \phi_{25}^* & \phi_{26}^* & \phi_{27}^* & \phi_{28}^* \\ \phi_{31}^* & \phi_{32}^* & \phi_{33}^* & \phi_{34}^* & \phi_{35}^* & \phi_{36}^* & \phi_{37}^* & \phi_{38}^* \end{pmatrix} \begin{pmatrix} \Delta \text{poil}_t \\ \Delta \text{poil}_{t-1} \\ 1 \\ S1 \\ S2 \\ S3 \\ D1991Q4 \\ D1992Q4 \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{pmatrix}
\end{aligned}$$

In (4) we have restricted the dummies according to the recipe given above. In particular, the dummy D1986Q2, which is the structural dummy informing real activity, is restricted to only enter the behavioral equation of real activity. Likewise the dummies for the extraordinary big credit expansion in 2000 Q3 and the stock market crisis in the fourth quarter of 1987 are both restricted to enter, respectively, only the behavioral credit equation and the behavioral asset price equation. To anticipate events somewhat we may already at this point mention that the final outcome of our procedure of Simultaneous Structural Model Design by chance turns out to be robust as to all of the four identification schemes just mentioned. That, is whether the first, second, third or fourth alternative referred to above is used to exactly identify our system the final outcome will nonetheless be the same and accepted by the test of overidentifying restrictions.

As already mentioned, the structural status of some of the dummies referred to above is rather unclear. Combined with an imminent danger of rendering the identification scheme weak, not least due to a general lack of break observation periods, this makes it prudent to look for alternative and supplementary sources of exact identification, like e.g. the long-run feedback structure of the system and its lag structure. As far as

$$\begin{pmatrix} \lambda_{11}^* & 0 & \lambda_{13}^* & 0 & \lambda_{15}^* \\ 0 & \lambda_{22}^* & \lambda_{23}^* & 0 & \lambda_{25}^* \\ 0 & 0 & \lambda_{33}^* & \lambda_{34}^* & \lambda_{35}^* \end{pmatrix} \text{ or } \begin{pmatrix} \lambda_{11}^* & 0 & \lambda_{13}^* & 0 & \lambda_{15}^* \\ \lambda_{12}^* & \lambda_{22}^* & \lambda_{23}^* & 0 & 0 \\ \lambda_{13}^* & 0 & \lambda_{33}^* & \lambda_{34}^* & 0 \end{pmatrix}$$

²⁵This statement is related to the order condition. However, the claim that (4) is exactly identified hangs evidently on the rank condition also being fulfilled, which thus is tacitly and implicitly assumed in this assertion.

the first of these sources is concerned there are often good reasons to believe that error correction is a structural property, in the sense of representing a mechanism that is specific to one -or at least not more than to a limited subset- of the behavioural equations. For example in the error correction structure identified in Table 2 there is much to indicate that the last cointegrating vector must pertain to the structural asset price equation only, while the second one in principle could be related to both the structural credit and asset price equation, but not to the structural GDP equation. The status of the first cointegrating vector is, however, more questionable in this respect due to its interpretation of an output gap. Imposing restrictions on the lag structure is on the other hand slightly more controversial, but if one on a priori grounds are willing to accept that the eigendynamic part of a structural equation's lag structure is more informative for the evolution of the variable endogenous to that structural equation than dynamic terms pertaining to extrinsic endogenous variables one might use such a presumption to aid our identification scheme as well.

In (5) we are thus presenting an alternative identification scheme where the process of exact identification is sought accomplished through a combination of utilizing structural dummies (as in (4)) and imposing restrictions on the system's lag- and long-run feedback structure. As far as the cointegration structure is concerned we have hence restricted the second and third cointegrating vector to only enter the structural equations to which they – on a priori grounds – are supposed to inform structurally. To be more explicit this means that we have imposed the third cointegrating vector to only enter the structural asset price relationship while the second one is on a priori grounds allowed to inform structurally both the structural credit and asset price relationship. In addition we have restricted the first cointegrating vector – the output gap – only to enter the first two structural equations and not the structural asset price equation.²⁶ Combined with a zero restriction on one of the coefficients related to the structural dummies of the other two equations – i.e. credit and asset prices – these restrictions should be sufficient to accomplish exact identification of respectively the first and last structural relationship. What remains is to identify the second one as a linear combination of the first two equations still will be eligible as a candidate credit equation without further restrictions imposed. However, a close look at (5) reveals that we may overcome such a problem by simply imposing the lag structure of the credit variable not to include the lag of the real output variable.

²⁶Unfortunately, a corollary of this would be a necessity to waiver a direct testing of the structural property of the output gap effect in the reduced form asset price relation. However, such a drawback might be easily overcome by resorting to an alternative set of identifying restrictions that leaves the structural property of the output gap unconstrained, an example of such a scheme being the set of exactly identifying restriction referred to in corroborating the scheme of (4). Noteworthy one may also be able to dispose of the use of structural dummies in the identification scheme altogether by imposing additional restrictions on the long run feedback structure of the system, an obvious candidate in that respect being to let the second cointegrating vector only to inform the structural credit equation, and then to combine the implied feedback structure with restrictions on the lag structure, like the ones referred to in the text.

