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A financial accelerator in the business sector of a macroeconometric model of a small open economy☆

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ABSTRACT

We have incorporated a financial accelerator mechanism operating through investments in the business sector in a dynamic macroeconometric model of the Norwegian economy. In this new and amended model aggregated credit and equity prices are determined simultaneously in a system characterized by a two-directional contemporaneous causal link, which has been designed and estimated by a new procedure for simultaneous structural model design. Combined with a mechanism where credit and asset prices are mutually influenced by real investments, this creates a financial accelerator amplified by a credit-asset price spiral. Simulations illustrate how the introduction of a financial accelerator significantly reinforces and extends the economic cycles in projections and forecasts, in particular when confronted by a severe shock. Furthermore, monetary policy has a markedly stronger effect in the short and medium term, while the impact of fiscal policy is affected to a relatively small degree as it is more remotely linked to financial markets.

1. Introduction

The idea that conditions in credit markets could affect business cycles has had broad support in the economic literature for many years; see, for example, Hubbard (1998) and Bernanke et al. (1999). The theory of a financial accelerator postulates a reciprocal relationship between access to credit and fixed investment that helps amplify cyclical fluctuations, see Bernanke and Gertler (1989). Kiyotaki and Moore (1997) took this further by introducing an explicit equity price and credit spiral. There has emerged a substantial empirical literature that largely found support for a relationship between (various indicators of) credit availability and macroeconomic fluctuations, see for example Silvestrini and Zaghinib (2015). These works were based largely on the equilibrium models of the real business cycle literature (RBC) (see Kydland and Prescott, 1982; Hartley et al., 1998). In addition, to some extent there are implemented financial accelerator mechanisms in the so-called new Keynesian DSGE models (see Smets and Wouters, 2007; Christensen and Dib, 2008). However, few attempts have been made to incorporate such a mechanism into structural macroeconometric models. An exception is Hammersland and Træe (2014), where two reciprocal and interacting financial accelerator mechanisms are implemented in a macroeconometric model (Bårdsen and Nymoen, 2009) to study the effect of different types of shocks on the financial stability of the Norwegian economy. This model is, however, highly aggregated, and although it contains financial accelerators with origins in both the household and business sectors, the interaction between the real economy and the financial variables happens directly via aggregate production (GDP Mainland Norway) and not, as according to economic theory, via

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its structural sub-components, household consumption and business investment, respectively.

This paper documents the estimation and implementation of a financial sub-model in a structural macroeconometric model for the Norwegian economy, KVARTS, partly inspired by Hammersland and Træe (2014).[1] However, our implementation is more disaggregated and theory consistent than in previous studies, 1) in that the financial variables affect investment directly and 2) by taking into account that the effect of changing credit and equity prices on investments can be industry-specific. KVARTS is expanded by a financial sub-model where aggregate credit and equity prices in Norway are determined simultaneously in a system characterized by a two-directional contemporaneous causal link, designed and estimated with the help of a new procedure for simultaneous structural model design (Hammersland, 2017). Moreover, the equations in KVARTS for capital formation in each industry are expanded with aggregate credit and/or Norwegian equity prices. The industry-specific real capital is then aggregated to total capital formation, in which the change from one point in time to the next is defined as investment in the same period and included as an explanatory variable in the financial sub-model. Thus, equity prices and credit in this model affect real investments, which in turn affect equity prices and credit, and so on.

In the financial sub-model, aggregate credit to the mainland industry in the long term is determined by Norwegian equity prices, represented by the Oslo Børs benchmark index and aggregate business investment in mainland Norway, in the short term also by real interest rates, all deflated by the deflator for GDP Mainland Norway. Norwegian equity prices are in the long term determined by international equity prices, represented by the global equity price index Morgan Stanley Capital International World (MSCI), real oil prices and the real interest rate, in the short term also by credit to non-financial corporations in mainland Norway (henceforth referred to as credit).

In KVARTS, gross fixed capital formation (JK) is divided into two main groups of industries; 1) investments in extraction and pipeline transport, and 2) investment in mainland Norway.[2] Investments in the latter group can be divided further into a) investments in public administration, which is an exogenous variable in the model, b) housing investment, which is determined in a separate sub-model for the housing market, where there is also an accelerator mechanism between credit and investment (see Anundsen and Jansen, 2013), and c) business investments, which is the group of industries directly affected by the financial accelerator presented in this paper.

The capital stock is determined in KVARTS by 13 estimated, industry-specific equations. The explanatory variables are production and relative factor prices and other relevant variables, such as employment.[3] Norwegian equity prices and credit are only included in the short-term dynamics of each equation, and consequently do not affect capital stock in the long term. This is in line with the Modigliani-Miller theorem (Modigliani and Miller, 1958). We find support for an effect of Norwegian equity prices and/or credit in all equations. Gross investment in each industry appears by definition as the change in capital stock from the period before, adjusted for depreciation.

The importance of the financial accelerator for the economy as represented in KVARTS is illustrated by three exogenous shifts and a counterfactual experiment that is based on a fairly recent experience related to the Norwegian economy. We start with a shift in the global equity price index, MSCI, which only appears in the financial sub-model. A permanent increase of 10 percent in the MSCI leads to a rise in Norwegian equity prices of 10 percent during the first two quarters, followed by a rapid decline gradually decreasing in strength, and converging towards a long-term effect of approximately 5 percent after 6–7 years. As credit and (Norwegian) equity prices are only included in the short-term dynamics of the capital equations, we only get a short-term increase in business investment at just over 1 percent, which gradually disappears within ten years. We then show the *additional* effect of changes in the money market rate and public demand, respectively, which is attributable to the financial accelerator in KVARTS. A permanent reduction in the three-month money market rate of 1 percentage point leads to a short-term *additional* increase in business investment of 1.4 percent after three years due to the financial accelerator. After 8–10 years this effect is gone. Next, a permanent increase in government consumption, investment and employment by 1 percent provides only a marginal *additional* increase in business investment. The *additional* effect is weak because there is no direct link in the model from public spending to business investment and financial markets. Finally, we look at a counterfactual shock to oil prices and oil investments where these quantities, instead of following their historical paths[4] given by the baseline scenario, are set to follow a random walk, basically implying that we maintain the level of these variables at the beginning of 2013 over the entire simulation period. As the data of our baseline scenario implies a substantial and protracted fall in oil prices as well as oil investments of close to, respectively, 40 and 30 percent at the end of the historical sample period in 2017 and only a gradual increase thereafter, this would amount to a substantial boost to the Norwegian economy. If we look at the *additional* effects of such a counterfactual shift that are due to the inclusion of a financial variable per se, these clearly turn out to bear out the relative importance of the financial accelerator in the wake of shocks, as the *additional* effect attributed to

[1] KVARTS is developed by the research department of Statistics Norway. A full description of KVARTS is beyond the scope of this paper. See Boug et al. (2013a, Appendix A) for an outline of KVARTS. We also refer to Bowitz and Cappelen (2001); Boug et al. (2006); Boug and Fagereng (2010); Benedictow and Boug (2012); Jansen (2013) and Boug et al. (2013a, 2013b) and Hungnes (2016) for descriptions of the main sub-sections of the model.

