Norwegian Aggregate Model

Documentation of NAM

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Summary:

Norwegian Aggregate Model, NAM, is a dynamic econometric model developed to forecast and analyse the Norwegian macro economy. The documentation begins with chapters that give an overview of the model, and examples of NAM usage for forecasting and scenario analysis. Methodological issues in the construction of a macroeconometric model, and how they have been tackled in the development of NAM, are discussed in separate chapters. NAM allows for non-stationarity and structural breaks. NAM is an equilibrium correction model, but the equilibrium can change due to for example institutions adapting to the changing environment. NAM is not a 'natural rate' (of unemployment) model. The documentation contains detailed explanation of the economic relationships of the model. Lastly, the documentation includes a full set of definitions of the exogenous and endogenous variables, as well as a listing of estimation results.

Contents

> "I think it should be generally agreed that a model that does not generate many properties of actual data cannot be claimed to have any 'policy implications'..."
>
> Clive.W. J. Granger (1992), p. 4.

1 INTRODUCTION

Norwegian Aggregate Model (NAM) is a dynamic econometric model for the Norwegian macro economy. The model is estimated on quarterly data. NAM can be used to analyse the recent events in the Norwegian macro economy, as an aid to formulate medium term macroeconomic forecasts, and to quantify the dynamic responses to shocks from the 'world economy', or from policy changes and structural changes in the domestic economy and in wider society.[1]

NAM has been developed with the view that the specifications of firm behaviour and of wage formation are important for the overall model properties, cf. Nickell (1988). In NAM, the markets for industrial products are assumed to be monopolistically competitive. Industries are characterised by differences in market power, but as a main rule product prices are determined by a mark-up of prices on unit labour costs, so called normal cost pricing. This assumption is largely confirmed by the data. As for wage formation, the mainstay is a system of collective agreements, with a wage-leading sector (in practice manufacturing) and the other sectors that accept the outcome of that settlement as their wage-norm. This system has provided a degree of horizontal wage coordination, which has been of importance for macroeconomic performance both under the first post-war decades with fixed exchange rate regime, and with a floating exchange rate (formal inflation targeting since 2001).

Taken together, normal cost pricing and collective bargaining-based wage formation, can be referred to as the Incomplete Competition Model (ICM) of the supply side of the macro economy. The ICM has important consequences for the analysis of macroeconomic stability. It implies that the markets for industrial products mainly clear through quantity, rather than mainly through price and wage adjustment mechanisms. This in turn implies that both production and employment are vulnerable to shocks—both from outside and from domestic shocks from e.g. financial imbalances. On the other hand, such an economy may be responsive to the instruments of monetary and fiscal policy.

[1] As always, the relevance of the response analysis depends on assumptions about a certain degree of invariance of the parameters that drive the dynamic responses, with respect to the shocks. These assumptions can be validated with a high degree of probability in some cases, in other cases they are less likely to hold (or believed to hold). Relative parameter *invariance* will come up repeatedly in this model documentation

FRAME 1: LINEAGES OF NORWEGIAN AGGREGATE MODEL, NAM

NAM originated from the early econometric assessment of wage-and price formation in Nymoen(1989a,1989b,1991) , further developed in Bårdsen et al. (1998), Bårdsen and Fisher (1999), Bårdsen and Nymoen (2003), and the monetary transmission model of Bårdsen and Klovland (2000). Early versions of the model were presented in Bårdsen and Nymoen (2001) and Bårdsen et al. (2003), while a more complete version can be found in Bårdsen and Nymoen (2009a). NAM builds on the methodological position presented in the book on macroeconometric modelling by Bårdsen et al. (2005).

Collective action in wage setting, and price setting according to the normal cost principle, have therefore important implications for macroeconomic policy analysis. For example, they imply that demand shocks affect the rate of inflation through markets for labour, foreign exchange or existing assets such as the residential housing, rather than directly through the pricing behaviour of firms. It also follows that the model of the transmission mechanism (how monetary policy affects real variables) is also conditioned by the system of wage and price setting, cf. Bårdsen et al. (2003) and Akram and Nymoen (2009).

Because of its importance for the total model's properties, the chapters about methodology (mainly Chapter 4 and 5) use the modelling of wage and price setting as the example that illustrates our approach to econometric model specification and evaluation. The performance of the operation NAM model has been reviewed through forecasting[2], re-estimation of the model equations four times a year (each time a new Quarterly National Accounts), and through feed-back from model users. This ensures that NAM is dynamic, also in the meaning of 'constantly being under development'.

In the face of the structural changes that take place frequently in modern economies, adaptive specification and continuous model development can be seen as a necessary investment in order to maintain relevance of the model. Keeping a model specification unchanged for long periods of time inevitably leads to a gradual deterioration in model performance and relevance. By the law of entropy, as the consequences of structural changes pile up, an unattended model will become defunct, usually sooner than later.

Hence, it is easy for the current day empirical modeller to recognise that Lawrence Klein, one of the founding fathers of macroeconometric modelling, hit the nail on the head when he said:

> By the time a system has been designed to give explicit display to a variable that has appeared to be important, the econometrician may find that some new variable, formerly submerged in aggregation, is now important. ... Every two or three years the model must be revised to keep it up to date. Klein

[2] `http://www.sv.ntnu.no/iso/gunnar.bardsen/nam/forecasts/index.html`

(1962, p.269)

Nevertheless, even though the detailed specification of a viable empirical model will have to be changed frequently, there will also be features of the model that are relatively stable and "permanent". Examples of such structural features may be found in partial invariance in long-run relationships or in the direction of causality. It is these permanent properties that give the model its character,and makes it recognisable from one estimated version to the next.

The organisation of the documentation reflects the twin purpose of giving background to the economic theory and econometric methodology that has been used to formulate the model, and providing detailed and updated information about the concrete model specification for model users.

We begin in Chapter 2, with a brief overview of the markets and sectors of the Norwegian economy that are covered by the model. Several of the most important macroeconomic relationships of the model are illustrated with the aid of flow-charts. Finally, Chapter 2 mentions some of the standard ways of characterising different macro models. For example, NAM is an equilibrium correction model, but in several important respect different from the standard NAIRU model. NAM contains blocks or modules consisting of simultaneous or recursive equation. This places the model in the line of structural econometric models (SEMs), and therefor to issues of identification and estimation (cf. subchapter 2.6). Finally, NAM have some features in common with modern so called New-Keynesian dynamic stochastic general equilibrium models (DSGS), but there are also important differences, that are stated briefly at the end of the chapter.

Chapter 3 explains briefly how the operational version of NAM is programmed, estimated and simulated (using the software package EViews). The chapter also contains examples of model usage, in forecasting the Norwegian macro economy and for policy and scenario analysis.

Building an empirical model involves a long list of decisions that, together with the statistical data used (one of the decisions!), have strong implications for the properties of the operational model. Although it is not necessary to know a lot about how NAM has been build in order to use it, it may nevertheless at some point be of interest to assess the process, and not just the end-product of the specification process. In particular, if you consider becoming a modeller yourself, or simply because you are interested. With that in mind, Chapter 4 and 5 address methodological aspects of empirical macroeconomic model building. Several modelling concepts are motivated and explained in these chapters, as they are referred to in later chapters when we go through the detailed documentation of the model.

Chapter 6 explains why the formulation used for the supply-side of the model conditions several of the overall-model properties (whether a so called NAIRU is a parameter of the total model or not, and whether an aggregate demand shock affects mainly prices or mainly quantities). In turn the core relationships of the supply-side are those that represent price-setting and wage formation.The chapter also gives an illustration of how the methodology of Chapter 5 has been put into use. Chapter 7 contains a sector-by-sector presentation of the complete NAM-model. As wage-and-price setting has been the topic of Chapter 6, the presentation of the supply-side of the model in Chapter 7 can be kept brief, and more space is given to the components on the demand side, and the modelling of assets markets (including the market for residential housing). The presentation focuses on the economic interpretation and the main empirical results. In Chapter 8 the endogenous and exogenous variables of the model are listed and defined, while the detailed estimation results are given in Chapter 9. The estimation results are given in terms of the actual NAM variables names (i.e. the variables names used in the NAM computer code).

FRAME 2: HOW TO READ AND USE THE DOCUMENTATION

The next two chapters give an overview of the model (Ch. 2), and examples of NAM usage (Ch. 3). It is probably a good idea to read them first to get an idea of the scope and analytical capabilities of NAM. Then decide whether to continue with the general methodological Chapter 4 and 5, or to jump directly to the economic and econometric documentation of NAM that in Chapter 6 and 7. Chapters 8 and 9 are resources for those who wish to use the model for their own analysis and forecasting, or who want to explore the details of the estimation results.

2 OVERVIEW AND CHARACTERISATION OF NAM

In this chapter, we give a characterisation of NAM, in terms of size and coverage, and where it positions itself in the field of empirical macroeconomics. We start with a short section about data sources and model size. The second section of the chapter is the longest and attempts to give an impression of the economic relationships that are represented in NAM, which parts of the Norwegian macro economy are explained by endogenous variables in the model, and which parts are represented by exogenous variables.

The last sub-chapters have a more methodological and econometric different focus, and explains similarities and differences between NAM and other popular approaches to quantitative macro models, in particular DSGE (Dynamic Stochastic Equilibrium) models.

2.1 DATA SOURCES AND MODEL SIZE

The database of the model is constructed by using data from StatBank Norway[3] as well as from the web sites of other national and international organizations and institutions. The data input is also based on an agreement with Statistics Norway about access to data from the KVARTS model.

As noted in the Introduction, and as the name suggests, NAM is a not a large macro econometric model, by Norwegian standards.[4] But NAM is not a miniature model either. The present version of the model contains 165 endogenous variables and 68 exogenous variables.[5] Among the exogenous variables, the majority is made up of deterministic variables for seasonality, trends and intermittent structural breaks. There are only a dozen of exogenous variables that need to be projected outside the model.[6] NAM is therefore a fairly closed model, so the most important variables for the Norwegian economy are determined by the model, while conditioning on foreign prices and output, the price of raw oil, and domestic policy variables like (a few) tax rates, government consumption and public investments.

NAM splits private Mainland-Norway gross domestic product (GDP) into three endogenous variables:manufacturing,production of other goods and service production, and retail trade, and one exogenous: government administration. Total GDP is obtained by adding the value creation in the oil sector and in international transportation (mainly by sea). Total supply is made up of Norway's GDP and total imports (an endogenous variable). On the demand side of the macro economy, the main components are modelled as endogenous variables, and only exports of raw oil and natural gas are treated as exogenous variables.

In NAM, and in the real world, GDP supply and demand interact with the labour market, and both labour demand, wage and price setting and unemployment is formed in that process. In the next sub-section we attempt to give an introduction to that part of the model, and without going into details about the econometric specification.

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[3](www.ssb.no/en/statistikkbanken)

[4]See Cappelen (1991) and Bjerkholt (1998) for an account of the Norwegian modelling tradition, where the multi-sectoral models developed by Statistics Norway have been central.

[5]The numbers of endogenous and exogenous variables vary between different user specific versions of the model. But the cited numbers for the main-model version are representative.

[6]One important caveat is that practitioners are will be aware of, are step-indicator functions that represent semi-permanent structural breaks. The change in Norges Bank interest rate setting when the the financial crisis arrived in Norway is an example.

2.2 ILLUSTRATION OF RELATIONSHIPS BETWEEN PRODUCT MARKETS AND LABOUR MARKETS IN NAM

The economy can be analysed as a complex system, with dynamics and joint causality between variables as a dominant features. NAM is a simplified representation of the real world complex economic system. Figure 1 illustrates some of the relationships in NAM. In Figure 1 we focus on two of the markets that are represented in the model: The Product market and the Labour market.

Norwegian firms compete with foreign firms, both in the Export market, and in the Norwegian, Domestic, marked for goods and services. Both export competing firms and those competing with imports in the domestic market, are affected by changes and developments in Norway's trading partners, and in the global markets for commodities and credit (e.g., oil price and world interest rates and price of equity). In Figure Figure 1, the dependence on the foreign sector is indicated by the lines from the circle labelled World to the two square nodes that are labelled Exports and Imports. For example, a general fall in income in foreign countries may lead to a fall in international trade, and to reduced exports, even if Norwegian exporting forms manage to maintain their export market shares. This relationship is represented by the line from World to Exports. A period of reduced international prices on imported goods, may lead to reduced market shares in the import competing part of the Domestic product market. This is the line from World to Imports-Domestic.

Markets are assumed to be monopolistically competitive, which is consistent with a high degree of specialization, flat short-run cost marginal cost functions (until full-capacity has been reached) which are typical of industrialized production. As a result, the prices that domestic firms obtain on their product sales are influenced by both domestic costs, and by the prices on competing products.

At the aggregate level, the main short-term cost component is wage costs per unit of labour, which we for simplicity just refer to as the wage level of the Norwegian economy. The wage level is determined in the Labour market part of the figure, but it depends on the prices set by firms (through two well known factors in wage setting: cost-of-living developments and profitability of production). Hence, Wage and price setting is an example of a sub-system characterized by joint dependency, and it is indicated as such in the figure.

In a small open economy like the Norwegian, prices and and wages are also directly influenced by foreign variables. One direct linkage is when a price change (in Norwegian kroner) on imported consumer goods affect the Norwegian consumer price index. Another is when foreign prices (together with productivity growth) defines the sustainable 'scope' for wage increase in the wage-leading Norwegian manufacturing sector. In the figure, the line from the World circle to the Wage and price ellipse illustrates such de-

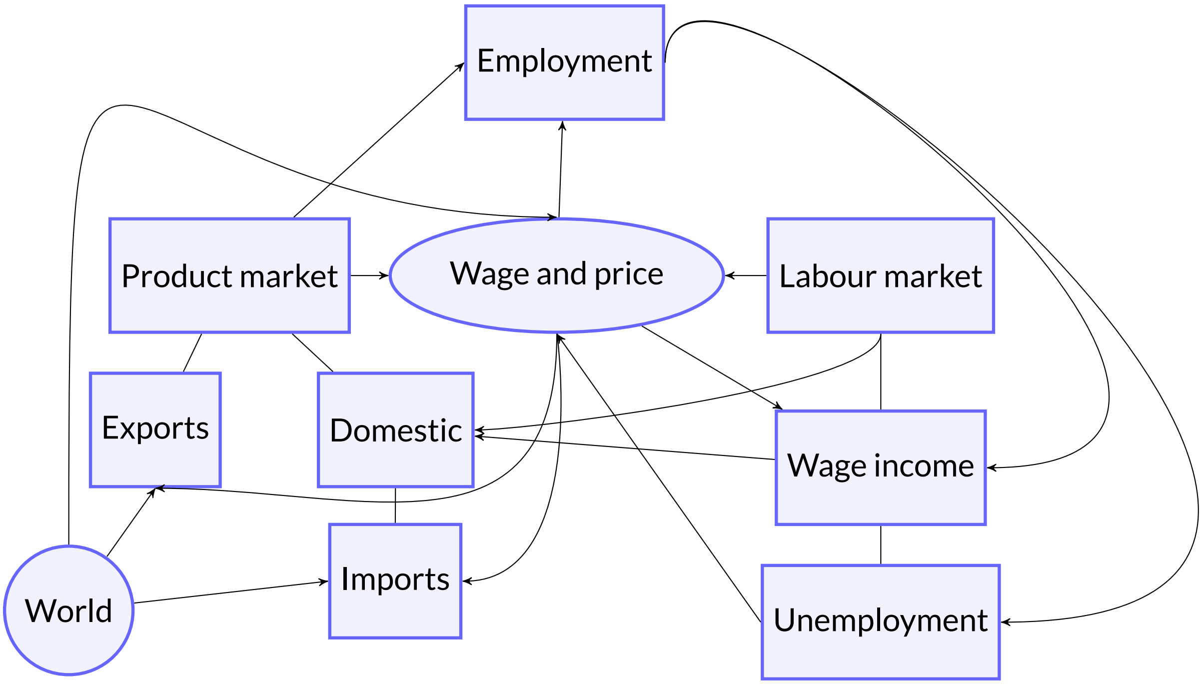

Figure 1: Illustration of relationships and joint-dependencies between product markets and the labour market.

pendencies between domestic and foreign prices and wages.

The outcome of wage and price setting has consequences Norwegian firms international cost-competitiveness, represented by the lines from the Wage and price ellipse to the squares representing Exports and Imports.

Monopolistically competitive firms also make hiring decisions which in sum amount to aggregate employment in the economy, indicated by the line from Product market to the square node labelled Employment. Hiring decisions are also influenced by the outcome of Wage and price setting and changes in productivity. For example, a high real wage cost level puts a premium on productivity developments in order to maintain required operating surplus. Clearly, this effect tends to reduce labour demand, for a given level of product demand. But there is another effect of a rise in wages as well, and that is to increase the real wage of individuals and households, for a given level of employment. Hence, the graph includes a line showing the relationship between Wage and Price setting and Wage income, and a (very long) line from Employment to Wage income, representing that the level of employment in the economy is the other main factor of the part of income to households that is due to labour market participation. Finally, Wage income affects the demand in the Domestic product markets, completing another closed-circuit set of relationships between macroeconomic variables.

Finally, Employment, or more precisely, growth in employment, is a main determinant of the rate of Unemployment in the Norwegian economy. Changes in the level of unemployment in turn impinge on wage-and-price setting, as indicated in the figure. One function of the relationship from Unemployment to Wage and price setting is to provide a channel for so called internal depreciation or appreciation. Assume for example that, after a period of buoyant product markets, the level of unemployment has become so low that it contributes to significant rise in real wage costs. Since at least part of the wage increases are rolled over to prices set by Norwegian forms, the overall price level in Norway starts to increase faster that the price level of Norway's trading partners. Over time, this process of internal appreciation (keeping the nominal exchange rate out of the picture for the moment) will affect international competitiveness in a negative way that may lead to lower income growth and to an increase in the unemployment rate. Figure 1, represents these effects of a real appreciation, by the lines from Wage and price setting, to market shares in both Export competing and Import competing product markets.

The example with internal appreciation shows that the *real exchange rate*, defined as the relative price level between Norway and abroad, denominated in kroner, is a central variable in NAM. As chapter 6.6.1 formally shows, the process that determines the dynamics of the real exchange rate is closely linked to wage and price formation. This mutual dependency is indicated in Figure 2 by the line with two-way arrows between the ellipses representing Wage and price setting and the Real exchange rate.

2.3 CREDIT, ASSET MARKETS AND THE REAL ECONOMY

With a floating exchange rate regime, the real exchange rate is directly influenced by the market for foreign currency exchange, labelled FEX market in Figure 2.Theoretically, in the portfolio approach that we make use of in chapter 7.6, the nominal exchange rate is driven by changes in the factors that determine net supply of foreign exchange to the central bank, cf. Rødseth (2000, Ch. 1 and 2). The model of the effective exchange rate in NAM supports a role for the difference between Norwegian and foreign interest rates, oil price, as well as a the lagged exchange rate itself (with a negative signed estimated coefficient, consistent with regressive depreciation anticipations over the sample). The impact of foreign interest rates and oil prices on the nominal exchange rate is indicated by the line from the World node, to the FEX market node.

With floating exchange rates, and a flexible inflation targeting monetary policy, the sight deposit interest rate determined by the central bank is the main instrument of monetary policy. Monetary policy is represented by the circle node Policy in the north-west corner of Figure 2.

If the central bank changes its policy rate, banks and other financial institutions in the Credit market normally adjust the interest rates on loans and deposits. Higher or lower

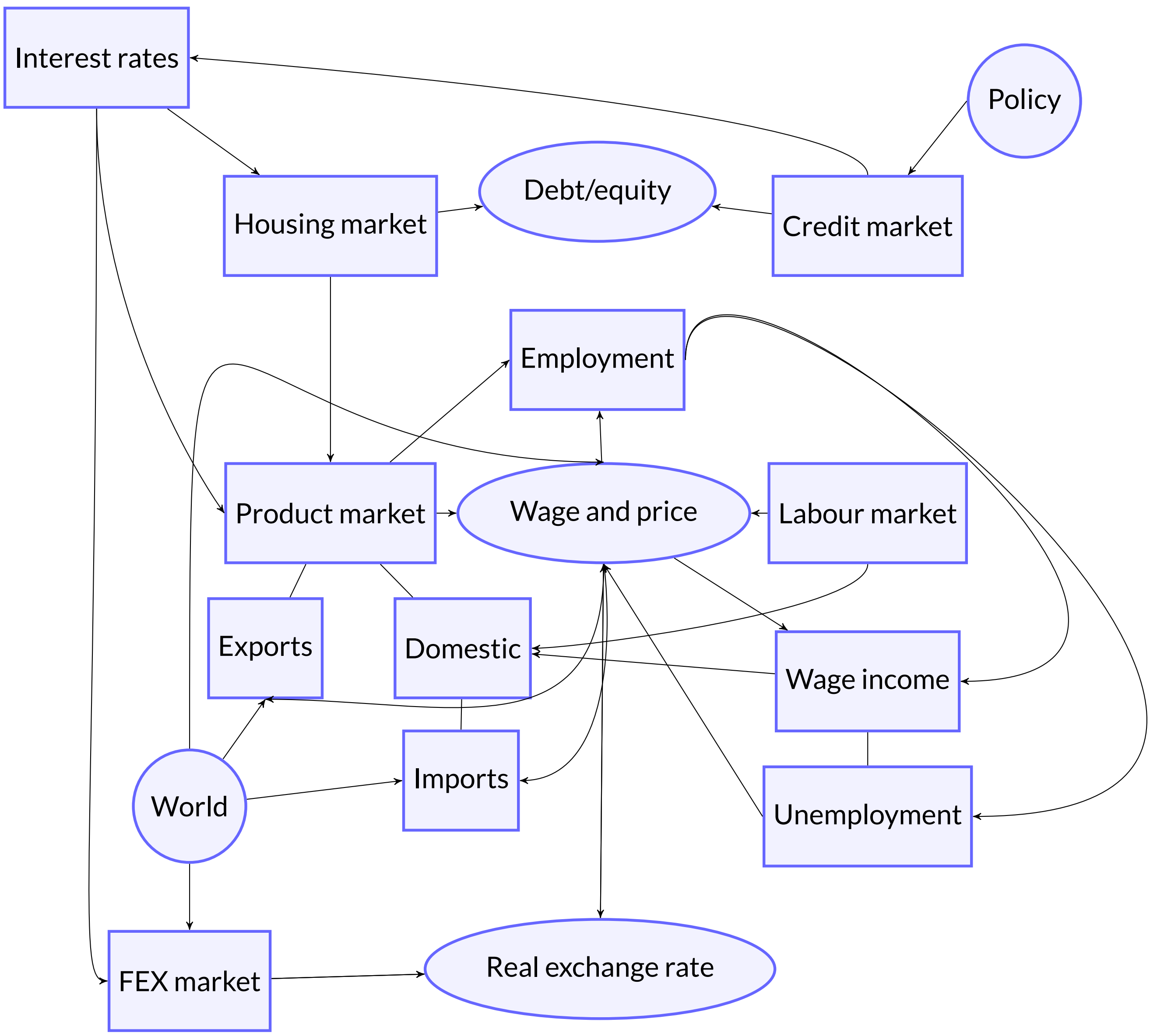

Figure 2: Illustration of relationships and joint-dependencies, extended by asset markets (foreign exchange and housing) and credit.

market interest rates affect product markets as indicated by the line from the Interest rate node to the Product market node. This is an interest rate channel of monetary policy, through which monetary policy affect private consumption, and capital formation in the business sector and in residential housing, cf. Bårdsen et al. (2003).

There is also an effect of interest rates on the real economy that goes through the Housing marked. In the model, household debt increases with rising disposable income and house prices, and with lower lending rates. The model contains an accelerator mechanism whereby higher house prices, contributing to higher collateral values, lead to heavier household debt, which in turn fuels a further increase in house prices, and thereby even heavier borrowing by households, cf.Anundsen and Jansen (2013), and Chapter 7.7.3 below. This process is represented by the Debt/equity ellipse node in the figure.

If interest rates are lowered by monetary policy, both credit and house prices tend to increase. As chapter 7.7.3 discusses, the need for collateral when a housing loan is granted, may lead to positive feed-back effects between credit expansion, and housing prices. A process with parallel build-up of debt and equity may result if interest rates are kept low for a long period of time. Many commentators refer to this as a bubble in the housing and credit market, since positive equity may be turned to negative equity if the net demand for housing drops for some reason.

NAM captures that housing prices and credit have effects on the real economy, and that thet are affected by it. One well documented empirical effect is the effect of housing dominated private wealth on consumption expenditure, cf. Brodin and Nymoen (1992), Eitrheim et al. (2002). The relationships between credit, house prices and aggregated demand have been useful in the modelling of imbalances in the household sector, see Finanstilsynet (2014b). For example households' "interest payment burden" is determined by the lending rate and household debt. An increase in the debt burden tightens households' liquidity, thereby reducing housing demand.

In the open economy there are other effects of monetary policy as well. The most important is perhaps that a change Norwegian market interest rates will affect the market for foreign exchange, with the opposite sign effect of foreign interest rate. This then, is the foreign exchange rate channel of the transmission mechanism of monetary policy.

Although the Policy node may indicate that the policy interest rate is exogenous in the model, this is not actually the case. The policy interest rate is endogenized in NAM with the aid of a interest rate reaction function, that includes the intermediate target of monetary policy, the deviation of inflation from the target of 2.5 per cent annual inflation as well as indicators of the state of the real-economy (GDP-gap and/or unemployment rate). Empirically, we find a break in the "reaction function" after the financial crisis of 2009. Understandably, the central bank then had much less haste than before in projecting the inflation rate on to the target.[7] Hence, we should in principle have added lines from Wage and price inflation to Policy in Figure 2, but since the picture has already become complicated we have omitted that connection.

For the same reason, we have not drawn the lines that could represent that both Housing market and Credit market are influenced by incomes that are generated in the product and labour markets.

Hence, although Figure 1 and 2 are useful to get an idea about which markets and sectors of the economy that are covered by NAM, it nevertheless underestimates both coverage and the number of relationships between the different markets, process and sub-systems.

Another, very important model feature which is "hidden" in the diagrams, is that most

[7]There was a change in this direction already in the summer of 2004, showing that the time horizon for the bank's inflation forecast represents one important dimension of policy, see R. and Falch (2011) and Akram and Nymoen (2009).

of the relationships represented by lines are dynamic relationships. This means that a line can represent a relationship that is mainly of a short-run nature, while another line is suggesting a long-run relationship, that can be weak in the short-run but it get stronger as the the time horizon is increased. In order to come to grips with dynamics, numerical model simulation of the model is needed. Computer simulation is therefore the main tool of analyses when using NAM. Chapter 3 contains some examples NAM usage, and therefore of simulation results.

2.4 NON-MODELLED (EXOGENOUS) VARIABLES

While Figure 1 and 2 give an impression of model coverage by focusing on what is included in NAM, it also possible to get an impression by asking the opposite question: What is not explained by NAM, but instead represented by non-modelled (exogenous) variables?

As already noted: Foreign interest rates (money market and ten-year yield on government bonds) are exogenous variables in NAM, together with the oil price (in US dollars). The other non-modelled foreign variables are the indicator of international trade, a consumer price index and a producer price index (both of them are trade wighted and in foreign currency). These variables are not modelled since they are assumed independent of domestic variables.

Domestic non-modelled variables include government consumption (expenditure on purchases and salaries) and investments, and capital formation in oil and gas production and transportation.

Due to the considerable fiscal policy independence represented by the Norwegian "oil-fund", there is really no binding fiscal policy rule in Norway. [8]. This does not mean that fiscal policy has been entirely discretionary. On the contrary, since the start of the new millennium there has been a rule that link the governments use of 'oil money' to the rate of the return of the oil-fund.

The real meaning of fiscal policy independence is therefore that the government can choose itself to adhere to such a rule, it is not forced by the markets, or by international institutions, to adopt a ruled based fiscal policy. Hence, it makes sense to keep government expenditures as non-modelled variables, and to use the projections from the government budgets to formulate a baseline for forecasting. Investments in oil production and transportation is of course not a government controlled variable. It is clearly 'economy endogenous', and with the oil price as one of the explanatory variables. However, we have not been able to model oil investments in a way that would be of much use for

[8] Formally The Government Pension Fund Global. The fund is a construction that goes back to the start of the 1990s (then with no money in it). Today it is the world's largest pension fund. See for example `http://www.nbim.no/en/`

forecasting. The next chapter give example of the importance of oil-investments for the NAM forecasts, and of the estimated effects of reduced oil investments on the mainland Norwegian economy,

2.5 EQUILIBRIUM CORRECTION MODEL; NOT NAIRU-MODEL

NAM is a dynamic model that aim to represent the typical trends in many macroeconomic time series, so called unit-root non stationarity, but also the theoretically plausible (non-trending) steady-state relationships between non-stationary variables. NAM is therefore a so called equilibrium-correction model. The equilibria can change due to for example institutions adapting to the changing environment. Together, this means that NAM allows for both unit-root non-stationarity, cointegrationg and structural breaks.

One of the variables in NAM that has a well defined equilibrium, steady-state, is the rate of unemployment. However, NAM is not a 'natural rate' (of unemployment) model. This follows from the theory of wage and price formation, which represents an important form of coordination of wage and prices through collective agreements, and their extension to the labour market, cf. section 6.3. Unlike NAIRU macro models, where the rate of unemployment consistent with stable inflation is given as a single point on the real line, the theoretical properties of NAM implies that there is a range of constant values of unemployment that are consistent with stable inflation. [9].

This however, does not entail that NAM can be said to support inflationism , or to imply that there is a trade-off between higher levels of inflation and lower levels of unemployment (often associated with a downward-sloping long-run Phillips-curve). The implication is instead that the relationship between the steady state of inflation and of unemployment is much weaker than in the standard macroeconomic theory with some form of Phillips curve as the key relationship on the supply side.

In the medium run time perspective, output in the NAM is however strongly influenced by aggregate demand. As the above discussion tried to argue, this is theoretically plausible given the nature of industrial production (flat, or even decreasing, marginal cost curves until capacity is reached) and the nature of competition with some degree of market power and price setting by firms.

2.6 IDENTIFICATION, ESTIMATION AND SPECIFICATION

The model contains blocks with simultaneous equations, for wage and price formation and housing prices and credit. For these sub-systems identification is achieved in the two well known steps: First, identification of the cointegration relationships, and second, of

[9]NAIRU is acronym for the Non Accelerating Inflation Rate of Unemployment. Rather inconsistently, empirical NAIRU models often provide estimates of the NAIRU which fluctuates much more than seems to be reasonable, given how labour market institutions have evolved

the short-run dynamics, cf. Hsiao (1997). Estimation is by FIML. The rest of the model consists of single equations estimated by OLS, with the interpretation of conditional expectations, where agents form and act on contingent plans. The parameters of interest of these equations are therefore regression parameters, and they are identified.

Although the model in its present form has proven to be of some use in forecasting and policy analysis, it also has weaknesses that are easy to see. It is always a question whether this is mainly due to choice of parameters of interest and identification, or whether there are more mundane reasons like invalid conditioning, or simply poor empirical modelling. Based on experience, gradual model improvement is a viable way forward, and that dialogue with model users is essential in that process. In this we have found confirmation of the observations made by Granger (1990). With frequent structural breaks in the economy, there is a price to pay in the form of forecast-failures (and maybe wrong policy advice) for being non-adaptive in the model specification.

2.7 RELATIONSHIP TO DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODELS (DSGES)

At a certain technical level, there is a close relationship between DSGEs and NAM. In NAM, the reduced form is a (high dimensional) VAR with a well defined companion form representation.[10] The solution of a DSGE model, if it exists and is unique, is also a VAR, see Bårdsen and Fanelli (2015). Hence, the principal difference between NAM and a DSGE is the respective identifying restrictions on the VAR.

Identification is a question of economic theory, and therefore the relevance and evaluation of the identifiable theory for the Norwegian economy remains a topical issue. For example, In NAM the steady state is not imposed *a priori*, but estimated as cointegrated relationships.

It should comes a no surprise that our position is that the theoretical framework used in the construction of NAM is of greater relevance for analysing the Norwegian macroeconomic system, than the general and microeconomic theoretical underpinnings of DSGEs. But apart from that position statement, there is no crusade against DSGEs, or other models or methodologies, in this documentation. Basically, all different methodologies currently on offer must be expected to be useful for some purpose, for some users.

At descriptive level, another difference is the direct modelling of the macroeconomic data in NAM, versus the "prepared" data modelled in DSGEs. In NAM the deviation from equilibrium is represented explicitly in the model, with estimated steady-state parameters, while in DSGEs the variables are usually filtered, representing deviations from steady-state paths. Since both types of models will be damaged by structural breaks in the equi-

[10] The companion form is method of transforming a system of difference equations of higher order into first order, see e.g. Bårdsen and Nymoen (2014, Chap. 6.63).

librium relationships, it seems better to have steady-state parameters explicitly in the model specification, to assess their significance and to monitor signs of breaks.

All in all, it is better to place NAM in the tradition of Structural Econometric Models (SEMs) tradition than as an ‘deconstructed’ DSGE model. Since one of the main usages of NAM is been specification and analysis of macroeconomic financial stress scenarios, it is interesting to note that economicsts at the Bank of England has recently used the SEM approach to develop a new framework for analysing money, credit and unconventional monetary policy, cf. Cloyne et al. (2015).

3 EXAMPLES OF NAM USAGE

As noted in the Introduction, the exact number of variables can vary somewhat between different versions of the model. The model dubbed NAM-FT, used by Finanstilsynet[The Financial Supervisory Authority of Norway], has a larger number variables than the ordinary version of the model. [11] In practice, using NAM comes down to running and editing a computer program. Therefore it is also very easy for model users to define new endogenous variables to fit the purposes of the analysis.

3.1 NAM AND ECONOMETRIC SOFTWARE: EVIEWS AND OXMETRICS

NAM is implemented as a program file (recognized by the filename extension “.prg”) in the econometric software package Eviews.[12] The current version of NAM runs on EViews 9 and EViews 8 and Eviews 7. The NAM prg-file serves several functions. The first is to load a number of files with quarterly data sets that are needed to estimate the model’s equations, and to complete the model with definitional relationships. Maintaining and updating the data files is a main task connected to using NAM.

The data files that are loaded by the NAM-prg file are either recognized directly as EViews databases, or they can be transformed to such databases. The file format of the OxMetrics family of econometric software is an example of a format which is recognized as a database. We use the econometrics program PcGive in OxMetrics in the specification of the sub-models that are implemented in NAM . PcGive is a manifestation of a coherent approach to dynamic econometric modelling,Doornik and Hendry (2013a,b), Hendry and Doornik (2014). [13]

[11] The 2014 and 2015 issues of the supervisory’s Risk Outlook Report (downloadable from `http://www.finanstilsynet.no/en/`) show examples of using NAM in macro financial stress analysis. In the 2015 report, the NAM-based analysis is found in: THEME I. FINANCIAL VULNERABILITY IN THE EVENT OF LOWER INCOME AND HIGHER INTEREST RATES, p. 48-57

[12] EViews is provided by IHS Global Inc. See http://www.eviews.com/home.html.

[13] See http://www.oxmetrics.net/ for information about Oxmetrics and PcGive.

Figure 3 shows a picture of a section in a NAM.prg file where data is loaded. In this case, the first database loaded ("150521fra_r314v04bw4.in7") gets the EViews nickname "fra". Later in the NAM-prg file, the data series in all the different databases (with their new nicknames) are re-defined as data series objects in an EViews workfile. The workfile is the main user interface in EViews.

```
'*************************************************
' START OF IMPORT OF DATA FROM DATABASES
'*************************************************
   ' OPEN DATABASES

   DBOPEN 150521fra_r314v04bw4.in7 as fra


   DBOPEN 150521WBI.IN7 as wbi
   DBOPEN 150521FRA_KVARTS.in7 as KVARTS
   DBOPEN 150521FOLIO.in7 as folio
   DBOPEN 150521RW_EURO.in7 as RWEURO
   DBOPEN 150521StatBank.in7 as Statbank
```

Figure 3: Screen capture of data-import section of a NAM-prg file. The file extension ".in7" indicates OxMetrics databases. DBOPEN is an EViews command for "open database".

When a NAM-prg file has been executed successfully, the NAM-workfile appears on the computer screen. The upper left corner of the workfile may look like Figure 4. In this screen-capture, only data series objects are visible, they are indicated by the time-plot icon and their variable names. The first variable in this workfile is A, which is total exports in million kroner in fixed prices. You can check that out in Chapter 8, which contains an overview of the most important data symbols used, and the corresponding data definitions in NAM.

Note that the screen-capture shows there is not one single *A* variable object in the workfile. There are many. This is because the execution of the NAM-prg file has contained a lot of operations. In addition to data import, and estimation of the models equations, the model has also been solved (in fact, it has been solved several times for different purposes). In the screen-capture, *A_0* is the time series with the deterministic solution for *A*. Another example is *A_0m*, which holds the mean of a large number of stochastic simulations of the model (actually 1000 repetitions in this case).

In most cases, the mean of the stochastic simulation (e.g. *A_0m*) will be close to, but not identical with the deterministic solution (e.g. *A_0*). The reason for nevertheless doing stochastic simulation is to obtain estimates of the degree of uncertainty of the results. Forecast uncertainty is used to construct forecast graphs with prediction intervals. Estimates of parameter uncertainty is used to construct confidence intervals for dynamic multipliers (i.e. the derivatives with respect of a change in an exogenous variable).

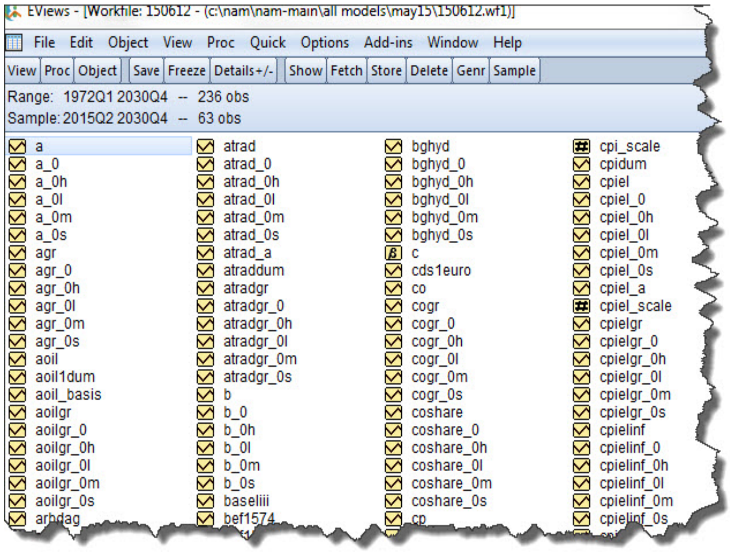

Figure 4: Screen capture of section of an Eviews workfile produced by running a NAM-prg file.

FRAME 3: LEARNING EVIEWS CONVENTIONS AND LANGUAGE

Inevitably, although one can achieve a lot by running a ready-made NAM-prg file, and then work with the data objects (and other objects) in the workfile by using the EViews menu system, you will want to learn about naming conventions, functions and basic programming commands in EViews. There is a good online help system, and both basic and advanced manuals are provided with EViews.

3.2 FORECASTING

A typical usage of NAM is to obtain forecasts of the endogenous and report the results in the form of graphs and tables. Possibly with information of the degree of forecast uncertainty envisaged by NAM.

One essential step in a NAM-forecast is to first update the data of the endogenous variables so that the forecast can be conditional on a time period, call it T, which is close to where you are in real time. In the example we look at, the period we condition on, also called the period of initialization, is the first quarter of 2015, which you can write as 2015q1 or 2015(1) in EViews.