$$\begin{aligned}
& \begin{pmatrix} 1 & b_{12} & b_{13} \\ b_{21} & 1 & b_{23} \\ b_{31} & b_{32} & 1 \end{pmatrix} \begin{pmatrix} \Delta gdp_t \\ \Delta c_t \\ \Delta s_t \end{pmatrix} = \begin{pmatrix} \alpha_{11}^* & 0 & 0 \\ \alpha_{21}^* & \alpha_{22}^* & 0 \\ 0 & \alpha_{32}^* & \alpha_{33}^* \end{pmatrix} \begin{pmatrix} gdp - 0.0073 \text{ TREND} \\ c - s \\ s - 0.26 \text{ poil} - 0.01 \text{ TREND} \end{pmatrix}_{t-1} \\
& + \begin{pmatrix} \gamma_{11}^* & \gamma_{12}^* & \gamma_{13}^* \\ 0 & \gamma_{22}^* & \gamma_{23}^* \\ \gamma_{31}^* & \gamma_{32}^* & \gamma_{33}^* \end{pmatrix} \begin{pmatrix} \Delta gdp_{t-1} \\ \Delta c_{t-1} \\ \Delta s_{t-1} \end{pmatrix} + \begin{pmatrix} \lambda_{11}^* & \lambda_{12}^* & \lambda_{13}^* & \lambda_{14}^* & \lambda_{15}^* \\ \lambda_{21}^* & \lambda_{22}^* & \lambda_{23}^* & \lambda_{24}^* & \lambda_{25}^* \\ \lambda_{31}^* & 0 & \lambda_{33}^* & \lambda_{34}^* & \lambda_{35}^* \end{pmatrix} \begin{pmatrix} D1986Q2 \\ D2000Q3 \\ D1987Q4 \\ D1992Q3 \\ D1997Q2 \end{pmatrix} \quad (5) \\
& + \begin{pmatrix} \phi_{11}^* & \phi_{12}^* & \phi_{13}^* & \phi_{14}^* & \phi_{15}^* & \phi_{16}^* & \phi_{17}^* & \phi_{18}^* \\ \phi_{21}^* & \phi_{22}^* & \phi_{23}^* & \phi_{24}^* & \phi_{25}^* & \phi_{26}^* & \phi_{27}^* & \phi_{28}^* \\ \phi_{31}^* & \phi_{32}^* & \phi_{33}^* & \phi_{34}^* & \phi_{35}^* & \phi_{36}^* & \phi_{37}^* & \phi_{38}^* \end{pmatrix} \begin{pmatrix} \Delta \text{poil}_t \\ \Delta \text{poil}_{t-1} \\ 1 \\ S1 \\ S2 \\ S3 \\ D1991Q4 \\ D1992Q4 \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{pmatrix}
\end{aligned}$$

Based on different varieties of the two exactly identified example structures referred to above where the two sets of identifying restrictions might be combined and amended in a number of different ways, we are now ready to get down to the process of reducing our exactly identified simultaneous equation model down to a parsimonious structural representation of the information contained in our data set. The fact that we by resorting to structural dummies and restrictions on the dynamic structure have managed to avoid laying the exactly identifying restrictions on the contemporaneous response matrix – or for that sake the covariance matrix– implies that we by way of tests for over-identifying restrictions now are in full command when designing the contemporaneous causal structure of the model. The result of this process of simultaneous structural model design is our preferred parsimonious structural model, given by (6).

The first thing to notice in (6), and as already alluded to in the second last paragraph in the text, is that the model is robust as to many ways of how to exactly identify the system, including in this all the variants commented on in conjunction with corroborating our two example schemes in (4) and (5). As far as the two example schemes are concerned this follows as a consequence of the fact that the union of all the identifying restrictions imposed – including in this all the restrictions implied by the four different ways to exactly identify the system by help of structural dummies in (4) – by chance happens to be fully contained in (6). This can be easily confirmed by taking a closer look at the final structural model in (6) where all the structural break dummies enter the system in accordance with their a priori structural intention.²⁷Likewise, all restrictions imposed

²⁷Too see this note that the dummies D1987Q4 and D1992Q3, earlier being both characterized as carriers of structural information related to asset prices, do only happen to enter the behavioral asset price equation in (6). Likewise, the two alternative dummies characterized as carriers of structural information related to real activity, D1986Q2 and D1997Q2, do only enter the system's behavioral

on either the feedback- or lag structure in (5) are equally found to be accepted by our reduction procedure and thus to be contained in (6). In addition to this comes the fact that several of the restrictions imposed on the structure to arrive at (6) – and not explicitly referred to as being a part of the set of restrictions used to accomplish exact identification in the text – could alternatively have been used to help with the exact identification of the system as well. All in all, therefore, this should demonstrate that the final outcome of our design procedure in (6) is robust against a fairly wide set of alternative identification schemes.

Furthermore, it is important to bring attention to the fact that the test of the over-identifying restrictions does not reject the null hypothesis of the final parsimonious simultaneous equation model, (6), constituting a valid reduction of an exactly identified version of the model.²⁸ The system diagnostics given below our preferred system indicate also that the system describes data fairly well, as none of the standard vector tests indicate presence of autocorrelation, non-normality or heteroscedasticity. Moreover, the single equation and vector stability tests of Figure 8 in Appendix A do indicate that the system as such is relatively stable over the estimation period as in fact none of the recursive tests breaks a test level of 1%. Figure 9 shows furthermore that the model provides relatively good fit to GDP, real domestic credit to enterprises and real equity prices. Moreover, the model predicts GDP growth 4 quarters ahead fairly well when it is estimated using data up to and including 2005Q2 and simulated dynamically to 2006Q3 (see Figure 10). Figure 11 shows that the model is also able to produce ex ante forecasts that are not too bad given the circumstances all the way out 2010Q2, though some huge forecast errors certainly contribute to mar the overall impression. As expected the model is neither able to foresee the unexpectedly strong drop nor the subsequent strong recoil in asset prices following in the aftermath of the Lehman Brothers default on September 15 2008. Nor is the model able to explain the sudden precipitous drop in DGP growth that came as a consequence of the outbreak of the financial crises.²⁹

In the SVECM model of (6) the contemporaneous feedback matrix reveals a contemporaneous two-directional causal link between credit and real activity. Accordingly, a shock to productivity that momentarily leads to higher activity growth will feed into a contemporaneous increase in credit growth. Higher credit growth will on the other hand spur further growth in activity, a feature that reveals a mechanism through which the initial shock to productivity is amplified. Evidently, (6) is thus characterized by the existence of a financial accelerator. Furthermore, in (6) growth in real domestic credit to

equation of real activity. Finally we see that the structural credit dummy only enters the structural credit equation in (6).

²⁸Since there is a one-to-one mapping between an exactly identified simultaneous equation model and a reduced form, an equivalent statement would be that the parsimonious simultaneous equation model does not represent a significant loss of information compared to the reduced form VAR of order 2 used in the cointegration analysis.