[2] Strictly speaking we could also include investments in shipping as a third group here. However, these investments amounted to just 1 percent of the total gross fixed capital formation in 2014. By comparison, 1) was about 29 percent, while 2) a, b and c represented 30, 21 and 20 percent, respectively.

[3] Employment (hours worked) is determined in a factor demand system in the same way as real capital, by production and relative factor prices, and, additionally, technological progress (represented by a deterministic trend).

[4] As this experiment is based on simulating the model from the beginning of 2013 to the end of 2020, the last part of the historic data refers to our quarterly forecasts for the period that goes beyond the period for which we have actual data.

such a model extension is simulated to give an additional boost of close to 1 percent to GDP.

Our results show that introducing a financial accelerator significantly reinforces and extends the economic cycles in the projections and forecasts in KVARTS. In particular, assumptions about future developments in international equity prices prove important for the estimated business cycle. Monetary policy gets a markedly stronger effect in the short and medium term, while the impact of fiscal policy is affected to a relatively small degree. As far as the counterfactual experiment is concerned, it clearly contributes to demonstrating the intensive role of the financial accelerator in the propagation of severe shocks.

In Section 2, we explain the theoretical background of a financial accelerator and discuss the estimation results for the financial sub-model. In Section 3 we discuss the background for the capital equations in KVARTS, which is the point of connection for the financial sub-model, and the estimation results. In Section 4 we highlight the impact of introducing a financial accelerator into a large macroeconomic model by comparing the effects of shifts in exogenous variables in KVARTS *with* and *without* the financial accelerator. Section 5 summarizes and concludes.

2. The financial sub-model

2.1. Procyclicality and the financial accelerator

The main point of connection between the real economy and financial markets is the private sectors' need for the external financing of investments. External financing can be obtained either through an expansion of equity by issuing shares or by increasing foreign capital through borrowing.

The hypothesis of a financial accelerator assumes that equity prices are procyclical. Increased economic activity will lead to higher equity prices, which in turn can give rise to increased investments, higher production and so on. Such a self-reinforcing mechanism can be explained by standard economic theory. For example, procyclical behavior in the business sector can be justified by increasing equity prices causing the market price of capital to increase relative to its replacement cost, the relationship known as Tobin's Q (Tobin, 1969). This in turn, increases investments.[5]

However, what is known as a financial accelerator in the literature is strictly speaking an addition to the classic procyclicality described above and arises from the presence of so-called financial frictions. Financial frictions denote conditions that disrupt the players' behavior in the financial market, and in principle cover all costs associated with financial transactions, be it fees, taxes, time spent, asymmetric information, etc. (see, for example, Brunnermeier et al., 2012, for a literature review). Asymmetric information can for instance cause banks to limit their lending to investors who cannot provide sufficient collateral, so that otherwise profitable investments are not being undertaken. Under such circumstances, previously rationed investors may increase borrowing and realize new investments as higher equity prices boost collateral. This may in turn cause the equity prices to rise further, and so on. This illustrates how a financial accelerator with a credit and equity price spiral may reinforce economic cycles.

Financial frictions are one possible explanation for deviations from the classical financial theory of market adjustments and the hypothesis of efficient markets launched by Eugene Fama (1965).[6] Stiglitz and Weiss (1981) and Stiglitz (1982) argue that asymmetric information in particular poses a significant problem and can explain financial instability as well as financial crises. See Brunnermeier (2001, 2008) for literature surveys on bubbles and financial frictions and Jermann and Quadrini (2012) and Hirano and Yanagawa (2016) for more recent studies. The international financial crisis around 2008 intensified the interest in financial frictions and their effects on the real economy. Hall (2011) finds empirical evidence for the existence of such frictions and the importance for financial markets as well as the real economy. Stiglitz (2010) argues that the effects are significant and that the authorities may advantageously reduce frictions through economic policies. Adrian et al. (2013) also find some evidence for financial frictions, although the business sector's overall access to financing due to the financial crisis was largely maintained because bank lending was to a great extent replaced by bonds. Hammersland and Træe (2014) find clear evidence for financial frictions in the Norwegian economy.

2.2. Empirical results for the financial sub-model

The financial sub-model in KVARTS consists of two econometric equations where aggregate credit[7] and equity prices are determined simultaneously and interactively, and total gross investments in the business sector is included as an explanatory variable.[8] This specification will capture the presence of both classical procyclicality and a financial accelerator as described above, but cannot tell them apart. For simplicity, we will refer to all procyclicality arising through the financial sub-model in KVARTS as a "financial accelerator".[9]

[5] Friedman's permanent income hypothesis (Friedman, 1957) describes a similar mechanism in the household sector, linked to a positive wealth effect on consumption.

[6] The field of behavioral finance offers an alternative explanation model, which is not bound by classical economic assumptions about rational actors and efficient markets, but instead has its basis in psychology discipline hypotheses about human behavior. This path is not followed in the present paper (see, for example, Diamond and Vartiainen, 2012, for a discussion).

[7] Actual credit, i.e. the market solution: We are not able to distinguish between supply and demand for credit.

[8] A large proportion of non-financial enterprises in mainland Norway is not listed, but the main index on the Oslo Stock Exchange can be an indicator for the development in unlisted companies as well.

[9] Two alternative methods were considered for incorporating a financial accelerator in KVARTS. The second was to estimate new equations for