In this specific example, we were able, by uploading data from the Norwegian quarterly national accounts (and other sources) in the way indicated by Figure 3, to establish 2015q1 as the initialization period T. This part of the work with peparing the forecast was completed on 21 May 2015, which is also why the date 150521 is repeatedly used as part of the name for the imported databases in Figure 3.

In order produce a forecast for 2015q2 ($T + 1$), 2015q3 ($T + 2$), and so on up until the end of the forecast period ($T + H$), we have to specify values for all H quarters (often called the forecast horizon). As noted in the Introduction, there are more than 50 exogenous variables in NAM. Providing values for all these variable many quarters ahead may at first appear as time consuming tasks. However, most of the exogenous variables only vary over the estimation period, so it is easy to forecast them automatically as part of the NAM-prg file.

Therefore, it is a considerably smaller number of exogenous, less than a dozen, variables that you have to consider carefully in order to obtain meaningful (and hopefully quite good) forecasts of the endogenous variables. It is advisable to generate the exogenous variables for the periods from $T + 1$ to $T + H$ within the NAM-prg file. In that way it is easy to go back and review the assumptions later, and update them as new information comes in. Therefore a NAM-prg file will always contain a clearly defined section where the values of exogenous variables in the forecast period are either generated (by algebra) or imported from a databank with the forecast. This can be good alternative for e.g. spot energy prices where expected spot prices can be derived from the prices in forward market.

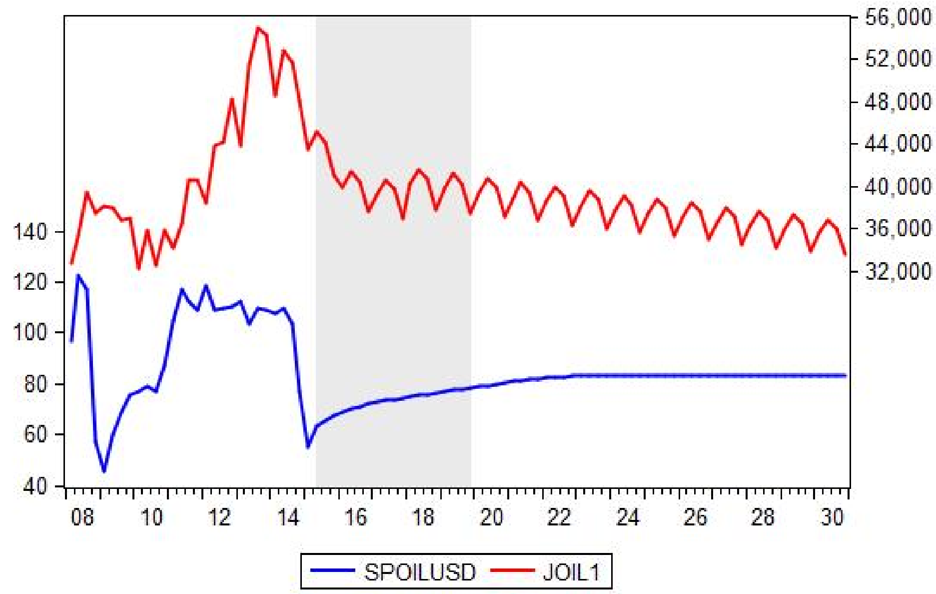

Figure 5: Time plot of two focus exogenous variables in a NAM-forecast for the period 2015q2-2030q4. SPOILUSD (left axis) is the price of North-Sea oil in USD, and JOIL1 (right axis) is gross capital formation in oil and gas extraction and transportation in million NOK (fixes 2012 prices)

When forecasting the Norwegian economy in the first half of 2015, the attention was on how the Norwegian macro economy would become affected by the fall in the oil price that had begun already in the autumn of 2014. Because of the central government's "oil fund", concerns for public finances could be put to the side. The focus was instead on how much the investments in the petroleum sector would become negatively affected, since the fall in the oil price seemed to be regarded by the oil companies as a permanent price reduction.

Figure 5 shows time plots for the two focus-variables for the period 2008(1) to 2030(4). Oil investments is labeled *JOIL1* and the label for the oil price is *SPOILUSD*. The shaded part of the figure indicates the period where we have made qualified guesses for the likely development for the variables (building on future oil prices and published investment plans from the oil companies). The assumed developments for 2020q1-2030q4 are included since it is often useful to simulate the model over a longer period than the focus horizon, in order to get an impression of the stability or otherwise of the model solution.

When the NAM-prg file with the assumptions for *JOIL1* and *SPOILUSD* in Figure 5 (and the other exogenous variables) has been executed, the EViews workfile contains forecasts for all the model's endogenous variables. The forecasts are available in different form: As time series variables (*A_0* and *A_0m* mentioned above are examples), in graphs and in tables.

Figure 6: NAM forecast for annual growth percentages in value added in Mainland-Norway and in three production sectors. Forecast start is 2015q2 and the last forecast period is 2030q4. The forecasts are shown with $+/-$ 2 forecast standard errors as dotted lines.

Figure 6 is an example of a graph-object in the workfile. It shows the annual growth rates (percentage change from quarter j in year t to quarter j in year $t+1$) for Mainland Norway GDP (NAM variable YF) and for value added in three production sectors: Manufacturing (*YFP1*), Production of other goods, including the construction sector, (*YFP1*) and Private service production (*YFP3*).

The graphs include actual growth rates for the period 2008q1-2015q1. The start of the forecasts in 20015q1 is easily seen by the appearance of three lines: The middle line is the mean of the simulated forecasts (i.e. a *_0m* series in the workfile), while the two dotted lines indicate the upper and lower bounds of the 68 % prediction intervals (they can be found as *_0h* and *_0l* series in the workfile).

The graphs shows that the growth rates of both *YFP1* and *YFP2* are projected to be damaged by the weakening of "oil-investments" in Figure 5. For manufacturing and production of goods, the upper bound of the 68 % prediction intervals includes negative numbers early in the forecast period, meaning that the model regards a recession in this sector as a very likely event. However, the predicted downturns in 2015 are much lower than what was seen after the financial crisis in 2008, which are included in the plots for comparison.

Note that the forecasted growth rates in the graphs quickly become almost straight lines. This is a typical trait of forecasts from a dynamically stable model: The model forecasts converge to the unconditional means of the variables. The strange "blip" in the middle of the forecast period is a result of a temporary deviation from the long-run mean, because of shift in working days between the first and second quarter of the year (which again has to do with Easter holiday moving between in the first or second quarter).

The workfile contains several more graphs of individual variables and of groups of variables. And new plots can easily be constructed from the data files in the NAM-workfile.

The NAM-workfile also contains tables with the forecasted model variables. Sometimes one will want to get a quick impression of what the annual number are. But since we have forecasted at the quarterly frequency, it is easy to construct the annual forecasts from the model solution in the forecast period. Figure 7 shows an example, of two groups of forecasts, one dubbed TOTS for "Total supply" and another dubbed TOTD for "Total demand".

In a macro model, the forecasts of the components of the demand and the supply side of the economy need to be made consistent. Otherwise total demand can be forecasted to grow significantly different from total demand, and the basic identity of the national accounting system will then become violated. In many macro models this consistency is 'hidden' by not modelling the two sides of the economy separately. In a completely demand driven model, GDP is determined from the demand side. In a real business cycle model the opposite position is taken. In NAM, GDP-supply and GDP-demand are however modelled separately, and the equality between GDP-supply and and GDP-demand in the forecasts then becomes a non-trivial case. Briefly, in NAM, consistency is achieved by letting the demand component "changes in inventories" in the national accounts be an endogenous variable that balances GDP from the demand and the supply sides of the economy. Chapter 7.2 contains more details.

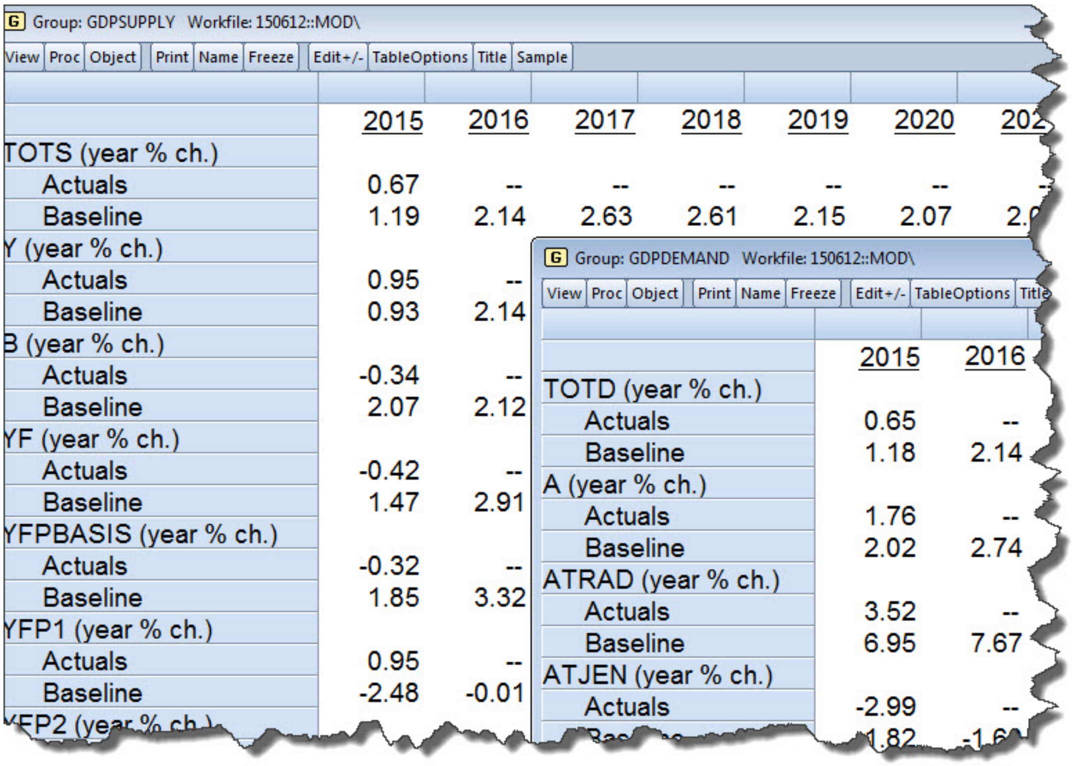

Figure 7: Screen-capture from a NAM workfile showing two group objects with forecasted growth percentages of total supply (TOTS) and total demand (TOTD) and their components. The forecasts has been transformed from quarterly data to annual data before tabulation. The variables names are explained in Chapter 8.

Figure 7 shows that in 2015, there is a small deviation between the growth rate of TOTS and TOTD. This is because the 2015 numbers are made up of actual values from 2015q1 and model simulated number for the last three quarters of 2015. For 2016, the first year that the forecast is made up of only simulated data, the two growth rates are equal, showing that NAM produces GDP-forecasts that are consistent with basic accounting relationships.

3.3 POLICY AND SCENARIO ANALYSIS

A main purpose of macroeconomic model building is to quantify the effect of changes in one or more exogenous variables on the endogenous variables of the model. Policy analysis addresses the likely effects of a change in a variable that can be changed by economic policy. More generally it is also of interest to quantify the effect of other exogenous events, such as reduced income in the countries that represent Norway's main trading partners, increased international interest rates and so on. We can loosely refer to analysis of this type as scenario analysis.

As is well known, the reliability of policy analysis hinges on the assumption that there is no systematic feed-back from the endogenous variables to the model-exogenous variables in the analysis. Formally this assumption is called "one-way Granger causality", meaning that a change in the exogenous variable should affect the endogenous variables, but that these changes should not feed-back on the variable that are subject to shock in teh analysis.

Another assumption needed to validate policy-analysis is that the parameters of the model have a high degree of *invariance* with respect to the shock that we focus on. We discuss both Granger non-causality, and the role of parameter invariance in the chapters on methodology below.

Heuristically, policy analysis is done by first specifying both a reference path and "shock" path for the non-modelled variables that we want to study the effects of. The model is then simulated (solved) two times: First with the reference-paths for the exogenous variables, and then with the shock-paths. The effects on the endogenous variables can be read off by comparing the solutions corresponding to the two paths of the exogenous variables.

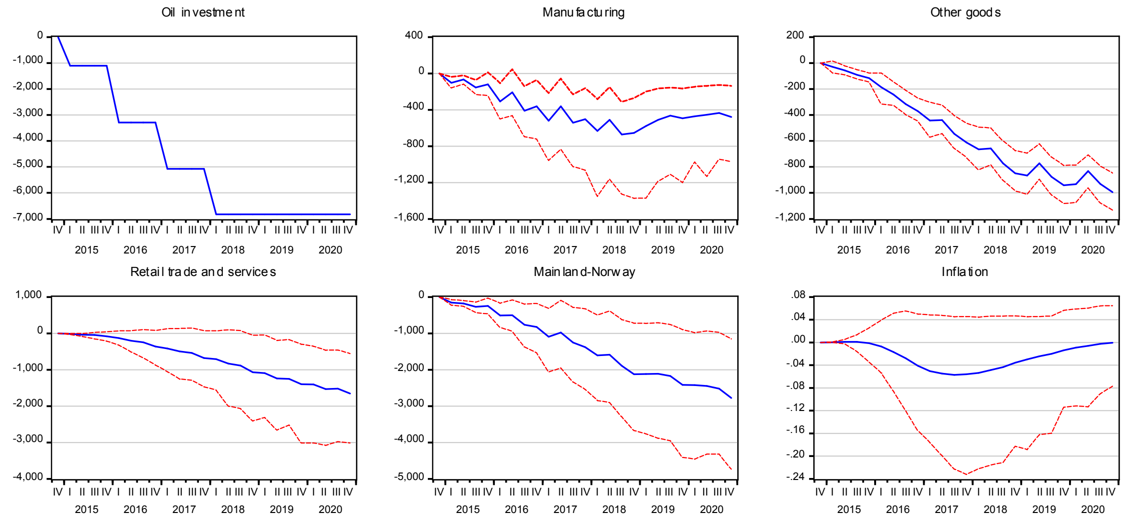

Figure 8: The effects of reduced capital formation in oil and gas production and transportation on Mainland-Norway GDP: Value added in three production sectors and inflation. The units on the vertical axes are million kroner in 2012 prices, except for the inflation graph where the units are percentage points. The distance between the red (or dotted) lines represent 95 % confidence intervals.

With the aid of EViews the two simulations can be be automatized, and the results can also be plotted or tabulated by a few commands that can be included in the NAM-prg file. As an example of this usage of NAM, we look at a reduction in 'oil investments', which in the model is represented by the variable *JOIL1* that we introduced above.

JOIL1 is probably 'exogenous enough' to be an relevant focus variable to shock. Although we can imagine that oil companies can revise their investment decisions if a reduction lead to markedly lower wage costs (for Norwegian engineers), that effect is not likely to be very large. Hence, one-way Granger causality seems to a tenable assumption.

Invariance of the parameters with respect to a shock is impossible to prove once and for all. But we have been generating forecasts with NAM over 10-year period where oil investments have changed quite a lot, as shown in Figure 5. If the model parameters were very sensitive to positive and negative shifts in *JOIL1*, it would have led to noticeable forecast errors. But so far we have not been able to pin forecast inaccuracies in NAM to lack of invariance of model parameters with respect to oil-investments.

The graph to the right in the first row of panels in Figure 8 shows the deviation between the reference and the shock-path of *JOIL1*. Oil investments are reduced gradually by around 7 billion kroner over a two year period. This is a large reduction, although the level of investment would still be at level comparable with 2008-2010.

The other graphs in Figure 8 show the responses in a few of the endogenous variables of NAM. Mainland-Norway GDP is negatively affected, but we see that the reduction is less than the investment reduction. The interpretation is that imported investment goods is reduced when *JOIL1* falls, and that Norwegian producers are predicted to be able to adjust (to some extent) to the weakening of demand from oil-investments. The graph shows that effects are still "building up" at the end of the simulation period though

Value added in both manufacturing and in production of other goods are negatively affected, as the graphs show. As can be expected, the private service sector is least affected among the three private sectors in the model. Finally we note that there is a small negative effect on Norwegian inflation. Why this is reasonable is discussed in the chapters about wage and price formation below.

Formally the dynamic responses shown in Figure 8 are model parameters. We can therefore use stochastic simulation to quantify the parameter estimation uncertainty. The distance between the red (or dotted) lines represent 95 % confidence intervals. Based on this simulation we therefore conclude that the effects on GDP and to of the sector's value added are statistically significant different from zero.

FRAME 4: JUMP FROM HERE?

As noted in the Introduction, it is possible to skip the two next chapters, which address several general methodological issues connected to the task of formulating a macroeconometric model, and move to Chapter 6 which is about the supply-side of a macro model of NAM's type. The methodological chapter introduce several modellings concepts that are used in the rest of the documentation. It is of course possible to look them up later even if you first jump directly to Chapter 6.

4 EMPIRICAL MACROECONOMIC MODELLING

4.1 THEORETICAL AND EMPIRICAL MODELS

We have already several times referred to NAM as an empirical econometric model. But how should we define empirical model in the first place? Obviously, an empirical model 'uses data', it contains numerical parameter values for parameters, and it can be used to produce numerical fitted valued for endogenous values that can be compared to actuals.

But this descriptive definition is not enough to clearly delineate an empirical econometric model. In fact, the description could also fit a theoretical model with a specified functional form, and with values that are calibrated with the use of data. Such a model can also generate numbers, as a numerical solution, for the endogenous variable, by adding numbers for the disturbance that are drawn from a theoretical distribution with theoretically known (or calibrated) parameters.[14] Hence for a theoretical model of the relationship between Y and X we can write

$$\underbrace{Y_i}_{solution} = \underbrace{h(X_i)}_{calibrated} + shocks_i \tag{1}$$

where the disturbances are numbers generated with the aid of a random number generator calibrated to a known statistical distribution.

In (1), the shocks are part of the model, with postulated properties that are in principle independent of Y. For an empirical model of the relationship between Y and X, a similar decomposition between the 'systematic part' ($h(X_i)$ and the random part of the model can be made. But since the joint distribution of Y and X (the data generating process, DGP) is unknown to the empirical macroeconomic modeller, the aim is instead to construct an explanation of Y with the aid of sample observations (x_i, y_i) of the two variables. If we denote the explanation by $g(x_i)$, a function with parameters that are estimated from the data, we can write an empirical model as

$$remainder_i = \underbrace{y_i}_{observed} - \underbrace{g(x_i)}_{explained} \tag{2}$$

Hence, unlike the independent shock of a theoretical model, the remainder of an empirical model is a not a part of the model, and their properties are derived; they are not independently postulated as the shocks of a theoretical models are. This is a consequence of having 'passive data' or observational data rather than experimental data, see Hendry and Nielsen (2007, Ch. 11.1-2) and Bårdsen and Nymoen (2011, Kap. 8.1).

Despite its simplicity, the formulation in (2) is generic: Empirical econometric models are really decompositions of observed data rather than causal entities. At first sight, this

[14]Calibration is often used in practice, for example the variance parameter can be chosen with the purpose of matching the amplitude of the solution of Y_i.

may be seen as pulling the rug under the feet of the macroeconometric project. But we can nevertheless construct a viable approach to analysing data in a non-experimental research situation. Reverse causation (Y causing X), simultaneity (joint causation between Y and X) and spurious correlation (both Y and X caused by a third variable Z), are all possible relationships in the data that are consistent with (2). But finding empirically that there are significant elements of independent variation in X, and that this variation systematically changes Y, increases our confidence in the model. Likewise, if adding Z to the model does not affect the properties of the remainder, then we have reason to believe that it does not determine Y, and so on. In chapter 5 we present a coherent approach to macroeconometric model construction under the real-word assumption of non-experimental data and unknown data generating process.

The characteristics of empirical econometric models can also be illustrated with the aid of the diagram in Figure 9.

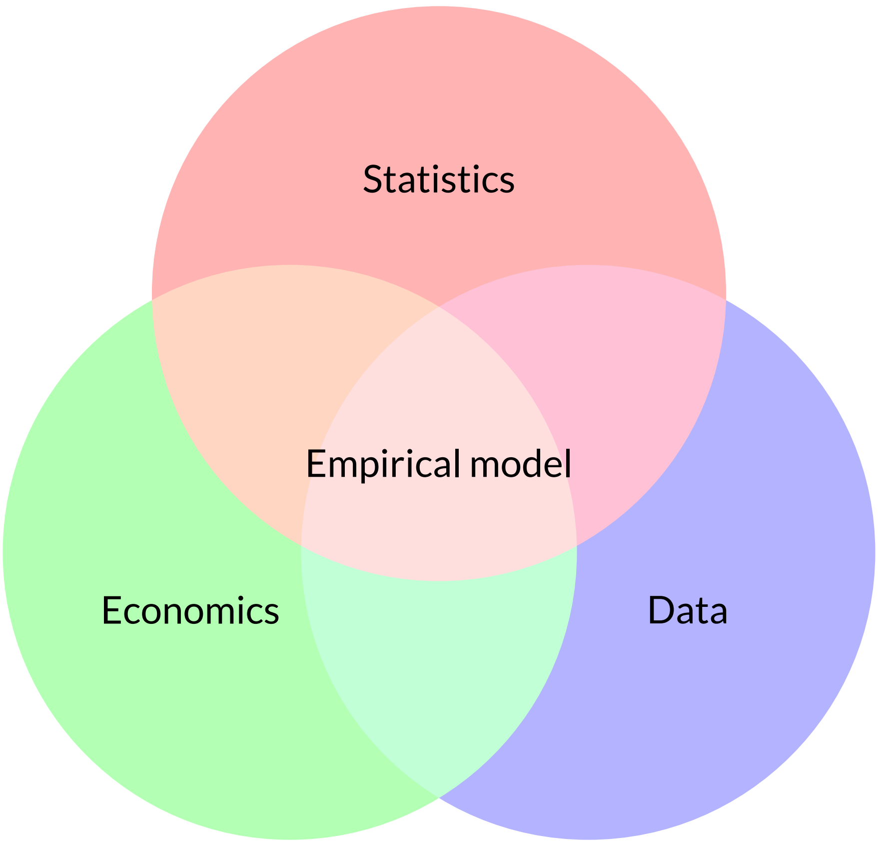

Figure 9: Illustration of an empirical macroeconometric model as the intersection of information fields of statistical theory, economic theory and the information in observed data

It illustrates the empirical model of as representing the combination of three different field of knowledge and information, statistical theory, economic theory and observed data. In macroeconometric model building, at least for the purpose for medium-term analysis, institutions are also of great importance. But in order to avoid complicating the picture, we can subsume institutions in the circle labelled Economics (since economic theory has something to say about how institutions affect the macroeconomic variables) and in the Data circle (since it often is possible to obtain data about how institutions have changed during the the sample period)

Economic theory (Economics in the diagram) is vast field by itself, and econometric model construction will build on the theory that is judged to be most relevant for the purpose of a model building project. The chosen segment of economic theory suggest which variables are interrelated and in what ways, possibly the functional form (cf. $g(x_i)$ in (2)). Both Chapter 6 and 7 gives several examples of the importance of economic theory in the construction of NAM.

The data that we use are time-series observations, meaning that economic theory that indicate something about the dynamic specification of the model is particularly relevant. However, the available theory is often representing the behaviour of economic agents in a steady-state, and are therefore static. Historically, given the trends in time series data, this created the pit-fall of *spurious regression* in econometric time series modelling. But due to the advances in statistical theory at the end of the millennium, we are now able to make use of static (long-run) economic theory in dynamic models of non-stationary time series in a consistent way. The key-words here are unit-roots in individual time series, testable cointegration between two or more time series variables, and equilibrium correction models, as one important class of Empirical models that represent the intersection between Economics, Statistics and Data.

The profession's collective understanding of the causes and possible remedies of model limitations, both in forecasting or in policy analysis, has improved markedly over the last decades. The Lucas (1976) critique and the Clements and Hendry (1999) analysis of the sources of forecast failures with macroeconometric models are milestones in that process. Interestingly, the methodological ramifications of those two critiques are different: The Lucas-critique have led to the current dominance of representative agents based macroeconomic models. Hendry (2001), on the other hand, concludes that macroeconometric systems of equations, despite their vulnerability to regime shifts, but because of their potential adaptability to breaks, remain the best long-run hope for progress in macroeconomic forecasting. Since monetary policy can be a function of the forecasts, as with inflation forecast targeting, cf. Svensson (1997), the choice of forecasting model(s) is important.

The tradition of macroeconometric models that NAM belongs to aims to make coherent use of economic theory, data, and mathematical and statistical techniques. This approach of course has a long history in econometrics, going back to Tinbergen's first macroeconometric models, and have enjoyed renewed interest in the last decades. Recent advances in econometrics and in computing means that we now are much better tools than say 20 years ago, for developing and maintaining macroeconometric models in this tradition—see Garratt et al. (2006) for one recent approach.

4.2 INVARIANCE AND STRUCTURE

A long standing aim of macroeconometric model building is that the model should contain invariant relationships, or at least as invariant as feasible see Haavelmo (1944, Chapter II). The caveat reminds us, in case we should forget, that there can be no such thing as a 100 percent invariant behavioural relationship in empirical economics. Sooner or later, like other products of civilization, even the most theoretically sound and relieably estimated relationships will break down. Therefore, a realistic target to set for economic model is a high degree of invariance, and in particular to avoid unnecessary low degree of invariance, by for example abstracting from the structural breaks that have occurred in the sample period.[15]

According to one dominant view, macroeconomic models that are "theory driven" and of the representative agent, intertemporal optimizing, type are said to have structural interpretations, with 'deep structural parameters' that are immune to the Lucas critique. However, when the model's purpose is to describe the observed macroceconomic behaviour, its structural properties are conceptually different. Heuristically, we take a model to have structural properties if it is invariant and interpretable—see Hendry (1995c). Structural properties are nevertheless relative to the history, the nature and the significance of regime shifts. There is always the possibility that the next shocks to the system may incur real damage to a model with high structural content hitherto. The approach implies that a model's structural properties must be evaluated along several dimensions, and the following seem particularly relevant:

1. Theoretical interpretation.
2. Ability to explain the data.
3. Ability to explain earlier findings, i.e., encompassing the properties of existing modes.
4. Robustness to new evidence in the form of updated/extended data series and new economic analysis suggesting e.g., new explanatory variables.

Economic analysis (#1) is an indispensable guidance in the formulation of econometric models. Clear interpretation also helps communication of ideas and results among researchers, in addition to structuring debate. However, since economic theories are necessarily simplifying abstractions, translations of theoretical to econometric models must lead to problems like biased coefficient estimates, wrong signs of coefficients, and/or residual properties that hampers valid inference. The main distinction seems to be between

[15] In practice this includes breaks in the data measurement system, due to e.g. changes in definitions or in data sources

seeing theory as representing *the* correct specification, (leaving parameter estimation to the econometrician), and viewing theory as a guideline in the specification of a model which also accommodates institutional features, attempts to accommodate heterogeneity among agents, addresses the temporal aspects for the data set and so on—see Granger (1999).

Arguments against "largely empirical models" include sample dependency, lack of invariance, unnecessary complexity (in order to fit the data) and chance finding of "significant" variables. Yet, ability to characterize the data (#2) remains an essential quality of useful econometric models, and given the absence of theoretical truisms, the implications of economic theory have to be confronted with the data in a systematic way.

We use cointegration methods on linearized and discretized dynamic systems to estimate theory-interpretable and idenitifed steady state relationships, imposed in the form of equilibrium-correction models. We also make use of an automated model-selection approach to sift out the best theory-interpretable and identified dynamic specifications. Hoover and Perez (1999), Hendry and Krolzig (1999) and Doornik (2009) have shown that automated model selection methods have a good chance of finding a close approximation to the data generating process, and that the danger of over-fitting is in fact (surprisingly) low. Conversely, acting *as if* the specification is given by theory alone, with only coefficient estimates left to "fill in", is bound to result in the econometric problems noted above, and to a lower degree of relevance of the model for the economy it claims to represent.

In order to develop scientific basis for policy modelling in macroeconometrics, a new model's capability of encompassing earlier findings should be regarded as an important aspect of structure (#3). There are many reasons for the coexistence of contested models for the same phenomena, some of which may be viewed as inherent (limited number of data observations, measurement problems, controversy about operational definitions, new theories). Nevertheless, the continued use a corroborative evaluation (i.e., only addressing goodness of fit or predicting the stylized fact correctly) may inadvertently hinder accumulation of evidence taking place. One suspects that there would be huge gains from a breakthrough for new standards of methodology and practice in the profession.

Ideally, empirical modelling is a cumulative process where models continuously become overtaken by new and more useful ones. As noted above, by useful we understand models that are relatively invariant to changes elsewhere in the economy, i.e., they contain autonomous parameters, see Haavelmo (1944), Johansen (1977), Aldrich (1989), Hendry (1995c). Models with a high degree of autonomy represent structural properties: They remain invariant to changes in economic policies and other shocks to the economic system, as implied by #4 above.[16]

[16] see e.g., Hendry (1995a, Ch. 2,3 and 15.3) for a concise definition of structure as the invariant set of attributes of the economic mechanism.

However, structure is likely to be (only) *partial* in two important respects: First, autonomy is a relative concept, since an econometric model cannot be invariant to every imaginable shock. Second, all parameters of an econometric model are unlikely to be equally invariant, and only the parameters with the highest degree of autonomy represent structure. Since elements of structure typically will be grafted into equations that also contain parameters with a lower degree of autonomy, forecast breakdown may frequently be caused by shifts in these non-structural parameters.[17]

4.3 THE ROLE OF FORECAST PERFORMANCE IN MODEL EVALUATION

The view that forecast failures represent telling evidence against a macro model is still widely held and accepted. In the following we remind the reader that a strategy for model evaluation that puts a lot of emphasis on forecast performance, without taking into account the causes of forecast failure, runs a risk of discarding models that actually contain important elements of structure and relevance for policy analysis.

Importantly, Doornik and Hendry (1997) and Clements and Hendry (1999, Ch. 3) show that a main source of forecast failure is location shifts (shifts in means of levels, changes, etc.), and not shifts in the focus parameters in policy analysis, namely the derivative coefficients of endogenous variables with respect to changes in exogenous variables. Therefore, a rough spell in terms of forecasting performance does not by itself disqualify a model's relevance for policy analysis. If the cause of the forecast failure is location shifts, they can be attenuated *ex post* by intercept correction or additional differencing 'within' the model, Hendry (2004). With these add-ons, and once the break-period is in the information set, the model forecast will adapt to the new regime and improve again. Failure to adapt to the new regime, may then be a sign of a deeper source of forecast failure, of the form that also undermines the models relevance for policy analysis, Falch and Nymoen (2011). In general, without adaptive measures, models with high structural content will lose regularly to simple forecasting rules, see e.g., Clements and Hendry (1999), Eitrheim et al. (1999). Hence different models may be optimal for forecasting and for policy analysis, which fits well with the often heard recommendation of a suite of monetary policy models.

Structural breaks are always a main concern in econometric modelling, but like any hypothesis or theory, the only way to judge the significance of a hypothesized break is by confrontation with the evidence in the data. Moreover, given that an encompassing ap-

[17] This line of thought may lead to the following practical argument against large-scale empirical models: Since modelling resources are limited, and some sectors and activities are more difficult to model than others, certain euations of any given model are bound to have less structural content than others, i.e., the model as a whole is no better than its weakest (least structural) equation.

proach is followed, a forecast failure is not only destructive but represent a potential for improvement, if successful respecification follows in its wake, cf. Eitrheim et al. (2002). . In the same vein, one important intellectual rationale for DSGE models is the Lucas critique. If the Lucas critique holds, any "reduced-form" equation in a model is liable to be unstable also over the historical sample, due to regime shifts and policy changes that have taken place in the economy. Hence according to the Lucas-critique, parameter instability may be endemic in any model that fails to obey the Rational Expectations Hypothesis (REH), with the possible consequence that without integration of REH, the model is unsuited for policy analysis. However, as stated by Ericsson and Irons (1995), the Lucas critique is a possibility theorem, not a truism, and the implications of the Lucas critique can be tested, see also for example Hendry (1988), Engle and Hendry (1993) and Ericsson and Hendry (1999).

In Bårdsen et al. (2003) we have shown, by extensive testing of a previous version, that the Lucas critique has little force for our system of equations. This finding is consistent with the international evidence presented in Ericsson and Irons (1995) and Stanley (2000). On the basis of these results, our model is more consistent with agents adopting robust forecasting rules, in line with the analysis and suggestions of Hendry and Mizon (2010). In that case the Lucas critique does not apply with any force, although the degree of autonomy remains an issue that needs to be evaluated as fully as possible, given the information available to us.

4.4 REDUCTIONISM AND CONSTRUCTIONISM IN ECONOMICS

The macro economy is a large-scale system with joint-causality between variables as a dominant trait. Behind the neoclassical and New-keynesian macroeconomics that has dominated the field for decades, is the position that the large scale macroeconomic system can be understood by working up from the small-scale. This is a kind of strong reductionism entails that the behaviour of the macroeconomy should be derived directly from microeconomics. It has been dominant since shortly after the WW2, and the DSGE models which case into fashion during the first decade of the 2000s are regarded as one of the successes of this school of economic thought.

Meanwhile, in the natural sciences the role of reductionism has been reconsidered. It still has its place (and probably with better reasons than in economics), but scientists are now aware of the fallacy in the belief that that the best way to understand any system is from bottom up. In a much cited paper entitled 'More is different' Anderson (1972) called this fallacy constructionism. Anderson thought it was uncontroversial to accept the proposition that there was a hierarchy to science, so that the elementary entities of science S_j obey the laws of science S_{j-1}. But he rejected the idea that any S_j field of scientific knowledge might be treated as "just applied S_{j-1}". In economics that would mean that macro econometric modelling ought not to be seen as applied microeconomics. Instead, it would seem to lead logically to the position expressed by Lawrence Klein (1962, p.180) :

> Macroeconomics is an essentially different branch of economic theory, and similarly, econometric model construction in the field of aggregative economics has a few of its own distinctive characteristics.

Neither did the reductionist hypothesis imply constructionism. “The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe” (Anderson (1972, p. 393). Instead, one must be open to new concepts and new laws as we move from ’low’ to ’higher’ in the hierarchy. The basis of this position was in particular the discovery of ‘emergent properties’ of physical systems: Sometimes the whole is more than the sum of its parts (“more is different”) and behaviour between the entities at the aggregate level cannot be explained by the behaviour at the component level. Examples of emergent behaviour in economics include dynamic macro models that display fluctuations between a full employment equilibrium and a depression equilibrium, see e.g., Anundsen et al. (2014), that aggregated saving may fall as a results of increased saving among all individual households and that productivity growth may be positively related to the degree of coordination in wage formation. While the natural sciences embraced the discovery of emergent behaviour and started to develop e.g. chaos theory to model it, the reductionist fallacy has continued to hold sway in macroeconomics. Nowhere is this more clearly expressed than in the strongly expressed view that macro models that are derived from neoclassical micro theory contain more structure, and are better suited for policy analysis than models that are based on theoretical and econometric analysis at the aggregate level. If economics is anything like the other quantitative sciences this view will at some point change to one that recognises that there are clear limits to what can be learnt from using neoclassical micro economic theory to specify the properties of the macroeconomic system.

4.5 THE ‘PROS AND CONS’ OF EQUILIBRIUM MODELLING

In spite of taking a firm step away from constructionism, NAM is a model where the concept of equilibrium plays an important role. Specifically, we will usually assume that individual variables follow unstable paths, but we will also investigate closely the possibility that such non-stationary variables may be jointly stationary. In the simplest case in form of ratios that have well defines means that are independent of initial conditions. The means that in NAM, dynamics is represented as in part a manifestation of disequilibrium, and in part an equilibrium phenomenon.

In this section, we briefly address the paradox represented by inclusion of equilibrium dynamics when one of purposes of a macroeconometric model is to analyse scenarios where the macroeconomic stability is fragile (not an equilibrium situation). How can a model with with equilibrium correction nevertheless be useful for "disequilibrium analysis"?

The solution to the paradox is that although our purpose is the detection of e.g., financial and macroeconomic stress, fragility and disequilibrium, such an analysis requires that we, to begin with, have a relatively clear idea about what an equilibrium situation looks like. Otherwise there will be no operational, model based, way of identifying stress-dynamics from "normal" equilibrium dynamics.

A special version of NAM, dubbed NAM-FT, has been developed to aid the analysis of macro-financial stress of the Norwegian economy, see Finanstilsynet (2014a, Theme II, pp. 69-78). As part of that analysis the model is used to produce solution time-paths for the future development of e.g., house prices, credit growth, problem loans, debt to income ratios, interest rate margins, debt leverage, loan and default rates, given a specified stress scenario. The value of the exercise is increased by comparison of any of these variables in the stress scenario with their historical and theoretical representative values, or (which is more usual) by a 'baseline solution which covers the same time period as the stress period. Based on the sets of future paths, one can construct graphs and summary statistics of key variables and ratios.

Not all differences between for example debt leverage levels and equilibrium leverage represent stress. Therefore, it makes sense for the baseline simulation to allow for disequilibria that are inherited from history at the start of the stress-test period. An equilibrium model will tell you that these disequilibria will disappear over the stress test period, and it is valuable to be able to separate equilibrating dynamics from system threatening stress dynamics. Hence, even though stress testing is about dis-equilibrium, the analysis will always be made relative to a path with normal equilibrium dynamics. This is why it is only a mild paradox that stress testing can be based on an a quantitative macroeconometric model with well defined equilibrium time paths for the variables of interest.

NAM offers at least three "handles" that can be used in the construction of financial stress scenarios. First, non-modelled (exogenous) variables can be changed from their typical non-stress time paths to typical stress values. For example, in a stress-scenario that represents a new financial crisis, international money market interest rates can plausibly be increased by a significant amount with reference to increased risk premia in required rates of return. In the same scenario, international demand for Norwegian exports will be damaged by reduced incomes in foreign countries, which will plausibly also make the oil price fall to a very low level.

Second, a situation with financial stress can lead to changes in the intercepts and autonomous growth rates that are parameters in the model's estimated equations. It has now become recognized that structural breaks of this type contribute to a large extent to the variation in economic time series. In the construction of NAM this aspect has been addressed explicitly and the model therefore includes a set of identified stress-indicator variables that are custom built to represent structural breaks that can characterize a plausible financial stress scenario. Some of the indicator variables have the property that they change the estimated long-run mean of estimated equilibrium relationships. With these stress-indicator variables activated in the model, the stress-test simulation will resemble regime-shift analysis, for example as with Markov Switching.

Neither of the two first tools for scenario design change the dynamics of NAM. A third class of interventions that can be made is therefore to change one or more speed-of-adjustment parameters. The result will be particularly striking if a parameter associated with equilibrium dynamics is set to zero in the stress scenario. Of course, in order not to become too speculative, such changes in the structure of the model needs to be careful motivated. On the other hand, it is also quite possible that a model that uses time series for a period where crises has not occurred end up being 'too optimistic' about the number of invariant equilibrium relationships.

However, the relevance and the plausibility of the predicted equilibrium dynamics can usefully be assessed and discussed by the stress-analyses team. For example, the assessment may bee that financial stress is already so far developed in the initial conditions that equilibrium correction is in decline. In fact, a scenario where equilibrium correction first dies away, and then comes back after a long crisis period need not be pure speculation. Recently, Anundsen (2014) has provided an analysis along these lines of the US subprime bubble. Again, the premise for this type of advanced analysis is that the relevant variables and parameters are clearly stated in the description of the stress scenario for the model used.

This is why it is only a mild paradox that stress testing can be based on an a quantitative macroeconometric model with well defined equilibrium time paths for the variables of interest. There is nothing in this position that contradicts the view that conventional equilibrium models can have made economists too readily accept that market economies are stable, thus failing to ask the fundamental question about how to design more stable systems, cf. Stiglitz (2014).