²⁹Estimating the model on data out 2010Q2 does not lead to a break down of the structure designed on data out 2006Q3. However, the long run effect of oil prices on asset prices is significantly dampened when data for the whole ex ante forecast period is included in the information set. Likewise, the contemporaneous effect of credit in the structural GDP equation becomes no longer significantly estimated, though the effect is still estimated positively and close to 0.1. However, to study these particularities in further detail would require a complete structural redesign of our model on the new and extended data set, a process that would require a paper of its own due to the complexity of the structural design process advocated in this paper

firms is contemporaneously affected by the growth in asset prices. And at the same time,

$$\begin{aligned}
& \begin{pmatrix} 1 & -0.15 & 0 \\ (0.079) & & \\ -0.58 & 1 & -0.075 \\ (0.17) & & (0.035) \\ 0 & -1.3 & 1 \\ (0.33) & & \end{pmatrix} \begin{pmatrix} \Delta gdp_t \\ \Delta c_t \\ \Delta s_t \end{pmatrix} = \begin{pmatrix} -0.51 & 0 & 0 \\ (0.074) & & \\ 0 & -0.15 & 0 \\ (0.09) & & \\ 0.75 & 0.44 & 0.46 \\ (0.21) & (0.26) & (0.086) \end{pmatrix} \begin{pmatrix} \Delta gdp_{t-1} \\ \Delta c_{t-1} \\ \Delta s_{t-1} \end{pmatrix} \\
& + \begin{pmatrix} -0.16 & 0 & 0 \\ (0.05) & & \\ 0.38 & -0.041 & 0 \\ (0.083) & (0.0075) & \\ 0 & 0 & -0.201 \\ (0.037) & & \end{pmatrix} \begin{pmatrix} gdp - 0.0073 \text{ TREND} \\ c - s \\ s - 0.26 \text{ poil} - 0.01 \text{ TREND} \end{pmatrix}_{t-1} \\
& + \begin{pmatrix} 0 & 1.93 & -0.053 & -0.094 & -0.066 & 0 & 0 \\ (0.60) & (0.007) & (0.006) & (0.005) & & & \\ -0.047 & -4.05 & 0.057 & 0.056 & 0.033 & -0.069 & 0.066 \\ (0.0167) & (0.97) & (0.016) & (0.014) & (0.0125) & (0.02) & (0.02) \\ 0.164 & 0.687 & 0 & 0 & 0 & 0 & 0 \\ (0.06) & (0.126) & & & & & \end{pmatrix} \begin{pmatrix} \Delta \text{poil}_t \\ 1 \\ S1 \\ S2 \\ S3 \\ D1991Q4 \\ D1992Q4 \\ D1986Q2 \\ D2000Q3 \\ D1987Q4 \\ D1992Q3 \\ D1997Q2 \end{pmatrix} \quad (6) \\
& + \begin{pmatrix} 0.06 & 0 & 0 & 0 & -0.04 \\ (0.014) & & & & (0.009) \\ 0 & 0.08 & 0 & 0 & 0 \\ (0.02) & & & & \\ 0 & 0 & -0.28 & -0.18 & 0 \\ (0.073) & (0.074) & & & \end{pmatrix} \begin{pmatrix} D1986Q2 \\ D2000Q3 \\ D1987Q4 \\ D1992Q3 \\ D1997Q2 \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \\ u_{3t} \end{pmatrix}
\end{aligned}$$

System diagnostics and test of restrictions

LR-test for over-identifying restrictions:	$\chi^2(38)$	=	42.497[0.2835]
Vector test for autocorrelation of order 1-5:	F(45, 164)	=	0.7368[0.8843]
Vector test for normality:	$\chi^2(6)$	=	7.111[0.3107]
Vector test for heteroscedasticity:	F(198, 203)	=	0.73695[0.9843]

these asset prices are affected by credit growth. The dynamic interaction between credit and asset prices thus turns out to be a transmission mechanism by which the effects of shocks could persist and amplify, a feature that is given some support by looking at the impulse responses to shocks (see below). This is totally in accordance with the mechanism characterized by the general equilibrium model developed in 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 as we have seen no long-run link between financial variables and the real economy. Hence, while innovations to asset prices and credit do cause short run movements in production, and while real activity spurs credit, such innovations do not precede real economy movements in the long run.³⁰ As mentioned in the introduction this stands in contrast to what is found in Beaudry and Portier (2006, 2005) where shocks to stock prices have a lasting long run effect on the US and Japanese real economy. Noteworthy, it also contributes to reconcile the two opposing views of the literature in that the short run outcome of the model is characterized by a financial accelerator at the same time as the financial variables are irrelevant for the model's long run solution. Furthermore, looking at the error correction coefficients we do see that the output gap do not play a behavioral role in the asset price relations. The highly significant and positive output gap coefficient of the reduced form asset price equation in Table (2) is therefore confirmed to be due to a strong contemporaneous link between credit and asset prices. Otherwise, according to (6) higher oil prices affects 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 a oil price hike is estimated to have on asset prices in the long run.

4.3 Impulse responses

To make our model as elastic as possible when confronted with data, we have so far chosen to leave the model's covariance matrix unrestricted. However, given that we now have "found" our model and we want to preserve a structural interpretation to shocks, time has come to change tack. Thus all impulse responses in the following have been orthogonalized in the sense of referring to a diagonal covariance matrix where the non-diagonal elements have been imposed a zero restriction.³¹

³⁰Note that this finding refutes the notion that there is no relationship between real GDP growth and the performance of equity markets. Arguably, according to (6) there is a two-directional causal contemporaneous link between equity returns and GDP growth in the short run, though the contemporaneous effect of a change to equity prices on GDP growth is rather minuscule and the effect on equity prices of higher gdp growth comes predominantly via higher credit growth in the short run. This gives partial support to the conclusion in J. O'Neill and Wrisdale (2011) of a link between GDP growth and equity returns. However, the absence of a corresponding long-run link between equity prices and GDP in (6) is on the other hand fully in accordance with research giving support to the view that there is no such link between equity returns and real activity growth over longer time spans (see e.g. Ritter (2005) for a study on cross sectional data).

³¹In this respect it is important to mention that leaving the covariance matrix untouched, in the sense of not imposing the non-diagonal elements to be equal to zero, had only a minor impact on the impulse