The financial accelerator is estimated and designed simultaneously with a new procedure for simultaneous structural model design (Hammersland, 2017).[10] Based on an exact identified general model structure, the final dynamic model is designed and estimated simultaneously using the maximum likelihood method. The first step in this procedure is to identify the long-run solution using the methodology of Johansen (1995). There we found support for three cointegrating vectors for credit, equity prices and aggregate investments, respectively. Credit is homogeneous of degree one in equity prices and investment, while the equity price is homogeneous of degree 1 in oil prices and international equity prices, plus an additional interest rate effect. Investment is a function of the relationship between equity prices and the replacement cost of capital, i.e. Tobin's Q. As investments in KVARTS are already determined by the capital equations, the investment equation in the estimated system is replaced by aggregate investments as determined in KVARTS, i.e. the identity presented in Eq. (7) in Section 3.1. Thus, when we estimate the dynamic simultaneous structure in Eq. (1), the investment equation is taken out of the system.[11] The broad (real) equity price index on the Oslo Stock Exchange (*rborsi*, hereafter referred to as Norwegian equity prices) and real credit to non-financial corporations in mainland Norway (*rk2nff*, hereafter referred to as credit) is precisely identified by assuming that the deviation of credit from its long-term equilibrium, *rk2nff*-0.77*rborsi*-0.23*jk*, where *jk* is real industry investments, only helps to explain the structural, dynamic course of credit, while disregarding contemporary effects from changes in international equity prices (msci) in the dynamic relation for real credit.[12],[13],[14]

$$\begin{pmatrix} 1 & b_{12} \\ b_{21} & 1 \end{pmatrix}\begin{pmatrix} \Delta rk2nff \\ \Delta rborsi \end{pmatrix}_t = \sum_{j=1}^{k}\Gamma_{y,j}\begin{pmatrix} \Delta rk2nff \\ \Delta rborsi \end{pmatrix}_{t-j} + \sum_{j=1}^{k}\Gamma_{x,j}\begin{pmatrix} \Delta jk \\ \Delta rpoil \\ \Delta msci \\ \Delta RR \end{pmatrix}_{t-j} + \Theta D_t$$
$$+\begin{pmatrix} \alpha_{11} & \alpha_{11} \\ 0 & \alpha_{22} \end{pmatrix}\begin{pmatrix} rk2nff - 0.77rborsi - 0.23jk \\ rborsi - 0.5rpoil - 0.5msci + 0.04RR \end{pmatrix}_{t-1} + \begin{pmatrix} \gamma_{11} & \gamma_{12} & 0 & \gamma_{13} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{33} \end{pmatrix}\begin{pmatrix} \Delta jk \\ \Delta rpoil \\ \Delta msci \\ \Delta RR \end{pmatrix}_t \quad (1)$$

Other explanatory variables in the system are the real oil price in Norwegian kroner ($rpoil_t$), the real interest rate (RR_t) and

(*footnote continued*)
investments in every single industry, where the industry-specific investments, aggregate credit and equity prices were estimated simultaneously as a three-dimensional structure. Applying this methodology, however, only two industries (81 and 85) turned out to be suitable for empirical modeling in line with economic theory. It may be that there are conditions in macro that are not captured in the disaggregated figures. Another problem was that we did not have access to industry-specific figures for credit and equity prices. Thus, we concluded that the most appropriate approach is to estimate the financial accelerator at an aggregated level and consequently include aggregate credit and equity when estimating the industry-specific capital equations, as described in this report.

[10] To give the reader an idea of what this procedure is all about, we here give a brief account of the steps involved (for a more profound and detailed treatment, the interested reader is referred to Hammersland, 2017). The point of departure in the general case is an n-dimensional conditional reduced form VAR of order k where the conditional set of variables, in addition to including ordinary exogenous variables, deterministic terms and dummies, possibly includes a set of "structural" variables that can later serve the role of auxiliary tools to help with the exact identification of the structural model, both in the long and short run. Starting out with what hopefully constitutes a congruent general unrestricted reduced form model (GUM), the first step then involves reducing the model down to a more parsimonious order and then to undertake the long-run analysis (identification, design and estimation) on this version of the model by resorting to the multidimensional procedure of Johansen (1995). In addition to theory, exogenous and deterministic variables with a structural information content (earlier referred to as "structural" variables) can here be utilized to accomplish exact identification. Given exact identification is accomplished, the next step then involves designing the parsimonious version of the long-run structure by letting theory in conjunction with a test of overidentifying restrictions inform the rest of the long-run design process. Having thus arrived at the long-run structure of the model, one then maps the reduced form of the model over to a structural representation (or form) utilizing some of the "structural" exogenous variables included at the outset as tools of exact identification, possibly in conjunction with restrictions on the long-run feedback structure of the model. It is important in this respect to realize that by utilizing so-called structural exogenous information, or restriction on the long-run feedback structure, we can thus accomplish exact identification without having to resort to procedures imposing non-testable restrictions on either the contemporary feedback matrix or the covariance matrix, both attended with highly contentious and controversial issues given their important role in conditioning the properties of the model. After having designed the long-run structure and exactly identified the dynamic structure, conditional on this, the last and final step of the procedure then involves a fully simultaneous and structural reduction (or design) process where all the structural equations are jointly designed by letting tests of overidentifying restrictions inform the reduction process.

[11] See Appendix B Table B.5 for the econometric specification of the long-run aggregate investment relationship. Confer also footnote 15.

[12] All variables are deflated by the GDP deflator for mainland Norway, except MSCI, which is interpreted as an indicator of developments in international financial markets.

[13] This is just one of many possible ways of accurately identifying (initializing) the design process. Alternatively, one could for example have chosen to ignore the fact that a discrepancy between one of the endogenous variables and its long-term solution can affect the dynamic course of one of the other endogenous variables in the system. One could also have made use of a priori information on the structural properties of some of the deterministic variables in D_t (structural dummy variables), while imposing alternative restrictions on the system's Γ-matrices, i.e. on the coefficients that capture the effects of exogenous factors and lags of the dependent variable, is as another option.

[14] The long-term structure here is overidentified and represents the result of a long-term analysis where the exact identifiable restrictions imply the absence of oil price/international stock price effects in the credit equation and homogeneity of degree one between real stock prices, real oil prices and international equity prices in the long-term solution for equity prices. As in the case of the dynamic structure, this is just one of many ways of accurately identifying the long-term structure.

deterministic variables (D_t) like a constant, seasonal dummies and dummies for structural breaks. Lower case letters indicate logs and Δ indicates change from the preceding period. Θ, Γ_x and Γ_y represent coefficient matrices for the effects of deterministic variables and dynamics, while b, γ and α represent coefficients that capture effects of the contemporary causal relationship between the model endogenous variables, contemporary dynamic effects of changes in exogenous factors and equilibrium correction. Because of a general lack of automatic "general to specific" modeling algorithms for structural systems, the structural design and reduction process has been carried out manually on quarterly data from Q1 1991 to Q4 2013. The result of this process is given by (2) and (3).[15],[16]

$$\Delta rk2nff_t = 0.04\Delta^2 rborsi_t + 0.03\Delta jk_{t-2} - 0.003\Delta RR_t + 0.24\Delta rk2nff_{t-4} - 0.06(rk2nff - 0.77rborsi - 0.23jk)_{t-1} \quad (2)$$

$$\Delta rborsi_t = 2.79\Delta rk2nff_t - 0.03\Delta RR_t + 0.80\Delta msci_t + 0.27\Delta msci_{t-1} + 0.17\Delta msci_{t-2} + 0.22\Delta rpoilnok_{t-1} - 0.19\Delta rpoilnok_{t-1} - 0.46(rborsi - 0.5rpoilnok - 0.5msci + 0.04RR)_{t-1} \quad (3)$$

In Eq. (2), credit in the long run is determined by Norwegian equity prices and aggregate investments in fixed capital. Additionally, short-term real interest rates are included in the short term (as well as lags of the dependent variable). Eq. (3) shows how Norwegian equity prices can be explained by the real oil price, international equity prices and real interest rates in the short and long term, as well as credit in the short term. See Appendix B for more detailed estimation results and tests.