5 ECONOMETRIC MODEL BUILDING METHODOLOGY

In this chapter we set out a coherent approach to dynamic macroeconometric model building, that can be used in the case of practical interest, namely when we do not know the specification from the outset.

Because there is a need to bridge the gap between economic theory and an empirical model, it follows that the properties of empirical models depend not only on the initial theoretical position or framework used. Instead the properties of empirical models to a large extent depend on how they are have been formulated, selected and estimated, as well as by the data quality, institutional knowledge and (one would hope) the findings of previous studies. All these steps in model specification represents difficulties for the modeller and may lead to mis-specification in one dimensions or another.

It is well known that models can become mis-formulated by omitting important determinants. This can happen as a results of downright variable omission, or by misinterpreting a weakly exogenous variable as an instrumental variable rather than as an explanatory variable, cf. Castle et al. (2014) who show how this step can bias the results obtained for tests of the significance of lead-in-variables. Other cases of mis-formulation are mis-specification of dynamic reactions, inappropriate functional forms or not accounting or structural breaks.

5.1 THE CONCEPT OF A DATA GENERATING PROCESS

To state that a model is mis-specified entails that there exists an object for which it is not the correct representation. In the following we refer to that object as the local data generating process (with the acronym LGDP), namely the process by which the variables under analysis were generated, including how they were measured, see Hendry and Doornik (2014, Ch. 1.1)

As the values of all major economic variables are announced regularly, it is easy to believe that a LDGP can exist. It is an interesting philosophical question whether the true generating mechanism can (ever) be completely described, but the usefulness of the concept does not hinge on the answer to that question. The main point is that once the real economic world, in its enormous, ever-changing, complexity, is accepted as a premise for macroeconomic modelling, it follows that the main problems of macroeconometrics are model specification and model evaluation, rather than finding the best estimator under the assumption that the model is identical to the data generating process.

The LDGP is changing with the evolution of the real world economy—through technical progress, changing pattern of family composition and behaviour and political reform. Sometimes society evolves gradually and econometric models are then usually able to adapt to the underlying real-life changes, i.e. the without any noticeable loss in "usefulness" Often, however, society evolves so quickly that estimated economic relationships break down and cease to be of any aid in understanding the current macro economy and in forecasting its development even over the first couple of years. In this case we speak of a changing local approximation in the form of a regime shift in the generating process, and a structural break in the econometric model. Since the complexity of the true macroeconomic mechanism, and the regime shifts also contained in the mechanism, lead us to conclude that any model will at best be a local approximation to the data generating process, judging the quality of, and choosing between, the approximations becomes central.

In the rest of this chapter we present our approach to the task of formulating an econometric model (and econometrics of course subsumes economic theory) estimated with time series data, that can be interpreted as a an approximation to an unknown local DGP.

In the next section we review the mathematical argument for the claim that a linear dynamic model, formulated in discrete time, can be considered as a valid approximation to a dynamic system in continuous time with unknown functional form.

5.2 FROM A GENERAL THEORETICAL RELATIONSHIP TO A SPECIFIED ECONOMETRIC MODEL

The method involves three steps in going from general to specific. The first step is theoretical, and establishes a framework for linearizing and discretizing an approximation to a general theory model with constant steady state values. The second step is to estimate, and solve, the steady-state model in the form of over-identified cointegrating relationships and common trends. The third step is to identify and estimate the dynamic structure of the model.

The main points can be illustrated by considering a system with only two variables, x and y. For concreteness we can think of y as a real wage variable, and x as a productivity variable.

Following Bårdsen et al. (2004), the theoretical relationship between the two variables in represented by the general differential equation:

$$\frac{dy}{dt} = f(y, x) , \qquad x = x(t) , \tag{3}$$

in which a constant input $x = \bar{x}$ induces $y(t)$ to approach asymptotically a constant state $\bar{y}$ as $t \to \infty$. Clearly $\bar{x}$ and $\bar{y}$ satisfy $f(\bar{y}, \bar{x}) = 0$.

Appendix A shows that $f(y, x)$ can be written as

$$f(y, x) = a\,(y - \bar{y}) + \delta\,(x - \bar{x}) + R \tag{4}$$

where $a = \partial f(\bar{y}, \bar{x})/\partial y$ and $\delta = \partial f(\bar{y}, \bar{x})/\partial x$ are constants, and the approximation reaminder R is given by

$$R = \frac{1}{2!}\left(\frac{\partial^2 f(\xi,\eta)}{\partial x^2}(x-\bar{x})^2 + 2\frac{\partial^2 f(\xi,\eta)}{\partial x \partial y}(x-\bar{x})(y-\bar{y}) + \frac{\partial^2 f(\xi,\eta)}{\partial y^2}(y-\bar{y})^2\right)$$

and (ξ, η) is a point such that ξ lies between y and $\bar{y}$ while η lies between x and $\bar{x}$.

We want to transform the theory in (4) to a discrete time version. The appendix shows how that 'discretization' can be worked out to give the following theoretical expression:

$$\begin{aligned}\triangle y_t = a\,(y - bx - c)_{t-1} + R_{t-1} + \frac{1}{2}\,a(\triangle y_{t-1} - b\triangle x_{t-1}) + \frac{1}{2}\triangle R_{t-1} \\ + \frac{5}{12}\,a(\triangle^2 y_{t-1} - b\triangle^2 x_{t-1}) + \frac{5}{12}\triangle^2 R_{t-1} + \cdots .\end{aligned}$$

in which $b = -\delta/a$ and $c = \bar{y} + (\delta/a)\bar{x}$ and R_{t-j} are discrete time versions of the approximation remainder.

Although the appearance of the R_{t-j} terms complicates the notation, the equation is recognizeable as a equilibrium correction model, ECM.

At this point two comments are in place. The first is that an econometric specification will mean a truncation of the polynomial both in terms of powers and lags. Diagnostic testing is therefore important to ensure a valid local approximation, and indeed to test that the statistical model is valid, see Hendry (1995b) and Spanos (2008). The second comment is that the framework allows for flexibility regarding the form of the steady state. The standard approach in DSGE-modelling has been to filter the data, typically using the so-called Hodrick-Prescott filter, to remove trends, hopefully achieving stationary series with constant means, and then work with the filtered series, DeJong and Dave (2007, Ch.3). Another approach, is to impose the theoretical balanced growth path of the model on the data, expressing all series in terms of growth corrected values. However, a third poosibility also existsm and that is to estimate the balanced growth paths in terms of finding the number of common trends and identifying and estimating cointegrating relationships. It is the route with that involve cointegration that we are interested in in the following, since it is that approach we usein the specification of NAM.

FRAME 5: DETERMINISTIC AND STOCHASTIC TRENDS

An important part of model specification is the specification of the trend. The main distinction is between a *deterministic* trend and a *stochastic* trend.

A linear trend model is easy to evaluate statistically by the use of standard inference theory. However, if the trend model is mis-formulated and the LDGP contains a stochastic trend, standard inference becomes unrelieable, leading to *spurious regression* and seriously underestimated forecast uncertainty intervals. A stochastic trend model therefore requires the use of non-standard inference theory. Spurious regression is avoid and forecast uncertainty bands become wider and more realistic.

Deterministic trends and stochastic trends can be combined. The simplest example is a time series x_t, $t = 0, 1, 2, ...$generated by the process known as Random-walk with drift

$$x_t = \alpha + x_{t-1} + \epsilon_t \tag{5}$$

where a is a parameter and ϵ_t is a time series which is independent of future x_t's if we condition on X_{t-1}. For simplicity, each ϵ_t can be assumed to have identical standard normal distribution. (5) contains both a deterministic trend given by ta (when the solution is conditional on period by tx_0) and a stochastic trend $\sum_{i=0}^{t} \epsilon_i$. The stochastic trend is a consequence the unit-root in the characteristic equation associated with (5): r - 1 =0, where r denotes the root.

Due to the unit root, (5) is a non-stationary process. The differenced series $\Delta x_t =: x_t - x_{t-1}$ is however stationary since the process becomes simply

$$\Delta x_t = \alpha + \epsilon_t \tag{6}$$

and the characteristic root is equal to one. Following custom, a time series that becomes stationary after differencing are integrated of order one, and denoted $I(1)$. If double differencing is needed to achieve stationarity it is denoted $I(2)$, integrated of order 2.

To illustrate the above approach in terms of cointegration, consider real wages to be influenced by productivity, as in many theories.[18] Assume that the logs of the real wage

[18] Presently, we let the unemployment rate be constant and disregard it for simplicity. We return to the role of the rate of unemployment in Chapter 6.

rw_t and productivity z_t are each integrated of order one, but found to be cointegrated, so

$$rw_t \sim I(1), \Delta rw_t \sim I(0) \tag{7}$$

$$z_t \sim I(1), \Delta z_t \sim I(0) \tag{8}$$

$$(rw - \beta z)_t \sim I(0). \tag{9}$$

where we make use of the notation for order of integration from Frame 5. Equation (9) represents the cointegration property, namely that there exists a linear combination of the two $I(1)$ time series that defines a new time series that is integrated of order zero, $I(0)$.

Letting $y_t \equiv (rw - \beta z)_t$ and $x_t \equiv \Delta z_t$ then gives

$$\Delta rw_t = -ac + a(rw - \beta z)_{t-1} + \frac{a}{2}\triangle (rw - \beta z)_{t-1} + \beta \Delta z_t - ab\triangle z_{t-1} - \frac{ab}{2}\Delta^2 z_{t-1} + \cdots .$$

We can also start from a system of differential equations and go through the steps of linearization and dicretization, instead of regarding x as an exogenous forcing variable as in 3. The details are found in Appendix A. For the example with real wage and productivity, the result becomes

$$\begin{aligned} \triangle rw_t &= -\alpha_{11} c_1 + \alpha_{11}(rw - \beta z)_{t-1} + \beta \Delta z_t - \alpha_{12} \Delta z_{t-1} \\ \Delta z_t &= -\alpha_{22}\left(\bar{y}_2 + \frac{\alpha_{21}}{\alpha_{22}}\bar{y}_1\right) + (\alpha_{22} - 1)\ \Delta z_{t-1} - \alpha_{21}(rw - \beta z)_{t-1} \end{aligned}$$

with parameters that are given in the appendix. The case of exogenous z corresponds to setting $\alpha_{21} = 0$ and $|\alpha_{22} - 1| < 1$ the system simplifies to the familiar exposition of a bivariate cointegrated system with z being weakly exogenous for β:

$$\begin{aligned} \triangle rw_t &= -\alpha_{11} c_1 + \alpha_{11}(rw - \beta z)_{t-1} + \beta \Delta z_t - \alpha_{12} \Delta z_{t-1} \\ \Delta z_t &= -\alpha_{22}\,\bar{z} + (\alpha_{22} - 1)\ \Delta z_{t-1} \end{aligned}$$

and where the common trend naturally is a productivity trend.

The relationship between the real wage level and productivity in equation (9) is only a 'skeleton-model'. Likewise the stylised model of real wage dynamics is fine as an illustration of the methodology, but it probably too simple to fit the data.

In Chapter 6 we present a theory of real-wage formation that is a more complete framework, at least in some dimensions. One fact about real-life wage setting that we take account of is that negotiations are about nominal wage changes. This is not to say that 'monetary illusion' is involved. The point is instead that while both firms and workers form targets about the real wage, workers can only influence the nominal wage (through wage bargaining), and firms can influence the real wage through their fixing of the nominal product price.

While the model that allows for incomplete control of real wage targets becomes is a little more complicated algebraically, that theory also fits nicely into the methodology of cointegration and equilibrium correction, as Chapter 6 will show.

5.3 COINTEGRATED VARS AND STRUCTURAL MODELS

The previous sub-chapter presented a formal rationalization for ECMs, and more generally cointegrated VARs, as models that approximate systems of dynamic non-linear equations. Econometric models are sometimes criticized for being too optimistic about the self-correcting ability about the macroeconomic system. While there might be something in this critique, the more constructive debate is perhaps not about complete stability or no stability, but about our ability to identify the strong equilibrum correction mechanism, and to avoid the inclusion of spurious error correction.

The same critics would have a point if it could be argued that our methodology 'leads' to the imposition of equilibrium dynamics without test whether it is actually there. That would however be a misunderstnading, since our approach in particular will be to test the restrictions on parameter α_{11} and α_{22} (more generally the characteristic roots of the linearized and discretizised system) that lead to rejection of equilibrium dynamics. Hence, in principle, it is quite possible to discover empirically that the starting point in equation (3) is wrong.

But the opposite type of question can also be asked. Namely, if we by testing the stability of linear-in-parameter models (and abstracting from non-linear terms) will end up rejecting equilibrium dynamics too often? However, by reference to long established mathematical theorems, we know that this is not the case: Dynamics stability is a property of the 'linear part' of a dynamic model. If the linear part does not deliver stability, then stability cannot be salvaged by higher order non-linear terms.

We will keep the rest of this section brief, as comprehensive treatments about the estimation of cointegrated VARS can be found many places—for example in Hendry (1995a), Johansen (1995b, 2006), Juselius (2007), Garratt et al. (2006), and Lütkepohl (2006)—and only make some comments on issues in each step in the modelling process we believe merit further attention.

A coherent approach can be presented as consisting of three steps, but now starting from system of difference equations that represent the result of the linearization and discretization of chapter 5.2, only generalized to the multivariate case.

5.3.1 FIRST STEP: THE STATISTICAL SYSTEM

As just noted, our starting point for identifying and building a macroeconometric model is to find a linearized and discretized approximation as a data-coherent statistical system representation in the form of a cointegrated VAR

$$\Delta \mathbf{y}_t = \mathbf{c} + \mathbf{\Pi}\mathbf{y}_{t-1} + \sum_{i=1}^{k} \mathbf{\Gamma}_{t-i}\Delta \mathbf{y}_{t-i} + \mathbf{u}_t, \tag{10}$$

with independent Gaussian errors $\mathbf{u}_t$ as a basis for valid statistical inference about economic theoretical hypotheses.

The purpose of the statistical model (10) is to provide the framework for hypothesis testing, the inferential aspect of macroeconometric modelling. However, it cannot be postulated directly, since the cointegrated VAR itself rests on assumptions. Hence, validation of the statistical model is an essential step: Is a model which is linear in the parameters flexible enough to describe the fluctuations of the data? What about the assumed constancy of parameters, does it hold over the sample that we have at hand? And the Gaussian distribution of the errors, is that a tenable assumption so that (10) can supply the inferential aspect of modelling with sufficient statistics. The main intellectual rationale for the model validation aspect of macroeconometrics is exactly that the assumptions of the statistical model requires separate attention, Johansen (2006),Spanos (2008) In practice, one important step in model validation is to make the hypothesized statistical model subject to a battery of misspecification tests using the OLS residuals $\hat{\mathbf{u}}_t$ as data.[19]

As pointed out by Garratt et al. (2006), the representation (10) does not preclude forward-looking behaviour in the underlying model, as rational expectations models have backward-looking solutions. The coefficients of the solution will be defined in specific ways though, and this entails restrictions on the VAR which can utilized for testing rational expectations, see Johansen and Swensen (1999, 2004) and Bårdsen and Fanelli (2015).

Even with a model which for many practical purpose is small scale it is usually too big to be formulated in “one go” within a cointegrated VAR framework. Hence, model (10) for example is not interpretable as one rather high dimensional VAR, with the (incredible) long lags which would be needed to capture the complicated dynamic interlinkages of a real economy. Instead, as explained in Bårdsen et al. (2003), our operational procedure is to partition the (big) simultaneous distribution function of markets and variables: prices, wages, output, interest rates, the exchange rate, foreign prices, and unemployment, etc. into a (much smaller) simultaneous model of wage and price setting—the labour market— and several sub-models of the rest of the macro economy. An econometric rationale for specification and estimation of single equations, or of markets, subject to exogeneity assumptions, before joining them up in a complete model is discussed in Bårdsen et al. (2003), and also in Bårdsen et al. (2005, Ch. 2). That said, step-wise modelling, which has proven to be useful in practice, has yet to be be given a solid foundation in statistical theory, and this represent an important task for future research.

[19]The distinction between the inferential and model validation facets of modelling is due to Spanos (2008), who conclusively dispels the charge that misspecification testing represents an illegitimate “re-use” of the data already used to estimate the parameters of the statistical model, see also Hendry (1995b, p. 313-314).

5.3.2 SECOND STEP: THE OVERIDENTIFIED STEADY STATE

The second step of the model building exercise will then be to identify the steady state, by testing and imposing overidentifying restrictions on the cointegration space:

$$\Delta \mathbf{y}_t = \mathbf{c} + \boldsymbol{\alpha}\boldsymbol{\beta}^{'}\mathbf{y}_{t-1} + \sum_{i=1}^{k} \mathbf{\Gamma}_{t-i}\Delta \mathbf{y}_{t-i} + \mathbf{u}_t,$$

thereby identifying both the exogenous common trends, or permanent shocks, and the steady state of the model.

Even though there now exists a literature on identification of cointegration vectors, it is worthwhile to reiterate that identification of cointegrating vectors cannot be data-based. Identifying restrictions have to be imposed *a priori*. It is therefore of crucial importance to have a specification of the economic model and its derived steady state before estimation. Otherwise we will not know what model and hypotheses we are testing and, in particular, we could not be certain that it was identifiable from the available data set

5.3.3 THIRD STEP: THE DYNAMIC SEM

The final step is to identify the dynamic structure:

$$\mathbf{A}_0\Delta \mathbf{y}_t = \mathbf{A}_0\mathbf{c} + \mathbf{A}_0\boldsymbol{\alpha}\boldsymbol{\beta}^{'}\mathbf{y}_{t-1} + \sum_{i=1}^{k} \mathbf{A}_0\mathbf{\Gamma}_{t-i}\Delta \mathbf{y}_{t-i} + \mathbf{A}_0\mathbf{u}_t,$$

by testing and imposing overidentifying restrictions on the dynamic part—including the forward-looking part—of the statistical system.

First, the estimated parameters and therefore the interpretation of the model dynamics are dependent upon the dating of the steady-state solution. However the steady-state multipliers are not—see Bårdsen and Fisher (1993, 1999)

Third, the economic interpretations of the derived paths of adjustment are not invariant to the identification of the dynamic part of the model, whereas the steady-state parts of the model are—again see Bårdsen and Fisher (1993, 1999).

In the next chapter we use the task of modelling wage-and-price and price formation as an example of how the methodology can be applied. The discussion will also serve as an introduction to the characteristics of the supply side of NAM, which has to do with how we model wage-price dynamics, and the role of wage and price setting in the determination of the medium term macroeconomic equilibrium.

6 WAGE AND PRICE SETTING

6.1 A QUESTION OF SUPPLY

A main issue of an medium term empirical macro model is always going to be the supply side. This is also well illustrated by the history of macroeconomic models.

The early models by Tinbergen and Klein were specified in accordance with the Keynesian view that, unless demand was greater than supply capacity at full employment, an increase in demand would lead to lower unemployment. The point made by the theory sometimes called the 'L-shaped' aggregate supply curve, was not that wages and prices were fixed, but that there were no determinate link between them and demand, see Forder (2014, Ch. 1.3). Viewed against this intellectual background, it is understandable that the medium-run macroeconometric models that were developed in many countries during the 1950s, 1960s and 1970s, were much more detailed about the demand side of the economy than about the supply-side. In hindsight it is however easy to see that this situation made the models vulnerable to real world shocks that could make the 'L-shaped' aggregated supply curve shift.

Eventually, the problems experienced by trying to cope with the coexistence of stagnating real economic growth at the same time as inflation persisted, the phenomenon called to *stagflation*, led to a process of amendments and extensions of the models. Another important stimulus for change was the theoretical criticism which insisted that the 'demand driven models' should be replaced by equilibrium models which assumes that prices and wages continuously clear markets and that agents continuously optimize, see Wallis (1995, Ch. 2). This critique originated in the real business cycle school of thought, and later developed into modern neoclassical macroeconomics. As a response both real world problems, and the noted intellectual critique, macro modellers began to pay more attention to the representation of the supply side of the models.

As Nickell (1988) explained, the key parts of the supply-side are represented by those equations that describe the behaviour of firms, in particular price setting, and those that reflect the determination of wages. Important questions are then whether a model possesses a medium term *Non-Accelerating Inflation rate of Unemployment*, known by the acronym NAIRU, which is invariant to shocks to aggregate demand, but which may not be invariant to changes in institutional features of the labour marked.

Bårdsen and Nymoen (2009c) pointed out that it is often useful to be clear about the distinction between the steady-state rate of unemployment possessed by a macroeconomic model, and the NAIRU. A model may possess a steady-state rate of unemployment even if a NAIRU is not implied by the model. Technically, the existence of a model-determined steady-state rate of unemployment is secured if all the characteristic roots associated with the *final form equation* for the rate of unemployment are less than one in absolute value.[20]

Both the implied dynamics, and the steady-state of the rate of unemployment may well depend on parameters from outside the wage-and price-setting equations of the macroeconometric model. Bårdsen and Nymoen (2003) showed that the independence of the steady-state rate of unemployment of parameters from outside the wage-price sub-system can be tested without specifying the total model. If a test required us to specify the full model, the feasibility of testing the NAIRU-proposition (e.g. a vertical long-run aggregate supply schedule) would have been much less.

However, as discussed by Kolsrud and Nymoen (2014,2015), care must be taken in the specification of the wage-price sub-model used for the testing of NAIRU-properties. In particular, although the contrary is sometimes suggested, there is little that can be learned about NAIRU-properties from the estimation of static models of wage-and price setting. For one thing, the dynamic stability of the rate of unemployment "around" the estimated NAIRU is then taken for granted. We return to this point later in this chapter.

The importance of the wage- and price modelling for overall model properties also makes it interesting to use it as an illustration of the approach to econometric modelling that formulated in relatively general terms in the previous chapter.

Therefore, the rest of this chapter gives a relatively detailed example of a theoretical and econometric specification of the wage-price block of a (still stylized) macro model. The first step is the specification of the relevant economic theory to test. We next develop the theoretical relationships into hypotheses about cointegration, that can be tested in a statistical model and identified as steady state relationships, Step 1 and 2 above. We also go through Step 3 in detail. Throughout the rest of the chapter we let lower-case letters denote natural logarithms of the corresponding upper-case variable names, so $x_t \equiv \ln(X_t)$.

6.2 THEORY OF WAGES AND THE NEED OF A BRIDGE TO WAGE FORMATION

Our starting point for the modelling of labour markets is the idea that firms and their workers are engaged in a partly cooperative and partly conflicting sharing of the rents generated by the operation of the firm. Wage formation in particular takes place in a social context where there is awareness of the co-existence of both conflict *and* common

[20] To account for complex roots, 'absolute value' should be interpreted to also include the modulus of complex root-pairs. See Wallis (1977) for the definition of the final form equation which in the linear in parameter case seems to have a close correspondence with the homogeneous part of the forecasting equation obtained for a variable which is endogenous in a system of linear difference equations. Nymoen and Sparrman (2015) uses this approach in a study of unemployment rate dynamics in a panel of OECD countries.

interests. [21] However, this characteristic also makes it difficult to model wage formation from the principle of individual rational choice, the level of analysis preferred by neoclassical economics.

The formulation of a theory of wage setting requires an assessment of not only self-interest among workers and firms, but also of compromise. As pointed out by Usher (2012), 'compromise' is then not just another way of talking about self-interest, and social, political and institutional forces are not merely cover-ups for imprecisely modelled individuals rational actions, they are among the fundamental determinants of decisions. In this view, even a full analysis of rational behaviour leads to an indeterminacy of wages, and other considerations had to be introduced to resolve it.

The recognition among leading economists that there is an indeterminacy in the economic theory of wages goes back to the 1950s, see Forder (2014, Ch. 1.4) who cites Samuelson (1951, p. 312) and Hicks (1955, p. 390) and other leading theorists. The economic theory of supply and demand could set some limits to what wages can be set, but within those limits closer determination requires that other relationships are introduced.

A related, but perhaps more general critique is sometimes directed against the tradition in economics, especially in macroeconomics, that in nearly all respects the labour market is just like other markets. In the European legal tradition, the fundamental asymmetry in the relationship between the individual worker and employer was early pointed out, leading to the legitimate installation of labour market regulation (usually a combination of laws and collective agreements). One forceful critique of this type, coming form a leading economist, is found in Solow (1990), who made the point that notions of fairness are well developed on both sides of the market, and that there often is a shared understanding of partly common, partly conflicting, interests between firms and workers. Solow brought his arguments to bear on the notion of a stable "natural rate of unempolyment", which he wrote "has been given more widespread acceptance than it has earned". [22].

The indeterminancy of wages from theory also characterizes the Diamond-Mortensen-Pissarides (DMP) search and matching model. In the DMP model, the wage is usually determined in a Nash bargaining game. But is the wage logically equal to the Nash solution given the assumptions of the DMP model? As Hall (2005) pointed out, any wage in the bargaining is in principle consistent with private efficiency on the part of both the firm and the worker. In that sense, the equilibrium wage rate is only "set-identified". He then

[21] Historically, the system of wage formation in Norway developed as a result of the lowering of the conflict level in Norwegian society that started a few years before WW-II and which continued in the post war decades. At the same time, the gradual development of a system of wage formation also contributed to the complicated process of conflict reduction.Reiersen (2015) analyses it as primarily driven by a change of strategy by the two main confederate organizations, from conflict to compromise and cooperation.

[22] (Solow (1990, p. 5))

went on to analyze a solution where the real wage is fixed, which however is only one possibility of what in the DMP-literature is referred to as wage 'stickiness'. [23]

While economists have difficulty determining wages theoretically, we observe that actual wage bargains are struck year after year, and that they are rationalized by considerations of profits, actual and required (to attract investments), cost of living and relative wages (fairness). The importance of profits in wage formation, in particular, has been a staple of the literature based on studies of actual wage determination for decades (cf Forder (2014, Ch. 1.4), and covering different institutional arrangements. The same literature also confirms the general salience of fairness and the particular importance of adjustments of wages to compensate for changes in the cost of living.

These observed regularities give reason to believe that wage formation can be subject to econometric treatment, in particular as part of a macroeconometric model projects, see, Bårdsen et al. (2005, Ch 3-6), Bårdsen and Nymoen (2009b) and Bårdsen et al. (2012).

In line with the academic literature, we too represent wage formation theoretically by using a formal bargaining solution, in the next sub-chapter 6.3. In order to avoid creating an unnecessary large gap to bridge, we specify a formal model that conforms to the Norwegian system with relatively strong confederate labour market organizations that take the role of setting a wage norm for the overall adjustments of nominal wages. In this system, it is understood that this form of 'rational' wage setting can (at best) secure a degree of international cost competitiveness that, in turn, makes it possible for the government (and central bank) to pursue a policy of high employment. In essence, this tripartite agreement represent a cornerstone in the Norwegian model of wage formation.

Linked up with an assumption of monopolistically competitive firms, it gives a version of the incomplete competition model that we mentioned in the Introduction, and which we refer to as ICM in the following.

As just noted, a too literal interpretation of a formal bargaining model may lead us to believe that the wage level is well determined from theory, which it is not, as we have just noted. However, as long as we limit ourselves to use the formal bargaining solution as a way of organizing the various factors that are likely to influence the real world bargaining outcome, the danger of over-interpretation is not large.

However, there is another, more easy to see, shortcoming of the formal bargaining solution: Time plays no role in the theory and the derived relationships are static. Real world wage level adjustment in contrast, is almost always and everywhere gradual and

[23] Following Hall (2005), several papers have incorporated rigid wage setting in search models. For instance, Gertler and Trigari (2009) present a DMP model where the frequency of wage bargaining is constrained by Calvo (1983)) style lottery, leading to sticky wages. Blanchard and Galí (2010) combine a reduced form of search model with real wage rigidity with a New Keynesian model to study how this impacts monetary policy. Krogh (2015) generalizes the Hall-approach to a small open economy model where there is a non-trivial distinction between the consumer real wage and the producer real wage.

non-instantaneous.

Therefore, the gap between the formal relationships of the theory and the empirical relationships that may be present in the data must be closed. This is where the methodology of the previous chapter comes in, and where the assumption about $I(1)$-ness in particular becomes an important part of the bridge between theory and data. This is because $I(1)$-ness allows us to interpret the theoretical wage and price equations as hypothesized cointegration relationships. In particular, an essential part of the bridge is the interpretation of the wage-norm 'determined' by the Nash-solution as a point of gravitation in an dynamic model of nominal wage and price changes. From that premise, a dynamic model of supply side in equilibrium-correction model (ECM) form follows logically.

6.3 AN INCOMPLETE COMPETITION THEORY OF WAGE AND PRICE SETTING

Although the model of perfectly competitive labour markets is still sometimes used as an 'easy to use' model for how the wage level is determined, that theory is not only incomplete, it is also unrealistic. Except perhaps for some epochs after the industrial revolution, when 'Manchester-liberalism' was the ruling principle. Then, each individual worker was left to agree their own wage and working conditions the best they could. Historically with very grim results.

The underlying reason for the impossibility of perfect competition and acceptable working conditions economics equality , is the asymmetry in the relationship between the individual worker and the employer. The recognition of this fact has led societies that belong to the European legal tradition in the direction of extensive labour market regulation, usually by the combined use of of laws and collective agreements about wage compensation and working conditions, cf. Evju (2003).

In Norway, for period of 80 years, collective agreements have played a comparatively large role in labour market regulations. In particular when it comes to wage formation.

Viable collective agreements in the labour market require a certain degree of sheltering against unwanted competition, hence the name incomplete competition theory. In our model, incomplete competition also refers to the product markets, since we assume that firms engage in monopolistic competition.

6.3.1 FIRMS' SETTING OF A PRICE TARGET

We start with the assumption of a large number of firms, each facing downward-sloping demand functions. The firms are price setters, and equate marginal revenue to marginal costs. With labour being the only variable factor of production and constant returns to scale (see Frame 6), we have the price setting relationship for firm i

$$Q_i = \frac{El_Q Y_i}{El_Q Y_i - 1} \frac{W_i(1 + T1_i)}{Z_i}, \tag{11}$$

where $Z_i = Y_i/N_i$ is average labour productivity, Y_i is output and N_i denotes labour input. $W_i(1 + T1_i)$ is the compensation paid per unit of labour paid by firm i. From now on we refer to W_i simply as the nominal wage rate. $T1_i$ represents a payroll tax rate.

$El_Q Yi$ denotes the absolute value of the elasticity of demand facing each firm i with respect to the firm's own price. In general, $El_Q Y_i$ depends on Q_i and on competing prices, set by both foreign and domestic firms. However, a common simplification is to assume that the demand elasticity is a constant parameter and that it is the same for all firms. As is well know, a formal condition for profit maximization is the elasticity is larger than one in absolute value, ie, $El_Q Y_i > 1$.

FRAME 6: COMPETITION, CAPACITY AND PRICING BEHAVIOUR

The argument that product market competition will drive firms to use all their fixed capital leads to the conventional assumption of increasing marginal and average costs. However, neither theory nor evidence about how firms themselves perceive their cost curves (e.g. Blinder (1998), Keen (2011, Ch.5)) give particular reason to believe that a large percentage of industrial products is produced under conditions of markedly rising marginal costs. With no spare capacity a firm has no flexibility to take advantage of sudden, unexpected changes in the market. Excess capacity may thus be quite essential for survival in a market economy.

In this chapter we adopt the constant returns to scale assumption as a simple way of representing the, we believe, widespread phenomenon of non-increasing marginal costs. The hypothesis has strong implications for macroeconomics, since it entails that markets for industrial products clear mainly through quantity, rather than price.

In practice, even for quite narrowly defined industries, there is going to a be a productivity distribution at each point in time. However, for the purpose of this section, we assume that $Z_i = Z$ for all i. Under that simplifying assumption, it may be logical for the firms to take wage setting 'out of the competition' between them. Hence, we also set $W_i = W$, and we get the simple 'aggregate' product price equation:

$$Q = \frac{El_Q Y}{El_Q Y - 1} \frac{W(1 + T1)}{Z} \tag{12}$$

6.3.2 BARGAINING BASED WAGE-TARGET (WAGE-NORM)

In theory, as well as in practice, there are different ways of equalizing wage-costs between firms, including monopsony, wage laws (or a even a corporative state), or collective agreements between a employer organization (confedration of firms) and a labour union. We assume a framework with collective wage setting.

In the following we will assume that the utility of the firm-side organization is simply proportional to the real profit of the individual firm. Real profit is denoted by Π and is defined by $\Pi = (Y - W(1+T1)N/Q$. With the use of (12), the expression for real profits (Π) can be written as:

$$\Pi = Y - \frac{W(1+T1)}{Q}N = (1 - \frac{W(1+T1)}{Q}\frac{1}{Z})Y.$$

As noted above, we will assume at this point, that the wage rate W is settled in accordance with the principle of maximization of the Nash product:

$$(V - V_0)^{\mho}\Pi^{1-\mho} \tag{13}$$

where V denotes union utility and V_0 denotes the fall-back utility or reference utility. The corresponding break-point utility for the firms has been set to zero in (13), but for unions the utility during a conflict (e.g., strike, or work-to-rule) is non-zero because of compensation from strike funds. Finally $\mho$ represents the relative bargaining power of unions. It seems logical to assume that $0 < \mho < 1$, to rule out that one of the parties gets full bargaining power and the other gets none (which would lead to another type of wage formation).

We assume that union utility V depends on the consumer real wage of an unemployed worker and the aggregate rate of unemployment, thus $V(\frac{W}{P}, U, A_{\nu})$ where P denotes the consumer price index.[24] The partial derivative with respect to wages is positive, and negative with respect to unemployment ($V'_W > 0$ and $V'_U \leq 0$). The last argument in the union utility function, A_{ν}, represents other factors in union preferences.

The fall-back or reference utility of the union depends on the overall real wage level and the rate of unemployment, hence $V_0 = V_0(\frac{\bar{W}}{P}, U)$ where $\bar{W}$ is the average level of nominal wages which is one of factors determining the size of strike funds. If the aggregate rate of unemployment is high, strike funds may run low in which case the partial derivative of V_0 with respect to U is negative ($V'_{0U} < 0$). However, there are other factors working in the other direction, for example that the probability of entering a labour market programme, which gives laid-off workers higher utility than open unemployment, is positively related to U.

With these specifications of utility and break-points, the Nash-product, denoted $\mathcal{N}$, can be written as

[24] It might be noted that the income tax rate $T2$ is omitted from the analysis. This simplification is in accordance with previous studies of aggregate wage formation, see e.g., Calmfors and Nymoen (1990) and Nymoen and Rødseth (2003), where no convincing evidence of important effects from the average income tax rate $T2$ on wage growth could be found.

$$\mathcal{N} = \left\{ V(\frac{W}{P}, U, A_{\nu}) - V_0(\frac{\bar{W}}{P}, U) \right\}^{\mho} \left\{ (1 - \frac{W(1+T1)}{Q}\frac{1}{Z})Y \right\}^{1-\mho}$$

or

$$\mathcal{N} = \left\{ V(\frac{RW}{P_q(1+T1)}, U, A_{\nu}) - V_0(\frac{\bar{W}}{P}, U) \right\}^{\mho} \left\{ (1 - RW\frac{1}{Z})Y \right\}^{1-\mho}$$

where $RW = W(1+T1)/Q$ is the producer real wage, and $P_q(1+T1) = P(1+T1)/Q$ is the so called *wedge* between the consumer and producer real wage, see Frame 7.

FRAME 7: REAL-WAGE WEDGE AND REAL-EXCHANGE RATE

Since we have already abstracted from an income tax-rate, the real-wage wedge is defined as

$$WEDGE =: \frac{W(1+T1)/Q}{W/P} = P(1+T1)/Q = P_q(1+T1)$$

where P_q is the relative price $P_q = \frac{P}{Q}$ as defined in the main-text.
P_q is in many ways the most interesting component of the wedge, because it is an endogenous variable in a macro model. Specifically, in the model we develop, P_q becomes proportional to the relative price between the domestic products and the price of imports denominated in domestic currency. Hence P_q is interpretable as a *real-exchange rate variable* (assuming that import prices in foreign currency is proportional to the price level abroad).

Note that, unlike many (standard) expositions of the so called bargaining approach to wage modelling, for example Layard et al. (1991, Chapter 7), there is no aggregate labour demand function—employment as a function of the real wage—subsumed in the Nash product. In this we follow Hahn (1997, Ch. 5.3), who see it as an important point that their theoretical treatment of wage formation is consistent with the fact that actual wage bargaining is usually over the nominal wage, and not over real-wages, let alone over employment.

In the following, we therefore define (industry) output Y to be a parameter in the Nash-product. The interpretation is that in the Norwegian system of wage setting, with collective bargaining as a mainstay, there exists a social contract (mutal understanding, respect and trust) where unions and employer confederations take the responsibility for regulation of the overall wage level, while demand management (and therefore the fixing of Y) is the responsibility of the government and the central bank. Although obviously simplified (one might say 'rose painted'), this characteristic nevertheless resounds well with the political and institutional set-up in Norway. Also OECD economists, often sceptical towards collective bargaining because and concerned about reduced labour market flexibility, now see things differently, for Norway.

> Rather than wages being determined by the relative bargaining strength of different sectors, the general wage level is set by the social partners first considering the wage increases that the traditional sector can "afford".[25]

Summing up our assumptions, and in particular with P_q, $\bar{W}$, U and Y regarded as parameters, maximizing $\mathcal{N}$ with respect to W is the same as maximizing with respect to RW. As noted, the economic interpretation we want to make is that the solution for the real-wage, represents the target (or norm) for the real-wage that the parties can reasonably agree on.

The first order condition for a maximum is given by $\mathcal{N}_{RW} = 0$ or

$$\mho \frac{V'_W(\frac{RW}{P_q(1+T1)}, U, A_\nu)}{V(\frac{RW}{P_q(1+T1)}, U, A_\nu) - V_0(\frac{\bar{W}}{P}, U)} = (1-\mho)\frac{\frac{1}{Z}}{(1 - RW\frac{1}{Z})}. \tag{14}$$

In a symmetric equilibrium, $W = \bar{W}$, leading to $\frac{RW}{P_q(1+T1)} = \frac{\bar{W}}{P}$ in equation (14), the aggregate bargained real wage RW^b is defined implicitly as

$$RW^b = F(P_q(1+T1), Z, \mho, U), \tag{15}$$

or, using the definition

$$RW^b \equiv W^b(1+T1)/Q$$

we obtain the solution for the bargained nominal wage:

$$W^b = \frac{Q}{(1+T1)} F(P_q(1+T1), Z, U, \mho) \tag{16}$$

Equation (16) gives a framework for thinking about the arguments in a wage-norm generating function. That function's arguments include several main wage determining factors that are known from empirical studies of real world wage bargaining (see e.g. Forder (2014, Ch. 1.4))

- Factors that influence profitability, namely productivity Z and the product price Q (as well as the payroll tax rate $T1$)
- The cost of living, through the wedge variable $P_q = P/Q$
- Indicators of labour market pressure, represented by U
- Relative bargaining power, as formally captured by the parameter $\mho$

Missing from the list is relative wages, or reference wage, as some conception of fairness of the wage always seem to be important in reaching an agreement, cf e.g. Solow (1990, Ch.1). Another important dimension that sink under the horizon if we focus too closely on

[25] OECD (2012, p. 15)

the Nash-solution, has to with compromise and co-operation, as mentioned in previous sub-section.

To incorporate these important elements we could use the trick of postulating that a certain fraction of the wage-settlements reflect ”hard-bargains”, that are captured by the Nash-solution, and that another fraction reflects the emergence of cooperation as dominant strategy.[26] But we will not do that. Instead we will interpret a linarized version of (16) somewhat more loosely, than as a strict Nash-solution.