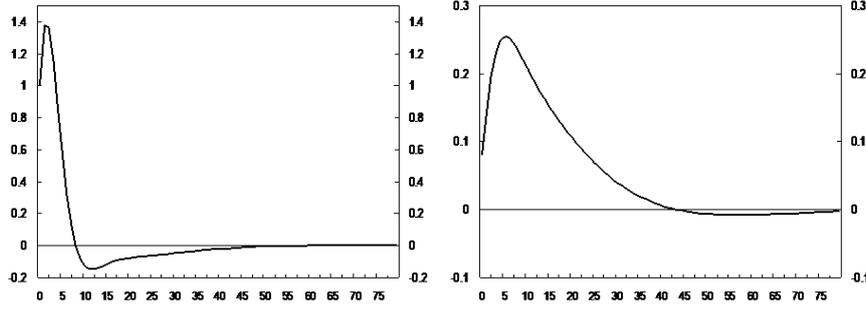
Figure 5 (a-c) show the response in real share prices, real credit and real GDP respectively, to a positive asset price shock. The positive shock is normalized to raise real share prices with one per cent the first quarter. The share price innovation has an immediate effect on credit to firms: the credit aggregate is raised by close to 0.1 per cent the first quarter. The effect peaks after 1 to $1\frac{1}{2}$ years when credit has been pushed up by 0.25 per cent, before the effect slowly vanishes. The asset price shock does also have a contemporaneous (in the same quarter) positive influence on GDP, although the effect is small as expected. An innovation that raises asset prices by 10 per cent will simultaneously increase GDP by 0.1 per cent. The positive stock market effects on credit and GDP in the first and subsequent quarters feed back to asset prices. Thus, share prices continue to increase for two quarters after the shock before the effect starts to fade away. Accordingly, there are mutually reinforcing effects between asset prices, credit and GDP a few quarters after the stock market shock, illustrated by the delayed peak in all three figures. In the long term however, real share prices, real credit and real GDP are all unaffected by the shock.

Correspondingly, figures 6 (a-c) plot impulse responses for the same variables following a positive credit shock, which is normalized to increase real credit to firms with one per cent the first quarter. The credit shock immediately raises real share prices by 1.3 per cent, and the jump in asset prices raises credit, which feeds back to share prices and so on. The result is that real share prices are enhanced by about 2 per cent two quarters after the shock, before the effect gradually dies out. GDP is raised by 0.15 per cent when the shock occurs, and the effect declines thereafter. The positive responses in share prices and production amplify the effect of the credit shock to the credit aggregate, and the innovation has a very persistent influence on credit to firms.

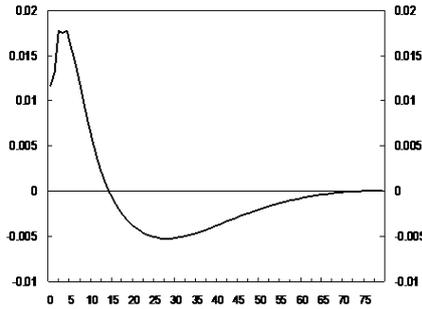
Figures 7 (a-c) show responses to a real GDP shock, where the shock is normalized to increase production with one per cent the first quarter. The shock to production has an immediate and positive effect on share prices and credit. Real share prices jump with almost one per cent while real credit to firms is augmented by nearly 0.75 per cent when the shock emerges. The GDP shock triggers a credit-asset price spiral. The interdependence between asset prices and credit is evident, and the peak in share prices

responses produced in this paper. When we non-the-less have chosen to refer to the orthogonalized impulse responses in the text, this must be understood based on a desire to preserve a structural interpretation of shocks and thus to an implicit disapproval of the potential benefit related to using the estimated structural covariance matrix as a proxy for the true underlying stochastic properties of the model. While such a strategy may at first seem a little bit hard to understand it amounts to little else than to a strategy that should in some sense be complimentary to the preferred design procedure advocated in this paper. In this procedure the reason for not imposing a priori a diagonal structural covariance matrix – and thus as a part of the exactly set of identifying restrictions – is a desire to render the design of the non-stochastic part of the structure as elastic as possible when confronted with data and thus to avoid letting restrictions on the covariance structure interfere with the prospects of ending up with a deterministic structure with good interpretable and statistical properties in the first place. For while using a diagonal structural covariance matrix as a design criterium might be a legitimate thing to do based on theory, it would certainly have clear negative implications for the sample space related to the deterministic part of the structure. The opposite would naturally also be the case. That is, placing restrictions on the deterministic structure and leaving the covariance matrix unrestricted, would have to seep out in a non-diagonal covariance matrix, at least as long as the deterministic structure does not lie in the sub-space related to structures backed out on the basis of imposing a diagonal covariance matrix in the first place.

Figure 5: Orthogonalized impulse responses of an asset price shock



(a) Response to a share price shock. Real share price (per cent) (b) Response to a share price shock. Real credit to firms (per cent)



(c) Response to a share price shock. Real GDP (per cent)

occurs three quarters after the shock while the maximum effect on credit appears three years after the shock. The positive GDP shock could capture a positive productivity shock, and the following dynamic interaction between asset prices and credit to firms reminds clearly of the theoretical mechanisms described in Kiyotaki and Moore (1997), see Figure 1. However, the effect of the shock eventually dies out with respect to all real variables in the model.

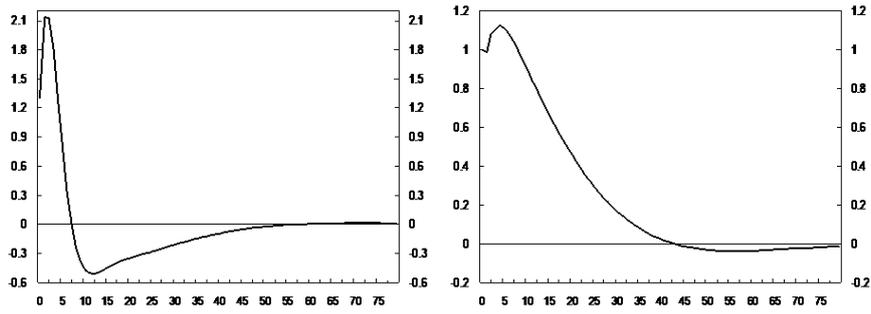
All in all the impulse response analysis demonstrates that the model implies cyclical fluctuations and persistence that gradually dies out in the long term in the wake of shocks. Independent innovations to borrower net worth³² are thus initiating sources of real fluctuations. This stands in contrast to the perfect information case, but is consistent with a model where agency costs introduces cyclical fluctuations into an environment which is not rigged to exhibit such a feature in the long run, when agency costs are not present(see e.g. Bernanke and Gertler (1989)).

Noteworthy, in the wake of sequential shocks to borrower net worth, the credit-asset price spiral reinforced financial accelerator of our SVECM would for some time contribute to bring the economy further and further away from its equilibrium path.³³ However,

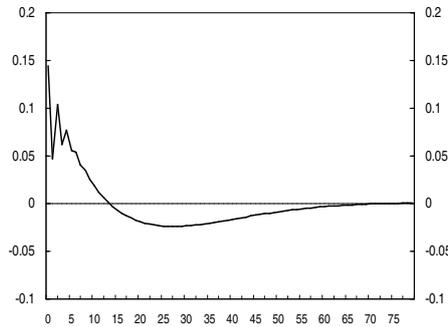
³²And which in the wake of induced changes to agency costs, would lead to a redistribution of income between borrowers and lenders.