Fig. 1 illustrates the dynamic projections of the simultaneous structural equation systems (2) and (3) within the estimation period from Q3 2007 to Q4 2013. The fit is relatively good throughout this period, even through the financial crisis in autumn 2008.[17]

The financial sub-model described above is connected to KVARTS via investments, as determined in the estimated industry-specific equations for capital, where Norwegian equity prices and credit are included as explanatory variables, as explained in the following section.

3. Demand for capital

3.1. Modelling of industry investments

Industry investments are determined endogenously in KVARTS through 13 industry-specific, estimated equations for real capital. The explanatory variables in these capital equations have traditionally been production and relative factor prices, plus other relevant variables such as employment, as shown in

$$\Delta k_{i,t} = \alpha_i + \sum_{j=1}^{5} \alpha_{K,i,j}\Delta k_{i,t-j} + \sum_{j=0}^{5} \alpha_{X,i,j}\Delta x_{i,t-j} + \sum_{j=0}^{5} \alpha_{P,i,j}\Delta p_{i,t-j} + \sum_{j=0}^{5} \alpha_{Z,i,j}\Delta z_{i,t-j} + \beta ecm_{i,t-1}, \quad (4)$$

where $k_{i,t}$ is real capital, $x_{i,t}$ production, $p_{i,t}$ relative factor prices and $z_{i,t}$ represents other relevant variables in industry i, period t. α and β are estimated parameters. The long-term solution for real capital is given by

$$ecm_{i,t} = k_{i,t} + p_{i,t} - \frac{1}{\kappa}x_{i,t} + \frac{1}{\kappa}\gamma_i trend \quad (5)$$

where κ is the elasticity of scale and γ captures technological development. These two parameters are estimated in a system, as they are common to the demand of all inputs within each industry, see Hungnes (2016). In the present paper, we extend the factor demand relationships (4) by including aggregate credit (c) and equity prices (a) in the short-term dynamics, the latter in addition to the capital cost involved in the long-term relationship through the user cost of capital, so that

$$\Delta k_{i,t} = \alpha_i + \sum_{j=1}^{5} \alpha_{k,i,j}\Delta k_{i,t-j} + \sum_{j=0}^{5} \alpha_{x,i,j}\Delta x_{i,t-j} + \sum_{j=0}^{5} \alpha_{p,i,j}\Delta p_{i,t-j} + \sum_{j=0}^{5} \alpha_{z,i,j}\Delta z_{i,t-j} + \sum_{j=0}^{5} \alpha_{c,j}\Delta c_{t-j} + \sum_{j=0}^{5} \alpha_{a,j}\Delta a_{t-j} + \beta ecm_{i,t-1}, \quad (6)$$

where c_t is credit to non-financial corporations and a_t represents the main index on the Oslo Stock Exchange at time t. Note that for credit and equity prices, we use the same aggregate variable in all equations. This is because we do not have data available for these variables at the industry level. This simplification implies assuming that aggregate credit and equity prices are good indicators for all

[15] Actually, the structural design process as described in Hammersland (2017) and summarized in Appendix B was originally undertaken on a three-dimensional structure for the fully simultaneous determination of credit, asset prices and aggregate investment. However, as the investment equation in Appendix B Table B.5 is redundant for the practical implementation of the financial accelerator in KVARTS and the partial model of credit and asset prices in Eqs. (2) and (3) is not only included in the system represented by the equations in Tables B.3–B.5, but also precisely estimated without having to specify the investment equation, it seems safe to assume that aggregate investment is exogenous to the dynamic process determining asset prices and credit, that is, contingent on the long-run structure. This is further substantiated by the χ^2 (5)-test in the Appendix, which fails to reject the lack of a contemporaneous causal link going from investment to either asset prices or credit. However, this does not necessarily mean that the estimated long-run structure of the partial model for asset prices and credit is exogenous for the process driving investment in the long run, which is firmly demonstrated by the fact that there, according to the long-run structure of the system in Tables B.3–B.5, is a two-way causal link between asset prices and credit on the one hand and investment on the other. This is also why the cointegration analysis referred to in the text was undertaken on a fully simultaneous model for the joint distribution of credit, asset prices and investment in the first place.

[16] All estimation and model design in this paper has been made utilizing OxMetrics 7.00 (Doornik, 2007).

[17] In these dynamic forecasts it has not been necessary to include dummies for the financial crises or other events after the end of the estimation period in the third quarter of 2007. That is, these are the unfettered forecasts of the dynamic structure in (2) and (3) itself.

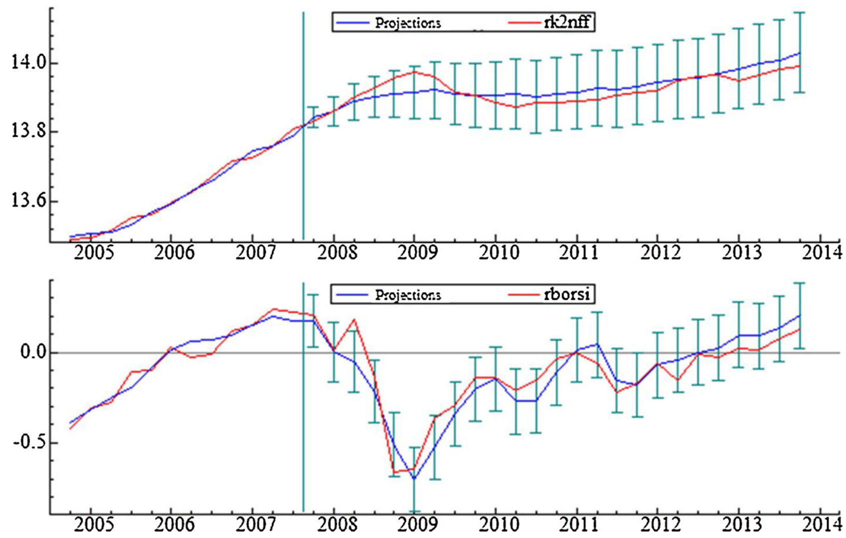

Fig. 1. Credit (*rk2nff*) and Norwegian equities (*rborsi*), with corresponding, model-based projections.

industries, i.e. when the main index on the Oslo stock exchange rises and when aggregated credit increases, so does the availability of external financing in general at a disaggregated level.