Letting lower-case latin letters denote logs of variables, the linearized equation for the wage-norm defined by (16) becomes: (16), gives:

$$w^b = m_w + q_t + (1 - \delta_{12})(p - q) + \delta_{13} z - \delta_{15} u - \delta_{16} T1. \tag{17}$$
$$0 \leq \delta_{12} \leq 1, 0 < \delta_{13} \leq 1, \delta_{15} \geq 0, \ \ 0 \leq \delta_{16} \leq 1.$$

As noted, we open up to different interpretations of this equations. The constant term m_w, we interpret as a parameter that depends on bargaining power (as in the narrow interpretation), wage-setting institutions and the degree of coordination in wage formation, see Nymoen and Sparrman (2015)).

Below, when we get to the specification of the econometric model, we will see that the constant term m_w is interpretable as the mean of a long-run cointegrating equation for the wage level. Hence, also in an econometric interpretation, the parameters $\delta_1 j$ ($j = 2, 3, 5, 6$) are long-run elasticities. [27]

The elasticity of the product price is set to one. Together with the relative price $(p{-}w)$, with elasticity $(1 - \delta_{12})$ this secures that the equation that defines the long-run wage-norm is homogeneous of degree one. δ_{13} is the elasticity of the bargained wage with respect to a permanent change in labour productivity. An appealing restriction on this parameter, both in terms of economic theory and in term of econometric modelling (see below) is to set $\delta_{13} = 1$, see Nymoen (1989a,b). This restriction implies that the “profit-argument” in the wage function simply becomes $q + z$, which is often referred to as the (wage) *scope* variable.

We also need to comment on the wedge elasticity $(1 - \delta_{12})$, since, even though few would doubt that cost-of-living considerations are important in the process of reaching real-world wage agreements, the role if the real-wage wedge in a long-run equation like (16) is contested in the literature. In part, this is because theory (of the type we have used in this sub-chapter) fails to produce general implications about the wedge coefficient $(1-$

[26]Forming a linear combination of theories that by themselves are incomplete or unrealistic, is as old as the hills. For example: supplementing the consumption Euler-equation with consumption due to ‘rule-of-thumb’ behaving credit constrained households, or creating a ‘hybrid New Keynesian Phillips Curve’ by combining forward-looking price setters with backward-looking ones.

[27]The first subscript 1 is used to indicate that they are parameters in the first equation in the a two equation wage-price system. Using two subscripts may seem cumbersome at first, but they help keep track of the several re-parameterization of the model that we review below.

δ_{12})—it can be shown to depend on the specification of the utility function V and V_0 above (see, for example Rødseth (2000, Ch. 8.) for and exposition).

As can be seen in the line below (16), we restrict $(1 - \delta_{12})$ to be non-negative and stricty less than one. This runs against the formal theoretical analysis in Forslund et al. (2008), stating that there can be no wedge effect in a model where the unions has bargaining power.[28] At one level, this result is an example of the point mentioned above, that from a carefully formulated theory, the 'no wedge' result can follow. However, the relevance of that degree of specificity is not so clear. In any case there seem to be little reason to impose $(1 - \delta_{12}) = 0$ without trying to test that restriction. When one estimate a long-run equation for wages in the traded goods sector (the part of the product market most exposed to foreign competition), it is not uncommon to find that the wedge coefficient can be set to zero after testing. This conforms with the common view that in these sectors, profitability and productivity are measured and observed at the plant and industry level, and the scope variable may then become the only telling long-run determinant of the wage level.

Hence, in econometric models of wage setting in manufacturing, the hypothesis of $\delta_{12} = 1$, is typically not rejected statistically. This means that the wedge variable can be omitted, supporting the view that the target nominal wage is linked one-to-one with the scope variable $q+z$ see e.g., Johansen (1995a) (Norway) and Nymoen and Rødseth (2003) (Nordic countries).

However, in the sheltered sectors of the economy, negotiated wages may be linked to the general domestic prices level, and this may explain why econometric testing of the $(1 - \delta_{12}) = 0$ is usually rejected when the aggregation level of the econometric analysis is higher.[29]

In the current version of NAM, the theoretical wage-target equation (16) has been implemented for hourly wages in the private sectors of Mainland-Norway. While this leaves out the government sector (as well and the workers in off-shore oil and gas extraction), it is still a broad aggregate that includes both the manufacturing sector (which in practice is the wage-norm setting industry) and the private service sector and retail trade. Given this operational definition of the wage variable, it is not surprising that we find a high wedge coefficient in the model.

The impact of the rate of unemployment on the bargained wage is given by the elasticity $-\delta_{15} \leq 0$. Blanchflower and Oswald (1994) provided evidence for the existence an empirical law, stating that the value of $-\delta_{15}$, the slope coefficient of their *wage-curve*, is 0.1 more or less everywhere. Other authors have instead maintained that the slope of the wage-curve is likely to depend on the level of aggregation and on institutional factors. For

[28] See e.g. Forslund et al. (2008, Proposition 1)

[29] As will be shown in a later sub-chapter, the dynamic stability of the wage-share and the relative price of imports hinges on the long-run wedge coefficient.

example, one influential view holds that economies with a high level of coordination and centralization is expected to be characterized with a higher responsiveness to unemployment (a higher $-\delta_{15}$) than uncoordinated systems that give little incentive to solidarity in wage bargaining, Layard et al. (2005, Ch. 8). Finally, from the definition of the wedge, one could set $\delta_{16} = \delta_{12}$ but we keep δ_{16} as a separate coefficient to allow for partial effects of the payroll tax on wages.

As noted above, equation (17) is a general proposition about the negotiated intended wage. When the agreement is at the confederate level, we can speak of it as a wage-norm. It can serve as a starting point for describing wage formation in any sector or level of aggregation of the economy. In following we regard equation (17) as a model of the average wage in the total economy, and as explained above we therefore expect $(1 - \delta_{12}) > 0$, meaning that there is a wedge effect in the long-run wage equation.

That was a lot about the formulation and interpretation of a theory of the long-run wage. We now return to the long-run price equation, namely equation (12) which represents a price setting rule which is consistent with so called normal cost pricing. This hypothesis states that any procyclical fluctuations in the mark-up of prices over actual unit costs are merely side effects of fluctuaions in productivity, cf. Barker and Peterson (1987, Ch. 13.5). Upon linearization we have

$$q^f = m_q + (w + T1 - z) \tag{18}$$

where we use q^f as a reminder that this is a theoretical equation for firms' optimal price-setting.

6.3.3 NAIRU

Influential contributions like Layard et al. (1994) and Nickell et al. (2005) have made use of a two-equation system like (17) and (18) to argue that the equilibrium rate of unemployment is uniquely determined from the wage and price setting, i.e., the supply side of the model.

The main argument is easily (re)constructed by noting that $(w^b - q)$ from (17) can be written as

$$(w^b - q) = m_w + (1 - \delta_{12})(p - q) + \delta_{13}z - \delta_{15}u - \delta_{16}T1, \tag{19}$$

and $(w - q^f)$ from (18) can be written as

$$(w - q^f) = -m_q - (T1 - z) \tag{20}$$

Following our interpretation of the Nash real-wage, (19) represents the common real-wage norm coming out of the negotiations. Equation (18) on the other hand gives the unilateral firm side real-wage target. Without further assumptions, the two real wage targets are not equal. In fact, we have no less than four endogenous variables: $(w - q^f)$,

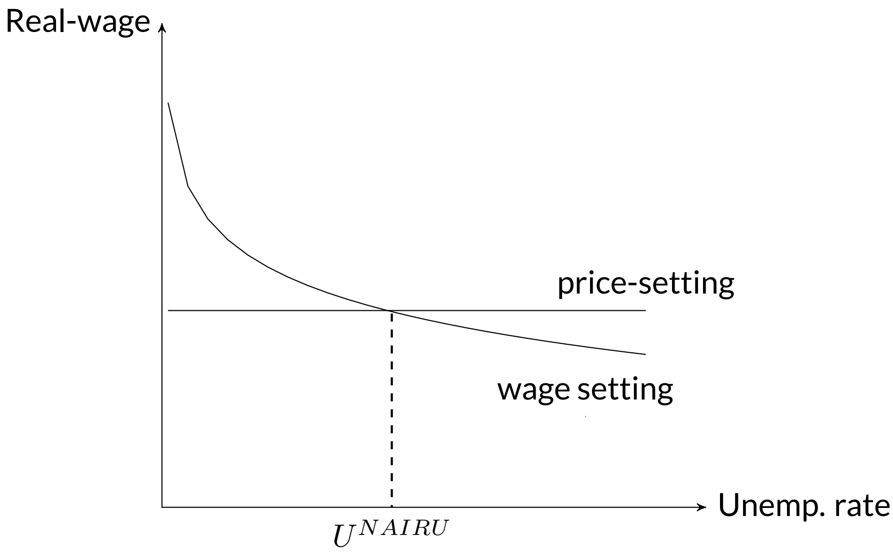

Figure 10: Wage and price formation with a unique NAIRU.

$(w^b - q)$, $(p - q)$ and u, but only two equations. The model is "under-determined". However, at this point a heuristical argument is invoked, saying that a medium-run equilibrium requires that the two wage rates to be identical. Assuming

$$(w^b - q) = (w - q^f) = (w - q)^{NAIRU} \tag{21}$$

will then let us solve the two equations for the NAIRU-rate of unemployment, u^{NAIRU}. As already noted, NAIRU which is acronym for the Non Accelerating Inflation Rate of Unemployment. The graphical representation is given in Figure 10.
Equation (19) is the downward sloping curve labelled wage setting in Figure 10, while (20) is the horizontal line named price-setting. The variables are assumed to be measured in their original units in the graphs, which is why the wage-setting curve is convex. Looking back at (19) and (20) we note that there are (still) three variables $(w - q)$, u and $(p - q)$ but only two equations. In the graph, this means that the position of the wage-curve (not the slope) will change whenever there is a movement in $p - q$. Hence, the solution for unemployment is not unique unless the wedge variable $(p-q)$ is determined from outside, for example by assuming that it is determined by a requirement about current-account balance.

Another problem with this model is that it is static. It can therefore have no implications about how wages and prices evolve outside the equilibrium. However, to make up for this weakness, the framework is backed-up by the mentioned heuristics which (in addition to the two real-wage targets must be equal) states that inflation will be non-constant (hence outside equilibrium and 'dynamic') in periods when $U_t \neq U^{NAIRU}$. As discussed by Kolsrud and Nymoen (2015), who look critically on the NAIRU-heuristics, it may have come to put too much weight *one* equilibrating mechanism, namely unemployment variations, and that there may be other adjustments processes that are also consistent with the long-run wage setting and price setting schedules.

However, all these problems can be resolved if we move from a static framework, to a genuinely dynamic model of wage and price formation. In doing so, we do not need to throw away anything of the above, about the economic theory of wage and price setting. Instead, we re-interpret them as hypotheses about identified long-run cointegrating equation, and next formulate dynamics that are logically consistent with those equations.

6.4 COINTEGRATION AND LONG-RUN IDENTIFICATION

We first show how the two theoretical relationships (17) and (18) can be transformed into hypothesized relationships between observable time series. As noted above, our maintained modelling assumption is that the real-wage and productivity are $I(1)$ series. The rate of unemployment is assumed to be $I(0)$, possibly after removal of deterministic shifts in the mean.

Using subscript t to indicate period t variables, equation (17) defines w_t^b as an $I(1)$ variable. Next define:

$$ecm_t^b = rw_t - rw_t^b \equiv w_t - w_t^b.$$

Under the null-hypothesis that the theory is correct, the 'bargained wage' w_t^b cointegrates with the actual wage, hence $ecm_t^b \sim I(0)$, which is a testable hypothesis. We can write the long-run wage equation following from bargaining theory as:

$$w_t = m_w + q_t + (1 - \delta_{12})(p_t - q_t) + \delta_{13} z_t - \delta_{15} u_t - \delta_{16} T1_t + ecm_t^b. \tag{22}$$

With reference to equation (18), a similar argument applies to price setting. The 'firm side' real wage can be defined as

$$rw_t^f \equiv w_t + T1_t - q_t^f = -m_q + z_t,$$

and the difference between the actual real wage and the real wage implied by price setting becomes

$$ecm_t^f = rw_t - rw_t^f = w_t + T1_t - q_t - \{-m_q + z_t\}.$$

Hence, the implied long–run price setting equation becomes

$$q_t = m_q + (w_t + T1_t - z_t) - ecm_t^f \tag{23}$$

where $ecm_t^f \sim I(0)$ for the equation to be consistent with the modelling assumptions.

The two cointegrating relationships (22) and (23) are not identified in general. But in several cases of relevance, identification is quite credible, see Bårdsen et al. (2005, p. 81). An one example, we consider a case which is relevant for an aggregated model of the supply side in an open economy. Equation (22) and (23) can then be combined with a definition of the consumer price index p_t,

$$p_t = (1 - \zeta) q_t + \zeta pi_t + \eta T3_t, \; 0 < \zeta < 1, \quad 0 < \eta \leq 1, \tag{24}$$

where the import price index pi_t naturally enters. The parameter ζ reflects the openness of the economy.[30] Also, the size of the parameter η will depend on how much of the retail price basket is covered by the indirect tax-rate index $T3_t$. By substitution of (24) in (22), and of (23) in (24), the system can be specified in terms of w_t and p_t:

$$\begin{aligned} w_t = m_w + \left\{1 + \zeta \frac{\delta_{12}}{(1-\zeta)}\right\} p_t \\ - \frac{\delta_{12}\zeta}{(1-\zeta)} pi_t - \frac{\delta_{12}\eta}{(1-\zeta)} T3_t + \delta_{13} z_t - \delta_{15} u_t - \delta_{16} T1_t + ecm_t^b \end{aligned} \tag{25}$$

$$p_t = (1-\zeta) m_q + (1-\zeta)\{w_t + T1_t - z_t\} + \zeta pi_t + \eta T3_t - (1-\zeta) ecm_t^f \tag{26}$$

By simply viewing (25) and (26) as a pair of simultaneous equations, it is clear that the system is unidentified in general. However, for the purpose of modelling the aggregate economy, we choose the consumer price index p_t as the representative domestic price index by setting $\delta_{12} = 0$. In this case, (26) is unaltered, while the wage equation becomes

$$w_t = m_w + p_t + \delta_{13} z_t - \delta_{15} u_t - \delta_{16} T1_t + ecm_t^b \tag{27}$$

The long-run price equation (26) and the long-run wage equation (27) are identified by the order condition.

6.5 VAR AND IDENTIFIED EQUILIBRIUM CORRECTION SYSTEM

The third stage in the operationalization is the equilibrium-correction system, where we follow Bårdsen and Fisher (1999). In brief, we allow wage growth Δw_t to interact with current and past price inflation, changes in unemployment, changes in tax-rates, and previous deviations from the desired wage level consistent with (27)

$$\begin{aligned} \Delta w_t - \alpha_{12,0} \Delta q_t = c_1 + \alpha_{11}(L) \Delta w_t + \alpha_{12}(L) \Delta q_t + \beta_{12}(L) \Delta z_t \\ - \beta_{14}(L) \Delta u_t - \beta_{15}(L) \Delta T1_t \\ - \gamma_{11} ecm_{t-r}^b + \beta_{18}(L) \Delta p_t + \epsilon_{1t}, \end{aligned} \tag{28}$$

where Δ is the difference operator, the $\alpha_{1j}(L)$ and $\beta_{1j}(L)$ are polynomials in the lag operator L:

$$\begin{aligned} \alpha_{1j}(L) &= \alpha_{1j,1} L + \cdots + \alpha_{1j,(r-1)} L^{r-1}, j = 1, 2, \\ \beta_{1j}(L) &= \beta_{1j,0} + \beta_{1j,1} L + \cdots + \beta_{1j,(r-1)} L^{r-1}, j = 2, 4, 5, 6. \end{aligned}$$

The $\beta-$polynomials are defined so that they can contain contemporaneous effects. The order r of the lag polynomials may of course vary between variables and is to be determined empirically.

[30] Note that, due to the log-form, $\zeta = is/(1 - is)$ where is the import share in private consumption.

In the case where $\gamma_{11} < 0$, this formulation is an equilibrium correction model, known as ECM, for nominal wages, see Sargan (1964) and e.g., Nymoen (1991). The Phillips-curve version of wage dynamics, which for a long period of time become the American version of wage dynamics modelling, is derived by setting $\gamma_{11} = 0$—see Blanchard and Katz (1999).

Although we regard the case of cost functions which are flat over wide intervals for output produced as the main case, it is possible that prices can rise as output rises. Feasible reasons for this include the inflexibility of supply in some markets within a certain time frame and firms exploiting high demand to set higher margins. To allow for such effects we let output above the trend exerts a (lagged) positive pressure on prices, measured by the output gap_t, indeed as in price Phillips-curve inflation models—see Clarida et al. (1999). In addition, product price inflation interacts with wage growth and productivity gains and with changes in the payroll tax-rate, as well as with corrections from an earlier period's deviation from the equilibrium price (as a consequence of e.g., information lags, see Andersen (1994, Ch. 6.3)):

$$\begin{aligned}\Delta q_t - \alpha_{21,0}\Delta w_t &= c_2 + \alpha_{22}\left(L\right)\Delta q_t + \alpha_{21}\left(L\right)\Delta w_t + \beta_{21}\left(L\right)gap_t \\ &- \beta_{22}\left(L\right)\Delta z_t + \beta_{25}\left(L\right)\Delta T1_t - \gamma_{22} ecm^f_{t-r} + \epsilon_{2t},\end{aligned} \tag{29}$$

where

$$\begin{aligned}\alpha_{2j}(L) &= \alpha_{2j,1}L + \cdots + \alpha_{2j,(r-1)}L^{r-1},\ j = 1, 2, \\ \beta_{2j}\left(L\right) &= \beta_{2j,0} + \beta_{2j,1}L \cdots + \beta_{2j,(r-1)}L^{r-1}, j = 1, 2, 5.\end{aligned}$$

Solving equation (24) for Δq_t (i.e., the equation is differenced first), and then substituting out in equations (28), and (29), the theoretical model condenses to a wage-price model suitable for estimation and similar to the early multiple equation equilibrium-correction formulation of Sargan (1980):

$$
\begin{aligned}
&\begin{bmatrix} 1 & -a_{12,0} \\ -a_{21,0} & 1 \end{bmatrix} \begin{bmatrix} \Delta w \\ \Delta p \end{bmatrix}_t = \begin{bmatrix} \alpha_{11}(L) & -a_{12}(L) \\ -a_{21}\left(L\right) & \alpha_{22}(L) \end{bmatrix} \begin{bmatrix} \Delta w \\ \Delta p \end{bmatrix}_t + \\
&\begin{bmatrix} 0 & \beta_{12}\left(L\right) & -\zeta\frac{\alpha_{12}(L)}{1-\zeta} & -\beta_{14}\left(L\right) & -\beta_{15}\left(L\right) & -\eta\frac{\alpha_{12}(L)}{1-\zeta} \\ b_{21}\left(L\right) & -b_{22}\left(L\right) & \zeta\alpha_{22}(L) & 0 & b_{25}\left(L\right) & \eta\alpha_{22}(L) \end{bmatrix} \begin{bmatrix} gap \\ \Delta z \\ \Delta pi \\ \Delta u \\ \Delta T1 \\ \Delta T3 \end{bmatrix}_t \\
&-\begin{bmatrix} \gamma_{11} & 0 \\ 0 & \gamma_{22} \end{bmatrix} \times \begin{bmatrix} 1 & -\left(1+\zeta d_{12}\right) & -\delta_{13} & \zeta d_{12} & \delta_{15} & \delta_{16} & \eta d_{12} \\ -\left(1-\zeta\right) & 1 & \left(1-\zeta\right) & -\zeta & 0 & -\left(1-\zeta\right) & -\eta \end{bmatrix} \begin{bmatrix} w \\ p \\ z \\ pi \\ u \\ T1 \\ T3 \end{bmatrix}_{t-r} \\
&+\begin{bmatrix} e_1 \\ e_2 \end{bmatrix}_t ,
\end{aligned}
\tag{30}
$$

where we have omitted the intercepts to save space, and have substituted the equilibrium correction terms using (25) and (26) above. The mapping from the theoretical parameters in (28) and (29) to the coefficients of the model (30) is given by:

$$
\begin{aligned}
a_{12,0} &= \frac{\alpha_{12,0}}{1-\zeta} + \beta_{18,0}, \\
a_{21,0} &= \left(1-\zeta\right)\alpha_{21,0}, \\
a_{12}\left(L\right) &= \frac{\alpha_{12}\left(L\right)}{1-\zeta} + \beta_{18}(L), \\
a_{21}\left(L\right) &= \left(1-\zeta\right)\alpha_{21}\left(L\right), \\
b_{2j}\left(L\right) &= \left(1-\zeta\right)\beta_{2j}\left(L\right), j = 1, 2, 5, \\
d_{12} &= \frac{\delta_{12}}{1-\zeta}, \\
e_1 &= \epsilon_1, \\
e_2 &= \left(1-\zeta\right)\epsilon_2.
\end{aligned}
\tag{31}
$$

The model (30) contains the different channels and sources of inflation discussed so far: Imported inflation Δpi_t, and several relevant domestic variables: the output gap, changes in the rate of unemployment, in productivity, and in tax rates. Finally the model includes deviations from the two cointegration equation associated with wage bargaining and price setting which have equilibrium correction coefficients γ_{11} and γ_{22} respectively. Consistency with assumed cointegration implies that the joint hypothesis of $\gamma_{11} = \gamma_{22} = 0$ can be rejected.

6.6 ECONOMIC INTERPRETATION OF THE STEADY STATE OF THE DYNAMIC WAGE-PRICE MODEL

The dynamic model in (30) can be re-written in terms of real wages $(w-p)_t$ and a real exchange rates defined as $(pi-q)_t$, since $(p-q)_t \equiv (1-\zeta)(pi-q)_t$.

6.6.1 STEADY STATE OF THE WAGE-PRICE SYSTEM

Using a specification with first order dynamics, Bårdsen et al. (2005, Ch. 6) discusses several different aspects of this model. Most importantly, the dynamic system is asymptotically stable under quite general assumptions about the parameters, including for example dynamic homogeneity in the two equilibrium correction equations. The steady state is conditional on any given rate of unemployment, which amounts to saying that our core supply side model does rely on a particular level of the unemployment rate to givne a well defined (and stable) steady-state. There is a stalemate in the dynamic “tug-of-war” between workers and firms that occurs for in principle, any given rate of unemployment, see Bårdsen and Nymoen (2003) and Kolsrud and Nymoen (2014) for proofs.

Since there are no new unit root implied by the generalized dynamics in equation (30) above, the asymptotic stability holds also for the version of the model with higher order dynamics. We therefore have the following important results: The dynamics of the supply side is asymptotically stable in the usual sense that, if all stochastic shocks are switched off, then $(pi_t - q_t) \rightarrow rex_{ss}(t)$, and $(w_t + T1_t - q_t) \rightarrow wq_{ss}(t)$, where $rex_{ss}(t)$ and $wq_{ss}(t)$ represent deterministic steady state growth paths of the real exchange rate and the producer real wage.

Generally, the steady-state growth paths depend on the steady state growth rate of import prices, and of the mean of the logarithm of the rate of unemployment, denoted u_{ss}, and the expected growth path of productivity $z(t)$. However, under the condition that $\delta_{13} = 1$, homogeneity of degree one with respect to productivity, which we have seen is implied theoretically by assuming bargaining power on the part of unions, $z(t)$ has a zero coefficient in the expression for rex_{ss}, which therefore is constant in the steady state. Moreover, assuming $\delta_{13} = 1$, the implied steady state wage share, $wq_{ss}(t) - z(t) = ws_{ss}$ which also is also a constant in steady state.

With $\delta_{13} = 1$, the implied steady-state inflation rate therefore follows immediately: Since $\Delta(pi_t - q_t) = 0$ in steady state, and $\Delta p_t = (1-\zeta)\,\Delta q_t + \zeta \Delta pi_t$, domestic inflation is equal to the constant steady state rate of imported inflation,

$$\Delta p_t = \Delta pi_t = \pi. \tag{32}$$

The above implicitly assumes an exogenous, and for simplicity, constant, nominal exchange rate. For the case of of a floating exchange rate it might be noted that since

$$pi_t = e_t + pf_t,$$

where e_t is the logarithm og the nominal exchange rate, and the logarithm of index of import prices in foreign currency is denoted pf_t, the stability of inflation requires stability of Δe_t. This condition can easily be verified if the floating nominal exchange rate follows a random-walk process, e.g., $e_t = e_{t-1}+$ *drift* + *shock* where drift is a parameter (possibly, but not necessarily zero), and *shock* is a random variable with mean zero. Hence, an unstable nominal exchange rate level (customarily associated with freely floating exchange rate) does logically imply that the dynamic system of wq_t and rex_t becomes unstable. Nor nor does it imply unstable dynamics for the Δw_t, Δq_t and Δp_t.

It is only if Δe_t. becomes unstable due to endogenous responses that the model of wage and price setting can become dynamically unstable. Hence the specification of the model for the market for foreign exchange, and how it interact with the rest of the model, is going to be an important step in the assessment of total model properties. In practice however, this is easily done by dynamic simulation of the complete NAM model.

6.6.2 THE NAIRU REVISITED

The supply-side determined steady state has a wider relevance as well. For example, what does the model tell about the dictum, illustrated in Figure 10 that the existence of a steady state inflation rate requires that the rate of unemployment follows the law of the natural rate or NAIRU?

As noted aboce, the version of this natural rate/NAIRU view of the supply side that fits most easily into our framework is the one succinctly expressed by Layard et al. (1994)

> 'Only if the real wage (W/P) desired by wage-setters is the same as that desired by price setters will inflation be stable. *And, the variable that brings about this consistency is the level of unemployment*'.[31]

Translated to our conceptual framework, this view corresponds to setting $ecm_t^b = ecm_t^f = 0$ in (22) and (23), with $\delta_{13} = 1$, and solving for the rate of unemployment that reconciles the two desired wage shares, call it u^{NAIRU} [32]

$$u^{NAIRU} = \frac{m_w + m_q}{-\delta_{15}} + \frac{1-\delta_{12}}{-\delta_{15}}(p-q) + \frac{1-\delta_{16}}{-\delta_{15}}T1,$$

[31] Layard et al. (1994, p 18), authors' italics.

[32] Strictly, we take the expectation through in both equations.

which can be expressed in terms of the real exchange rate $(p - pi)$, and the two tax rates as:

$$u^{NAIRU} = \frac{-(m_w + m_q)}{\delta_{15}} + \frac{1-\delta_{12}}{\delta_{15}(1-\zeta)}\zeta(p - pi) + \frac{1-\delta_{12}}{\delta_{15}(1-\zeta)}\eta T3 + \frac{1-\delta_{16}}{-\delta_{15}}T1 \tag{33}$$

This is one equation in two endogenous variables, u^{NAIRU} and the wedge $(p - pi)$, so it appears that there is a continuum of u^{NAIRU} values depending on the size of the wedge, in particular of the value of the real exchange rate. It is however custom to assume that the equilibrium value of the wedge is determined by the requirement that the current account is in balance in the long run. Having thus pinned down the long run wedge as a constant equilibrium real exchange rate $\overline{(p - pi)}$, it follows that NAIRU u^{NAIRU} is determined by (33). If the effect of the wedge on wage claims is not really a long run phenomenon then $\delta_{12} = 1$ and u^w is uniquely determined from (33), and there is no need for the extra condition about balanced trade in the long-run, see Layard et al. (2005, p. 33).

The last paragraph reminds us of the static model of the NAIRU rate of unemployment in sub-chapter 6.3.3 above. In fact, the expression for u^{NAIRU} in (33) will indeed be identical to the expression for the NAIRU we noted could be obtained as the solution to the two static equations (19) and (20), and which we referred to as U^{NAIRU} in Figure 10. Hence, Figure 10 is consistent with a (very) *special case* of the dynamic model of wage and price setting.

Compare this to the asymptotically stable equilibrium consisting of $u_t = u_{ss}$, $\Delta p_t = \pi$ and $w_t + T1 - q_t - z_t = ws_{ss}$. Clearly, inflation is stable, even though u_{ss} is determined 'from the outside', and is not determined by the wage-and price-setting equations of the model. Hence the (emphasized) second sentence in the above quotation has been disproved: It is not necessary that u_{ss} corresponds to the NAIRU u^{NAIRU} in equation (33) for inflation to be stable with a well defined value in steady state.

Bårdsen et al. (2005, Ch 6) show which restrictions on the parameters of the system (30) that are necessary for $u_t \to u_{ss} = u^{NAIRU}$ to be an implication, so that the NAIRU corresponds to the stable steady state. In brief, the model must be restricted in such a way that the nominal wage and price setting adjustment equations become two conflicting dynamic equations for the real wage. Because of the openness of the economy, this is not achieved by imposing dynamic homogeneity. What is required is to purge the model (30) of all nominal rigidity, which is unrealistic on the basis of both macro and micro evidence.

As the estimation results will show, the strict form of dynamic homogeneity is not supported by the data used to estimate NAM, which is why we in Figure 11 refer to the case of non-unique NAIRU as "the case in NAM". In Figure 11 we use the same price-setting and wage-setting curves as in Figure 10, but they are now interpreted as long-run cointegrating relationships, that are consistent with for example one steady-state rate of unemployment at $U_{ss,1}$, and another one at $U_{ss,2}$. In this model, variables that affect aggregate demand relatively directly, both foreign and domestic, can be among the determinants of

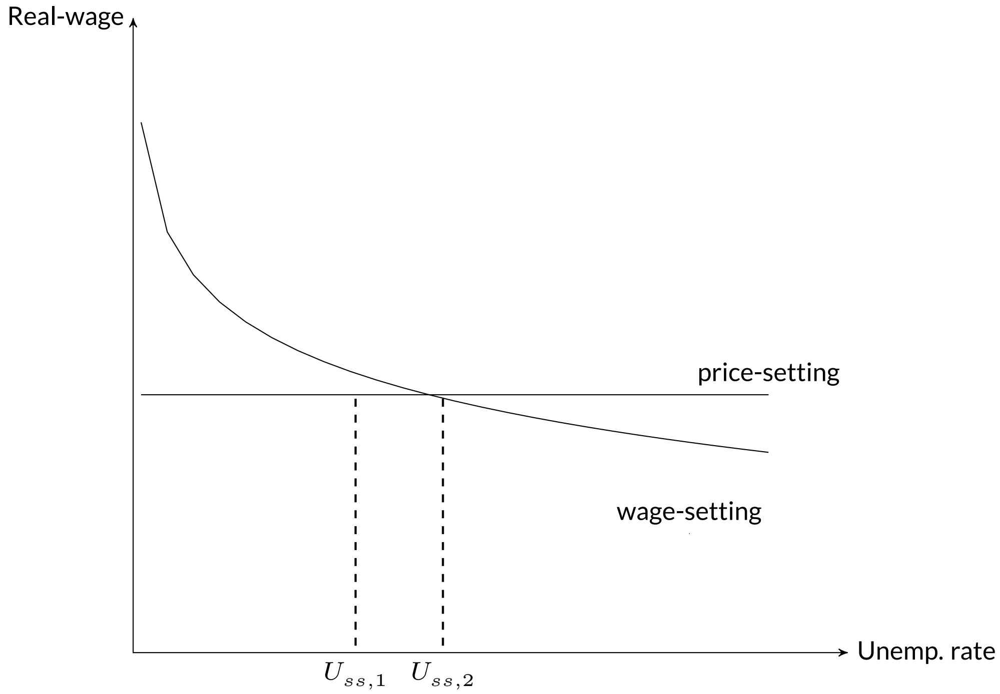

Figure 11: Wage and price formation when there is no unique NAIRU, the case in NAM.

the steady-state rate of unemployment, which also will depend on the efficiency of labour market institutions.

We have seen that the Layard-Nickell version of the NAIRU concept corresponds to a set of restrictions on the dynamic ICM model of wage and price setting. The same is true for the natural rate of unemployment associated with a vertical Phillips Curve Model, which we denote PCM.

This is most easily seen by considering a version of (28) with first order dynamics and where we abstract form short-run effects of productivity, taxes and unemployment ($\beta_{12} = \beta_{14} = \beta_{15} = 0$). With first order dynamics we have:

$$\Delta w_t - \alpha_{12,0}\Delta q_t = c_1 - \gamma_{11} ecm^b_{t-1} + \beta_{18}\Delta p_t + \epsilon_{1t},$$

and using (22) we can then write the wage equation as:

$$\begin{aligned}\Delta w_t = k_w + \alpha_{12,0}\Delta q_t + \beta_{18}\Delta p_t - \mu_w u_{t-1} \\ - \gamma_{11}(w_{t-1} - q_{t-1}) + \gamma_{11}(1-\delta_{12})(p_{t-1} - q_{t-1}) + \gamma_{11}\delta_{16}T1_{t-1} + \epsilon_{1t}\end{aligned} \tag{34}$$

where $k_w = c_1 + \gamma_{11} m_w$, and the parameter μ_w is defined in accordance with Kolsrud and Nymoen (1998) as:

$$\mu_w = \gamma_{11}\delta_{13} \text{ when } \gamma_{11} > 0 \text{ or } \mu_w = \varphi \text{ when } \gamma_{11} = 0. \tag{35}$$

The notation in (35) may seem cumbersome at first sight, but it is required to secure internal consistency: Note that if the nominal wage rate is adjusting towards the long run wage curve, $\gamma_{11} > 0$, the only logical value of for φ in (35) is zero, since u_{t-1} is already contained in the equation, with coefficient $\gamma_{11}\delta_{13}$. Conversely, if $\gamma_{11} = 0$, so the the model of collective wage bargaining fails, it is nevertheless possible that there is a wage Phillips curve relationship, consistent with the assumed $I(0)$-ness of the rate of unemployment, hence $\mu_w = \varphi \geq 0$ in this case.

Subject to the restriction $\gamma_{11} = 0$, and assuming an asymptotically stable steady state inflation rate π, (34) can be solved for the Phillips-curve NAIRU u^{phil}:

$$u^{phil} = \frac{k_w}{\varphi} + \frac{(\alpha_{12,0} + \beta_{18} - 1)}{\varphi}\pi$$

which becomes a natural rate of unemployment, independent of inflation subject to dynamic homogeneity $\alpha_{12,0} + \beta_{18} = 1$.

However, the claim that u_t^{phil} represents an asymptotically stable stable solution must be stated with some care. As shown in e.g., Bårdsen and Nymoen (2003) $\gamma_{11} = 0$ is a necessary but not a sufficient condition. The sufficient conditions include $\gamma_{22} = 0$ in addition to $\gamma_{11} = 0$ and instead of equilibrium correction in wages and prices, dynamic stability requires equilibrium correction in the unemployment equation or in a functionally equivalent part of the model. A main lesson is that dynamic stability or lack thereof, is a genuine system property. Sources of instability in one part of the system can be compensated by stabilization in another part, and vice versa. A relatively complete discussion of the dynamic properties of the ICM and PCM versions of wage and price setting systems like ours, is found in Kolsrud and Nymoen (2014).

Returning to Figure 11, if we assume that $U_{ss,1}$ represents an initial steady state situation, and $U_{ss,2}$ represents a new steady state after a shock, there must be a dynamic process that connects the two steady-states. Hence we must imagine that the wage-setting curve drifts way from its initial position, finally reaching its new stationary position after an adjustment period.

Figure 12 illustrates a scenario where unemployment increases from $U_{ss,1}$ to U_{shock} because if a large shock to the economy. The labour market, and wage and price setting in particular is in disequilibrium, and a dynamic adjustment process begins. In a new steady-state situation, the wage-curve has become aligned to the steady state $U_{ss,2}$.

What is the mechanism that drives the adjustment of the wage-curve? As discussed by several authors, a plausible candidate is that a real depreciation of the exchange rate takes place. This is also the case in NAM, and in the next sub-chapter we give a demonstration of this point, by the use of a stylized model that can be solved by simulation to clarify the dynamic properties.

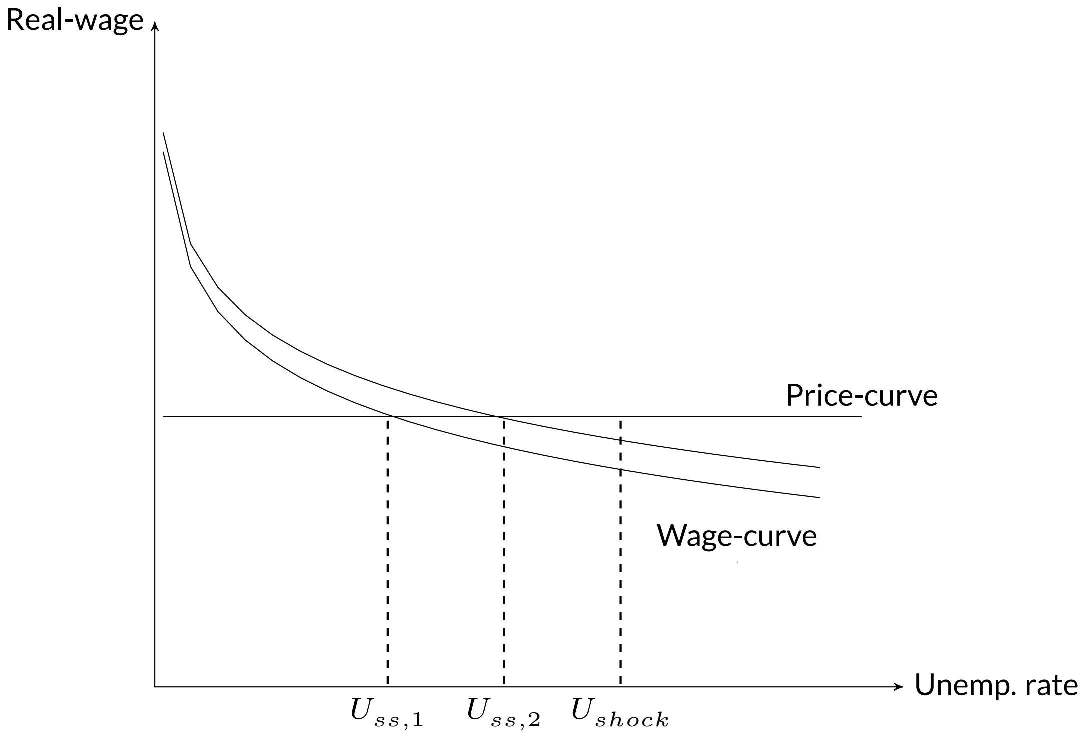

Figure 12: Initial stationary situation in $U_{ss,1}$. After a shock to the product market, or the financial market, the economy is at U_{shock}. $U_{ss,2}$ indicates a new stationary state

6.7 A SIMULATION EXAMPLE

Even tough it is important theoretically that the "wage and price spiral" can be dynamically stable for a targeted fixed rate of unemployment, it also means that unemployment cannot in general be determined from the supply side, by only using the equations that represent the model of wage and price setting. In order to endogenize the rate of unemployment we clearly need to extend the dynamic wage-price system. In order to illustrate the properties of this system we calibrate the wage-price system of the in the last sub-chapter with values that are consistent with conditional dynamic stability. Hence we simulate the (stable case) of ICM version of the supply side model above.[33] The only change we make in the wage-price model is that we, for simplicity, let the long-run wage norm equation depend on the rate of unemployment rather than the log of unemployment.

As noted above, one implication of monopolistic competition is that production and aggregate GDP will become closely correlated with the factors that influence aggregate demand. As a consequence, those factors will also influence employment and unemployment. More generally, this principle is called Okun's law, and it is useful in expositions like ours since it allows us to write the aggregate demand (AD) relationship either in terms of "GDP from trend", or in terms of the unemployment rate (U_t).