³³A possible interpretation of such a sequence of shocks, by accident reminiscent of recent excesses, could e.g. be a persistent bout of irrational exuberance among investors and borrowers a like.

Figure 6: Orthogonalized impulse responses of a credit shock



(a) Response to a credit shock. Real share price (per cent) (b) Response to a credit shock. Real credit to firms (per cent)



(c) Response to a credit shock. Real GDP (per cent)

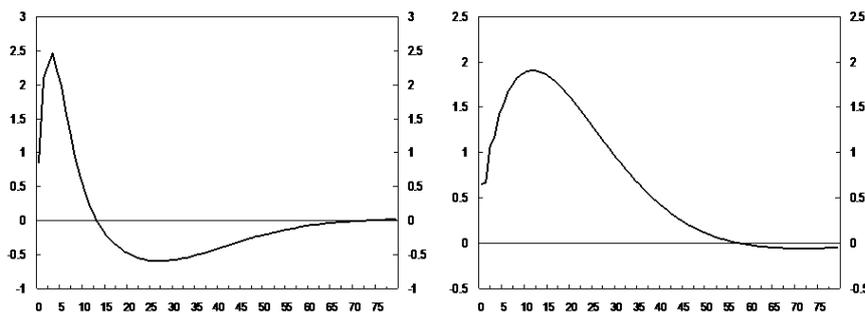
as the process goes on, eventually the economy would reach a crossroads where the equilibrium correcting forces starts to dominate the forces that until then has contributed to drag the economy still further away from its equilibrium path. From then on the disequilibrium position will start to unwind, well supported by a financial accelerator put in reverse. As suggested by the Figures 5-7, this unwinding of former excesses will not necessarily happen through a smooth reversal to the long run equilibrium path of the economy, but go through an interim period where the economy undershoots its long run equilibrium path before converging towards it in the long run.³⁴

5 Conclusions

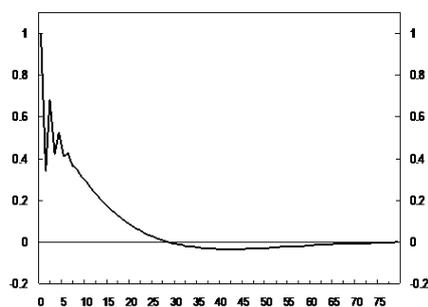
This paper addresses how to enhance the role of data in structural modeling by proposing a procedure of Simultaneous Structural Model Design. In this procedure particular emphasis is placed on handling the inherent problem of a potential simultaneity bias in design by resorting to an approach where all behavioral equations of a system are reduced and designed jointly. A central ingredient of such a procedure is the use of structural breaks as auxiliary tools of exact identification. This renders possible a design process

³⁴Given off course there are no further shocks to the economy.

Figure 7: Orthogonalized impulse responses of a real activity shock



(a) Response to a real activity shock. Real share price (per cent) (b) Response to a real activity shock. Real credit to firms (per cent)



(c) Response to a real activity shock. Real GDP (per cent)

where data are allowed to speak, i.e., a process where both the ordering of the variables and the contemporaneous structure of the model is the outcome of a testable dialog with the data.

In general, the outcome of such a process of Simultaneous Structural Model Design will involve an element of arbitrariness in that it depends on how the structural model was exactly identified. To add to the reliability of the final outcome it is therefore imperative to give credence to the identification scheme being used. In so doing, not only to the restrictions being imposed, but also to the extent that the auxiliary tools being used to exactly identify the system makes sense in the sense of having a potential structural and behavioral interpretation. To legitimate this being the case we have in this paper had to resort to some ad hoc reasoning, a fact that clearly illustrates that there is no such thing as a free lunch when it comes to exact identification. Whether one combines the imposition of a diagonal covariance matrix with SVAR-like restrictions on the contemporaneous feedback matrix or utilizes exogenous information in the form of structural breaks, one will never be able to fully free oneself from the curse of arbitrariness. However, to ignore using identification promoting exogenous information when it exists, is clearly not optimal in this respect, as it would represent a huge disservice to the aim of constructing models informed by data. In particular, such kind of information would enable us to avoid laying the exact identifying restrictions on information laden parts of the model, and to leave such kind of restrictions at the discretion of the data.

To illustrate the procedure and to study the simultaneous interplay between financial variables and the real side of the economy, a simultaneous equation model is constructed on Norwegian aggregate quarterly data. In the case of Norway, it turns out that to illustrate the working of a financial accelerator, in the setting of a fully simultaneous equation model that adequately and congruently portrays the evolvement of the real economy, one can do with a surprisingly small information set. In fact in addition to real GDP, the information set that forms the basis of our preferred simultaneous equation model comprises stock prices, an indicator of domestic credit and oil prices only. Though one evidently must exercise caution in drawing too strong conclusions based on such a simple and stylized description of the causal interplay between the real and financial economic spheres, it is nevertheless our firm belief that the model developed herein serves to illustrating some interesting real society traits or features. Not least due to the reasonableness of results and the model's good statistical properties.

As regards the results the model substantiates the leading indicator properties of the financial variables through the identification of a financial accelerator. However, what is interesting and new in this respect compared to former research, is the identification of a mechanism through which this accelerator is amplified and reinforced; A so called credit-asset price spiral. Such a finding is fully in accordance with new theoretic insight and, in this respect, the model developed in Kiyotaki and Moore (1997) in particular. As regards the long run structure of our simultaneous equation model we have been able to identify a one-to-one relationship between credit and stock prices in the long run. However, no such long-run relationship is found to tie together the real and financial side of the economy. Thus, while innovations to asset prices and credit do cause short run movements in production via the working of a financial accelerator, such innovations do not precede real economy movements in the long run. Noteworthy, this stands in contrast to what is found in Beaudry and Portier (2004, 2005) who find that shocks to stock prices have a lasting long run effect on the real economy. In the paper this dichotomy of model property is well illustrated by the impulse responses as the model implies cyclical fluctuations and persistence that gradually dies out in the long run in the wake of temporary shocks to credit or asset prices. Thus independent shocks to e.g. borrower net worth is an initiating source of real fluctuations. This stands in contrast to the perfect information case, but is consistent with a model where agency costs introduces cyclical fluctuations into an environment which is not rigged to exhibit such a feature in the long run.