As credit and equity prices are not included in the long-term relationships in (6), the level of these variables has in principle no effect in the long run.[18] As mentioned, only allowing for direct effects of credit and equity in the short term in the capital equations is in line with the Modigliani-Miller theorem, and implies that in the long term the financial structure, in other words how companies finance themselves, is not relevant to or dependent on the economic cycle.[19] Long-term effects of higher capital prices are, however, partially safeguarded by the user cost of capital.

The investments in industry *i* in period *t*, $JK_{i,t}$, appear as the change in capital stock from the previous period, adjusted for depreciation,

$$JK_{it} = \Delta KAGG_{i,t} - \delta^{*}KAGG_{i,t\text{-}1}, \tag{7}$$

where $KAGG_{i,t}$ is the capital stock and δ is the depreciation rate of capital.

3.2. Empirical results

The sector-specific equations for capital (6) are estimated by ordinary least squares and reduced using the general to specific methodology (see, e.g., Davidson et al., 1978). It is emphasized that the final estimated relations pass standard statistical tests of serial correlation, heteroscedasticity and normal distribution of the residuals. The estimation of the long-term structure (5) is documented in Hungnes (2016). Conditional on these ecm's, we reestimate the short short-term dynamics of each industry as shown in (6). Potential path dependency in the reduction process is handled with Autometrics (Doornik, 2009), which is also used to search for structural breaks and extreme observations. We have included dummy variables where this has contributed to a theory consistent model specification and/or improved the statistical properties.

Table 1 displays the size of investments in the various industries as a share of total industry investments. In 2014, total industry investments constituted 30.1 percent of total investments in the Norwegian economy and 42.3 percent of investments in mainland Norway. The table also shows that the capital equations for all industries excluding industry 86 includes credit as an explanatory variable and that equity prices are included in five of the 13 equations (see Appendix F for detailed estimation results).[20]

The financial sub-model/accelerator can easily be "switched off" by exogenizing credit and Norwegian equity prices. We exploit this in the next section in order to identify the impact of including the financial accelerator in KVARTS.

[18] Note that the price of capital is included in the definition of the user cost of capital. However, because there is no link in the model between the user cost of capital and the benchmark index on the Oslo stock exchange, the user cost of capital does not represent a channel for long-term effects between equity prices and the accumulation of capital.

[19] Strictly speaking, the Modigliani-Miller theorem applies under relatively strong assumptions of efficient markets and absence of taxes and asymmetric information, and provides little information about adjustments in the short term.

[20] Whether the data supports including aggregate credit and/or equity prices even in the long term may be an interesting topic for further research.

Table 1
Investment in each industry as a share of total industry investments (value). Inclusion of credit and/or equity prices as explanatory variables in the short-term dynamics of each equation is indicated by X.

Total industry investments in 2014	Share	Credit	Equity prices
Industry 10 – Agriculture etc.	3.6	X	
Industry 14 – Fishing and hunting	1.2	X	X
Industry 15 – Consumer goods	3.6	X	
Industry 25 – Intermediate goods etc.	3.2	X	X
Industry 30 – Energy-intensive goods	2.5	X	
Industry 45 – Engineering products	6.1	X	
Industry 55 – Construction	7.1	X	X
Industry 63 - Banking and insurance	3.6	X	
Industry 71 – Electricity	8.8	X	
Industry 74 – Domestic transport	9.3	X	
Industry 81 – Merchandising	6.5	X	
Industry 85 - Other private services	27.9	X	X
Industry 86 - Leasing commercial buildings	16.5		X
Total industry investments	100		
Industry investments as a share of total investments	30.1		
Industry investments as a share of total investments in Mainland Norway	42.3		

3.3. Impact of the financial accelerator

The importance of the financial accelerator is illustrated by three alternative simulations in KVARTS, in addition to a counterfactual experiment where we look at the effect of keeping the level of oil investments and the oil price up over an extended historic period where both quantities were subject to significant downward corrections.

First, a permanent increase in the MSCI of 10 percent gives a corresponding increase in Norwegian equity prices during the first two quarters, followed by a relatively rapid decline that gradually decreases in strength, converging towards a long-term increase of almost 5 percent after 6–7 years. Credit increases markedly during the first years, approaching 4 percent after 6–7 years. Note that fiscal policy and the money market interest rate are exogenously determined, so that the expansionary effects of higher international equity prices are not offset by tighter economic policies.[21] The *krone* exchange rate, on the other hand, is determined endogenously in the model in all three simulations. Note that this is a partial shift.

In reality, one could imagine that increasing international equity prices would go hand in hand with a global upturn in the business cycle, implying that increased international demand for Norwegian goods and services and increased optimism could push Norwegian investments and equity prices even further. As equity prices and credit are not included directly in the long-term solution of the capital equations, there is only a short-term additional increase in industry investments of 1.1 percent and 2 percent in manufacturing investments, which in both cases disappear within about ten years. GDP Mainland Norway gets an additional increase of 0.2 percent the first year, which decreases slowly towards zero. Unemployment falls rapidly by 0.1 percentage point, but this effect is almost gone after 10 years. The additional effect on traditional exports is very tiny, while imports increase more significantly because investments are relatively import-intensive. Table 2 and Fig. 2, together with the graphs in Appendix C, show the effects following from the change in the MSCI on a range of macroeconomic variables.[22] The graphs in Appendix D also show the effects of a temporary one-year increase in the MSCI index on all the variables listed in Table 2. With the notable exception of credit, they all seem to convey the impression of a very low degree of persistence in the process of adjustment to temporary shocks.

While the international equity price index is a new variable in KVARTS through the financial sub-model, interest rates and fiscal

[21] The rationale for the decision of disregarding endogenous policy responses in the main setup is based on the idea of wanting to purely cultivate the impact of the financial accelerator. However, as is suggested by the simulations in Appendix A, where, in addition to presenting some additional simulations related to the standard case, we look at the case where we have implemented (and switched on) an augmented open economy version of a Taylor rule (Taylor, 1993) in the model, policy rules in general only seem to contribute to moderate the effects of the original shifts studied and to dilute the proper contribution of the financial accelerator. As we primarily want to illustrate the partial effect of changes to some exogenous processes and in this respect to study the role played by the financial accelerator in particular, we have therefore chosen to concentrate on the partial effects of shocks, basing this decision on the absence of policy responses beyond what follows from non-discretionary endogenous behavioral model responses. As far as the need for a fiscal policy response is concerned, in this context it is also important to bear in mind that monetary policy after all is considered as the “first line” defense in coping with economic disturbances. With the relatively modest magnitude of the shocks studied in this paper, an exception granted for the counterfactual experiment in Appendix E, where the lack of a policy response overall probably contributes to overstating the role played by the financial accelerator in promoting shocks, there is therefore reason to assume that the role of fiscal policy would be rather limited. Also, fiscal policy enters the model (KVARTS) in a very complex and detailed way. While this makes it suitable for detailed impact analyses of a number of fiscal instruments, it is also makes it difficult to endogenize in a way that properly takes into account a realistic fiscal policy response.