[33] Kolsrud and Nymoen (2014) contains a relatively complete analysis, using both algebra and simulation, of both the ICM and PCM version

A simple dynamic relationship between U_t and the log of the real exchange rate, which we denote rex_t in the simulation, is given by

$$U_t = c_u + \alpha U_{t-1} - \rho rex_{t-1} + \epsilon_{u,t},\ \rho \geqq 0, -1 < \alpha < 1, \tag{36}$$

In the same way as above, rex_t is defined uch that an increase in the this variable leads to improved competitiveness. This increases exports and reduces imports so that GDP is positively affected, causing a fall in unemployment, hence $\rho \geqq 0$. The error term $\epsilon_{u,t}$ contains all other variables which might affect U_t.

It is worth stressing that even though NAM is an aggregated model, equation (36) omits several facors that are modelled in NAM. One key element is the real interest rate effect, which represents a key channel of monetary policy under inflation targeting. Other features that we omit have to do with the medium term effects of changes in labour supply, (e.g., labour immigration), with the degree of friction in the labour market, labour market policies. Despite its simplicity, (36) is general enough to serve as a representation when the purpose is to illustrate the qualitative properties of the joint modelling of wage and price setting and the demand side.

To define rex_t in terms of the variables of the wage-price model above, we have:

$$re_t \equiv (1-\zeta)(pi-q)_t, 0 < \zeta < 1 \tag{37}$$

q_t is an endogenous variable by the price setting of domestic producers, while pi_t is represented as a random-walk with drift:

$$pi_t = g_{pi} + pi_{t-1} + \varepsilon_{pit} \tag{38}$$

This equation represents a nominal stochastic trend model of the import price.

In the same way as above, we can let pf_t denote the foreign foreign price level in foreign currency, and we let the nominal exchange rate be denoted by e_t. By defining pi_t as $pi_t =: pf_t + e_t$ we see that the random-walk formulation in (38) is consistent with assuming that one of, or both of, foreign price pf_t and nominal exchange rate e_t is an integrated series, $I(1)$. It is reasonable to assume that $pf_t \sim I(1)$. If we assume that $e_t \sim I(0)$ in a fixed exchange rate regime, while $e_t \sim I(1)$ in a regime with floating exchange rate, we see that the $pi_t \sim I(1)$ is a formulation that is robust to a regime shift in the the exchange rate policy.

For concreteness, we think of (38) as a simple model of a system with fully floating nominal exchange rate. In NAM (38) is replaced by a separate module of the nominal exchange rate, and an equation for interest rate setting under inflation targeting. Clearly, if the model is stable in real terms with such a naive model of the nominal trend, it is reasonable to assume that it will also be stable when is replaced by (38) the more relevant equations found in NAM.

Finally, we include a common real trend, for the log of average labour productivity z_t that we have introduced in the theoretical model above.

$$z_t = g_z + z_{t-1} + \varepsilon_{at} \tag{39}$$

ε_{at}, and ε_{pit} are assumed to be innovations with zero expectations.

To illustrate the properties of the model, and of a simple one-off estimation of the equilibrium rate,we generate a data set (T=200) for re_t, ws_t, U_t, pi_t, z_t and p_t using parameter values that give dynamic stationarity, and with a single location shift in period 150. The structural disturbances are Gaussian and independent.

We then FIML estimate the structural equations corresponding to the long-run equations in section 6.4 and 6.5 on a data set that ends in period 160, and simulate the estimated structural form dynamically over a period that starts in period 160 and ends in period 200. The dynamic simulation is stochastic (1000 replications). The average of the solution paths represents the estimated expectations of the endogenous variables. Since we have estimated the true model, the solution converges to the imputed steady-state values of the endogenous variables.

Figure 13: Dynamic simulation of a wage-price model extended by equation (36) for unemployment, using data from a VAR representation and Monte Carlo simulation. Illustrating system stability with respect to a large temporary shock to unemployment in period 151.

The figure contains four panels with blue graphs of the actuals (i.e., the computer generated data) for re_t, ws_t, Δp_t (i.e., inflation) and U_t. The dashed green line is the average of the simulated model solutions. The red dotted lines are upper and lower 95 % prediction intervals around the solution.

The fourth panel shows the solution for the rate of unemployment. The solution starts at a relatively high level, which is a consequence of the imputed shock to unemployment in period 151. The three other graphs shows that there is a reduction of inflation early in the period. Since there is no direct effect of unemployment on prices in the model, the reduction in inflation is due to a reduction in wage growth. The figure for the wage-share shows a reduction in the beginning of the solution period, hence wage inflation is being more reduced than price inflation.

There is no response in the nominal exchange rate in this model, but the reduction in Δp_t nevertheless less leads to a depreciation of the real exchange rate, which is increased in the first panel in Figure 13. This is an example of so called internal devaluation.

The stable equilibrium nature of the solutions are evident. The line representing the solution for U_t declines smoothly towards the level stable level of 1.28 % unemployment showing that this is the equilibrium rate U^* for this structure (i.e. for the chosen parameter values). The NAIRU interpretation is also confirmed by the graph for inflation, which show a constant expectation, hence the price level is non-accelerating at the stable rate of unemployment, (NAIRU is 1.28 %). The wage-share graph is interesting since it shows a cyclical approach towards the steady-state level.

There are no structural breaks after period 151, so when two actuals for inflation are significantly outside the prediction interval, they are the result of tail-observations ("black swans"), and are not the result of location shifts.

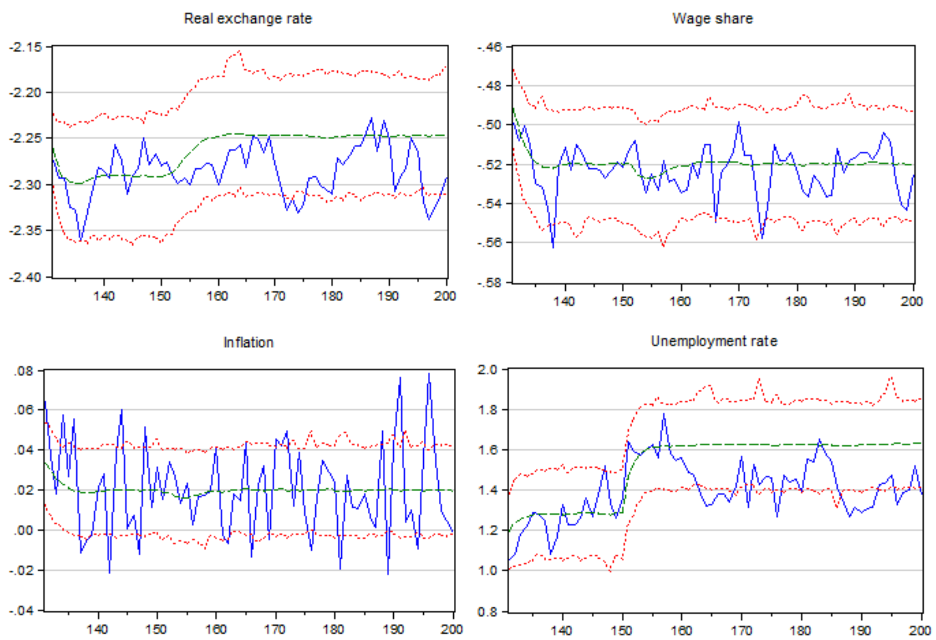

Figure 14: Dynamic simulation of a wage-price model extended by equation (36) for unemployment, using data from a VAR representation and Monte- Carlo simulation. Illustrating system stability with respect to a permanent shock to unemployment in period 151

While Figure 13 is illustrating stability after temporary (though large) shock, one can still question the system's ability to stabilize after a "permanent shock" to the rate of unemployment. In Figure 14 we therefore show the responses to a permanent shock. Again, we let the shock occur in period 151. We start the simulation in period 130 and the graphs therefore shows a tendency of adjustment toward the low equilibrium with $NAIRU = 1.28$ in the period between the start of the simulation and period 150. In period 151 the shock hits, and unemployment starts a gradual increase towards a new NAIRU of 1.62 % unemployment. As the 'Inflation' graph shows, inflation is constant both at the old and new NAURU level. The same is case to the wage share.

We note that although there is a temporarily reduction in the wage share after period 151, there is no long-run reduction. The explanation is, as noted above, that the long run producer real-wage is consistent with the price-setting curve, not the wage curve. Finally, note that there seems to be a permanent increase in the real exchange rate. Without this internal devaluation, the increase in the NAIRU level would have been larger.

In this way, the simulation with a shock to unemployment also confirms the graphical analysis in Figure 12 above, namely that the effects of a large shock is counteracted by a real-exchange rate depreciation. However, while a NAIRU-model would "require" that the deprecation is strong enough to completely offset the long-term effects of the initial shock, the more plausible case is that the cancellation of the shock is more partial.

6.8 IMPLEMENTATION IN NAM

In the current version of NAM, the above theory has been implemented in terms of a system of equations for the hourly wage (*WPFK*) and price (*PYF*) in the private sector of Mainland Norway, and an equation that links the producer price and the import price to the consumer price index (CPI). More details about the estimated wage-price equations are found in Chapter 7, and the actual estimation results are given in Chapter 9.

The theoretical discussion above, was based on the assumption that import prices in foreign currency were exogenous and unresponsive to the Norwegian cost and price level. Hence, in theory, kroner denominated import prices increases by one percent if the nominal exchange rate increases by one percent (a nominal depreciation). However, it is widely remarked that import prices have not fully reflected movements in the exchange rate. For example Naug and Nymoen (1996) and Wolden Bache (2002) who investigated import prices on Norwegian manufactures, estimated that the import price index increased by 0.6 percent if the nominal exchange rate is increased by one percent. In NAM, we find a similar empirical relationship for the (total) price index, indicating that so called "pricing to market" or imperfect exchange rate pass through is a characteristic of wage and price setting.

Allowing for less than full pass-through of exchange rate changes on import prices does not affect the basic analysis of the wage and price setting process that we have given above. The main modification is that nominal wages and prices are "sticky" with respect to exchange rate shocks. The same is the case for the *real* exchange rate since the domestic price level does not fully reflect the movements in the nominal exchange rate.

In order to keep the analysis tractable, we have so far assumed that the nominal exchange rate is not influenced by Norwegian wages or prices, or any other domestic variables like for example interest rates. Realistically speaking, the nominal exchange rate is not completely determined from outside. In Chapter 7.6 we account for how the nominal exchange rate has been modelled in NAM, with reference to the portfolio approach to the foreign exchange market. At this point, it is nevertheless worth pointing out that unless expectations formation about future depreciation are seriously de-stabilising the market, allowing for e.g., an effect of interest rate differentials on the nominal exchange rate will not lead to an unstable domestic wage-price setting process. Instead, it is reasonable that it can be stabilizing.

6.9 IMPLICATIONS FOR MODELLING

The result that the steady state level of unemployment is generally undetermined by the wage-price sub-model is a strong case for building larger systems of equations. Conversely, in general no inconsistencies, or issues about overdetermination, arise from enlarging the wage/price setting equations with a separate equation for the rate of unemployment, where demand side variables may enter.

For example, Akram and Nymoen (2009) show how the specification of the supply side, either as a Phillips curve model, PCM, or as incomplete competition model, ICM, given by equation (28) and (29) above, gains economic significance though the implications of the chosen specification for optimal interest rate setting. And how interest rate setting, affects the real economy mainly trough aggregate demand.

7 SECTOR AND SUB-MODELS IN NAM

In this chapter the different sectors or sub-models of NAM is discussed. We start with the wage-price block of the model. Since a good deal of attention has been given to the theoretical aspects of this part of the model already, the discussion is relatively short and with most emphasis on import price format. Therefore, Chapter 7.1 is titled *Extended wage-price block*, since the modelling of import prices can be seen as an extension of the system of wage and price equations that we have covered so far.

The rest of the chapter presents the main national accounts relationships in NAM, cf. Chapter 7.2. The two following sub-chapter document how we have modelled the components of the "general budget" equation of the Norwegian economy, i.e., the components of aggregate demand (domestic demand and exports) and of aggregate supply (domestic GDP and imports).

Since Norway is a small open economy, the market for foreign exchange is of great importance for macroeconomic stability and dynamics, cf Chapter 7.6. In the final sub-chapters we discuss how housing prices, interest rates and credit are modelled in NAM.

7.1 THE FULL WAGE-PRICE MODULE

The presentation in section 6 used the modelling of wages and prices as an example of our econometric approach.

In the operative version of NAM, the theory of wage-and price setting has been implemented in terms of a system of equations for the hourly wage (*WPFK*) and price (*PYF*) in the private sector of Mainland Norway, and an equation that link producer price and import price to the consumer price index (CPI). Esimation is by Full Infomation Maximum Likelihood (FIML). The detailed estimated wage-price equations are given in chapter 9.33.

The results show that the long-run equation for WPFK is of the form

$$log(WPFK)_t = 0.12ln(UR) + ln(PYF \cdot ZYF) + 0.7log(CPI/PYF) \quad (40)$$

where UR denotes the rate of unemployment, ZYF is average labour productivity and CPI is the consumer price index. The unemployment elasticity -0.12 is quite representative for the empirical literature. Since the elasticity of the wage scope variable $PYF \cdot ZYF$ is unity and the estimated wedge coefficient is 0.7, the results are supportive of dynamic stability of the wage-price system, cf. the discussion of conditions for dynamic stability above.

Section 9.33 also shows that producer price setting is of the 'normal cost pricing' type. It is only in the case of very low initial levels of unemployment that a further drop in unemployment creates "price pressure". This is implied by the $(1/UR^2)$ term in the estimated price equation.

As noted above, the model representation of domestic wage and price formation is not complete without a model how import prices a related to outside prices (in foreign currency) and to the exchange rate. In NAM, the investigated relationship is between the aggregate import price index, PB, an effective nominal exchange rate index (using trade data to construct the weights of the different bi-variate exchange rate), $CPIVAL$ and a price index of foreign producer price indexes (with the same trade weights), $PPIKONK$.

The estimation results in Chapter 9.20 imply that the medium term effect on PB of a permanent positive shock to the exchange rate is 0.45. This point estimate of long-run *pass-through* is lower than estimates of earlier studies, which may be due to differences in data definitions as well as different sample periods. The long run pass-through of shocks to foreign producer prices is one. The same difference shows up in the estimated short-run effects: The impact elasticity of the foreign price is 1.07 and only 0.45 for the nominal exchange rate.

FRAME 8: OTHER ENDOGENOUS WAGE VARIABLES IN THE MODEL

As noted, the main endogenous wage variable in the current version of the model is $WPFK$. But the model also includes endogenous wage rates for local and central government. These are modelled by 'wage-following' equations.

In sum, the estimated wage equation show a large effect of cost-of-living compensation in the medium term, while the long-run trend level is mainly determined by the factors that affect profitability. The estimated price equations confirm that, with the exception of situations with very rapid demand growth, when firms can be tempted to adjust their margins up, there is no direct product demand effect on prices. Finally, the results from estimating dynamic models for import prices show that there is an element of pricing to market and that there medium term pass through from the exchange rate to import prices is incomplete.

Taken together this represent proof that the theoretical implications of normal cost pricing and collective bargaining based wage formation have empirical relevance for the Norwegian economy. As noted above, this constellation of evidenced about wage- and price-setting has the important implication that markets for industrial products mainly clear through quantity, rather than mainly through price and wage adjustment mechanisms. This in turn implies that production, employment, as well as the degree of unemployment, will be responsive to aggregate demand and to how it interacts with credit and housing markets, and the foreign sector.

Against this background, the next sub-chapter describes how product demand and supply are modelled in NAM. We start with the National Accounting relationships, following by a brief description of the different components of supply and demand. While wage and price setting, and product markets are central, the Norwegian economy is also characterized by complex interactions with other markets, in particular the marked for foreign exchange, and credit and housing markets. Our approach to the modelling of these important markets are covered in the last paragraphs of this section.

7.2 NATIONAL ACCOUNTS RELATIONSHIPS

As an aggregated model, there is no detailed input-output tables in NAM. However, the general budget of the Norwegian economy is represented in the model, and there is a certain amount av disaggregation of the demand and supply side. In particular, because of the importance of the off-shore petroleum sector for the overall economic performance, oil exports and gross capital formation in that sector is represented with separate vari-

Table 1: Total supply (TOTS) and total demand (TOTD) in NAM

Total Supply	**TOTS**	$\equiv$	**TOTD**	**Total Demand**
Imports	*B*		*A*	Exports
Gross Domestic Product	*Y*		*CP*	Private consumption
-GDP Mainland Norway	*YF*		*CO*	Public consumption
-GDP oil-sector	$\left\{\begin{array}{l}\text{YOIL1}\\ \text{YOIL1}\end{array}\right.$		*JO*	Public investments
-GDP intern. shipping	*YSF*		*JBOL*	Investments in housing
Net product taxes	*AVGSUB*		*JFPN*	Private investments
			JOIL	Oil-investments
			JUSF	
			JL	Changes in inventories

ables. We also make the distinction, on the supply side, between Mainland-economy, and the production and transportation of oil and natural gas.

Table 1 shows the main national accounting identities In term of NAM variables, see section 4, total supply of goods and services in fixed prices (*TOTS*) is defined by

$$TOTS := B + YFbasis + YOIL1 + YOIL2 + YUSF + AVGSUB \tag{41}$$

where *B* is total imports and *YFbasis* is the GDP of Mainland-Norway. The value added created in the off-shore oil and gas producing sector is the sum of *YOIL1* and *YOIL2*, where *YOIL1* is production of oil and natural gas, and *YOIL2* is pipeline transportation of oil and gas. The second "offshore sector" of the Norwegian economy is international shipping (*YUSF*). As indicated by the variavble name, GDP of Mainland-Norway (*YFbasis)* is measured in basic values. In order to obtain total supply of goods and services in market values, we have to add the last variable *AVGSUB* in (41 which is net product taxes and subsidies.

In the model code, AVGSUB is defined as AVGSUB $:=$ LAVGSUB/PYF where LAVGSUB is net product taxes in current prices and PYF is the deflator of GDP in Maniland-Norway.

From the expenditure side of the national accounts, we define total demand (*TOTD*) as:

$$TOTD := A + CP + CO + JO + JBOL + JFPN + JOIL + JUSF + JL \tag{42}$$

A is total exports of goods and services (see below for details) and *CP* and *CO* are private and government consumption respectively. *JO* represents gross capital formation in general administration ("public investments"). There are two private Mainland-Norway investment variables, for residential housing, *JBOL*, and for private business investments, *JFPN*. Capital formation in the oil-sector (production and pipeline transportation capacity) is measured by *JOIL*. The final variable in (42) is *JL* which represents both changes in inventories and statistical errors.

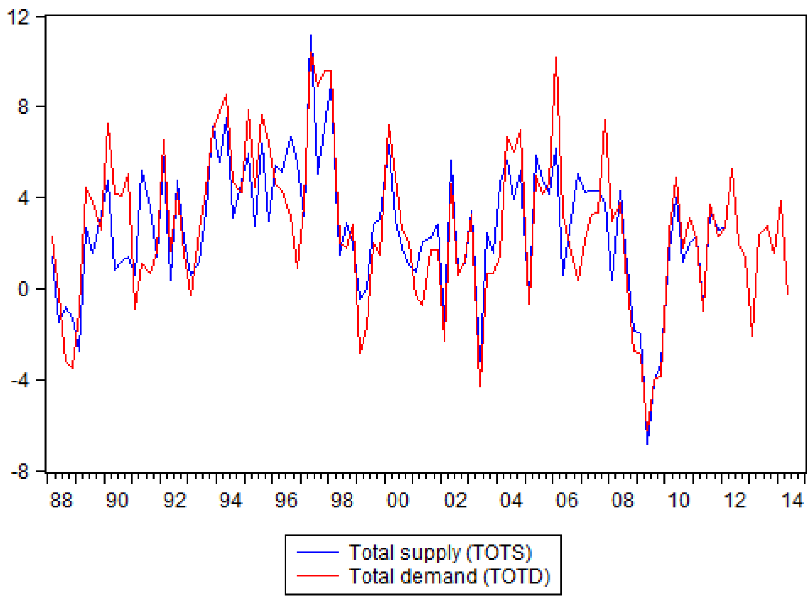

Figure 15: Four quarter percentage change in total demand, *TOTD*, and total supply, *TOTS*.

Figure 15 shows the growth rates of total demand and total supply of the Norwegian economy. Note that there are some discrepancies early in the sample in particular. This is an example of the fact that national accounts identities do not hold exactly when the variables are in fixed prices, except in the base year (2011 in this case). If we had defined total demand and supply in terms of variables in current prices, the match would have been perfect. But also for the fixed price variables that we have plotted figure 15, the discrepancies are so small that they do not represent a problem in practice.

Returning to (41), there is presently no decomposition of total imports (*B)* in NAM. GDP in Mainland-Norway is however decomposed as

$$YF := YFPbasis + YO \tag{43}$$

where *YFPbasis* is value added in private business at basic values, and *YO* is value added in general government. There are three private business sectors: Manufacturing and mining, *YFP1*, production of other goods (which includes the construction sector), *YFP2*, and private service activities, *YFP3*. The three private sector value-added variables are measured in basic values, hence we define *YFPbasis* as

$$YFPbasis := YFP1 + YFP2 + YFP3 \tag{44}$$

On the demand side, (42) already shows the decomposition of gross capital formation. The only other dis-aggregation in the present version of the model is for exports, which is given by

$$A = ATRAD + ATJEN + AOIL + ASKIP \tag{45}$$

where *ATRAD* and *ATJEN* are exports of traditional goods and of service activities respectively. *AOIL* is exports of oil and natural gas and *ASKIP* is exports of ships and of oil-platforms.

GDP for Norway in current prices is denoted *LY* and is defined as

$$LY := PYF \cdot YF + PYOIL1 \cdot YOIL1 + PYOIL2 \cdot YOIL2 + PYUSF \cdot \; YUSF \tag{46}$$

where PYF is the deflator of YF in (43). PYOIL1, PYOIL2 and PYUSF are the deflators of the corresponding fixed price varaibles in Table 1.

Disposable income for Norway is given by:

$$YDNOR \; := \; LY + RUBAL - LKDEP \tag{47}$$

where *LY* is GDP in current prices and *LKDEP* is capital depreciation in current prices.

Net incomes from abroad ("rente og stønadsbalansen") is included as an endogenous variable in NAM, *RUBAL*. Together with the trade surplus it can used to define current-account in fixed prices:

$$CUNOR := A - B + RUBAL\,/\,PY. \tag{48}$$

where *PY* is the GDP price deflator. In the base year this variable will correspond closely to net-finiancial investments.

7.3 AGGREGATE DEMAND

7.3.1 EXPORTS

In NAM there are five export variables.

- A: Total exports, fixed prices, Mill kroner
- AOIL: Exports of oils and natural gas, fixed prices, Mill kroner
- ATJEN: Exports of services, fixed prices, Mill kroner
- ATRAD:Exports of traditional goods, fixed prices, Mill kroner
- ASKIP: Exports of ships and oil platforms, fixed prices, Mill kroner

Total exports, A, is a the sum of the four components:

$$A =: ATRAD + AOIL + ATJEN + ASKIP. \tag{49}$$

which are shown in Figure 16.

The graphs show that exports of oil and natural gas accounted for the bulk of the increase in total exports between 1980 and the end of last millennium. Early in the 2000s, export of oil and gas peaked, and it has since been on a decline. This trend into a "post-oil" era for the Norwegian economy, is expected to continue.

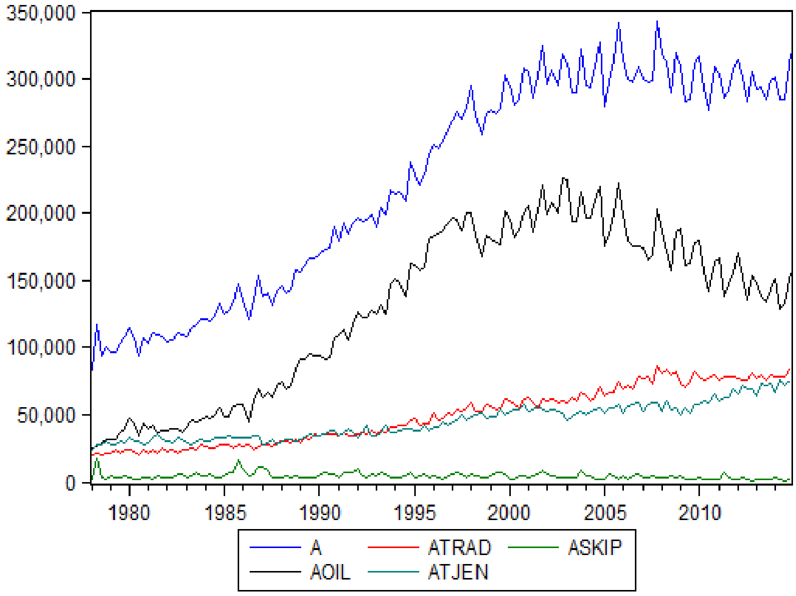

Figure 16: Total exports and its components

$AOIL$ is a non-modelled (exogenous) variables in NAM, while the three others are endogenous. As shown in Figure16, $ASKIP$ is a small component of total exports. It is modelled by a simple autoregressive process in NAM, cf. section 9.1. The exports of traditional goods ($ATRAD$) and services ($ATJEN$) are much more interesting for total exports, and we therefor comment on the modelling of those two variables separately.

Although convention and the principles of the national accounts lead us to categorise exports as "demand side"variables, these variables are mainly determined by firms. As already mentioned when we discussed price setting in Chapter 6.3, a main assumption in NAM is that firms (as a tendency) have excess capacity and that unit costs of production tend to fall within the capacity rage. In theory therefore, firms are happy to expand production and export goods if the opportunity presents itself. Such possibilities depend on for example income growth in foreign countries, and the costs level in Norway compared to the cost of trading partners.

In line with this, the estimated equation for $ATRAD$ in 9.3 has the (international) marked indicator (MII) and the real-exchange rate as the long-run determinants. Hence, the estimated long-run relationship is:

$$LOG(ATRAD) = 0.88LOG(REX) + 0.91LOG(MII) + Constant \tag{50}$$

where REX denoted the real exchange rate which in terms of the basic NAM variables is defined as

$$REX =: \frac{PCKONK \cdot CPIVAL}{CPI} \tag{51}$$

The foreign consumer price index PCKONK is an exogenous variable, but both the nominal exchange rate $CPIVAL$ and the consumer price index CPI. Therefore, the real exchange rate is an endogenous variable in NAM.

The role of the real exchange rate variable is to act as proxy for the price of traditional exports relative to the price of similar goods produced by foreign firms. In later version of the model we will endogenize the export price index. For the time being, the estimated elasticity of 0.88 in 50 shows that REX does a relatively good job in representing the long-run positive effect on exports of a permanent improvement in price-competitiveness.

The estimated elasticity of the export marked indicator MII is a little below unity, meaning that Norwegian exports depend on real depreciation to avoid a secular decline in the market-share.

The detailed estimation results in section (9.3) show that, traditional exports is adjusting fast to increased demand (increase in MII). The overall speed of adjustment is also quite fast, due to an equilibrium correction coefficient of -0.23.

The estimation results in section (9.2), show that the equation for exports of services has many of the same features as the model for traditional exports. However there is no evidence in the data of an effect of the real exchange rate, and the long-run relationship between MII and $ATJEN$ is simply

$$LOG(ATJEN) = 0.55LOG(MII) + Constant \tag{52}$$

As already noted, research leading up to later versions of the model will put priority on the development of operational variables that better capture price-competitiveness than the overall real exchange rate in 51. The results in section 9.2 shows that this is particularly important for improving on the current specification of the model for $ATJEN$.

7.3.2 PRIVATE CONSUMPTION

Consumer expenditure is the largest component of spending in the Norwegian economy, and in most other countries as wel, cf. Figure 17 which shows private and public consumption expenditure as shares of total demand. The specification of consumption dynamics is therefore of great importance both for the overall properties of NAM.

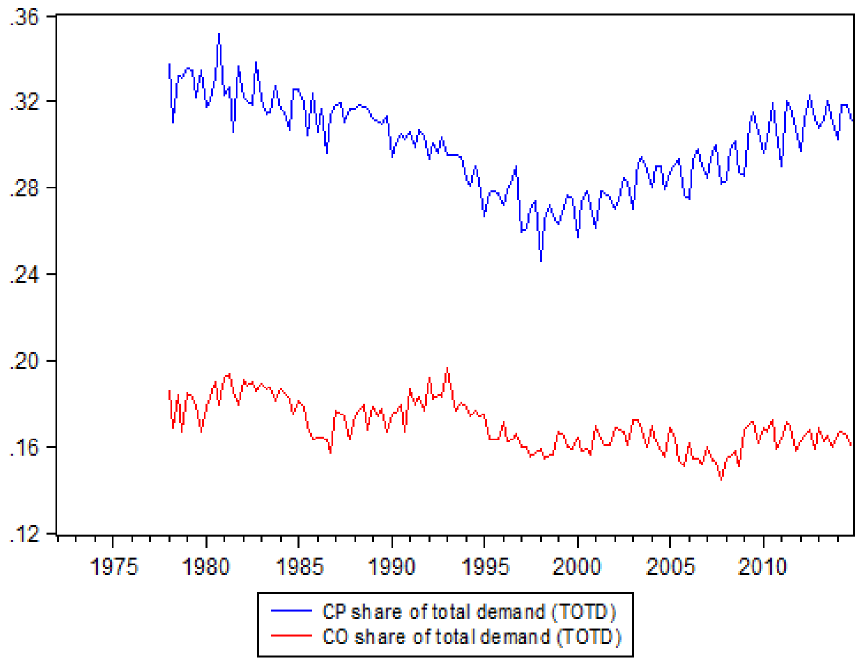

Figure 17: Private consumption (*CP*) and government consumption(*CO*) as shares of total demand *TOTD*

In NAM, the modelling of private consumption expenditure is anchored in a long-run relationship between private consumption expenditure, income and household wealth. In the current version of NAM, the net assets of household has not been completely represented. However since both the housing stock and the housing price index are endogenous variables in the model, we have chosen to include the real value of housing capital as a variable in the long-run relationship:

$$\ln(CP) = 0.6\ln(\frac{YDCD}{CPI}) + 0.1\ln(\frac{PH \cdot HK}{CPI}) + \mu_C \tag{53}$$

where CP denotes private consumption expenditure, $YDCD$ is disposable income after controlling for extraordinary dividend payments that took place in 2006 (this variable is called RAM300 and is exogenous in the model). CPI is the official consumption price index. PH is the housing price index and HK is the housing stock. The elasticities 0.6 and 0.1 are comparable to the estimates in Jansen (2013) who also includes financial wealth, and not only the real-value of housing. In particular, the small elasticity of 0.1 with respect to the “wealth variable” in (53) can be explained by the crude measure of wealth that have used so far. On the other hand, the real value of the housing stock will be very dominant in also in wealth variables that includes financial wealth.

FRAME 9: BANKING CRISIS AND CONSUMPTION MODELLING

As noted by Hofmann (2004), among others, the period after financial marked deregulation (mid 1980s) and the Norwegian banking crisis in 1989-90 was a probably driven by positive feed-back between housing prices and accommodating bank lending. The impact of such a process process on total consumption expenditure was first modelled by Brodin and Nymoen (1992) in the form of a cointegrating relationship between real consumption, real disposable income and a measure of household wealth that include the stock of residential housing capital, evaluated at marked prices (rather than at the price the price index of new construction costs). Subsequent offerings by Eitrheim et al. (2002) and Erlandsen and Nymoen (2008) confirmed the relationship between housing prices and consumption, via a wealth effect. In Erlandsen and Nymoen, the years with liberalized credit markets have a larger weight in the estimation sample than in the first studies, and for that reason the long-run relationship also include a real interest rate effect on consumption.

The log-linear specification of (53) can be regarded as an example of the ”step-one” linearization mentioned above. Statistically, it is interpreted as a cointegration relationship, since the modelling is based on the assumption that the three variables in the equation are integrated of order one, $I(1)$.

The empirical relationship (although with different operational definitions of the variables) in (53) has been reasonably stable over more than two decades, and the link between housing prices and aggregated demand that it captures, has international empirical support (cf. e.g. Goodhart and Hofmann (2007), Aron et al. (2012)). Nevertheless, many economists remain sceptical. One reason may be that (53) cannot easliy be reconciled with the mainstream theoretical presumption (actually an implication of the stochastic permanent income hypothesis) that saving is a stationary variable, Campbell (1987).[34] On the other hand (53) has the potential of accounting for periods with stable saving, but also for episodes with sudden movements in the savings rate.

One version of (53) that give insight, is to re-write it as

$$s = 0.4\ln(\frac{YDCD}{PH \cdot HK}) + 0.3\ln(\frac{PH \cdot HK}{CPI}) - \mu_C \tag{54}$$

where s is the approximate long-run private savings rate. Periods where the housing price index increases faster than both nominal disposable income and the CPI price index may also be associated with a tendency towards higher savings rates. A sudden collapse in the housing price may on the other hand lead to a higher saving rate if CPI growth and income growth are unaffected.

[34]Note however that stationarity of saving (in kroner) does not entail stationarity of the savings rate. On the contrary, if saving is without a unit-root, while income contains a trend, the savings rate may easily behave like a (near) unit root process.

Figure 18 shows the savings rate of the household sector together with the four quarter growth percentage in real housing prices.[35] Before financial liberalization in Norway, the savings rate was high and relatively stable. It was reduced markedly when real house prices first boomed and then collapsed during the second half of the 1980s. The savings rate increased during the period of financial consolidation. During the first decade of the new millennium, the savings rate was again relatively stable, but after the financial crisis it jumped to a level comparable to what we saw in the early 1980s.

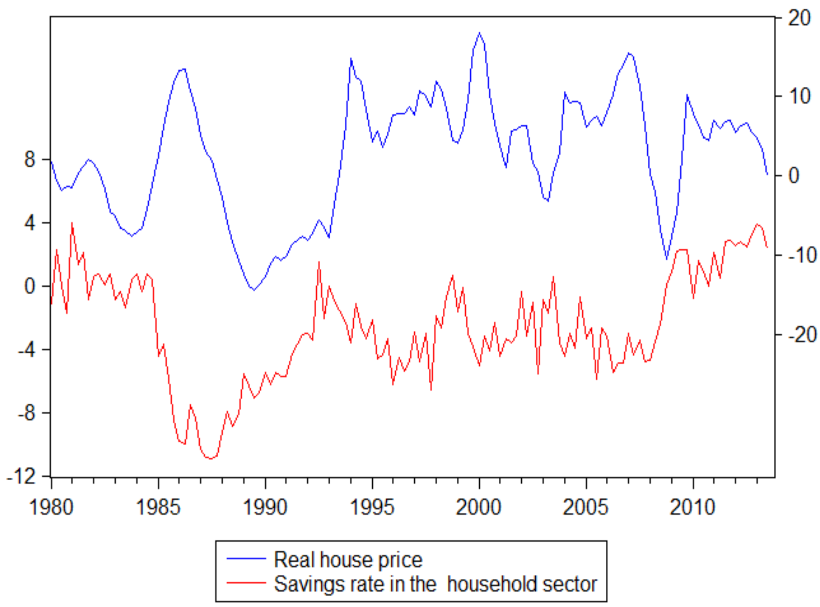

Figure 18: Four quarter percentage change in the real house price index and the private savings rate (dividend payments has been subtracted from the disposable income series, see fotnote).

Although there is no real interest rate variable in (53) and (54), this does not mean that there are no interest rate effect in the model. However, since we base the modelling on the assumption that the real interest rate is stationary (at least without unit root) the effect this variable is estimated separately in the "short-run" part of the model wich is documented in section 9.5. The economic interpretation is nevertheless that the interest rate strongly affect the level of the savings rate. Hence , using the results in section 9.5, we can rewrite (54) as

$$s = 0.4\ln(\frac{YDCD}{PH \cdot HK}) + 0.3\ln(\frac{PH \cdot HK}{CPI}) + 0.006(RL - INF) - \mu_C^{'} \qquad (55)$$

where RL is the nominal interest rate in percent, and INF is the annual percentage rate

[35] The savings rate is calculated for an income concept that is net of dividend payments. This is done to ease the interpretation of the evolution of the savings rate over time, since otherwise the graph would show a large jump in 2006 as a result of adjustment to changes in income taxation.

of change in CPI ($\mu_C^{'}$ is the intercept after the real interest rate effect has been taken out of μ_C).

Because (55) is interpreted as a long-run relationship, one important question is how it is maintained over long data samples, cf. Eitrheim et al. (2002). The seminal paper of Campbell (1987) pointed out that the rational expectations permanent income hypothesis (RE-PIH) implied that (Granger) causation should run from the savings rate to income growth, which became known as the *Saving for a rainy day hypothesis*. Conversely, the "Keynesian position" is that it is consumption that equilibrium corrects directly, while income is indirectly affected and mainly though the labour marked and thus the wage income component of $YDCD$. The estimation results in section 9.5 strongly support that consumption react to the equilibrium correction term $(s_{t-1} - \log(CP_{t-1}))$. According to the estimation results, consumption is nevertheless very smooth (abstracting from seasonal variation), but not as smooth as a consumption Euler-equation implied by RE-PIH.

Consequently, the dynamic specification of the 'consumption function' in NAM shows resemblances to the "error correction" model of Davidson. Hendry Srba and Yeo (1978) (DHSY). The main differences from the DHSY specification have to do with seasonality (which requires careful modelling on Norwegian data) and the presence of a housing prices, which were not relevant for the first generation of DHSY-models.

At the same time, versions of Euler-equations for consumption are nested within the consumption function in sub-Chapter 9.5. However, the interpretation is not necessarily that the consumption function in NAM is a hybrid equation that combines the consumption growth due to rational expectations consumers with another due to a proportion of liquidity constrained households, as suggested by Campbell and Mankiw (1989). It is more plausible that the estimated dynamic equation reflects that households form subjective expectations about income, housing market and credit developments, and that they attempt to follow contingent plans that entails relatively smooth consumption paths (we then abstract from seasonal variations, which are non-trivial).

FRAME 10: THE COMPONENTS OF PRIVATE DISPOSABLE INCOME

In the current version of the model, private disposable income, YD, is defined as follows

$$\begin{aligned} YD &= DRIFTH + LOENNH + RENTEINNH - RENTEUTH \\ &\quad + RESINNTH - SKATTH + YDORG \end{aligned}$$

$DRIFTH$ is income from operating surplus, $LOENNH$ is wage income, $RENTEINNH$ is interest payments and $RENTEUTH$ are interest expenditure. $RESINNTH$ is a residual income variable, while $SKATTH$ denotes taxes paid on income and wealth, and $YDORG$ is income to non-profit organizations.

$LOENNH, RENTEINNH$ and $RENTEUTH$ are endogenous variables. In NAM, both wages per hour worked, and the number of hours worked are endogenous variables, and $LOENNH$ then follows by a definition equation. Likewise, $RENTEINNH$ and $RENTEUTH$ depend by definition on loans and deposits and their respective interest rates. $SKATTH$ is modelled by a separate macro tax-function, cf. section 9.41. The remaining components are exogenous variables in the current model version.

7.3.3 BUSINESS INVESTMENTS

In NAM, the two main endogenous real investment variables are gross capital formation in private business in Mainland-Norway ($JFPN$) and in residential housing ($JBOL$).

Figure 19 shows that, for most of the sample period, business investments has made out the larger share of total demand than both government investments (JO) and "oil investments" ($JOIL$). The difference seems to have been largest in the first years of the new millennium. In 2013 private investment ratio was overtaken by oil investments for a short period.