All in all, the results contributes to reconcile the two opposing views of the literature. In the short run we find empirical evidence of a financial accelerator where credit to firms, asset prices and aggregate economic activity interact over the business cycle. However, while innovations to asset prices and credit do cause short run movements in production, and while real activity spurs credit, such innovations do not precede real economy movements in the long run. Hence, it might still turn out to be somewhat premature to scrap the empirical relevance of the Modigliani-Miller theorem altogether based on empirical evidence.

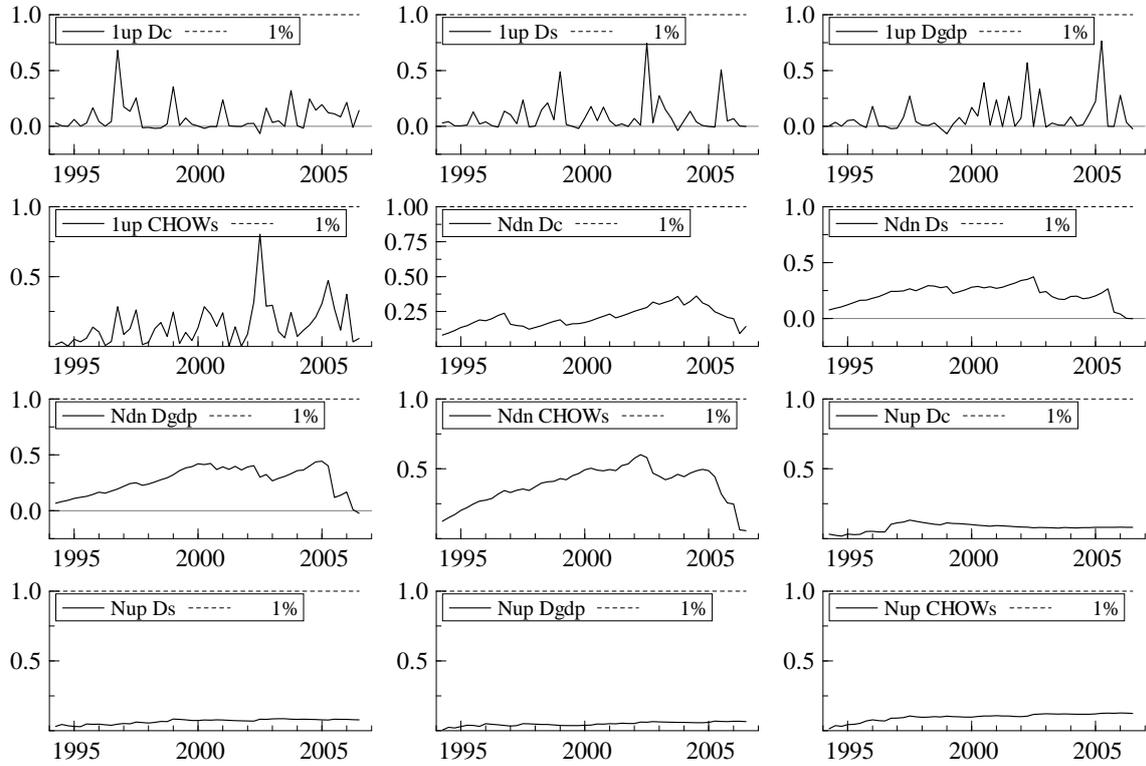
References

- Beaudry, P. and F. Portier (2005), ‘The news view of economic fluctuations: Evidence from aggregate Japanese data and sectoral U.S. data’, *Journal of the Japanese and International Economies* **19(4)**, 635–652.
- Beaudry, P. and F. Portier (2006), ‘Stock prices, news and economic fluctuations’, *American Economic Review* **96(4)**, 1293–1307.
- Bernanke, B. (1986), ‘Alternative explanations of the money-income correlation’, *Carnegie-Rochester Conference Series on Public Policy* **25**, 49–99.
- Bernanke, B. and M. Gertler (1989), ‘Agency costs, net worth, and business fluctuations’, *American Economic Review* **79(1)**, 14–31.
- Bernanke, B., M. Gertler and S. Gilchrist (1999), The financial accelerator in a quantitative business cycle framework, in J. Taylor and M. Woodford, eds, ‘*Handbook of Macroeconomics*’, Vol. 1, Elsevier Science B.V., pp. 1341–1393.
- Blanchard, O.J. and D. Quah (1989), ‘The dynamic effects of aggregate demand and supply disturbances’, *American Economic Review* **79**, 655–673.
- Blanchard, O.J. and M.W. Watson (1986), *Are Business Cycles all alike?*, Chicago, University of Chicago Press, pp. 123–156.
- Dell’Ariccia, G. and P. Garibaldi (2005), ‘Gross credit flows’, *Review of Economic Studies* **72(3)**, 665–685.
- Doornik, J. A. and D.F. Hendry (2001), *PcGive 10: Empirical Econometric Modelling using PcGive*, London, Timberlake Consultants Press.
- Ericsson, N.R. and H.A. Tran (1990), ‘Pc-give and David Hendry’s econometric methodology’, *Revista de Econometrica* **10**, 7–117.
- Gali, J. (1992), ‘How well does the IS-LM model fit postwar U.S. data?’, *Quarterly Journal of Economics* **107(2)**, 709–738.
- Gertler, M. and C.S. Lown (1999), ‘The information in the high-yield bond spread for the business cycle: Evidence and some implications’, *Oxford Review of Economic Policy* **15(3)**, 132–150.
- Hammersland, R. (2008), ‘Classical identification: A viable road for data to inform structural modelling?’. Statistics Norway, Discussion Papers. No. 562.
- Hammersland, R and C Bolstad Træe (2014), ‘The financial accelerator and the real economy: A small macroeconomic model for Norway with financial frictions’, *Economic Modelling* **36**, 517–537.
- Hendry, D.F. (1993), *Econometrics: Alchemy or Science? Essays in Econometric Methodology*, Oxford, Blackwell Publishers.