[22] Credit and Norwegian equity prices are not deflated in the tables of this report. However, the inflationary effects of the shift in international equity prices, and the additional inflation attributable to the financial accelerator in the interest rates and fiscal policy shifts, are marginal. The real effect is thus very similar to the nominal effect.

Table 2
Macroeconomic effects of a permanent increase in the MSCI by 10 percent. Deviations from the baseline scenario in percent.

Year	1	2	3	4	5	6	7	8	9	10
GDP Mainland Norway	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Household consumption	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.2	0.2
Unemployment rate (level)	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.0
Investment in Mainland Norway	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.2	0.2
Industries	1.1	1.1	0.9	0.7	0.5	0.4	0.3	0.2	0.2	0.1
Manufacturing	1.3	2.0	1.6	1.3	0.8	0.6	0.4	0.3	0.2	0.2
Exports traditional goods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1
Wage	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CPI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOKEUR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Household real disposable income excluding dividends	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Credit non-financial corporations Mainland Norway[a]	0.7	1.9	2.8	3.3	3.6	3.7	3.8	3.8	3.8	3.8
Oslo Børs benchmark index[a]	9.5	7.3	6.2	5.6	5.3	5.1	4.9	4.9	4.9	4.8
Memo										
MSCI	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

[a] Nominal.

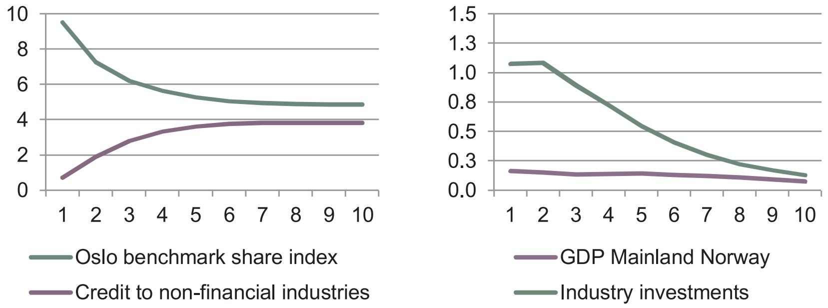

Fig. 2. Macroeconomic effects of a permanent increase in the MSCI by 10 percent. Deviations from the baseline scenario in percent (corresponding to Table 2).

policy are, naturally, important features in earlier versions of the model as well. To identify the importance of the accelerator mechanism for the quantification of the economy's sensitivity to changes in monetary and fiscal policy, we perform two times two calculations: For each policy area, we first look at the total effects when the financial accelerator is switched off, and then check how the financial accelerator changes this, i.e., the *additional* effect attributable to the financial accelerator.[23]

First, we look at a permanent 1 percentage point reduction of the money market interest rate compared to the baseline scenario. Initially, we keep credit and equity prices exogenous, meaning that the financial accelerator is "switched off". In this way, we can illustrate KVARTS without a financial accelerator before calculating the additional effect attributable to the financial accelerator when it is switched on. In KVARTS, the money market interest rate affects GDP Mainland Norway through two (close to) equally important channels. First, lower interest rates (relative to international rates) make the *krona* depreciate. That in turn leads to higher import prices and strengthens the competitiveness of Norwegian enterprises.

Thus, exports of goods and services increase. Second, lower interest rates lead to increasing household consumption and demand for housing, and enterprises in the mainland economy increase investments. Industry investments go up both as a direct result of reduced financing costs and due to increased demand for their products. Employment increases and unemployment falls. Real wages go up slightly after a while. After 7 years, overall industry investments are up by 5.6 percent and GDP Mainland Norway by 1.8 percent, see Table 3.

We then switch on the accelerator mechanism (letting the model determine credit and Norwegian stock prices) and find that a permanent 1 percentage point reduction in the three-month money market rate leads to a short-term *additional* increase in industry investments of 1.4 percent after two years and in manufacturing investment of 2.4 percent after three years, which can be attributed to the financial accelerator. GDP Mainland Norway is 0.2 percent higher after two years, before the effect gradually diminishes. Thus, while the effects of an increase in international equity prices on the real economy came during the first year, it takes 2–3 years before the maximum effect of the interest rate reduction is achieved (Fig. 3).

The interest rate is included in the long-term solution of the equity price equation, in the short-term dynamics of the credit equation and in the capital equations via the user cost of capital. Thus, the financial accelerator is engaged, both directly through

[23] In addition, Appendix A documents the total effects of the two policy shifts with the financial accelerator switched on, that is compared to the baseline scenario.

Table 3
Macroeconomic effects *without* financial accelerator of a permanent reduction in the Norwegian money market rates by 1 percentage point. Deviations from the baseline scenario in percent.

Year	1	2	3	4	5	6	7	8	9	10
GDP Mainland Norway	0.3	0.8	1.1	1.3	1.5	1.7	1.8	1.8	1.8	1.7
Household consumption	0.1	0.7	1.2	1.6	2.0	2.2	2.3	2.3	2.2	2.1
Unemployment rate (level)	−0.7	−0.8	−1.0	−1.2	−1.3	−1.6	−1.7	−1.7	−1.6	−1.4
Investment in Mainland Norway	0.5	1.6	2.3	3.3	4.2	5.1	5.7	5.7	5.5	5.1
Industries	1.0	3.4	3.8	4.3	4.7	5.3	5.6	5.5	5.2	4.8
Manufacturing	0.6	2.7	3.7	3.9	3.4	3.6	3.8	3.8	3.5	3.3
Exports traditional goods	1.6	1.7	1.9	1.8	1.6	1.4	1.3	1.2	1.1	1.1
Imports	0.1	0.7	1.1	1.4	1.7	2.0	2.2	2.2	2.1	1.9
Wage	0.3	0.6	0.8	1.1	1.4	1.6	1.8	1.9	2.1	2.2
CPI	0.4	0.7	0.8	0.9	1.0	1.0	1.1	1.0	1.0	0.9
NOKEUR	4.4	4.6	4.2	3.9	3.7	3.6	3.5	3.3	3.2	3.0
Household real disposable income excluding dividends	0.3	0.7	0.9	1.1	1.2	1.4	1.4	1.5	1.6	1.7
Credit non-financial corporations Mainland Norway[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oslo Børs benchmark index[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Memo										
Money market interest rate (percentage points)	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0	−1.0

[a] Nominal.