The estimated equation in section 9.13 shows that the contemporaneous and lagged growth rates of GDP in Mainland-Norway have a strong impact on the change in $LOG(JFPN)$). There at two terms on the left hand side of the model equation that capture this: The annual growth rate $D4LOG(YFPBASIS)$, and the lagged quarterly change $YFPBASIS(-4)$. The finding that gross capital formation is strongly related to output growth is quite standard in empirical macro, and it represents a version of the acceleration principle. That the relationship includes the lags of output growth rates is particularly interesting. It is what we would expect to observe if firms have excess capacity and non-increasing cost curves, as discussed above in Chapter 6.3. In that case, positive sales opportunities will first lead to increased production (towards full capacity), and second to realisation of investment

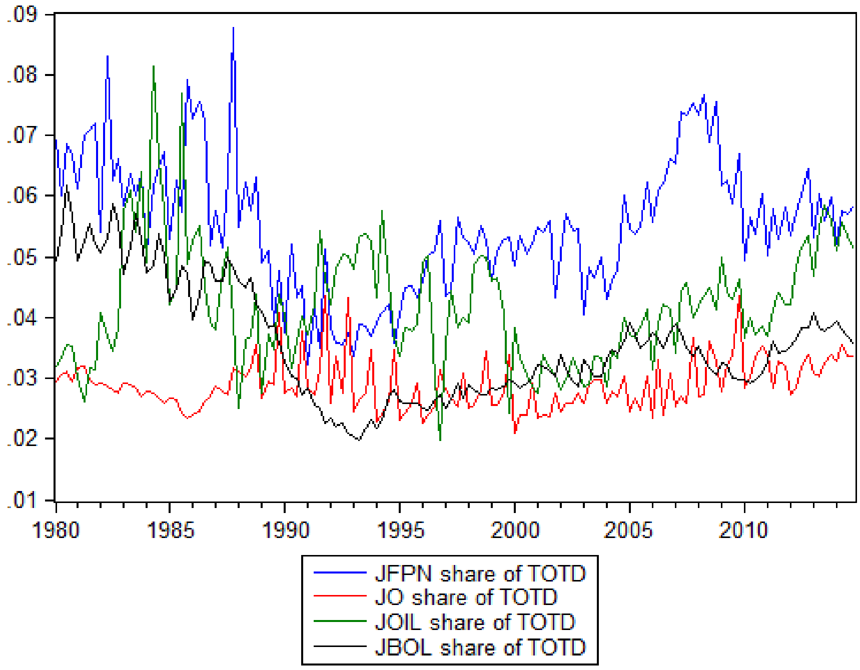

Figure 19: Gross capital formation as shares of total demand (*TOTD*). Private Mainland-Norway (*JFPN*), government (*JO*), production of oil and natural (*JOIL*), residential housing (*JBOL*)

plans in order to increase capacity again.

In addition, the estimated equation in section in Chapter 9.13 includes he real interest rate, with a negative, but statistically insignificant coefficient. This does not mean that there are no (negative) effects of interest rates on investment though. The effect is located in the significance of the profit-to-investment ratio $(YDFIRMS/PYF)/JFPN(-1)$, where $YDFIRMS$ is a variable that measures the disposable income of firms, see the definition in section 8.2. Interest payments on existing debt is one important component of $YDFIRMS$. Hence, if the interest rate level is raised, this is negative for firms' ability to finance capital formation. The effect can be direct (as when less profits can be used to finance investment), as well as indirect (as when the price, and maybe availability of credit, go up). Finally, the equation also includes the lagged growth of real credit $(K2IF(-1)/PYF(-1))$, to test that past credit growth (on its own) is predictor of changes in capital formation in the business sector. As the estimation results show, this variable has marginally significant positive coefficient. Hence there is an indication if a direct credit effect, but the evidence is not very strong.

7.3.4 INVESTMENT IN HOUSING

In the Norwegian Quarterly National Accounts, there is a close link between housing starts (HS) and gross capital formation ($JBOL$). Consequently the main "housing investment" variable modelled in NAM is housing starts (measured in thousand square meters). The estimated equation for housing starts is reported in Chapter 9.10, while the technical "transition equation" from housing chapter (HS) to investments is reported in Chapter 9.11.

A main result in Chapter 9.10, is the documented positive quantitative relationship between the real house price variable PH/PYF, where PH is the nominal housing price index, and housing starts. Again an interpretation along the lines of q-theory lies close at hand. It may be noted that in NAM, the variable PH is seen as a price which is mainly determined in the market for housing *stock* (see below) rather than in the market for the *flow* of new housing. For that reason, the present version of the models conditions on the housing price "from" the market for the existing housing capital stock.

Finally, the importance of house prices for housing starts, means that residential housing investments become closely related to the demand for the existing housing stock, to house price formation, and to credit to private households, cf. section 7.7.

FRAME 11: HOUSING STOCK AND FLOW VARIABLES

As mentioned in the main text, the gross capital formation variable $JBOL$ is closely linked to housing starts by the data conventions used to construct the quarterly national accounts. In NAM, it is not possible to represent the detailed calculations of the national accounts, and for that reason the model includes an estimated 'technical relationship' between the two flow variables. The housing stock variable in NAM is denoted HK and is from the quarterly national accounts. NAM includes a dynamic equation to represent the evaluation of this variable (adjusted for physical depreciation), cf. Chapter 9.12. Since $JBOL$ and HS are not exactly one-for-one in the quarterly data, the estimated equation for the evolution of the the housing stock makes use of both of these flow measures.

Another relationship documented by the estimation results in 9.10, though not very significantly, is the negative impact of interest payment as a share of household disposable income. It may reflect that in Norway, the economic situation of the households has a direct bearing on the activity in the construction sector, in addition to the effect that comes though the determination of total demand for housing stock.

7.4 AGGREGATE SUPPLY

Figure 20 shows different supply "components" as shares of total supply ($TOTS$). GDP of Mainland-Norway (YF) represents by far the largest component, with a share that varies between 60 and 70 percent over the sample period. The share of private Mainland-Norway (YFP) has been relatively stable over the period, with a 50 % share of total supply, only dipping a little below lower during the period when value added in oil and natural gas extraction and related services ($YOIL$) peaked at 30 percent of $TOTS$.

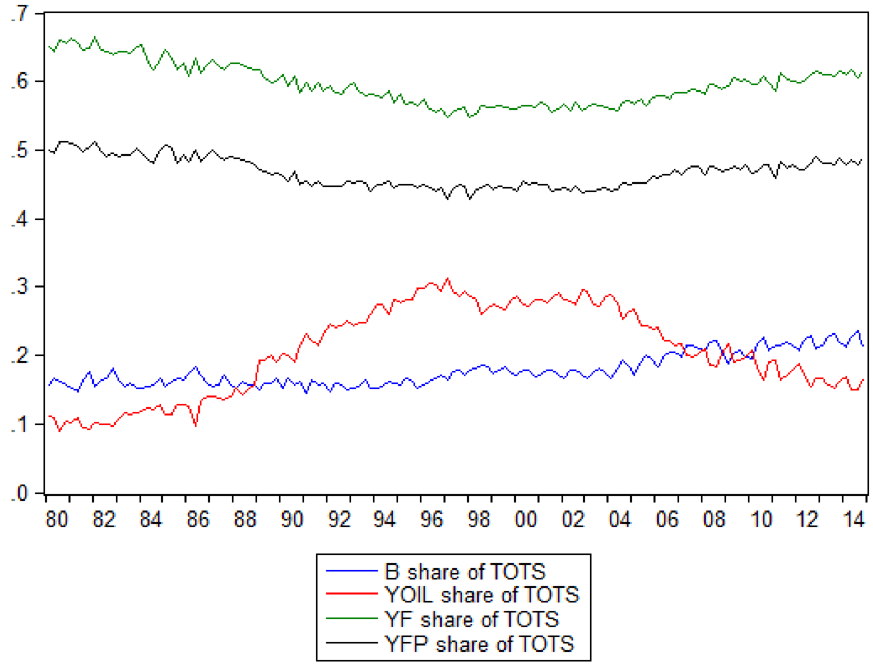

Figure 20: Import, oil and Mainland-Norway components of total supply *TOTS*

The share of imports (B) in total supply was very stable until the early 2000s, and has increased to a level just above 20 % quite recently.

All the components shown in Figure 20 are endogenous in NAM. For example YF is given by

$$YF = YFP1 + YFP2 + YFP3 + (LAVGSUB/PYF) + YO \tag{56}$$

where the three first terms make up YFP in Figure 20, and YO is value added in government administration.[36]

As noted, all the different components of aggregate supply are endogenous variables in NAM. The variables YO, and $YOIL$ are modelled as simple functions of their counterpart on the demand side: CO in the case of YO and $AOIL$ in the case of $YOIL$. For imports and the three components of private Mainland GDP, we have formulated more interesting models, which we comment on in turn.

7.4.1 IMPORTS

In the current version of NAM, the foreign part of aggregate supply is represented by a standard dynamic aggregate import function. The main characteristic is that there are separate marginal import propensities for different demand variables, see Chapter 9.4.

[36] As already noted LAVGSUB is net product taxes and and subsidies.

As a simplification import propensities are assumed constant. There is one exception, and that is for oil investments where the marginal propensity to import is declining in the share of oil and gas production of total GDP.

Another important modification is that the import equation includes the relative price index PB/PYF, where PB is the import price index, and PYF is the deflator of the Mainland-Norway GDP deflator. The estimated coefficient of this variable has a negative sign. Together with the estimated effect of the real exchange rate (REX) on traditional exports, this means that a real depreciation reduces the trade balance deficit (in real term) not only by boosting exports, but also by reducing imports.

7.4.2 VALUE ADDED IN MANUFACTURING

Chapter 9.30 contains the results for value added in manufacturing, $YFP1$. As discussed above, in connection with firms' price setting strategies, we expect that due to non-increasing marginal cost curves, we expect that product markets are mainly cleared by quantity rather than by price.

This view is confirmed by the estimation results which shows reflecting that the fit of this equation is due mainly to the domestic and foreign demand indicators, as well as the number of working days ($ARBDAG$). Note in particular that we estimate a direct effect of capital formation in oil and gas extraction ($JOIL1$), which is proof that Mainland-Norway manufacturing has managed to generate income from North-Sea oil activity.

The steady-state relationship implied by the estimation results becomes:

$$\begin{aligned} log(YFP1) = 0.6log(&0.1CP + 0.1CO + 0.35JOIL1 + 0.2JFPN + 0.25JBOL \\ &+ 0.1JO + 0.4ATRAD) - 0.49log(\frac{PB}{PYF}) \end{aligned} \tag{57}$$

showing that the manufacturing demand indicator is made up of components of aggregate demand with unequal weights. Exports and gross capital formation in oil and gas extraction have been attributed the largest weight in this version of the model, and private and public consumptions the lowest.

7.4.3 VALUE ADDED IN PRODUCTION OF OTHER GOODS

The supply sector called production of other goods, *YFP2* has value added in the construction sector as one component. This is reflected in the weights of the demand indicator for *YFP2* in Chapter 9.31:

$$\begin{aligned} log(YFP2) = 0.86log(&0.25ATRAD + 0.85CP + 1.0JO + 1.1JBOL \\ &+ 0.25JFPN + 0.9JOIL) \end{aligned} \tag{58}$$

showing that the largest weights are attributed to gross capital formation in residential housing, government admininistration, and oil and gas extraction.

7.4.4 VALUE ADDED IN PRIVATE SERVICE PRODUCTION AND RETAIL TRADE

Chapter 9.32 shows the estimation results for value added in the private service producing sector which also includes retail trade. Value added in this sector is larger than the two others taken together. The theoretical long run relationship is

$$\begin{aligned} log(YFP3NET) = 1.3log(&0.15CP + 0.25CO + 0.1JO + 0.25JBOL \\ &+ 0.2ATRAD + 0.05ATJEN + 0.10JFPN) \end{aligned} \tag{59}$$

where the ewights of the included variables are more equal than in (58) for example.

7.4.5 BALANCING TOTAL DEMAND AND TOTAL SUPPLY

As noted above, NAM incorporates the national accounting principle that total supply, $TOTS$, equals total demand, $TOTD$. Even though there are strong relationships between demand components and domestic supply in the model, consistent with the underlying assumptions about firm behaviour and wage setting, $TOTD$ and $TOTS$ are separate endogenous variables. They are not automatically (or by definition) equal in the model solution.

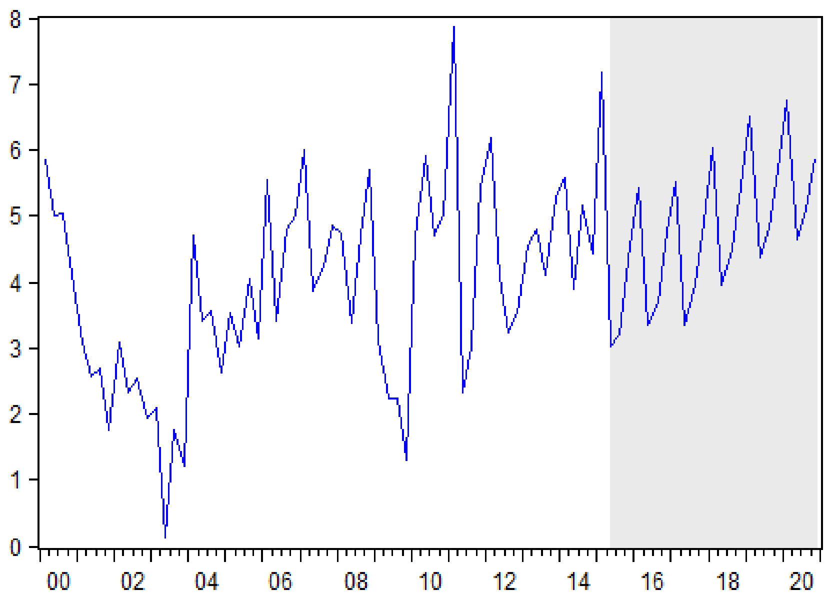

Figure 21: Changes in inventories in percent of GDP. Shaded area represent values from dynamic simulation of NAM, i.e. forecasts

In NAM, the balancing variable that secures that $TOTD = TOTD$ when the modelled is solved (for forecasting or policy purposes) is changes in inventories, denoted JL above.

This means that JL is an endogenous variable in the model, not by econometric modelling, but by the national accounting identity. In practice, this means that NAM forecasts are not based on assumptions about changes in inventories, which is the case for models where GDP is formally determined from the demand side. Instead the model solution for JL or, more practically, JL as a percentage of GDP which is easier to interpret, can be used a diagnostic. For example, if the model “delivers” forecasts where JL is much larger in proportion to GDP than historically, questions may be raised about the model’s ability to adequately represent demand and supply (i.e. without unrealistic solutions for changes in inventories).

Figure 21 shows historical data for JL in percent of GDP for the period 2000q1 to 2015q1, together with simulated values for the forecast period 20015q2 to 2020q4. The graph shows that normally changes in inventories are positive in the data, and that a typical range of values of JL in percent of GDP is between 2 percent and 6 percent. The simulated values from NAM are seen to be in that range, and the simulated level of inventory investments is therefore satisfactory. In this example, there is a trend towards larger values in the simulations. This may indicate that the growth in total supply (due to domestic GDP or imports) is somewhat overestimated relative to demand. Usually, closer inspection of the components of total demand and supply will suggest where the corrections by add-factors can be used to obtain better balance, if that found to be necessary.

7.5 HOURS WORKED, EMPLOYMENT AND THE RATE OF UNEMPLOYMENT

Chapter 6 showed that in a macro model that assumes collective and coordinated wage bargaining, and price setting firms with cost functions that are non-increasing it is realistic (an theoretically consistent) that the rate of unemployment can be modelled by a version of the Okun’s law relationship, cf. the theoretical equation (36) above where the unemployment rate depends on the rate of GDP growth.

In NAM there is a similar relationship, but it goes through firms’ demand for labour, both in terms of hours worked and employed persons, which is strongly related to the demand in import competing and export competing product markets. However, the public sector (government administration) may of course be a strong moderator of the aggregate relationship between product demand and employment. The estimated equations for hours worked and employed wage earners are reported in chapter 9.42 - 9.47.

As noted above, wage incomes is the largest component or private disposable income. In turn, hours worked is one of two factors in wage income. A one percent increase in real wage incomes can be achieved by a one percent increase in the consumer real wage, or by a one percent increase in hours worked.

As already noted there are two variables that measure the unemployment rate in NAM.

The estimation results for the registered unemployment (UR) rate is found in Chapter 9.28. As can be expected, the development the rate of unemployment mainly depends on the growth in labour demand and the changes in the size of the population in working age.

The equation for the Labour Survey based rate of unemployment ($UAKU$), obey the same type of relationship. In particular in the medium run, as Chapter 9.29 documents. But there are examples of shorter periods, in connection large macroeconomic shocks when the two variable becomes more decoupled.

FRAME 12: ASSET AND EQUITY PRICES IN NAM

The following sub-chapters presents the asset prices that are endogenous in NAM. Chapter 7.6 is about the foreign exchange rate. For most of the period since WW-2 Norway followed different variants of fixed exchange rate systems. After a period of transition during the 1990s, a regime with a floating exchange rate and inflation targeting was formally put into operation in 2001.
Chapter 7.7 presents how the price index of residential housing is modelled in NAM as an "inverted demand function" for housing. Because housing demand depends on the interest rate and on credit conditions there is a relationship between monetary policy and the housing and credit marked. In the early days of inflation targeting, the central bank took its eyes off this relationship, but the financial crisis changed that and made monetary policy much more balanced in its analysis of inflation forecasts and the future of financial stability.
The price of equity is a factor in firms' investments decisions, cf. Chapter 7.3.3. In NAM, the stock exchange price index is modelled as a function of foreign stock prices, see Chapter 7.9 and the detailed estimation results in 9.18 and 9.19.

7.6 THE MARKET FOR FOREIGN EXCHANGE

The following sub-chapters explain more closely how asset prices are represented in NAM. Arguably, the two most important asset prices are the nominal exchange rate and the price of residential housing.

As documented above, because it is essential in the wage and price setting process, the nominal exchange rate is important for the nominal path of the Norwegian economy. The market for foreign exchange represents an asset market that also has a large influence on the real economy. With nominal wage and price rigidity, changes in the nominal exchange rate affect the real exchange rate which is one determinant of aggregated demand of the open economy.

The starting point of the modelling of the nominal exchange rate is the portfolio approach (or stock approach) to the market for foreign exchange, cf. Rødseth (2000, Ch. 1

and 2). In this approach, the marked for foreign exchange is linked to the financial sector via the risk premium, defined as the difference between the domestic interest rate and the foreign interest rate, adjusted for expectations about currency depreciation. For example, a higher domestic interest rate (normally) increases the demand for Norwegian kroner, which pulls in the direction of currency appreciation.

Expectations about exchange rate depreciation is a partly endogenous (as just indicated), but also represent a large autonomous component in the determination of the exchange rate. As already noted, expectations can be stabilizing (as when depreciation is followed by appreciation and vice versa), but also destabilizing (as when a weak exchange rate level is expected to lead to further depreciation in the future). Expectations that are seriously destabilizing are usually a sign of a fundamental lack of confidence in the monetary system, which however does not seem relevant for the modern Norwegian economy.

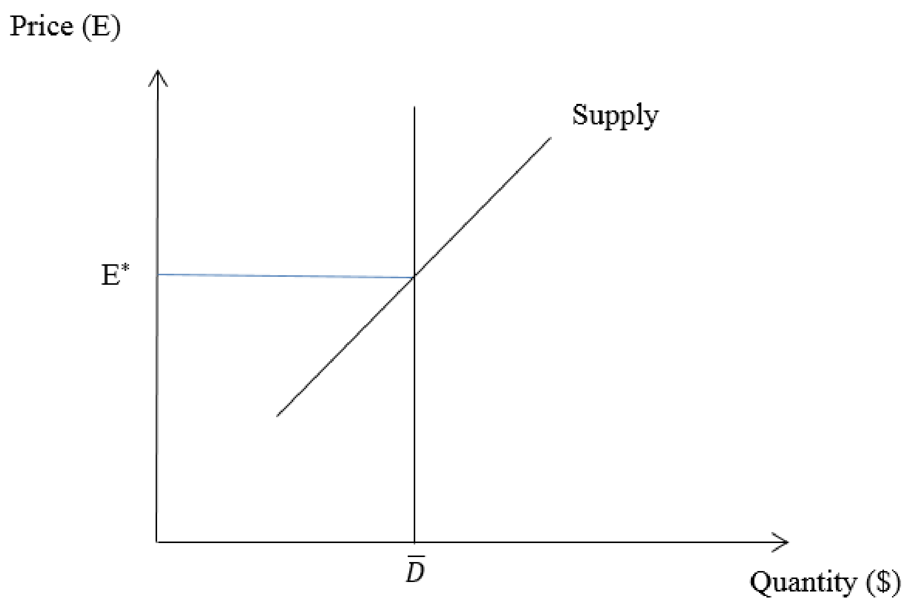

Figure 22: The market for foreign exchange, represented by a single foreign currency, USD ($). The price of foreign currency is the number of kroner per USD and is denoted E in the figure. $\bar{D}$ is the net demand of foreign currency by the domestic central bank. When $\bar{D}$ is exogenously determined, E^* is the equilibrium price

FRAME 13: THE STOCK APPROACH TO THE MARKET FOR FOREIGN EXCHANGE

The two main participants in the market for foreign exchange (FEX hereafter) are:

1. Investors: Private banks and financial institutions, as well as foreign central banks and domestic and foreign (production) firms.

2. The Central Bank: The central bank decides the demand for foreign exchange, while the investors' decisions determine the net supply of foreign exchange to the central bank (the exact counterpart to the net demand for kroner).

In the very short-run (the daily to monthly horizon), the net supply of foreign currency is dominated by capital movements: foreign currency is supplied as a result of the investors' management of huge financial portfolios. In the medium-run: the supply of currency is also affected by the flow of currency generated by current account surplus or deficit (exporting firms get paid in USD, and they will exchange USD to kroner).

We first review the basic characteristic of the FEX market when we abstract from the trade balance effect, which we may call the pure portfolio model of the FEX market. Figure 22 gives the main conceptual framework. Fg denotes the net demand of foreign currency, which is identical to the foreign currency reserves at the central bank. The supply of foreign currency is drawn as a curve that is increasing in the price of the good (i.e. the foreign currency).

In this model, known as the portfolio theory of the FEX market, the whole stock of foreign currency is determined. The determinants of the net supply of foreign currency are such factors that can, at any point in time, effect a revaluation of existing assets. One such variable is the price of the commodity, the nominal exchange rate E, which, for this reason is in the vertical axis of the graph. Other variables with an immediate effect on the net supply of foreign currency, are: The domestic interest rate, i, the foreign interest rate, i_f, and the expected rate of currency depreciation, one period ahead.

Although currency depreciation expectations are both complex and volatile, it serves a purpose to write it in simplified form as a function of one single argument, which is the price level in period t, i.e. $f(E_t)$. With the use of these conventions we define the risk-premium in the market for foreign exchange as:

$$r_t = i_t - i_t^f - f(E_t) \tag{60}$$

When the derivative of the expectation function is negative, $f'(E_t) < 0$, depreciation expectations are said to be regressive. The case of $f'(E_t) > 0$ is called extrapolative expectations and $f'(E_t) = 0$ is the case of constant expectations, see Rødseth (2000, Chapter 1). Expectations that are regressive contribute to stabilise the market around an equilibrium. Constant or extrapolative expectations are destabilising expectations.

The case of perfect capital mobility in the FEX market is an important reference point. In this case, the line representing supply of foreign currency becomes a straight horizontal line (supply is infinitely elastic) and risk premium r_t is zero, so that uncovered interest rate parity (UIP) holds:

$$i_t = i_t^f + f(E_t)$$

With perfect capital mobility, investors are indifferent between kroner assets and $ assets: the return on 1 mill invested in kroner assets is the same as the expected return on 1 mill invested in $ assets.

NAM is meant to represent current monetary policy regime in Norway, where the interest rate i_t is the policy instrument, and is set with an aim to stabilize inflation and the business cycle. Consequently, the interest rate i_t can be regarded as an exogenous variable in the FEX market. This means that we obtain a functional relationship between i_t and E_t, which we refer to as the Ei-curve.

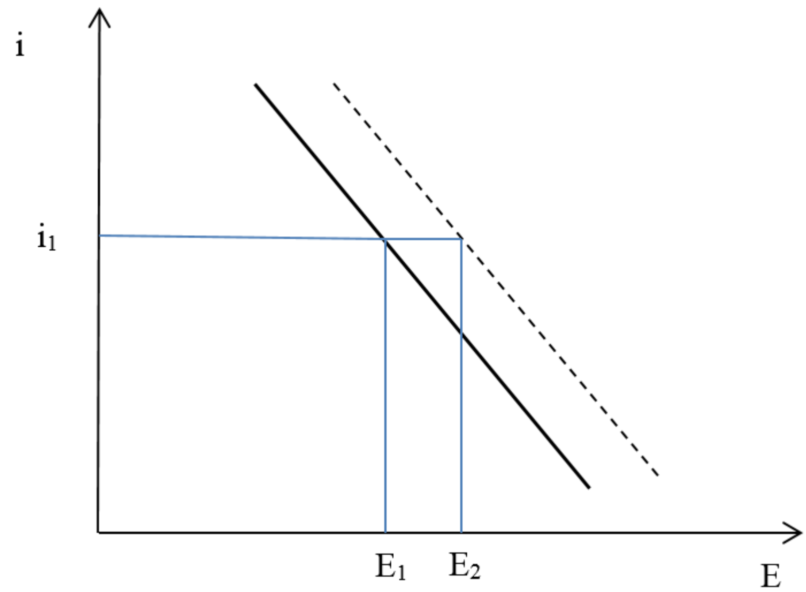

Figure 23: The Ei-curve shows equilibrium combinations of the interest rate and the nominal exchange rate in the FEX market.

In the case of perfect capital mobility (UIP), the slope of the Ei-curve depends only on the derivate of depreciation expectations. In that interpretation, the Ei-curve in Figure 23 corresponds to regressive expectations. In the case UIP, the only factors that can shift the Ei-curve are the foreign interest rate and shocks to depreciation expectations. Hence, the dashed line represents the equilibrium relationship after either an increase in the foreign interest rate, or an autonomous rise in depreciations expectations. The more specific interpretation depends on what we assume about the monetary policy regime. As just mentioned, we assume inflation targeting, in which case the initial equilibrium (i_1,E_1) is changed to (i_1,E_2) since the expectations about depreciation “will have to be” reduced by a discrete jump in the equilibrium price from E_1 to E_2.

In the absence of perfect capital mobility, the supply curve is imperfectly elastic, and (subject to no non-trivial assumptions) it is upward sloping as drawn in Figure 22. In this general case the Ei-curve is also defined, and it will be downward sloping under the same assumptions that secure an upward sloping supply curve. However, the slope coefficient of the Ei-curve is now a parameter that depends on other factors than just the expectations parameter. There is also a longer list of variables that can shift the Ei-curve, in addition to the foreign interest rate. This follows by considering the equation that defines the Ei-curve in the general case, namely the equilibrium condition

$$\bar{D} = S\left[E,\, \left(i - i^f - \alpha\left(E\right),\, P,\, P^f,\, Z\right)\right] \tag{61}$$

where P and P^f denote the domestic and foreign prize levels, and Z is a vector of other variables which influence the net supply of foreign currency. The Ei-function is obtaining by solving (61) for the market price E.

Theoretically, this is how we interpret the steady-state solution of the exchange rate equation in NAM, namely as an "inverted supply curve" model of the nominal exchange rate.

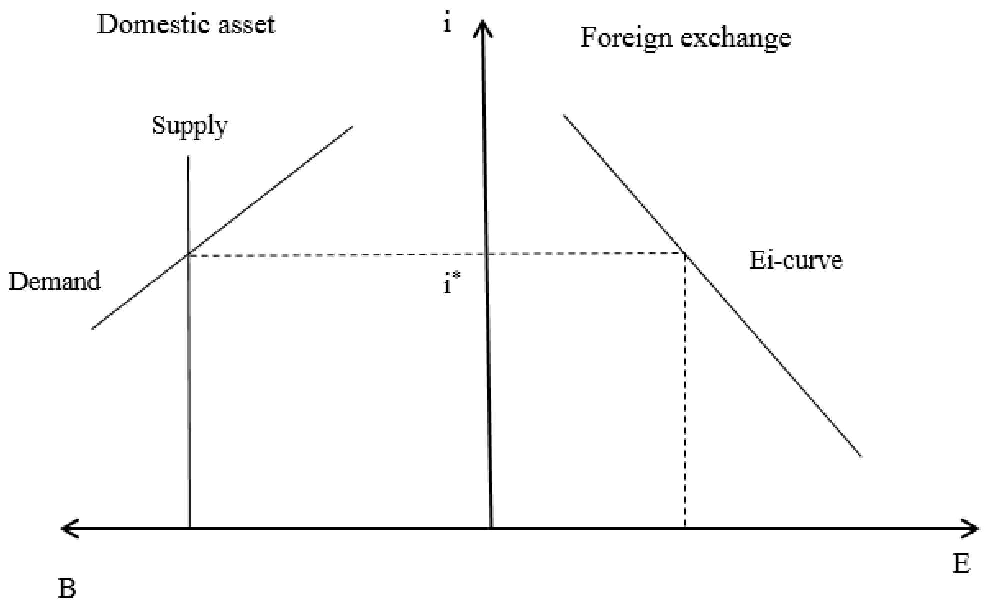

Figure 24: Joint equilibrium in the market for foreign exchange and in the domestic asset market.

Although, on a daily and monthly basis, almost all the variation in the net supply of currency to the central bank is explained by the factors that determine the expected short-term return on kroner denominated assets, NAM is a quarterly model, and over a three-month period the flow of currency from foreign trade net-surplus may be large enough to have an impact of the net supply of foreign currency. In particular, a period of trade surplus (or expected positive trade balances) may be expected to lead to currency appreciation.

Hence, in practice we interpret the Z-vector in (61) as including e.g., the price of North-Sea oil. Note also that another factor of foreign trade, namely the real exchange rate is (already) implicit in (61), but in any case it is natural to find an effect of a the lagged real exchange rate in an empirical model that explains the development of the nominal exchange rate.

In Figure 24 we make use of the Ei-curve to show the case of joint equilibrium in the FEX market and the domestic asset markets, here represented by one single interest bearing asset which is inelastic in supply for simplicity. In the graph there is no excess supply or demand in any of the markets. This would be the normal theoretical situation if the interest rate equilibriated the domestic asset markets and the there was a free-float in the FEX market (as assumed above). However, if the interest rate is set by other priorities (not capital markets equilibrium), it would be a coincidence if that interest rate was equal to i^*. In that way, it it is seen that for example interest rate setting with regard to inflation or other indicators of the (real) business-cycle can have financial market imbalance as a consequence. At least, such joint balance cannot be taken for granted.

If the portfolio approach is indeed empirically relevant for quarterly Norwegian data, we expect to find an effect of the differential between the domestic and foreign interest rate, which are denoted RSH and RW in NAM. This is confirmed in the documentation of the estimation results in Chapter 9.8, with the remark that the interest rate differential is between the real interest rates. The variable has negative coefficient, corresponding to the slope of the Ei-curve in Figure 24, and it is statistically significant.

The estimated model also contains a negative effect of the growth in the price of oil, confirming that over the sample period 2000q1-2014q1, the attractiveness of kroner assets is related to the price of North-Sea oil. Finally, the model contains the lagged level of the nominal exchange rate, with a negative coefficient. We interpret this as indicating that over this period nominal depreciation expectations have on average been regressive.

7.7 HOUSING PRICES AND CREDIT TO HOUSEHOLDS

Because the exchange rate is important for international competitiveness, the market for foreign exchange is important for analysis of the Norwegian macro economy. The housing market is equally important, since it is both depends on and affects the economic decisions of the household sector, and in particular affects the evolution of private consumption expenditure. Since banks lend money to housing purchases the housing market is also deeply integrated with the credit marked.

7.7.1 HOUSING PRICES AND THE MACROECONOMY

NAM includes several channels of joint influence between housing prices, aggregated demand and Mainland-Norway GDP and credit growth.

Disposable income and lending rates to households influence household consumption directly. Lower lending rates to households and higher disposable income lead in the model to increased housing demand and higher house prices (below we comment the estimation results in more detail). As we have seen, the model includes a wealth effect through private consumption's positive dependence on house prices. We have also noted above that increased housing starts, due to higher house prices, contributes, with a time lag, positively to housing investment and hence to aggregate demand. Increased building activity also has, after a while, a notable effect on the housing stock (and the total supply of housing services). An increased supply of housing reduces housing market pressures, all things equal.

It is also easy to imagine a two-way relationship between credit and housing prices. An increase/decrease in credit availability stimulates/depresses demand for housing (as well as other aspects of economic activity), because households and firms are constrained in their borrowing as a result of information asymmetries. On the other hand, property is commonly used as collateral, indicating that increasing/falling prices (and expectations thereof) can influence credit availability positively/negatively.

As noted, property prices can also influence households' consumption and saving decisions through wealth effects, and increase in property prices can lead to increases in construction activity, which may also lead to an increase in total credit demand.

In formal econometric investigation of an international data set, Hofmann (2004) documented that property prices appear to be an important determinant of the long-run borrowing capacity of the private sector, along with real GDP and the real interest rate. For Norwegian data, the same type of empirical relationship has recently been documented econometrically by Anundsen (2014).

In an econometric study that also include data from the financial crisis, Jansen (2013) document a long-run relationship between consumption, income, the interest rate and household wealth (including house capital). Compared to the earlier studies, which model total consumption expenditure, Jansen's operational definition is consumption net of housing services (and expenditure on health services). In that way, Jansen's results about a significant wealth effect strengthens the conclusions based on the econometric models that explain total consumption, of which housing services is a substantial part.

Figure 25 shows the four quarter growth rates in real housing prices together with real GDP growth and growth in real credit. A co-movement of housing prices and credit is clearly seen, with the house price index often turning before the credit variable, indicating that changes in house price growth could be a leading indicator for credit. The relationship between house prices and GDP growth is less clear and systematic, but the effect of the collapse of the housing market late in the 1980s is clearly seen in the GDP graph. The consequences of the fall in housing prices were not limited to the almost immediate reduction in consumption and increase in savings witch led to reduced GDP growth.

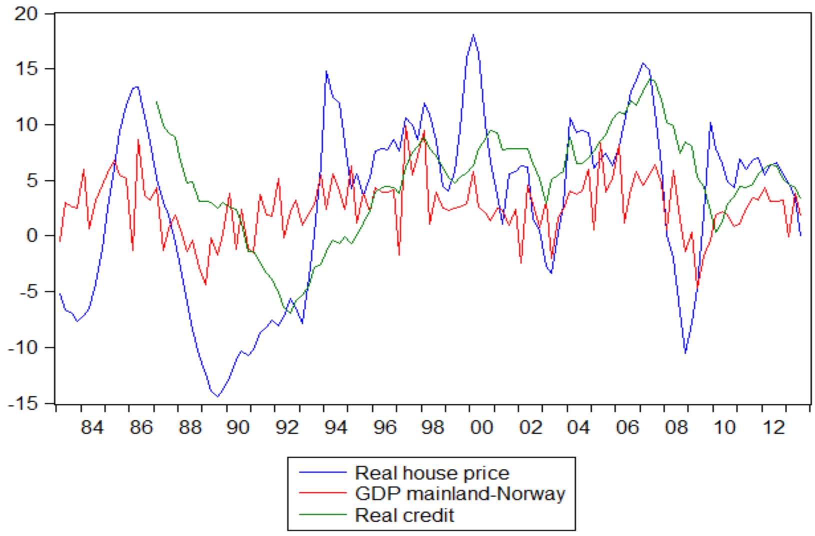

Figure 25: Four quarter percentage change: real house price index, real GDP Mainland-Norway and real credit (C2-indicator).

As many households saw the value of their real wealth (dominated by residential capital) fall short of their mortgage (negative equity), financial consolidation set in (Eika and Nymoen (1992)) at the same time as demand for housing took a new downward turn. The consequences for the real economy of were seen in the labour market: the rate of unemployment rose to a level that has not been seen since before WW-II.

NAM aims to quantify several of the relationships between the financial sector, the real economy and asset markets in a way that can aid for example macroeconomic surveillance. First there is a two-way relationship between surges in bank lending and asset prices. This relationship may be stronger in the case of real estate (NAM presently includes housing and does not include commercial property) than with equity. Equity markets may be less stable than housing markets in the first place though, meaning that even empirically quite weak relationship between credit and equity prices have to be "kept in the picture" when the purpose is financial stability assessment.

When a combined bank lending/property boom occurs, there is an increased likelihood of financial fragility occurring, although the lags in the process can be quite long. Financial fragility or instability can have damaging consequences for the real economy even if a full blown banking crisis is avoided. First, since cost-trade is likely to increase, the required rate of return may increase which can lead to reductions or cancellation of planned real investments. Second, even before a liquidity crisis, financial firms may want to increase interest rates in order to maintain their solidity. If the household sector is highly leveraged, the response will typically be to increase savings and avoid default. As is well known empirically, the negative consequence for aggregate demand may then be sudden and large. It is an aim to represent such complex response scenarios in NAM.

7.7.2 ECONOMIC THEORY OF HOUSING PRICE FORMATION AND CREDIT

The most commonly used framework in econometric time studies of housing prices using time series data is the life-cycle model of housing, see e.g. the seminal contribution of Dougherty and Van Order (1982), which is well founded in standard theory. In this section, we follow the exposition in Anundsen (2014, Introduction). Starting from the assumption of a representative consumer that maximizes his lifetime utility with respect to housing services, and consumption of other goods, the following equilibrium condition can be shown

$$MRS = P\left[(1-\tau) - \frac{\dot{P}_c}{P_c} - \delta - \frac{\dot{P}}{P}\right]. \tag{62}$$

MRS is the marginal rate of substitution in consumption. P is the housing price and P_c is the price of the consumption good, τ is the marginal tax rate, and δ is the rate of depreciating housing capital. $\dot{P}_c$ and $\dot{P}$ denote time derivatives. (62) states that the marginal rate of substitution between housing and the composite consumption good is equal to what it costs to own one unit of a property. Since the housing market also contains a rental sector, market efficiency requires the following condition to be satisfied in equilibrium

$$Q = P_h\left[(1-\tau)i - \frac{\dot{P}_c}{P_c} - \delta - \frac{\dot{P}}{P}\right] \tag{63}$$

where Q_t is the real imputed rent on housing services. Hence, the price-to-rent ratio is proportional to the inverse of the user cost:

$$\frac{P}{Q} = \frac{1}{UC} \tag{64}$$

where the user cost, UC, is defined as

$$UC = (1-\tau)i - \frac{\dot{P}_c}{P_c} + \delta - \frac{\dot{P}}{P}. \tag{65}$$

The real imputed rent is unobervable, but two approximations are common. Either to let the imputed rent be proxied by an observable rent R, or to assume that it is proportional to income and the stock of housing. Relying on the first approximation, the expression in (64) would read:

$$\frac{P}{Q} = \frac{1}{UC} \tag{66}$$

while if we instead assume that the imputed rent is determined by the following expression:

$$R = Y^{\beta_y}H^{\beta_h}, \beta_y > 0 \text{ and } \beta_h < 0$$

where Y denotes regular income and H represents the housing-stock, (64) becomes

$$\frac{P}{Y^{\beta_y}H^{\beta_h}} = \frac{1}{(1-\tau)i - \frac{\dot{P}_c}{P_c} + \delta - \frac{\dot{P}_h}{P_h}} \tag{67}$$

The expressions represented by (66) and (67) are commonly used as starting points in econometric models of housing price formation.