- Hendry, D.F. (1995), *Dynamic Econometrics*, Oxford, Oxford University Press.
- Hubbard, R.G. (1998), ‘Capital market imperfections and investment’, *Journal of Economic Literature* **36**, 193–225.
- J. O’Neill, A. Stupnytska and J. Wrisdale (2011), ‘Linking GDP Growth and Equity Returns’, *Monthly Insights From The Office Of The Chairman, Goldman Sachs Asset Management* .
- Johansen, S. (2006), Confronting the economic model with the data, in D.Colander, ed., ‘*Post Walrasian Macroeconomics: Beyond the Dynamic Stochastic General Equilibrium Model*’, Cambridge University Press, pp. 287–300.
- Kiyotaki, N. and J. Moore (1997), ‘Credit cycles’, *Journal of Political Economy* **105**(2), 211–248.
- Lown, C. and D. Morgan (2006), ‘The credit cycle and the business cycle: New findings using the loan officer opinion survey’, *Journal of Money, Credit and Banking* **38**(6), 1575–1597.
- Modigliani, F. and M. Miller (1958), ‘The cost of capital, corporation finance, and the theory of investment’, *American Economic Review* **48**, 261–297.
- Mody, A. and M.P. Taylor (2004), ‘Financial predictors of real activity and the financial accelerator’, *Economic Letters* **82**(2), 167–172.
- Paustian, M. (2007), ‘Assessing sign restrictions.’, *The B.E. Journal of Macroeconomics (Topics)* **7**(1), 1–37.
- Ritter, J.R. (2005), ‘Economic growth and equity returns’, *Pacific-Bain Finance Journal*) **13**(5), 489–503.
- Romer, Christina D. and David H. Romer (2004), ‘A new measure of monetary shocks: Derivation and implications’, *American Economic Review* **94**(4), 1055–1084.
- Romer, Christina D. and David H. Romer (2010), ‘The macroeconomic effects of tax changes: Estimates based on a new measure of fiscal shocks’, *American Economic Review* **100**(3), 763–801.
- Shapiro, M.D. and M.W. Watson (1988), *Sources of Business Cycle Fluctuations*, Cambridge, MA: MIT Press.
- Sims, C. A. (1980), ‘Macroeconomics and reality’, *Econometrica* **48**, 1–48.
- Swiston, A. (2008), A U.S. financial conditions index: Putting credit where credit is due. IMF Working Paper No. 08.
- Townsend, R. M. (1979), ‘Optimal contracts and competitive markets with costly state verification’, *Journal of Economic Theory* **21**, 265–293.
- Uhlig, H. (2005), ‘What are the effects of monetary policy on output? results from an agnostic identification procedure’, *Journal of Monetary Economics* **52**(2), 381–419.