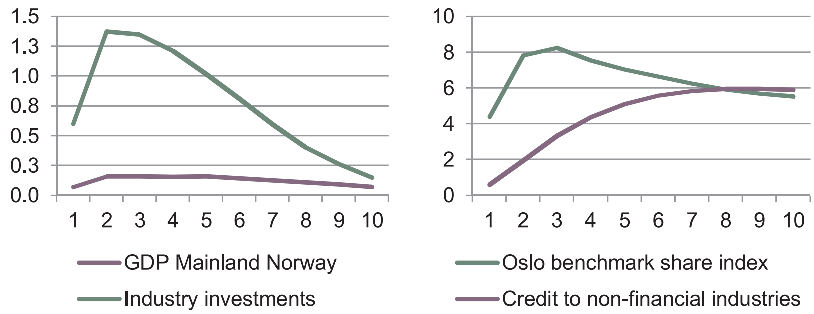

Fig. 3. Macroeconomic effects of a permanent reduction in the Norwegian money market rate of 1 percentage point of incorporating a financial accelerator. Deviations from the model without financial accelerator in percent (corresponding to Table 4).

increased demand for credit and equities and through increased investments due to lower user cost of capital. Furthermore, credit and equity prices are included in the capital equations, which, through investments, provide new feedback effects to equity prices and credit, and so on. After about 10 years, the additional effects on the real economy die out. Equity prices are permanently higher because interest rates are included in the long-term solution of (3) and credit is permanently higher because equity prices are included in the long-term credit relationship in (2). Table 4 and Fig. 4, together with the graphs in Appendix C, show the *additional* effects of the interest rate reduction as a result of incorporating a financial accelerator into KVARTS. However, as depicted by the

Table 4
Macroeconomic effects of a permanent reduction in Norwegian money market rates by 1 percentage point of incorporating a financial accelerator. Deviations from the effects without a financial accelerator in percent (ref. Table 3).

Year	1	2	3	4	5	6	7	8	9	10
GDP Mainland Norway	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Household consumption	0.1	0.3	0.3	0.3	0.4	0.3	0.3	0.2	0.2	0.2
Unemployment rate (level)	0.0	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1	0.0	0.0
Investment in Mainland Norway	0.3	0.6	0.7	0.6	0.5	0.5	0.4	0.3	0.2	0.2
Industries	0.6	1.4	1.3	1.2	1.0	0.8	0.6	0.4	0.3	0.1
Manufacturing	0.9	2.2	2.4	2.2	1.7	1.3	0.9	0.6	0.4	0.3
Exports traditional goods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1
Wage	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
CPI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOKEUR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Household real disposable income excluding dividends	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Credit non-financial corporations Mainland Norway[a]	0.6	2.0	3.3	4.4	5.1	5.6	5.8	5.9	6.0	5.9
Oslo Børs benchmark index[a]	4.4	7.8	8.3	7.6	7.1	6.6	6.3	5.9	5.7	5.5

[a] Nominal.

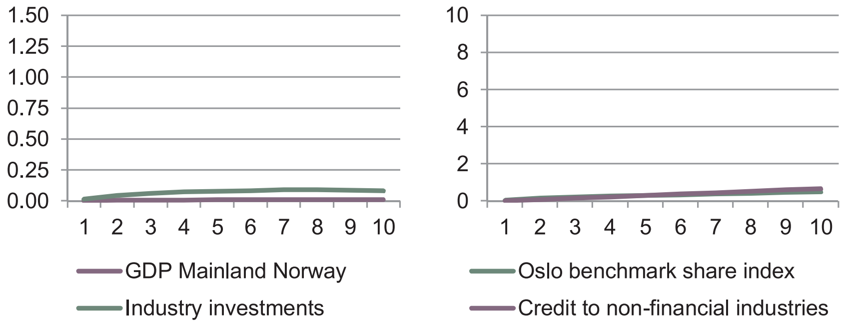

Fig. 4. Macroeconomic effects of a permanent increase in public expenditure by 1 percent of incorporating a financial accelerator. Deviations from the model without financial accelerator in percent (corresponding to Table 6).

graphs pertaining to a temporary one-year interest rate shock in Appendix D, the process of adjustment related to these *additional* effects are not very persistent for most variables, a notable exception again being the effect on credit.

Next, we simulate a permanent increase in government consumption, investment and employment by 1 percent, hereafter called public expenditure for convenience. In this calculation, the money market rate is also kept unchanged.[24] Conversely, if the interest rate was determined endogenously, the interest rate relation would "lean against the wind", responding to increased economic activity by higher interest rates, and thus counteract the expansionary fiscal policy. However, our concern here is how fiscal policy works. First, we increase public expenditure with exogenous credit and equity prices, i.e. with the financial accelerator switched off. Higher public expenditure increases GDP directly by leading to higher production in the public administration. That leads to higher demand and thus higher production, even in private industries. Higher production in both public and private sectors increases demand for employment and hence leads to lower unemployment and slightly higher wage growth.

Household demand increases as a result of higher wages and employment. Consumer prices increase less than nominal wages, resulting in higher real wages. After 10 years, GDP Mainland Norway is 0.6 percent higher, see Table 5.

When we make a new corresponding shift with expansionary fiscal policy, but with the financial accelerator switched on, we find that the accelerator only provides a marginal *additional* increase in industry investments and GDP, see Table 6 and the graphs in, respectively, Fig. 4 and the last part of Appendix C pertaining to the public expenditure shock, for a more detailed documentation. The additional effect is small because the model has no direct link from public expenditure to financial markets via the equations for equity prices and credit, but only an indirect link from increased demand working through the capital equations.[25] Looking at the graphs of the *additional* effect pertaining to a temporary one-year shock to public expenditures – albeit minuscule – reveals a rather substantial degree of persistence in the adjustment process for some of the variables, this time not only for credit.

Finally, we look at a counterfactual experiment that is based on a fairly recent experience related to the Norwegian economy and that demonstrates its dependence on oil. In particular, in this context we will look at what would have happened if oil prices and investments, instead of falling precipitously from 2013 onwards and staying low for an extended period of time thereafter, had stayed at their level before the shock took place at the end of 2013, beginning of 2014, over the simulation period. As shown in the memo of Table 7, such a shock would amount to a gradual increase in oil prices and oil investments relative to the baseline scenario of close to, respectively, 150 and 20 percent over a four- to five-year period, before settling down at approximately 80 and 16 percent at the end of the simulation period in 2020. As borne out by Table 7, which gives us the additional effects of the counterfactual shift attributable to the inclusion of a financial accelerator, the relative importance of the financial accelerator in wake of the shocks can be quite substantial. In Table 7 this *additional* effect is simulated to amount to an *additional* boost to GDP of close to 1 percent in 2017 before settling down to about 0,6 percent at the end of the simulation period. This process of enhancement is eventually propagated through a substantial upturn on the Oslo stock exchange and a subsequent strong increase in credit, both rendering possible a cyclical upturn in investment and consumption.