While the first has been used extensively in the US, it is less common in Europe, since the rental market is relatively small in countries such as e.g., the UK and Norway, or they may be heavily regulated in many continental European countries, Muellbauer (2012). The expression in (67) is similar to an inverted demand equation, and we now have seen how it can be derived from a life-cycle model.
(67) is therefore a relevant starting point for an Norwegian macro model. In semi-logarithmic form (to avoid the problem of possible non positive arguments in log) it becomes:

$$p = \beta_y y + \beta_h h - \beta_{UC} UC_t \tag{68}$$

7.7.3 THE EMPIRICAL MODEL OF HOUSING PRICES AND CREDIT

As noted, one movation to study the housing market in a macroeconomic context may be found in the theoretical literature on financial accelerators (see e.g. Bernanke and Gertler (1989) and Kiyotaki and Moore (1997)). The idea behind the financial accelerator is that imperfections in the credit markets necessitates the need for collateral when a housing loan is granted. Consequently,these models demonstrate how imbalances in the financial markets may generate and amplify imbalances in the real economy, and vice versa.

Figure 26 illustrates the joint dependency between housing prices and credit. cf. Anundsen (2014, Ch. 1). Because the supply of housing is fixed in the short-run, a positive shock to the net demand of house will quickly lead to higher prices in the housing market. Note that “shock” is interpreted widely in this context, and covers an increase in net demand which may be a response to model endogenous variables, the interest rate in particular. As noted above, increased property values if often recognized as increased collateral by banks and credit institutions, and the consequence may be that increased availability of credit can put further upward pressure on housing prices, as indicated in the figure.
The mutual positive relationship between credit and housing prices suggests framing the empirical modelling in a pair of relationships like

$$p = \beta_0 + \beta_d d + \beta_y y + \beta_h h - \beta_{UC} UC \tag{69}$$

$$d = \gamma_0 + \gamma_1 ph + \gamma_2 y + \gamma_h h + \gamma_i ((1-\tau)i - \frac{\dot{P}_c}{P_c})) \tag{70}$$

where the first equation is for example interpretable as a an inverted demand equation which as been adapted to account for direct effects of credit availability. (69) and (70) give the framework for the estimation of long-run relationships. The intercepts β_0 and γ_0 indicate costants, but in a word of credit marked imperfections and changing degrees of liquidity, it is possible that for example β_0 is not completely invariant and that it can contain threshold effect. In connection with housing demand in particular, a relevant hypothesis is that households who have preference for liquidity will reduce their exposition in

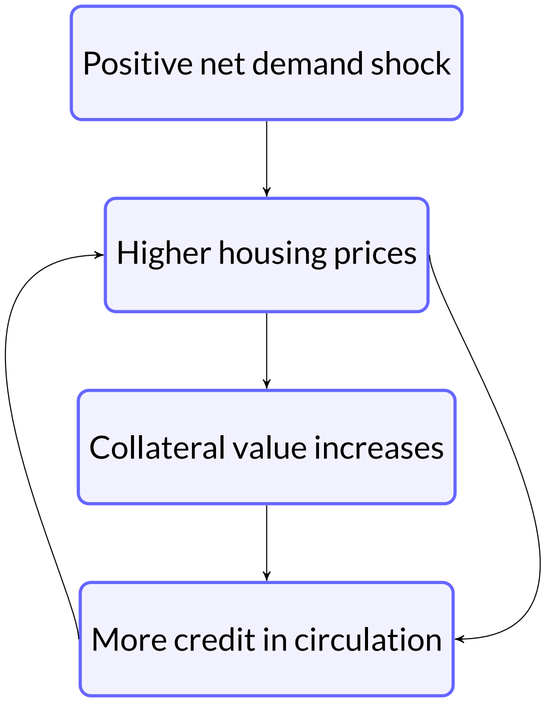

Figure 26: Two-way interaction between housing prices and credit

the housing market if the interest payment eats too deeply into disposable income. Such an "interest burden" effect is likely to be non-linear. In the empirical modelling we represent it by a threshold-function. When the interest payment rate is below the threshold, there is little effect of an increase in the interest rate. But on the threshold, an increase in interest rate payments can lead to large reduction in housing demand.

The following table lists the main variables in NAM that we have used in the empirical modelling of housing prices and credit to households (they are also listed in Chapter 8 along with the full set of variables)

Variable name	Description
PH	House price index
CPI	Consumer price index
$YDCD$	Disposable income to households
RL	Interest rate of private credit to households
BGH	Total household credit (debt)
HK	Residential housing capital stock
HS	Housing starts (dwelling units)
POP	The Norwegian population between 15 and 74 years.

It is reasonable to interpret the theoretical framework as a theory of real house price and real-credit to households. The main real variables are therefore: $P = PHN/CPI$ (real house price), $Y = YD/CPI$ (real disposable income to households) and $D = BGH/CPI$ (real credit to households). Housing stock, the variable named HH in NAM, is already a real variable, so we only simplify the notation by denoting the stock of housing capital by

H in (67).

We divide user-cost, UC above, into a real-interest rate ("direct user cost") denoted ri:

$$ri = (1 - \tau)RL - INF$$

where INF is the annual rate of inflation based on CPI, and housing price expectations, which is captured by the dynamics of the estimated equations. In this way we avoid making *ad-hoc* assumptions about the length of moving averages in expextations formation etc. The tax rate τ has been unchanged at 0.28 since a tax-reform in 1998.

In order to construct the liquidity variable mentioned above we have first created the interest rate payment from BGH and the quarterly interest rate (not RL which is an annualized interest rate). The ratio of interest payment to income is denoted $RUHYD$ below. We use a non-linear (logistic) transform of this variable:

$$rynl = \frac{1}{1 + \exp(-200(RUHYD - 0.13))}$$

which is like a step-indicator function, but with 0.13 as the threshold value.

In theory, with continuous time data, the supply of housing is given by HK at any point in history. With discrete, quarterly, data it is possible that there is small effect of changes in physical supply of housing. In particuar the increment in the number of housing units can be small or large relative to population (growth). As a measure of the "supply flow" imbalances we have included a three quarter long distributed lag in housing starts (measured in number of housing units) divided by the size of the population between 15 and 74 years old. We denote this housing starts relative to population variable by HS/POP_t.

The econometric modelling results give support of two cointegration relationships that are modifications of (69) and (70) along the lines just described:

$$log(PH/CPI) = 0.9log(BGH/CPI) - 0.2log(HS/POP)) - 0.3rynl \tag{71}$$

$$\begin{aligned} log(BGH/CPI) = {} & 0.9log(PH/CPI) - 0.9(log(YDCD/CPI) - log(HK)) \\ & - 0.15(RL(1 - 0.27) - INF)) \end{aligned} \tag{72}$$

Econometric identification of the two relationship is seen to be due to exclusions restrictions: First, $log(HS/POP)$) and the threshold variable $rynl$ are excluded from (72). Second, $log(YDCD/CPI) - log(HK)$ and the real interest rate are excluded from (71). [37]

Chapter 9.36 contains the detailed results from estimating a simultaneous equations model for the growth rates of PH and BGH. The results confirm that the two variables are closely associated, in particular in the medium and long run perspective. The equilibrium correction terms based on (71) and (72) are both highly significant, confirming that the two are relevant cointegration relationships.

[37] In practice, as the appendix shows, shows there is a second threshold variable, related to unemployment in ((71), but not in ((72). It is omitted here in order to save notation).

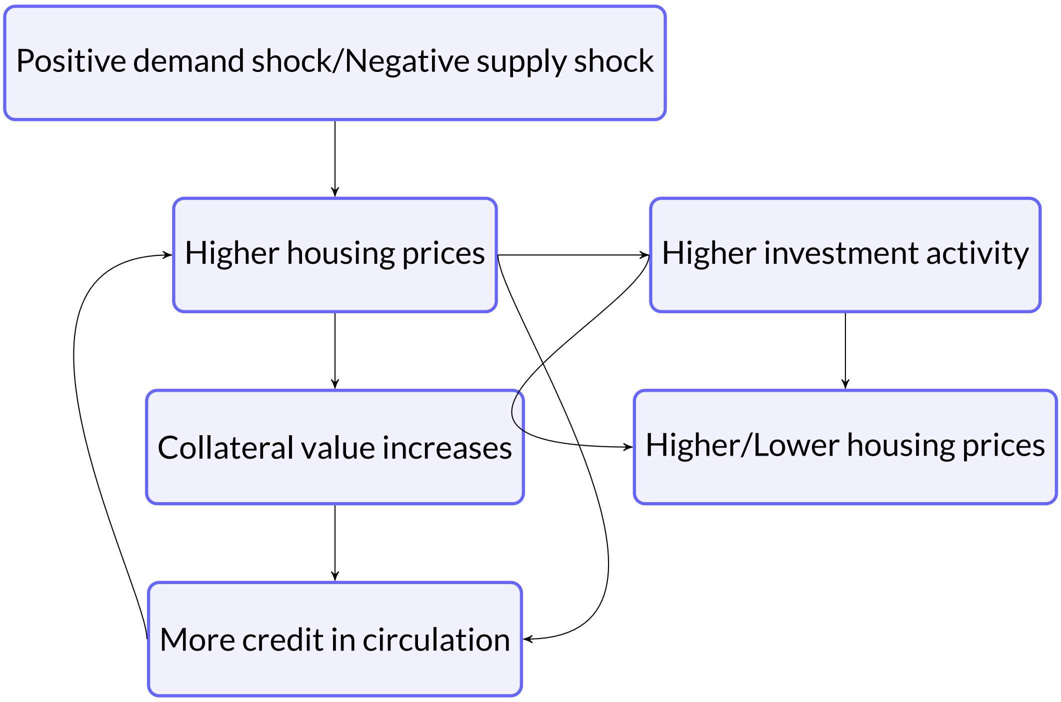

Figure 27: House price and credit system extended with effects of investments, which over a period of time will have a notable effect on the supply of housing.

As a result, both credit and the housing price indices are predicted to grow more slowly when the cost of lending is increased. Moreover, a tightening of credit conditions (a negative credit shock) will cool down the housing market according to our results. Conversely, a buoyant housing market can for long periods of time become self-propelled, since rising house prices can be used a collateral for credit to finance house purchases.

As noted, the econometric sub-model for PH and BGH is conditional on the housing stock. However, we have seen above that building activity is estimated to respond positively to increases in the real price of housing. When we take the effect on housing capital formation into account, we get the somewhat more complete picture in Figure 27, suggesting that there may be additional effects that can both increase or reduce the initial price hike after a positive demand shock. Higher investment activity will gradually increase housing supply, which will work in the direction of price reduction (and stabilization of the market). On the other hand, unless the effect on prices is quite large, the perceived total collateral value in the housing marked may still be increasing, also during a building boom caused by increase real price of housing. If that effect dominates in the medium run, we have a situation where demand is increasing in the price of the good. And upward sloping demand curves are not good news for market stabilization.

What this boils down t, is that the self-regulatory, stabilizing mechanisms in the housing and credit markets may be too few, and too weak, to support a strong belief in 'inherent stability' in the dynamic process between housing prices and credit. Hence, the discussion about housing market 'bubbles' versus fundamental drivers of house prices.

That said, supply growth is only one possible check on the credit-house price spiral. The price of credit, the real interest rate in or formulation, is another. If the interest rates is allowed to function as as equilibrating mechanism in the deregulated and liberalized capital market, both credit and captial formation are likely to develop more smoothly than they will do if the interest rate is decoupled from the capital markets. This is however exactly what happens if the interest rate is used for activity control or (even more evidently) for exchange-rate targeting, see e.g., Anundsen et al. (2014).

However, in our model, there is a third check on housing demand, and that is the non-linear effect of interest payment. Empirically, when interest expenses pass a threshold value relative to private income, Norwegian households have increased their financial savings sharply. Financial consolidation may lead to a sharp fall in housing prices. Hence we finally have a stabilizing mechanism. But since financial consolidation also affects product marked demand, this check on house price growth also has negative effect on the real economy.

FRAME 14: DEBT AND CREDIT INDICATOR (C2)

The main variable representing household debt is NAM is BGH which is modelled jointly with the housing price index. BGH conforms to the calculation of interest payments in the income accounts in the Norwegian quarterly national accounts which will be incorporated in a later version of the model. BGH is also similar to, but not identical with, the C2-indicator for houshold credit, which is NAM variable $K2HUS$. The link between BGH and $K2HUS$ is taken care of by simple estimated relationship in Chapter 9.14.
For completeness, NAM also contains equations for C2 to firms, see Chapter 9.15, and to Norwegian municipalicities, see Chapter 9.16.

7.8 INTEREST RATES

The interest rate level and the time structure of interest rates are formed by a combination of monetary policy and through market behaviour. In the case where Norges Bank forecasts inflation above the inflation target and a positive output-gap, the bank's projected interest rate will usually be adjusted upwards.[38] NAM includes an estimated "policy reaction function", which is documented in capter 9.25. This function has proven to be less stable than the first years of inflation targeting perhaps led us to believe. In the current version of the model, the function reflects the lasting impact of the financial crisis

[38] In Norway, the key policy rate is the interest rate on banks' deposits up to a quota in Norges Bank. The official forecasts of the policy rate is published at http://www.norges-bank.no/en/price-stability/monetary-policy-meetings/key-policy-rate/ . The forecasts are adjusted in each monetary policy report.

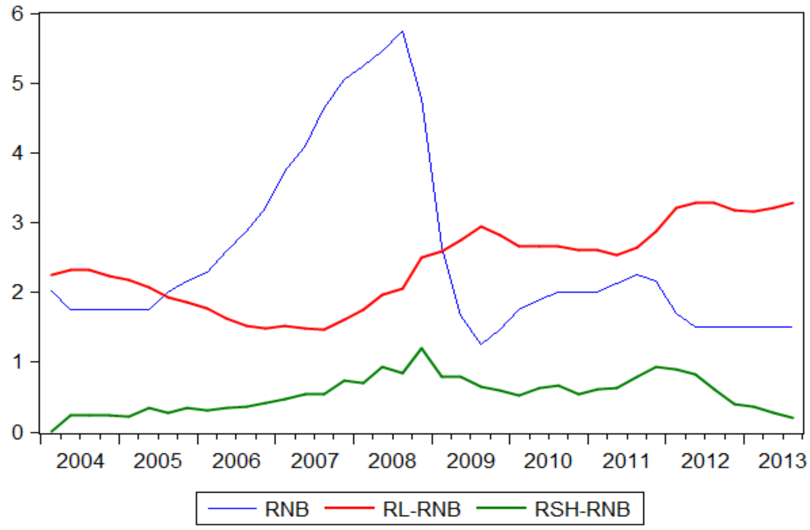

Figure 28: The policy interest rate (RNB); the difference between the interest rate on loans from Norwegian finance institutions to households and the policy rate (RL-RNB). The difference between the 3-month money market interest rate and the policy rate (RSH-RNB).

on monetary policy. In particular the estimation results show that the weight on inflation has been reduced to zero after the 2008q4.

Money and credit markets usually respond to changes in monetary policy, and in this way the banks decisions affects interest rates paid on households' debt and on credit to non-financial firms. As documented above, these interest rates are important chains in the 'transmission mechanism' of monetary policy in Norway under inflation targeting, also Bårdsen et al. (2003).

A high degree of liquidity in the Norwegian and international credit market represents the best climate for a smooth transmission of conventional monetary policy to market interest rates. Conversely, if the cost-of-trade increases in the capital market, liquidity is reduced. Loss of liquidity and trust means that the required rate of return will increase, even if the policy rate is kept constant or even reduced (in an attempt to counter reduced liquidity in the market with the use of conventional monetary policy). In such a situation there will be marked increases in difference between the 3-month money market rate and the policy rate. If the situation persists, the mortgage rate and the interest rate paid on credit to non-financial firm will also be pushed up, see e.g. Pedersen (2009)

Figure 28 shows evidence of a "cost-of-trade" driven increase in the difference between market interest rates and the policy rate, at least from mid-2007 to the outbreak of the international financial crisis in the autumn of 2008. The gap between the policy interest rate and the money market interest rate came down after (a short-lived) scare of major credit and job crisis also in Norway. Nevertheless, it was not until 2012 that this interest rate margin was reduced back to the pre-financial crisis level.

The estimated relationship between the policy interest rate (RNB) and the 3-month money market interest rate (RSH) is in Chapter 9.26. The results confirm that the risk-premium was temporarily affected during the financial crisis.

The evolution of the interest rate paid on household and firms loans in domestic financial institutions (NAM variable RL) also showed a market increase relative to the policy rate during the build-up to the international financial crisis. Unlike the money market rate, the gap between the market interest rate and the policy rate was not reduced right after the crisis was over. Instead it made a new jump in 2012. The increase in the interest rate margin for banks and other financial institutions has been interpreted as an adjustment to a post-crisis regulation regime with higher capital requirements than before, i.e., Basel-III. It is however not obvious that higher equity capital requirements need have a lasting impact on interest rate margins, see Admati et al. (2013).

Chapter 9.24 show that in NAM RL is related to RSH, as expected, and to the yield (RBO) on 5-year Norwegian government bonds. The dependency of RL on RBO reflects the high degree of integration between different segments of the credit marked.

Table 9.22 and table 9.23 contain the estimated relationships between the 3-month rate and the 5-year and 10-year ($RBOTENY$) government bond yields. Judging by the results, the two bond rates appear to follow a well defined term structure of interest rates relationship.

7.9 STOCK EXCHANGE PRICE INDICES

As noted above, the stock exchange valuation of Norwegian companies is one of the factors that influence gross capital formation and credit to the private business sector.

In NAM, we model the MSCI equity price for Norway (PA) and the MSCI for the world (PAW). Concretely, we model the logarithm of PA conditional on the logarithm of PAW. We follow custom and regard $log(PAW_t)$ as a random walk with drift (meaning that we abstract from the diffusion term).

The drift term is regarded as consisting a risk-free rate plus a risk-premium and minus dividend yield. The risk free rate is typically set to 2 % - 3 %. For the risk-premium, the broad historical average of 5 % may seem to be very high given the current outlook for the growth of the world economy. For the same reason the usual dividend yield assumption of 4 % (1880-2014) now seems relatively optimistic.

Based on judgement we have settled for a drift term of 4 % (= 3 % + 3 % -2 %), meaning the the dependent variable is $\Delta log(PAW_t - 0.04$. The estimation results in section 9.19 show that there is a stable positive autocorrelation in the series (with a coefficient of circa 0.3). The only covariate that we include in the present version of the model is the acceleration in international trade ($\Delta^2 log(MII_t$).

In section 9.18, the results for the Norwegian MSCI are reported. We find that $Deltalog(PA_t$ react one-for-one with $\Delta log(PA_t$, or even a little stronger, reflecting that the narrower Norwegian MSCI is more volatile than the world MSCI. We also find, as can be expected since our sample starts in 1985, that the Norwegian MSCI is influenced by the real price of oil.

8 LISTING OF VARIABLES

In this section we list the main NAM variables by name and a brief definition. We first give an alphabetical listing of the the main (or elementary) endogeous and exogenous model variables. In the second sub-section we list the definitional variables of the model, for example growth and inflation rates, and real-interest rates.

8.1 MAIN ENDOGENOUS AND EXOGENOUS VARIABLES

In the listing of variables **Endogenous variables** are underlined.

ARBDAG NUMBER OF WORKING DAYS PER QUARTER.

A TOTAL EXPORTS, FIXED PRICES, MILL. NOK.

AOIL EXPORTS OF OIL AND NATURAL GAS, FIXED PRICES, MILL. NOK.

ATJEN EXPORTS OF SERVICES, FIXED PRICES, MILL. NOK.

ATRAD EXPORTS OF TRADITIONAL GOODS, FIXED PRICES, MILL. NOK.

ASKIP EXPORTS OF SHIPS AND OIL PLATFORMS, FIXED PRICES, MILL. NOK.

B TOTAL IMPORTS, FIXED PRICES, MILL. NOK.

BASELIII DUMMY FOR BASEL III REGULATORY REGIME.

BEF1574 POPULATION SIZE 15-74 YEARS OLD. THOUSAND PERSONS.

BGH GROSS DEBT IN THE HOUSEHOLD SECTOR, MILL. NOK.

BFH GROSS FINANCIAL WEALTH IN THE HOUSEHOLD SECTOR, MILL. NOK.

BGHYD DEBT/INCOME RATE IN HOUSEHOLD SECTOR, PERCENT.

BGIF GROSS DEBT IN NON FINANCIAL CORPORATIONS, MILL. NOK

CO PUBLIC CONSUMPTION EXPENDITURE. FIXED PRICES, MILL. NOK

CORG CONSUMPTION EXPENDITURE IN IDEAL ORGANIZATIONS. FIXED PRICES, MILL. NOK

CP CONSUMPTION IN HOUSEHOLDS AND NON PROFIT ORGANIZATIONS. MILL. NOK FIXED PRICES.

CPI CONSUMER PRICE INDEX.

CPIJAE CONSUMER PRICE INDEX ADJUSTED ENERGY AND TAXES.

CPIEL ELECTRICITY PRICE COMPONENT OF CONSUMER PRICE INDEX.

CPIVAL NOMINAL EFFECTIVE EXCHANGE RATE INDEX.

DRIFTH INCOME FROM OPERATING SURPLUS, HOUSEHOLDS AND NON PROFIT ORGANIZATIONS, MILL. NOK.

FHSF AVERAGE WORKING TIME FOR SELF-EMPLOYED PERSONS, THOUSAND HOURS.

HK HOUSING STOCK. VALUE OF RESIDENTIAL HOUSING STOCK AT FIXED PRICES, MILL. NOK.

HPF HOURS PER WHOLE TIME EQUIVALENT WAGE EARNER, PRIVATE MAINLAND-NORWAY. THOUSAND HOURS.

HS HOUSING STARTS. NUMBER OF UNITS.

IM GROSS LABOUR IMMIGRATION RATE. PERCENT OF LABOUR STOCK.

JBOL GROSS FIXED CAPITAL FORMATION (GFCF) IN RESIDENTIAL HOUSING, FIXED PRICES, MILL NOK.

JFPN GROSS FIXED CAPITAL FORMATION (GFCF) IN PRIVATE BUSINESS, MILL NOK.

JL CHANGES IN INVENTORIES AND STATISTICAL ERRORS, FIXED PRICES MILL NOK.

JOIL1 GROSS FIXED CAPITAL FORMATION (GFCF), PRODUCTION AND PIPELINE TRANSPORT. FIXED PRICES, MILL. NOK.

JOIL2 GROSS FIXED CAPITAL FORMATION (GFCF) IN SERVICES RELATED TO OIL AND GAS. FIXED PRICES, MILL. NOK.

JO GROSS FIXED CAPITAL FORMATION (GFCF), GENERAL GOVERNMENT, FIXED PRICES, MILL. NOK

JUSF GGROSS FIXED CAPITAL FORMATION (GFCF), INTERNATIONAL SHIPPING. FIXED PRICES, MILL. NOK.

K2 DOMESTIC CREDIT TO GENERAL PUBLIC, K2 indicator. MILL.NOK.

K2HUS GROSS DEBT FROM DOMESTIC INSTITUTIONS HELD BY HOUSEHOLDS, C2-indicator, MILL. NOK.

K2IF GROSS DEBT FROM DOMESTIC INSTITUTIONS HELD BY NON-FINANCIAL FIRMS, C2-indicator. MILL. NOK.

K2KOM GROSS DEBT FROM DOMESTIC INSTITUTIONS HELD BY LOCAL GOVERNMENT ADMINISTRATION, C2-indicator. MILL. NOK.

HOUSEHOLDS' NEW DEPOSITS IN PENSION FUNDS. MILL. NOK.

LAVGSUB NET PRODUCT TAXES AND SUBSIDIES, MILL.NOK [39]

LKDEP VALUE OF CAPITAL DEPRECIATION IN NORWAY, MILL. NOK.

LGRAD ONE MINUS EQUITY RATE REQUIREMENT (ON HOME BUYERS)

LOENNH WAGE INCOME, HOUSEHOLDS AND NON PROFIT ORGANIZATIONS, MILL. NOK.

LYF GROSS DOMESTIC PRODUCT (GDP) MAINLAND NORWAY (MARKET VALUES), MILL.NOK.

LYFbasis GROSS DOMESTIC PRODUCT (GDP) MAINLAND NORWAY (BASIC VALUES), MILL. NOK.

LYFPbasis GROSS DOMESTIC PRODUCT (GDP) PRIVATE MAINLAND NORWAY (BASIC VALUES), MILL. NOK.

MAFVK BANK WHOLESALE FUNDING AS A PROPORTION OF TOTAL ASSETS.

MII INDICATOR OF FOREIGN DEMAND.INDEX.

NSF SELF-EMPLOYED PERSONS, THOUSAND.

NWPF WAGE EARNERS IN PRIVATE MAINLAND NORWAY, THOUSAND.

NWO WAGE EARNERS IN GOVERNMENT ADMINISTRATION, THOUSAND.

NWOSJ WAGE EARNERS IN OIL AND GAS PRODUCTION, TRANSPORTATION AND INTERNATIONAL TRANSPORTATION, THOUSAND.

NBCRIS DUMMY FOR NORGES BANK LEAVING NORMAL TAYLOR-RULE.

NT LABOUR FORCE 15-74 YEARS OLD, THOUSAND PERSONS.

NORPOOL NORWEGIAN ELECTRICITY PRICE, NORPOOL, OSLO TRADING AREA.

RESINNTH RESIDUAL INCOME TO HOUSEHOLDS (PENSIONS, TRANSFERS, OTHER CAPITAL INCOME).

PA MSCI EQUITY PRICE INDEX, NORWAY.

PAW MSCI EQUITY PRICE INDEX, WORLD.

[39] Note that this variable is in current prices. The variable AVGSUM mentioned in the section about accounting identites has for simplicity been defined as $LAVGSUM/CPI$.

PB IMPORT PRICE INDEX.

PCKONK FOREIGN CONSUMER PRICE INDEX (TRADE WEIGHTED)

PCEURO EURO AREA CONSUMER PRICE INDEX

PCKNR DEFLATOR OF PRIVATE CONSUMPTION

PH HOUSE PRICE INDEX.

PHCPI REAL HOUSE PRICE INDEX.

PPIKONK FOREIGN PRODUCER PRICE INDEX.

PYF GDP DEFLATOR MAINLAND NORWAY, MARKET VALUES.

PYFB GDP DEFLATOR MAINLAND NORWAY, BASIC VALUES.

PYFPB GDP DEFLATOR PRIVATE MAINLAND NORWAY, BASIC VALUES.

PYOFF VALUE ADDED DEFLATOR GOVERNMENT ADMINISTRATION.

PYOIL1 VALUE ADDED DEFLATOR OIL AND GAS PRODUCTION.

PYOIL2 VALUE ADDED DEFLATOR PIPELINE TRANSPORTATION.

PYUSF VALUE ADDED DEFLATOR INTERNATIONAL SHIPPING.

RAM300 DIVIDEND PAYMENTS TO HOUSEHOLDS.MILL. NOK.

RBD AVERAGE INTEREST RATE ON DEPOSITS. BANKS AND OTHER FINANCIAL INSTITUTIONS.

RBO EFFECTIVE YIELD ON 5-YEAR GOVERNMENT BONDS.

RBGH INTEREST RATE PER QUARTER ON HOUSEHOLD DEBT.

RBFH INTEREST RATE PER QUARTER ON HOUSEHOLD WEALTH.

REGLED REGISTERED UNEMPLOYED, THOUSAND PERSONS.

RENTEINNH INTEREST INCOME, HOUSEHOLDS AND NON PROFIT ORGANIZATIONS, MILL.NOK.

RENTEUTH INTEREST EXPENSES, HOUSEHOLDS AND NON PROFIT ORGANIZATIONS, MILL.NOK.

RIH INTEREST ON HOUSEHOLD WEALTH, MILL. NOK.

RL AVERAGE INTEREST RATE ON TOTAL BANK LOANS.

RNB NORGES BANK'S POLICY RATE, PERCENT.

RSH 3-MONTH NORWEGIAN MONEY MARKET RATE, NIBOR. PERCENT.

RSW 3-MONTH FOREIGN MONEY MARKET RATE.

RW EURO AREA 10-YEAR GOVERMENT BENCHMARK BOND YIELD, PERCENT.

RUBAL NET INCOMES AND TRANSFERS TO NORWAY FROM ABROAD ("Rente- og stønadsbalansen")

RUH INTEREST PAYMENT ON HOUSEHOLD DEBT, MILL. NOK.

RUHYD INTEREST PAYMENT ON HOUSEHOLD DEBT IN PER CENT OF DISPOSABLE INCOME.

TOTLED UNEMPLOYMENT RATE INCLUDING JOB CREATION PROGRAMMES.

SKATTH TAXES ON HOUSEHOLDS' INCOME AND WEALTH, MILL. NOK.

SPOILUSD SPOT BRENT OIL PRICE PER BARREL, USD.

SPUSD NOK/USD EXCHANGE RATE.

SPEURO NOK/EURO EXCHANGE RATE.

T1FK EMPLOYMENT ("PAYROLL")TAX RATE.

T3 INDIRECT TAX RATE.

TILT JOB CREATION PROGRAMMES ("ORDINÆRE TILTAK"), THOUSAND PERSONS.

TSF HOURS WORKED BY SELF EMPLOYED, MILL.

TWPF HOURS WORKED MY WAGE EARNERS IN PRIVATE MAINLAND-NORWAY, MILL.

TWO HOURS WORKED IN GOVERNMENT ADMINISTRATION, MILL.

TWOSJ HOURS WORKED IN OIL AND GAS AND INTERNATIONAL SHIPPING, MILL.

UR REGISTERED UNEMPLOYMENT RATE. PERCENT.

VOLUSA IMPLICIT VOLATILITY, STOCK OPTIONS MARKETS, USA.

UAKU UNEMPLOYMENT RATE MEASURED FROM LABOUR MARKET SURVEY.

WCFK WAGE COSTS PER HOUR (IN KVARTS), MAINLAND NORWAY, NOK.

WCPFK WAGE COSTS PER HOUR (IN KVARTS), PRIVATE MAINLAND NORWAY, NOK.

WFK WAGE PER HOUR IN KVARTS, MAINLAND NORWAY, NOK.

WH WAGE PER YEAR IN TOTAL ECONOMY (FULL TIME EQUIVALENT IN 1000), NOK.

WHGL WAGE PER YEAR IN LOCAL GOVERNMENT (FULL TIME EQUIVALENT IN 1000), NOK.

WHGSC WAGE PER YEAR IN CIVILIAN CENTRAL GOVERNMENT (FULL TIME EQUIVALENT IN 1000), NOK.

WPFK WAGE PER HOUR (IN KVARTS[40]), PRIVATE MAINLAND NORWAY, NOK

WGK WAGE PER HOUR (IN KVARTS), LOCAL AND CENTRAL ADMINISTRATION, NOK.

WBI1 AN INDICATOR OF THE DEGREE OF COORDINATION IN WAGE FORMATION.

Y GDP NORWAY, MARKET VALUES, FIXED PRICES, MILL. NOK.

YD PRIVATE DISPOSABLE INCOME, MILL. NOK.

YDCD PRIVATE DISPOSABLE INCOME, HOUSEHOLDS, CORRECTED FOR DIVIDEND PAYMENTS,MILL. NOK.

YDNOR DISPOSABLE INCOME FOR NORWAY, MILL. NOK.

YDORG INCOME T NON-PROFIT ORGANIZATIONS (PART OF YD). MILL. NOK.

YF GDP MAINLAND NORWAY, MARKET VALUES, FIXED PRICES, MILL. NOK.

YFbasis GDP MAINLAND NORWAY BASIC VALUES, FIXED PRICES, MILL. NOK.

YFPbasis GDP PRIVATE MAINLAND NORWAY (BASIC VALUES = MARKET VALUES), FIXED PRICES, MILL. NOK.

YFP1 VALUE ADDED MANUFACTURING AND MINING, BASIC VALUES, FIXED PRICES, MILL. NOK.

YFP2 VALUE ADDED PRODUCTION OF OTHER GOODS, BASIC VALUES, FIXED PRICES, MILL. NOK.

YFP3 VALUE ADDED PRIVATE SERVICE ACTIVITIES, BASIC VALUES, FIXED PRICES, MILL. NOK.

YFP3NET VALUE ADDED PRIVATE SERVICE ACTIVITIES, NET OF YFP3OIL, FIXED PRICES, MILL. NOK.

[40]KVARTS is the quarterly econometric model of Statistics Norway. We model the constructed hourly wage rate from the KVARTS database. The annual average of this variable is equal to the annual average of the wage rate per man hour in the Quarterly National Accounts

YFP3OIL VALUE ADDED IN SERVICES INCIDENTAL TO OIL AND GAS EXTRACTION, FIXED PRICES, MILL. NOK.

YO VALUE ADDED IN GOVERNMENT ADMINISTRATION (BASIC VALUES), MILL. NOK.

YOIL1 VALUE ADDED IN OIL AND GAS PRODUCTION (BASIC VALUES = MARKET VALUES), FIXED PRICES, MILL. NOK.

YOIL2 VALUE ADDED IN PIPELINE TRANSPORTATION (BASIC VALUES = MARKET VALUES), FIXED PRICES, MILL. NOK.

YUSF VALUE ADDED IN INTERNATIONAL SHIPPING (BASIC VALUES = MARKET VALUES), FIXED PRICES, MILL. NOK.

YFbasis GDP MAINLAND NORWAY (BASIC VALUES), FIXED PRICES, MILL. NOK.

YFPbasis GDP PRIVATE MAINLAND NORWAY (BASIC VALUES), FIXED PRICES, MILL. NOK.

YFR RESIDUAL GDP MAINLAND NORWAY (MARKET VALUES), FIXED PRICES, MILL. NOK

ZYF AVERAGE LABOUR PRODUCTIVITY MAINLAND NORWAY. GDP AT BASIC VALUES, FIXED PRICES, DIVIDED BY TOTAL HOURS WORKED. MILL. NOK.

ZYFP AVERAGE LABOUR PRODUCTIVITY PRIVATE MAINLAND NORWAY. GDP AT BASIC VALUES, DIVIDED BY TOTAL HOURS WORKED. MILL. NOK.

8.2 DEFINITION VARIABLES AND IDENTITIES

A Total exports, fixed prices.

A = ATRAD + AOIL + ATJEN + ASKIP

ATRADGR Growth in export of traditional goods.

ATRADGR = ((ATRAD - ATRAD(-4)) / ATRAD(-4))*100

ATJENGR Growth in export of services.

ATJENGR = ((ATJEN - ATJEN(-4)) / ATJEN(-4))*100

AOILGR Growth in export of oil and gas.

AOILGR = ((AOIL - AOIL(-4)) / AOIL(-4))*100

AGR Growth in exports.

AGR = ((A - A(-4)) / A(-4))*100

BGHINF Household debt growth.

BGHINF= (BGH/BGH(-4)-1)*100

BGHYD Debt income ratio in the household sector (percent).

BGHYD = BGH*100/(YDCD+YDCD(-1)+YDCD(-2)+YDCD(-3))

COSHARE Governmendt consumption share of Mainland-Norway GDP.

COSHARE = CO/YF

COGR Public consumption growth.

COGR = ((CO - CO(-4)) / CO(-4))*100

CPGR Private consumption growth.

CPGR = ((CP / CP(-4)) - 1)*100

CPIELGR Growth in energy part of CPI.

CPIELGR = ((CPIEL / CPIEL(-4)) - 1)*100

CPIELINF CPIEL percentage change.

CPIELINF = ((CPIEL- CPIEL(-4)) / CPIEL(-4))*100

CR Real credit, C2.

CR = (K2 / CPI)

CRGR CR, percentage change.

CRGR = ((CR / CR(-4)) - 1)*100

CRRATIO Credit rate (C2) households.

CRRATIO = (CR / (0.25*(YF+YF(-1)+YF(-2)+YF(-3))))*100

DEPR CPIVAL percentage change.

DEPR = ((CPIVAL - CPIVAL(-4)) / CPIVAL(-4))*100

DEPREURO SPEURO percentage change.

DEPREURO =((SPEURO - SPEURO(-4)) / SPEURO(-4))*100

DEPRUSD SPUSD percentage change.

DEPRUSD =((SPUSD - SPUSD(-4)) / SPUSD(-4))*100

DJLOFY Change in inventories as percent of Mainland-Norway GDP.

DJLOFY = (d(JL)/Y)*100

DOMD Domestic expenditure (demand).

DOMD = CP + CO + JF

FHWPF Average working time for wage earners, private Mainland-Norway, thousand hours.
FHWPF = TWPF/NWPF

FHWO Average working time for wage earners, government administration, thousand hours.
FHWO = TWO/NWO

FHWOSJ Average working time for wage earners, oil and gas production and international transportation, thousand hours.
FHWOSJ = TWOSJ/NWOSJ

INF CPI inflation.
INF = ((CPIE - CPI(-4)) / CPI(-4))*100

INFJAE CPI-AET inflation.
INFJAE = ((CPIJAE - CPIJAE(-4)) / CPIJAE(-4))*100

J Total gross fixed capital formation (GFCF), fixed prices.
J = JO + JBOL+ JFPN + JOIL1 + JOIL2 + JUSF

JBOLGR Residential housing investment growth.
JBOLGR = ((JBOL - JBOL(-4)) / JBOL(-4))*100

JOILGR Growth in oil investments.
JOILGR = ((JOIL - JOIL(-4)) / JOIL(-4))*100

JF Total gross fixed capitial formation (GFCF), Mainland-Norway, fixed prices.
JF = JBOL +JFPN +JO

JFP Gross fixed capital formation (GFCF), private Mainland-Norway, fixed prices.
JFP = JBOL +JFPN

JFPNGR Private non-oil business investment growth.
JFPNGR = ((JFPN - JFPN(-4)) / JFPN(-4))*100

JL Changes in inventories and statistical errors, fixed prices.
JL = TOTS - CP - CO - J - A

JOIL Gross fixed capital formation (GFCF), oil and gass production and pipeline transportation (JOIL1), and related services (JOIL2), fixed prices.
JOIL = JOIL1 + JOIL2

JLOFY Inventories and statistical errors is percent of Mainland-Norway GDP.
JLOFY = (JL/Y)*100

K2 C2 definition

K2 = K2IF+K2HUS+K2KOM

K2IFINF Growth in C2 debt, households.

K2HUSINF= (K2HUS/K2HUS(-4)-1)*100

K2HUSIFN Growth in C2 debt, non-financial firms.

K2IFINF= (K2IF/K2IF(-4)-1)*100

K2KOMINF Growth in C2 debt, local government.

K2KOMINF= (K2KOM/K2KOM(-4)-1)*100

K2HUSYD C2-Debt income ratio in the household sector (percent).

K2HUSYD = K2HUS*100/(YDCD+YDCD(-1)+YDCD(-2)+YDCD(-3)

K2GR C2, percentage change.

K2GR = ((K2 / K2(-4)) - 1)*100

KONKINF PCKONK percentage change.

KONKINF = ((PCKONK - PCKONK(-4)) / PCKONK(-4))*100

LOGWCFK Logarithm of WCFK.

LOGWCFK = LOG(WCFK)

LYF GDP Mainland-Norway in market values.

LYF = PYF*YF

LYFbasis GDP Mainland-Norway in basic values.

LYFbasis = YFPbasis*PYFPB+PYO*YO

LYFPbasis GDP private Mainland-Norway in basic values.

LYFPbasis = YFPbasis*PYFPB

LY GDP in market values.

LY = LYF+PYOIL1*YOIL1 + PYOIL2*YOIL2 + PYUSF*YUSF

MIIGR Growth in export marked indicator, MII.

MIIGR = ((MII / MII(-4)) - 1)*100

NWF Employed wage earners in Mainland-Norway, thousand.

NWF = NWPF + NWO + NSF

N Total employment, thousand.