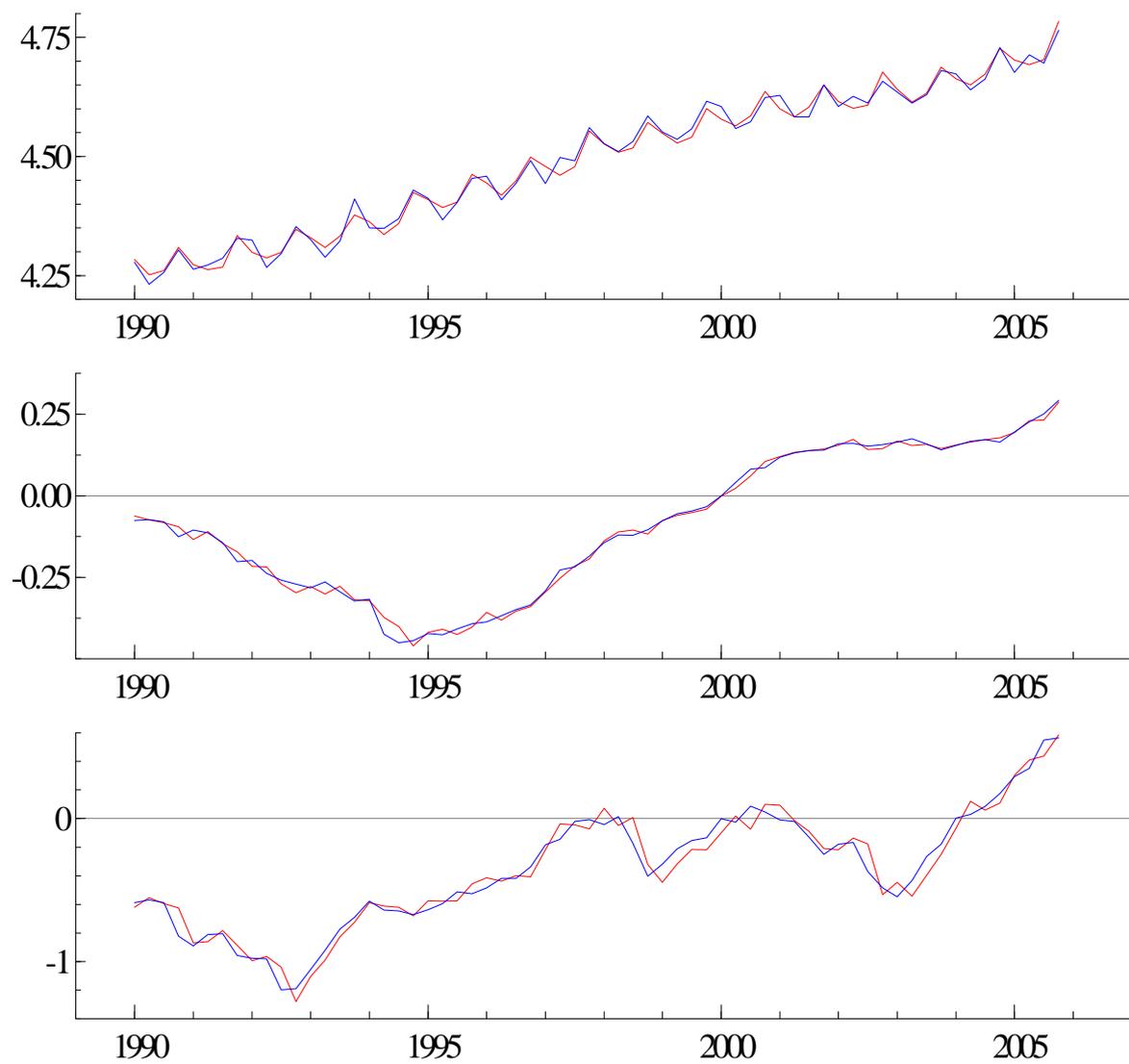
Appendix A

Figure 8: Stability tests



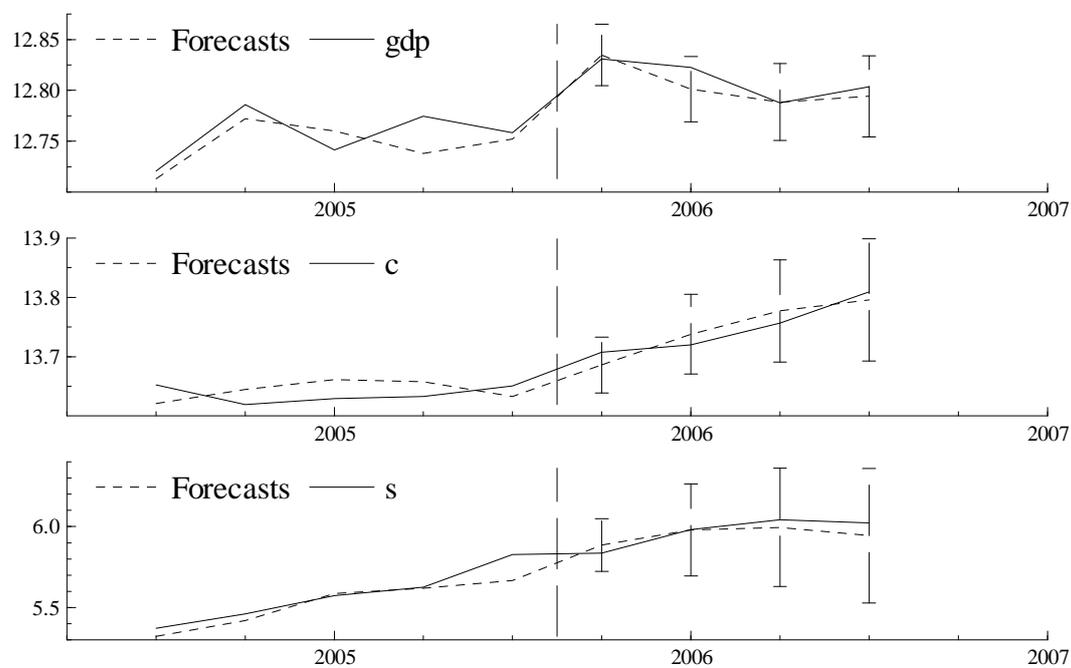
¹⁾ The single equation stability tests are respectively represented by the 1-step forecast tests (1up), Break-point F-tests (N down) and the Forecast F-tests (Nup) tests while the vector tests are represented by the corresponding Chow tests.

Figure 9: Actual and fitted values of GDP Mainland Norway, real domestic credit to enterprises, C, and real equity prices, S. Logarithmic scale. 1986Q2 to 2006Q3



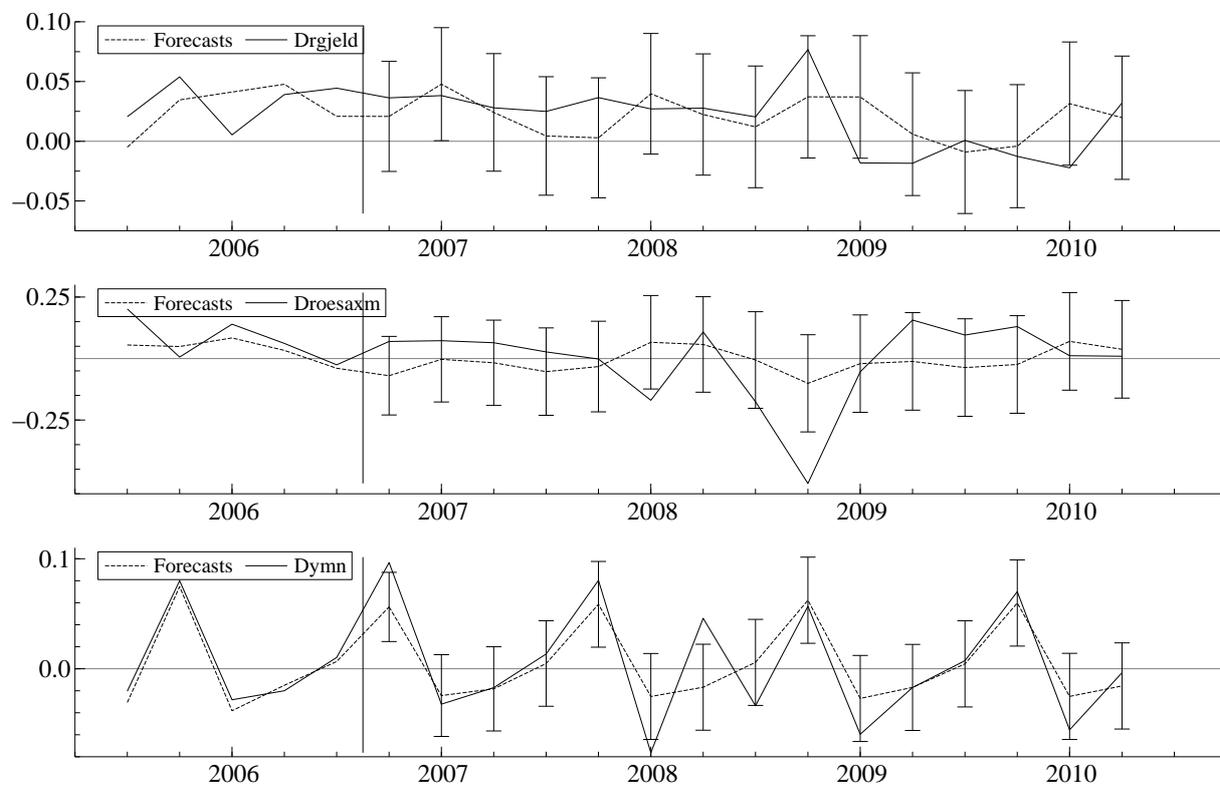
1) The red line symbolizes the fitted values while the blue line represents the actual ones.

Figure 10: Forecasted values of GDP Mainland Norway, real domestic credit to enterprises, C, and real equity prices, S, four quarters ahead from 2005Q3. Logarithmic scale. 2005Q3 to 2006Q3



1) The forecasts are represented by the red line while the the blue lines represents the actual values.

Figure 11: Ex ante forecasts of quarterly growth in real domestic credit to enterprises, Drgjeld, real equity prices, Droesaxm, and GDP Mainland Norway, Dymn, four quarters ahead from 2006Q3. Logarithmic scale. 2006Q3 to 2010Q2



1) The forecasts are represented by the red line while the the blue lines represents the actual values.