4. Conclusion

We have estimated and implemented a financial sub-model in a macro-econometric model of the Norwegian economy (KVARTS), which takes into account the pro-cyclical interaction between the real economy and financial markets via industry investments. Our implementation is more theory-consistent than previous studies, as the financial variables affect investments directly and we have taken into account that the effects of changing credit and equity prices on investments can be industry-specific. In the financial sub-model, aggregated credit and Norwegian equity prices are determined simultaneously in a two-dimensional structural system

[24] The results related to the effects of an increase in public expenditure when switching on the monetary policy rule in the model are given in Tables A.4 and A.5 in Appendix A, respectively. They all seem to convey the impression of a somewhat dampened response to shocks compared to what is the case without a policy rule.

[25] Mazzucato (2015) argues that there can be significant direct effects from public to private investment, including through public/private investment partnerships and so-called bell cow effects.

Table 5
Macroeconomic effects *without* financial accelerator of a permanent increase in public expenditure by 1 percent. Deviations from the baseline scenario in percent.

Year	1	2	3	4	5	6	7	8	9	10
GDP Mainland Norway	**0.3**	**0.4**	**0.4**	**0.4**	**0.5**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**
Household consumption	**0.1**	**0.3**	**0.4**	**0.5**	**0.6**	**0.6**	**0.7**	**0.7**	**0.7**	**0.7**
Unemployment rate (level)	−0.6	−0.4	−0.4	−0.4	−0.4	−0.5	−0.6	−0.6	−0.6	−0.6
Investment in Mainland Norway	0.3	0.3	0.5	0.6	0.8	1.0	1.1	1.2	1.2	1.2
Industries	0.1	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.7	0.7
Manufacturing	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Exports traditional goods	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.8	0.8
Wage	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8
CPI	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3
NOKEUR	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2
Household real disposable income excluding dividends	0.3	0.3	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6
Credit non-financial corporations Mainland Norway[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oslo Børs benchmark index[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Memo										
Public expenditure	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

[a] Nominal.

Table 6
Macroeconomic effects of a permanent increase in public expenditure by 1 percent of incorporating a financial accelerator. Deviations from the effects without financial accelerator in percent (ref. Table 5).

Year	1	2	3	4	5	6	7	8	9	10
GDP Mainland Norway	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Household consumption	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Unemployment rate (level)	0.00	0.00	0.00	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Investment in Mainland Norway	0.01	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.04	0.04
Industries	0.01	0.05	0.06	0.07	0.08	0.09	0.09	0.09	0.09	0.08
Manufacturing	0.03	0.09	0.12	0.14	0.14	0.15	0.15	0.15	0.15	0.14
Exports traditional goods	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Imports	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Wage	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
CPI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOKEUR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Household real disposable income excluding dividends	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Credit non-financial corporations Mainland Norway[a]	0.02	0.08	0.15	0.22	0.30	0.37	0.45	0.52	0.60	0.66
Oslo Børs benchmark index[a]	0.05	0.15	0.22	0.27	0.30	0.34	0.39	0.42	0.46	0.50

[a] Nominal.

Table 7
Macroeconomic effects of a countercyclical shock to oil prices and oil investments. Deviations from the effects without a financial accelerator in percent.

Year	2013	2014	2015	2016	2017	2018	2019	2020
GDP Mainland Norway	0.01	0.05	0.38	1.03	1.10	0.91	0.74	0.61
Household consumption	0.03	0.1	0.85	2.26	2.36	1.97	1.71	1.48
Unemployment rate (level)	−0.01	−0.03	−0.2	−0.54	−0.7	−0.71	−0.63	−0.45
Investment in Mainland Norway	0.04	0.15	1.04	2.9	3.45	3.08	2.47	1.9
Industries	0.09	0.35	2.48	7.07	8.4	7.13	5.23	3.37
Manufacturing	0.04	0.41	2.57	9.46	13.5	12.26	9.05	5.73
Exports traditional goods	0.00	0.00	−0.01	−0.05	−0.13	−0.20	−0.23	−0.21
Imports	0.23	0.08	0.69	1.91	2.13	1.86	1.6	1.31
Wage	0.00	0.01	0.03	0.11	0.23	0.36	0.48	0.58
CPI	−0.00	−0.00	−0.02	−0.07	−0.07	−0.03	0.03	0.08
NOKEUR	0.00	−0.00	−0.01	−0.06	−0.08	−0.04	0.01	0.07
Household real disposable income excluding dividends	0.01	0.03	0.17	0.32	0.49	0.54	0.57	0.55
Credit non-financial corporations Mainland Norway[a]	0.03	0.28	1.98	8.5	17.78	26.04	31.43	33.89
Oslo Børs benchmark index[a]	0.95	4.2	28.08	65.66	70.83	61.5	50.66	41.42
Memo:								
Oil price	3.499	13.10	109.91	155.48	122.87	106.51	92.39	80.08
Oil investments	0.41	0.48	5.67	15.87	21.66	19.94	17.09	16.06

[a] Nominal.

characterized by full contemporaneous causal interaction, where industry investments are included as an explanatory variable. Furthermore, aggregate credit and Norwegian equity prices are included as explanatory variables in the equations for total capital formation in each industry. The industry-specific real capital is aggregated to total capital formation in the mainland industries, which is included in the dynamics of the financial sub-model. In this way, equity prices and credit affect investments with feedback effects to equity prices and credit and so on.

The impact of the financial accelerator is illustrated by three shifts in exogenous variables in addition to a counterfactual experiment. A permanent reduction in three-month money market interest rates of 1 percentage point provides a short-term *additional* increase in industry investments by 1.4 percent, attributable to the financial accelerator. A permanent increase in public expenditure of 1 percent provides just a marginal *additional* increase in industry investments as a result of the financial accelerator, as there is no direct connection from public expenditure to the financial accelerator. We also shifted the global equity price index MSCI, which is included in both the short-term dynamics and the long-term structure in the equation for Norwegian equity prices. A permanent increase in the MSCI of 10 percent provides a long-term increase in Norwegian equity prices of about 5 percent and a short-term increase of about 1 percent only in industrial investments. As far as the counterfactual experiment is concerned, the *additional* effect that is attributed to the inclusion of the financial variable is simulated to give an additional boost to GDP of close to 1 percent. This is taken as clear evidence of the intensive role played by a financial accelerator in the propagation of shocks.

Including the financial sub-model in KVARTS reinforces and extends economic cycles in projections and forecasts for the Norwegian economy. Moreover, monetary policy gets a more important role, as the effect of a change in interest rates is significantly enhanced. The effects of fiscal policy, on the other hand, are affected to a relatively small extent as a result of this model extension.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ecosys.2019.100731.

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