N = NWPF + NWO + NWOSJ+ NSF

N Employment in Mainland-Norway, thousand.

NF = NWPF + NWO + NSF

NGR Annual change in employed persons. Percent

NGR = ((N - N(-4)) / N(-4))*100

NWFGR Annual change in employed persons, Mainland-Norway. Percent

SERIES NWFGR = ((NWF - NWF(-4)) / NWF(-4))*100

NWFPGR Annual change in employed persons, business sector Mainland-Norway. Percent

SERIES NWFPGR = ((NWPRF - NWPRF(-4)) / NWF(-4))*100

NORPOOLINF NORPOOL percentage change.

NORPOOLINF = ((NORPOOL- NORPOOL(-4)) / NORPOOL(-4))*100

PAINF Growth in Growth in MSCI equity price index, Norway.

PAINF= (PA/PA(-4)-1)*100

PAWINF Growth in Growth in MSCI equity price index, world.

PAWINF= (PAW/PAW(-4)-1)*100

PBINF Import price change, percent.

PBINF = ((PB - PB(-4)) / PB(-4))*100

PBREXR Import price relative to CPI.

PBREXR = (PB / CPI)*100

PHINF House price growth.

PHINF = ((PH - PH(-4)) / PH(-4))*100

PHCPI Real house price.

PHCPI = PH/CPI

PHCPIGR Real house price growth.

PHCPIGR = ((PHCPI - PHCPI(-4)) / PHCPI(-4))*100

PYFINF PYF percentage change.

PYFINF = ((PYF - PYF(-4)) / PYF(-4))*100

PPIINF PPIKONK percentage change.

PPIINF = ((PPIKONK - PPIKONK(-4)) / PPIKONK(-4))*100

RBOWFIVEY Actuarial five year real interest rate.

RBOWFIVEY = RBO- WINF

RDIFFRL Loan rate, policy interest rate differential.

RDIFFRL = RL-RNB

RDIFFRSH Money market rate, policy interest rate differential

RDIFFRSH = RSH-RNB

RDIFFRLRSH Loan rate, money market interest rate differential.

RDIFFRLRSH = RL-RSH

REXR Relative CPI.

REXR = ((CPIVAL*PCKONK) / CPI)

RRL Real interest rate, households.

RRL = RL - INF

RRSH Real money market interest rates.

RRSH = RSH - INF

RSDIFF Money market interest rate differential.

RSDIFF = (RSH - RSW)

RUH Quarterly interest payment on household debt.

RUH = RBGH*BGH

RUHK2 Quarterly interest payment on household debt, C2.

RUHK2 = RBGH*K2HUS

RUHYD Interest payment on household debt in percent of disposable income.

RUHYD = (RUH/(YDCD+RUH))*100

RUHK2YD Interest payment on household debt (C2) in percent of disposable income.

RUHK2YD = (RUHK2/(YDCD+RUHK2))*100

SAVINGPH SAVINGS, HOUSEHOLDS, MILL. NOK.

SAVINGPH = YDH -PCKNR(CP-CPORG) +

SAVINGPH SAVINGS, IDEAL ORGANIZATIOS, MILL. NOK.

SAVINGPH = YDORG -PCKNR(CPORG)

SAVINGPH PRIVATE SAVINGS, MILL. NOK.

SAVINGP = SAVINGPH + SAVINGPORG

SP Private savings rate.

SP=(SAVINGPH+SAVINGPORG)/YD

SPH Households' savings rate.
SPH=SAVINGPH/YDH

SPORG Private organizations' savings rate.
SPH=SAVINGPORG/YDORG

TOTD Total expenditure (demand), fixed price.s
TOTD = CP + CO + J + A + JL

TOTS Total supply, fixed price.
TOTS = Y + B

TF Total number of hours.
T = TF + TWOSJ

TF Total number of hours worked Mainland-Norway.
TF = TWF + TSF

TSF Hours worked by self employed, million.
TSF = NSF*FHSF

TWF Total number of hours worked by wage earners in Mainland-Norway.
TWF = TWPF + TWO

WCINF WCFK, percentage change.
WCINF = ((WCFK / WCFK(-4)) - 1)*100

WCPFK Wage costs per hour, private Mainland-Norway.
WCPFK = WPFK*(1+T1FK)

WFK Wage per hour, Mainland-Norway.
WFK = WCFK/(1+T1FK)

WGKINF Wage inflation, WGK based.
WGKINF = ((WGK / WGK(-4)) - 1)*100

WHINF WH, percentage change.
WHINF= ((WH / WH(-4)) - 1)*100

WFREAL Consumer real wage per hour, Mainland-Norway.
WFREAL = WFK/CPI

WFRINF WFREAL, percentage change.
WFRINF = 100*((WFREAL/WFREAL(-4))-1)

WINF Wage inflation, WFK based.

WINF = ((WFK / WFK(-4)) - 1)*100

WPFINF Wage inflation, WPFK based.

WPFINF = ((WPFK / WPFK(-4)) - 1)*100

WSHARE Wage-share Mainland-Norway.

WSHARE = (WCFK / (PYF * ZYF))

Y Total GDP, fixed prices market values.

Y = YF + YOIL1 + YOIL2 + YUSF

YD Household disposable income.

YDH = DRIFTH + LOENNH + RENTEINNH - RENTEUTH + RESINNTH - SKATTH

YD Private disposable income.

YD = YDH + YDORG

YDCD Private disposable income net of dividend payments.

YDCD = YD-RAM300.

YDFIRMS Disposable income of firms.

YDFIRMS = (1-T2CAP)(PYFPB*(YFP1+YFP2+YFP3) +LAVGSUB - (WFK*(1+T1FK))*(TWPF) -0.6*LKDEP -(RSH/100)(K2IF*0.25)).

YDREAL Real disposable income for households and ideal organizations.

YDREAL = YD/CPI

YDREALGR Real disposable income growth for households and ideal organizations.

YDREALGR = ((YDREAL - YDREAL(-4)) / YDREAL(-4))*100

YGR Real GDP growth.

YGR = ((Y - Y(-4)) / Y(-4))*100

YFGR Real GDP growth, Mainland-Norway.

YFGR = ((YF - YF(-4)) / YF(-4))*100

YFP1GR Gross product growth, manufacturing.

YFP1GR = ((YFP1 - YFP1(-4)) / YFP1(-4))*100

YFP2GR Gross product growth, production of other goods.

YFP2GR = ((YFP2 - YFP2(-4)) / YFP2(-4))*100

YFP3GR Gross product growth, retail sales and private production of services.

YFP3GR = ((YFP3 - YFP3(-4)) / YFP3(-4))*100

YOIL = Value added in oil and gas production and pipeline transportation.

YOIL = YOIL1 + YOIL2

YOIL1GR Gross product growth, in oil and gas production.

YOIL1GR = ((YOIL1 - YOIL1(-4)) / YOIL1(-4))*100

YFP3 Value added (gross product) in Mainland-Norway service sector.

YFP3 = YFP3NET + YFP3OIL

YFPbasis GDP for private sector Mainland.Norway, basic value.s

YFPbasis = YFP1+YFP2+YFP3

YFbasis GDP for Mainland.Norway, basic values.

YFbasis = YFP1+YFP2+YFP3+YO

YF GDP for Mainland-Norway, market value.s

YF = YFP1+YFP2+YFP3+YO+(LAVGSUB/PYF)

YDNOR Disposable income for Norway.

YDNOR = LY+RUBAL-LKDEP

ZYFP Average labour productivity Mainland-Norway.

ZYF = (YFPbasis+YO) / (TWPF+TSF+TWO))

ZYFGR ZYF, percentage change.

ZYFGR = ((ZYF / ZYF(-4)) - 1)*100

ZYFP Average labour productivity private Mainland-Norway.

ZYFP = YFPbasis / (TWPF+TSF))

9 DETAILED ESTIMATION RESULTS

The results are reported with explicit transformations of the original data series in section 8. Instead of the conventional mathematical expressions the transformations are given in Eviews code. The Eviews User's Guides[41] give the details, but examples of the most used transformations are listed in Table 2.

[41] See Eviews (2014a) and Eviews (2014b) ,

Table 2: Mathematical and EViews expressions for a time series variable X_t

Math. expression	EViews expression
X_t, X_{t-1},X_{t-4},	X, X(-1), X(-4)
$ln(X_{t-1})$	LOG(X(-1)
ΔX_t, ΔX_{t-1}	D(X), D(X(-1))
$\Delta ln(X_{t-1})$	DLOG(X(-1))

Note that EViews is not case sensitive, so that LOG(X), can also be written as log(X), or LOG(x). Sometimes, the variables in the estimated equations are more complicated transformations, or functions of the data series. In these cases, there are notes to the tables with estimations results, and there may also be be a text box below the table with additional information about the variables.

Most of the equations include an intercept, which is denoted *Constant* in the tables with estimations results. There are also many equations with seasonal dummies. These are centered in the sense that they sum to zero over the four quarters of the year. The centered dummies are denoted *CS1*, *CS2* and *CS3*. The fourth quarter is the reference quarter.

9.1 EXPORTS OF SHIPS, OIL PLATFORMS AND AIRPLANES

Table 3: Dependent Variable: DLOG(ASKIP). LS estimation. Sample size: 138 (1980Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(ASKIP(-1))	-0.460271	0.074457	-6.181746	0.0000
CS1	-0.076793	0.097554	-0.787186	0.4326
CS2	0.041785	0.097702	0.427679	0.6696
CS2	-0.020600	0.098288	-0.209586	0.8343
Constant	3.803280	0.617289	6.161267	0.0000
R-squared	0.235202	Mean dependent var	-0.006563	
Adjusted R-squared	0.212200	S.D. dependent var	0.456443	
S.E. of regression	0.405130	Akaike info criterion	1.066343	
Log likelihood	-68.57768	Hannan-Quinn criter.	1.109443	
F-statistic	10.22551	Durbin-Watson stat	2.028557	

9.2 EXPORTS OF SERVICES

Table 4: Dependent Variable: DLOG(ATJEN). LS estimation. Sample size: 141 (1979Q2 2014Q2).

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(MII)	0.573116	0.241900	2.369226	0.0193
ECM_{ATJEN}	-0.188099	0.059624	-3.154747	0.0020
DLOG(ATJEN(-1))	-0.307220	0.078605	-3.908428	0.0001
DLOG(ATJEN(-4))	0.262360	0.072368	3.625357	0.0004
Constant	1.608909	0.509960	3.154975	0.0020
CS1	-0.030572	0.012966	-2.357968	0.0198
CS2	0.012640	0.013378	0.944770	0.3465
CS3	0.040262	0.012969	3.104444	0.0023
R-squared	0.515856	Mean dependent var	0.007014	
Adjusted R-squared	0.490375	S.D. dependent var	0.070290	
S.E. of regression	0.050178	Akaike info criterion	-3.091398	
Log likelihood	225.9436	Hannan-Quinn criter.	-3.023411	
F-statistic	20.24454	Durbin-Watson stat	2.039707	

Notes:
$ECM_{ATJEN} = log(ATJEN(-1)) - 0.55 log(MII(-1)))$

9.3 EXPORTS OF TRADITIONAL GOODS

Table 5: Dependent Variable: DLOG(ATRAD). LS estimation. Sample size: 144 (1988Q1 2016Q3).

	Coefficient	Std. Error	t-Statistic	Prob.
D2LOG(MII))	0.586660	0.142514	4.116499	0.0001
D3LOG(ATRAD(-1))	-0.689143	0.080168	-8.596188	0.0000
ECM_{ATRAD}	-0.308615	0.070492	-4.378019	0.0000
Constant	2.335472	0.531683	4.392606	0.0000
CS1	-0.039337	0.012443	-3.161291	0.0020
CS2	-0.030910	0.011420	-2.706578	0.0079
CS3	-0.045521	0.011990	-3.796661	0.0002
ACOSTCUT	-0.101309	0.026286	-3.854151	0.0002
R-squared	0.634513	Mean dependent var	0.008567	
Adjusted R-squared	0.610602	S.D. dependent var	0.063708	
S.E. of regression	0.039755	Akaike info criterion	-3.545148	
Log likelihood	261.1792	Hannan-Quinn criter.	-3.467642	
F-statistic	26.53712	Durbin-Watson stat	2.111371	

Notes:
$ECM_{ATRAD} = LOG(ATRAD(-1)) - 0.96LOG((CPIVAL(-1)PCKONK(-1))/CPI(-1))$
$E - 0.83LOG(MII(-1))$

Additional notes

- ACOSTCUT is given in the EViews program file.

9.4 IMPORTS

Table 6: Dependent Variable: D(B). LS estimation. Sample size: 82 (1997Q1 2017Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
B(-1)	-0.565212	0.078807	-7.172100	0.0000
BDEM	0.745312	0.102041	7.304054	0.0000
PB/PYF	-13174.14	7741.306	-1.701798	0.0929
BDUM	1.002830	0.232349	4.316054	0.0000
CS1	1402.182	2208.979	0.634765	0.5275
CS2	9732.999	1703.572	5.713288	0.0000
CS3	8016.265	1797.453	4.459792	0.0000
R-squared	0.738117	Mean dependent var		1721.63
Adjusted R-squared	0.717167	S.D. dependent var		10214.12
S.E. of regression	5432.082	Akaike info criterion		20.11953
Log likelihood	-817.9009	Hannan-Quinn criter.		20.20202
Durbin-Watson stat	1.961190			

Note:
$BDEM = 0.29CP + 0.39JOIL1 + 0.66 * JUSF + 0.40JFPN$
$+0.32ATRAD + 0.25ATJEN + 0.086CO + 0.28JO + 0.21JBOL + 0.032AOIL$

Additional notes

- BDUM is given in the EViews program file.

9.5 PRIVATE CONSUMPTION

Table 7: Dependent Variable: DLOG(CP). LS estimation. Sample size: 106 (1988Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
ECM_{CP}	-0.320128	0.073169	-4.375171	0.0000
RL(-1)-INF(-1)	-0.001993	0.001066	-1.870175	0.0645
DLOG(CP(-4))	0.448413	0.079430	5.645406	0.0000
f(RUH)	-0.111653	0.095529	-1.168791	0.2454
DLOG(YCDC/CPI)	0.188849	0.081223	2.325071	0.0222
Constant	1.161091	0.254650	4.559550	0.0000
CS1	-0.047382	0.010367	-4.570474	0.0000
CS2	-0.011594	0.004793	-2.418855	0.0174
CS3	-0.016747	0.005636	-2.971510	0.0037
R-squared	0.9197153	Mean dependent var	0.005913	
S.E. of regression	0.01475	Akaike info criterion	-5.512883	
Log likelihood	301.1828	Hannan-Quinn criter.	-5.421226	
		Durbin-Watson stat	2.28510	

Notes:
$ECM_{CP} = LOG(CP(-1)) - 0.61 * LOG(YDCD(-1)/CPI(-1))$
$-0.10LOG((PH(-1)HK(-1))/CPI(-1)))$
$f(RUH) = (1/(1 + EXP(-3.0(RUH(-1)/(YDCD(-1) + RUH - 1)) - 0.13))))$

9.6 ENERGY PART OF CPI

Table 8: Dependent Variable: DLOG(CPIEL). LS estimation. Sample size: 34 (2006Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(NORPOOL)	0.367065	0.026114	14.05618	0.0000
DLOG(CPIEL(-1))	-0.158319	0.066198	-2.391610	0.0228
R-squared	0.861621	Mean dependent var	0.002347	
Adjusted R-squared	0.857297	S.D. dependent var	0.165104	
S.E. of regression	0.062370	Akaike info criterion	-2.654451	
Log likelihood	47.12566	Hannan-Quinn criter.	-2.623831	
Durbin-Watson stat	2.430580			

9.7 CPI ADJUSTED FOR ENERGY AND TAXES

Table 9: Dependent Variable: DLOG(CPIJAE). LS estimation. Sample size: 58 (2000Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(CPI)	0.402157	0.063510	6.332226	0.0000
DLOG(CPI(-1))	0.047328	0.040080	1.180855	0.2434
DLOG(CPI(-2))	0.028787	0.043446	0.662600	0.5107
DLOG(CPIEL))	-0.014701	0.002543	-5.780854	0.0000
DLOG(CPIEL(-1)	-0.008716	0.002938	-2.966739	0.0046
DLOG(CPIJAE(-2))	0.270124	0.101303	2.666488	0.0104
DLOG(CPIJAE(-4))	0.319856	0.092157	3.470759	0.0011
DLOG(SPOILUSD*SPUSD))	-0.003485	0.002698	-1.291498	0.2026
CPIJAEDUM3	0.002761	0.002219	1.244645	0.2192
R-squared	0.843588	Mean dependent var	0.004098	
S.E. of regression	0.001940	Akaike info criterion	-9.510072	
Log likelihood	284.7921	Hannan-Quinn criter.	-9.385533	
Durbin-Watson stat	2.116702			

9.8 NOMINAL EFFECTIVE (TRADE WEIGHTED) EXCHANGE RATE

Table 10: Dependent Variable: DLOG(CPIVAL). LS estimation. Sample size: 58 (2000Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
RSHDIFF	-0.004130	0.001306	-3.161233	0.0027
DLOG(SPOILUSD)	-0.078019	0.018103	-4.309665	0.0001
D(RSH)-D(RSW)	-0.032155	0.006173	-5.208998	0.0000
CRISIS08Q4	0.038220	0.019358	1.974336	0.0539
CRISIS09Q1	-0.048873	0.014781	-3.306422	0.0018
CRISIS09Q4	-0.033786	0.014285	-2.365162	0.0219
LOG(CPIVAL(-1))-Constant	-0.093552	0.035472	-2.637352	0.0111
Constant	0.125467	0.035576	3.526717	0.0009
R-squared	0.734491	Mean dependent var	-0.001650	
S.E. of regression	0.013466	Akaike info criterion	-5.649916	
Log likelihood	171.8476	Hannan-Quinn criter.	-5.539214	
Durbin-Watson stat	2.121991			

Notes:
$RSHDIFF = (RSH - @PCY(CPI(-1)) - (RSW - @PCY(PCKONK(-1))$

9.9 KRONE/EURO NOMINAL EXCHANGE RATE

Table 11: Dependent Variable: DLOG(SPEURO). LS estimation. Sample size: 64 (2000Q1 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG((PCKONK*CPIVAL)/CPI)	1.016083	0.105231	9.655741	0.0000
D(RSH)-D(RSW)-DLOG(SPEURO(-1))100	-0.000830	0.000625	-1.327582	0.1893
D(SPOILUSD*(AOIL/Y)	-0.001885	0.000890	-2.117509	0.0384
DLOG(PPIKONK)	0.063924	0.025169	2.539780	0.0132
DLOG(SPUSD)	-0.148503	0.054480	-2.725827	0.0084
R-squared	0.755261	Mean dependent var	0.002047	
Adjusted R-squared	0.743024	S.D. dependent var	0.026677	
S.E. of regression	0.013523	Akaike info criterion	-5.708355	
Log likelihood	186.6674	Hannan-Quinn criter.	-5.655200	
Durbin-Watson stat	1.777219			

9.10 HOUSING STARTS

Table 12: Dependent Variable: DLOG(HS). LS estimation. Sample size: 73 (1996Q1 - 2014Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(HS(-1))	-0.582393	0.096349	-6.044619	0.0000
DLOG(PH/CPI)	0.755043	0.717063	1.052966	0.2963
DLOG(PH(-3)/CPI(-3))	2.660696	0.574610	4.630436	0.0000
LOG(HK(-4))	-0.438330	0.120488	-3.637950	0.0006
f(RUH/YDCD)	-1.713610	0.863094	-1.985427	0.0514
HSDUM	1.022713	0.181947	5.620925	0.0000
Constant	11.81324	2.497173	4.730647	0.0000
CS1	-0.189008	0.049572	-3.812818	0.0003
CS2	-0.096493	0.042657	-2.262067	0.0271
R-squared	0.682353	Mean dependent var	0.004827	
Adjusted R-squared	0.642647	S.D. dependent var	0.190310	
S.E. of regression	0.113765	Akaike info criterion	-1.394357	
Log likelihood	59.89401	Hannan-Quinn criter.	-1.281821	
F-statistic	17.18519	Durbin-Watson stat	2.086786	

Note:
$f(RUH/YDCD) = (0.5(RUH(-4) + RUH(-5))/maYDCD) \cdot HSSTEP(-4)$, where
$maYDCD = 0.25 \sum_{i=4}^{7} YDCD(-i))$

Additional notes

- $HSTEP$ is a step indicator which is zero until 1989q1 and 1 afterwards

9.11 GROSS CAPITAL FORMATION, HOUSING

Table 13: Dependent Variable: DLOG(JBOL). LS estimation. Sample size: 98 (1990Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(HS)	0.252674	0.020076	12.58586	0.0000
DLOG(HS(-1))	0.179474	0.021063	8.521029	0.0000
DLOG(HS(-3))	0.058357	0.020372	2.864625	0.0051
R-squared	0.645715	Mean dependent var	0.006951	
S.E. of regression	0.035967	Akaike info criterion	-3.782314	
Log likelihood	188.3334	Hannan-Quinn criter.	-3.750307	
Durbin-Watson stat	2.280204			

9.12 HOUSING CAPITAL STOCK

Table 14: Dependent Variable: HK-0.998HK(-1). LS estimation. Sample size: 98 (1990Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
$f(HS)$	0.230431	0.035320	6.524053	0.0000
JBOL	0.818914	0.036331	22.54024	0.0000
JBOL(-1)	-0.043506	0.034363	-1.266072	0.2086
UR(-1)	-29.82799	60.80420	-0.490558	0.6249
Constant	-4229.945	400.0005	-10.57485	0.0000
R-squared	0.999999	Mean dependent var	2250225.	
S.E. of regression	423.4965	Akaike info criterion	14.98464	
Log likelihood	-729.2474	Hannan-Quinn criter.	15.03799	
F-statistic	17784189	Durbin-Watson stat	2.046614	
Prob(F-statistic)	0.000000			

Notes:
$f(HS) = HS + 0.6HS(-1) + 0.3HS(-3)$

9.13 GROSS CAPTIAL FORMATION, PRIVATE BUSINESS

Table 15: Dependent Variable: DLOG(JFPN). LS estimation. Sample size: 115 (1988Q2 2016Q4)

DLOG(JFPN(-1))	-0.464527	0.053745	-8.643180	0.0000
RL(-1)-@PCY(PYF(-1)	-0.001636	0.002349	-0.696221	0.4878
D4LOG(YFPBASIS)	1.047651	0.327011	3.203715	0.0018
DLOG(YFPBASIS(-4))	1.283513	0.203288	6.313776	0.0000
DLOG(K2IF(-1)/PYF(-1))	0.608699	0.378620	1.607676	0.1109
LOG((YDFIRMS/PYF)/JFPN(-1))	0.235766	0.054212	4.348987	0.0000
JFPNDUM	0.382934	0.116596	3.284275	0.0014
Constant	-0.227385	0.046460	-4.894213	0.0000
R-squared	0.716760	Mean dependent var	0.007058	
Adjusted R-squared	0.698230	S.D. dependent var	0.155701	
S.E. of regression	0.085532	Akaike info criterion	-2.01282	
Log likelihood	123.7375	Hannan-Quinn criter.	-1.935320	
Durbin-Watson stat	2.045861			

Notes:
$JFPNDUM$ is given in the EViews program file

9.14 CREDIT TO HOUSEHOLDS (C2-INDICATOR)

Table 16: Dependent Variable: DLOG(K2HUS). LS estimation. Sample size: 58 (2000Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(K2HUS(-4)/BGH(-4))	-0.021917	0.013320	-1.645402	0.1057
DLOG(BGH)	0.445050	0.093835	4.742904	0.0000
DLOG(BGH(-1))	0.244485	0.104679	2.335566	0.0233
DLOG(BGH(-2))	0.051397	0.109458	0.469563	0.6406
DLOG(BGH(-3))	0.180454	0.096617	1.867728	0.0672
K2HUSDUM	0.008133	0.001665	4.883348	0.0000
CS1	-0.003611	0.004298	-0.840195	0.4045
CS2	-0.002706	0.001398	-1.934944	0.0582
CS3	-0.002267	0.004488	-0.505167	0.6155
R-squared	0.874182	Mean dependent var	0.021605	
S.E. of regression	0.002581	Akaike info criterion	-8.949585	
Log likelihood	290.9119	Hannan-Quinn criter.	-8.829170	
Durbin-Watson stat	1.837796			

9.15 CREDIT TO NON FINANCIAL FIRMS (C2-INDICATOR)

Table 17: Dependent Variable:DLOG(K2IF/PYF). LS estimation. Sample size: 105 (1988Q2 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.066287	0.010547	6.285036	0.0000
ECM_{K2IF}	-0.048376	0.008094	-5.976585	0.0000
DLOG(K2IF(-1)/PYF(-1))	0.188621	0.067610	2.789830	0.0063
DLOG(YFPBASIS)	0.149550	0.065146	2.295619	0.0237
K2IFDUM	0.987805	0.107836	9.160269	0.0000
CRISIS	0.016779	0.008009	2.094993	0.0386
CS1	0.007397	0.007653	0.966637	0.3360
CS2	0.008348	0.006356	1.313429	0.1920
CS3	-0.003631	0.006098	-0.595537	0.5528
R-squared	0.665845	Mean dependent var	0.008431	
Adjusted R-squared	0.639636	S.D. dependent var	0.025963	
S.E. of regression	0.015586	Akaike info criterion	-5.407325	
Log likelihood	309.1065	Hannan-Quinn criter.	-5.318203	
Durbin-Watson stat	1.730475			

Notes:

$ECM_{K2IF} = LOG(K2IF(-1)/PYF(-1)) - LOG(YF(-1))$
$-0.4LOG(PA(-1)/PYF(-1)) + 0.02(RSH - @PCY(CPI)))$

K2IFDUM is defined in the EViews program file

$CRISIS = CRISIS08Q4 - CRISIS09Q3 - CRISIS09Q4 - CRISIS10Q$

9.16 CREDIT TO LOCAL ADMINISTRATION (C2-INDICATOR)

Table 18: Dependent Variable: DLOG(K2KOM/PYF). LS estimation. Sample size: 106 (1988Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.584735	0.185953	-3.144530	0.0022
LOG(K2KOM(-1)/PYF(-1))	-0.027677	0.015587	-1.775713	0.0789
$f(YF)$	0.064487	0.024555	2.626236	0.0100
D4LOG(YF(-1))+D4LOG(YF(-2))	-0.151561	0.040353	-3.755914	0.0003
CRISIS08Q4+CRISIS09Q1	0.016232	0.012245	1.325606	0.1881
CS1	0.003685	0.004555	0.809045	0.4204
CS2	-0.024985	0.004596	-5.436806	0.0000
CS3	-0.010240	0.004614	-2.219207	0.0288
R-squared	0.443059	Mean dependent var	0.011238	
S.E. of regression	0.016537	Akaike info criterion	-5.293916	
Log likelihood	288.5776	Hannan-Quinn criter.	-5.212444	
F-statistic	11.13729	Durbin-Watson stat	1.546730	
Prob(F-statistic)	0.000000			

Notes:
$f(YF) = LOG(YF + YF(-1) + YF(-2) + YF(-3) + YF(-4))$

9.17 ELECTRICITY PRICE (NORPOOL SYSTEM)

Table 19: Dependent Variable: DLOG(NORPOOL). LS estimation. Sample size: 58 (2000Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(NORPOOL(-1))	-0.201934	0.076875	-2.626766	0.0113
C(1)	5.322299	0.182869	29.10437	0.0000
DLOG(NORPOOL(-4))RIMFROST	-2.888978	0.540466	-5.345342	0.0000
CS1	-0.181821	0.094501	-1.924004	0.0598
CS2	-0.383508	0.094977	-4.037897	0.0002
CS3	-0.320550	0.094445	-3.394023	0.0013
R-squared	0.585068	Mean dependent var	0.004073	
S.E. of regression	0.249700	Akaike info criterion	0.160586	
Log likelihood	1.343019	Hannan-Quinn criter.	0.243611	
Durbin-Watson stat	1.553558			

9.18 MSCI EQUITY PRICE INDEX, NORWAY

Table 20: Dependent Variable: DLOG(PA). LS estimation. Sample size: 123 (1985Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(PAW)	0.808452	0.102217	7.909196	0.0000
LOG(PA(-1)-log(PAW(-1))	-0.068026	0.027225	-2.498611	0.0139
LOG(SPUSD(-1) ×SPOILUSD(-1) /PYF(-1))	0.032219	0.013917	2.315157	0.0224
D(RSH)	-0.024817	0.006117	-4.056783	0.0001
DLOG(SPUSD ×SPOILUSD)	0.201527	0.034090	5.911678	0.0000
D(VOLUSA)	-0.004869	0.001181	-4.124165	0.0001
VOLUSA(-1)	-0.002979	0.000752	-3.960479	0.0001
PADUM	0.986713	0.134094	7.358364	0.0000
Constant	-0.139458	0.085014	-1.640409	0.1037
R-squared	0.813828	Mean dependent var	0.015737	
S.E. of regression	0.048905	Akaike info criterion	-3.142635	
Log likelihood	200.2721	Hannan-Quinn criter.	-3.077626	
F-statistic	84.51314	Durbin-Watson stat	1.828259	
Prob(F-statistic)	0.000000			

Notes:
PADUM is defined is defined in the Eviews program file

9.19 MSCI EQUITY PRICE INDEX, WORLD

Table 21: Dependent variable: (DLOG(PAW)-0.01). LS estimation. Sample size: 123 (1986Q2 2016Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
(DLOG(PAW(-1))-0.01)	0.527534	0.056130	9.398396	0.0000
DLOG(MII/MII(-1))	0.423205	0.262641	1.611347	0.1098
D(VOLUSA)	-0.007471	0.000629	-11.87124	0.0000
VOLUSA(-1)	0.000149	0.000163	0.912919	0.3631
R-squared	0.643818	Mean dependent var	0.01370	
S.E. of regression	0.03946	Akaike info criterion	-3.595049	
Log likelihood	225.0955	Hannan-Quinn criter.	-3.55790	
F-statistic	0	Durbin-Watson stat	2.180061	
Prob(F-statistic)				

9.20 IMPORT PRICE

Table 22: Dependent Variable: DLOG(PB). LS estimation. Sample size: 141 (1982Q2 2017Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
ECM_{PB}	-0.146972	0.044126	-3.330758	0.0011
DLOG(CPIVAL)	0.494432	0.068572	7.210457	0.0000
DLOG(CPIVAL(-1))	0.253218	0.070090	3.612766	0.0004
DLOG(PPIKONK)	1.009032	0.165196	6.108090	0.0000
DUR	-0.004903	0.004540	-1.080011	0.2821
CS2	-0.011856	0.003552	-3.337854	0.0011
PBDUM	1.009032	0.165196	6.108090	0.0000
R-squared	0.520326	Mean dependent var	0.005555	
S.E. of regression	0.016233	Akaike info criterion	-5.348507	
Log likelihood	385.0698	Hannan-Quinn criter.	-5.280520	
Durbin-Watson stat	2.098843			

Notes:
$ECM_{PB} = LOG(LOG(PB(-1) - (PPIKONK(-1)CPIVAL(-1)))$
$+0.3LOG(CPIVAL(-1)PCKONK(-1)/CPI(-1))$

Additional notes

- PBDUM is defind in the Eviews program file.

9.21 FOREIGN CONSUMER PRICE INDEX (TRADE WEIGHTED)

Table 23: Dependent Variable: DLOG(PCKONK). LS estimation. Sample size: 78 (1996Q1 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(PCKONK(-1))	-0.242910	0.115280	-2.107125	0.0385
DLOG(PCEURO)	0.687507	0.041335	16.63261	0.0000
DLOG(PCEURO(-1))	-1.007964	0.431416	-2.336409	0.0209
DLOG(PPIKONK)	0.063924	0.025169	2.539780	0.0132
DDLOG(SPOILUSD)	0.001766	0.001206	1.463563	0.1476
R-squared	0.853246	Mean dependent var	0.003841	
Adjusted R-squared	0.845204	S.D. dependent var	0.003858	
S.E. of regression	0.001518	Akaike info criterion	-10.08109	
Log likelihood	398.1624	Hannan-Quinn criter.	-10.02061	
Durbin-Watson stat	1.647010			

9.22 5 YEAR GOVERNMENT BOND, EFFECTIVE YIELD

Table 24: Dependent Variable: D(RBO). LS estimation. Sample size: 85 (1993Q2 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
ECM_{RBO}	-0.135291	0.050276	-2.690982	0.0087
D(RSH)	0.358426	0.049374	7.259470	0.0000
D(RW)	0.643071	0.077212	8.328634	0.0000
CRISIS08Q4	-0.456468	0.301124	-1.515884	0.1335
Constant	0.019840	0.033035	0.600594	0.5498
R-squared	0.634791	Mean dependent var	-0.074203	
S.E. of regression	0.295229	Akaike info criterion	0.454893	
Log likelihood	-14.33294	Hannan-Quinn criter.	0.512687	
F-statistic	34.76316	Durbin-Watson stat	1.616603	
Prob(F-statistic)	0.000000			

Notes:

$ECM_{RBO} = RBO(-1) - 0.33RSH(-1) - (1 - 0.33)RW(-1)$

9.23 10 YEAR GOVERNMENT BOND, EFFECTIVE YIELD

Table 25: Dependent Variable: D(RBOTENY). LS estimation. Sample size: 116 (1985Q3 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
$ECM_{RBOTENY}$	-0.067143	0.029365	-2.286455	0.0241
D(RBO)	0.859552	0.023176	37.08857	0.0000
D(RBO(-1))	-0.259987	0.078903	-3.295040	0.0013
D(RBOTENY(-1))	0.251857	0.090135	2.794219	0.0061
R-squared	0.931970	Mean dependent var	-0.087479	
S.E. of regression	0.109574	Akaike info criterion	-1.550557	
Log likelihood	93.93230	Hannan-Quinn criter.	-1.512012	
Durbin-Watson stat	1.914420			

Notes:
$ECM_{RBOTENY} = RBOTENY(-1) - RBO(-1) - 0.25$

9.24 AVERAGE INTEREST RATE ON TOTAL BANK LOANS

Table 26: Dependent Variable: D(RL). LS estimation. Sample size: 91 (1993Q2 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
ECM_{RL}	-0.313119	0.024758	-12.89997	0.0000
D(RSH)	0.595611	0.024758	24.05731	0.0000
RLDUM	0.9980	0.060324	16.54515	0.0000
CRISIS09Q1	-0.488450	0.132565	-3.684602	0.0004
R-squared	0.96154	Mean dependent var	-0.100022	
S.E. of regression	0.117466	Akaike info criterion	-0.672106	
Log likelihood	33.56450	Hannan-Quinn criter.	-0.614312	
Durbin-Watson stat	1.413220			

Notes:
$ECM_{RL} = RL(-1) - 0.22RBO(-1) - (1 - 0.22)RSH(-1) - BASELIII + 0.31)$

9.25 MONETARY POLICY INTEREST RATE

Table 27: Dependent Variable: RNBG. LS estimation. Sample size: 53 (2001Q2 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
RNB(-1)	0.750963	0.033651	22.31593	0.0000
IT	0.513477	0.093837	5.472032	0.0000
UAKU	-0.285940	0.056918	-5.023717	0.0000
D(RSW)NBCRIS	0.677940	0.109426	6.195423	0.0000
NBCRIS	-1.201565	0.180487	-6.657360	0.0000
Constant	2.618247	0.276874	9.456444	0.0000
R-squared	0.985941	Mean dependent var	3.165848	
S.E. of regression	0.240705	Akaike info criterion	0.095778	
Log likelihood	3.461890	Hannan-Quinn criter.	0.181553	
Durbin-Watson stat	1.319637			

Notes:
IT= (@PCY(CPIJAE) - 2.5)-$\underset{(0.09)}{0.52}$(@PCY(CPIJAE) - 2.5)NBCRIS

Additional notes

- @PCY(CPIJAE) is EVIEWS code for the annual rate of change in CPIJAE, in percent.
- RNBG is identical to RNB, the sight deposit rate, over the estimation period (The distinction between RNBG and RNB has been made for simulation purposes)
- NBCRIS is a step-dummy which is zero for all periods until 2008q3 and 1 after.

9.26 3-MONTH MONEY MARKET RATE

Table 28: Dependent Variable: D(RSH). LS estimation. Sample size: 69 (1997Q2 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-0.323071	0.075198	-4.296240	0.0001
RSH(-1))	-0.414808	0.081268	-5.104183	0.0000
D(RNB)	0.925780	0.029886	30.97730	0.0000
RNB(-1)	0.347243	0.075409	4.604783	0.0000
D(RSW)	0.303362	0.042574	7.125525	0.0000
RSW(-1)	0.185749	0.026652	6.969463	0.0000
RSHDUM	1.002635	0.175859	5.701350	0.0000
RSHSTEP1	0.466333	0.093931	4.964649	0.0000
RSHSTEP2	-0.354995	0.070100	-5.064120	0.0000
RSHSTEP3	0.422824	0.068378	6.183610	0.0000
R-squared	0.978323	Mean dependent var	-0.024664	
S.E. of regression	0.098304	Akaike info criterion	-1.668217	
Log likelihood	67.55350	Hannan-Quinn criter.	-1.539762	
F-statistic	295.8705	Durbin-Watson stat	2.053645	
Prob(F-statistic)	0.000000			

Additional notes

- The codes for the indicator variables RSHDUM, RSHSTEP1, RSHSTEP2 and RSHSTEP3 are in the Eviews program filefor NAM estimation and simulation.

9.27 5-YEAR FOREIGN GOVERNMENT BOND YIELD

Table 29: Dependent Variable: RW. LS estimation. Sample size: 106 (1988Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.073254	0.231460	4.636894	0.0000
RW(-1)	0.648119	0.068449	9.468654	0.0000
D(RSW)	0.531018	0.117489	4.519734	0.0000
D(RSW(-1))	-0.403448	0.111449	-3.620025	0.0006
RSW(-1)	0.132928	0.037612	3.534180	0.0008
RWDUM	1.052379	0.211484	4.976153	0.0000
RWSTEP14Q2	-0.674345	0.308717	-2.184346	0.0327
R-squared	0.879855	Mean dependent var	4.198242	
S.E. of regression	0.298396	Akaike info criterion	0.515135	
Log likelihood	-10.77215	Hannan-Quinn criter.	0.605054	
F-statistic	75.67358	Durbin-Watson stat	2.104814	
Prob(F-statistic)	0.000000			

Additional notes

- The codes for the indicator variables RWDUM and RWSTEP14Q2 are found in the Eviews program file for NAM estimation and simulation.

9.28 UNEMPLOYMENT RATE (REGISTERED)

Table 30: Dependent Variable: DLOG(UR). LS estimation. Sample size: 144 (1980Q1 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(UR(-1))- LOG(URMEAN(-1))	-0.083494	0.020850	-4.004549	0.0001
DLOG(UR(-1))	0.217697	0.080006	2.721003	0.0074
D3LOG(NW)	-1.007964	0.431416	-2.336409	0.0209
D4(NWPF/NW)	-4.941499	1.178297	-4.193762	0.0000
DD4LOG(BEF1574)	23.32573	18.72896	1.245436	0.2151
CS1	0.217940	0.020715	10.52064	0.0000
CS2	-0.080023	0.017972	-4.452750	0.0000
CS3	0.180642	0.023118	7.813807	0.0000
R-squared	0.740199	Mean dependent var	0.005474	
Adjusted R-squared	0.726826	S.D. dependent var	0.136855	
S.E. of regression	0.071529	Akaike info criterion	-2.383486	
Log likelihood	179.6110	Hannan-Quinn criter.	-2.316444	
Durbin-Watson stat	1.716826			

Notes:
URMEAN is 1.5 until 1982q3, 2.4 until 1996q2
3 until 200q4 and 2.5 after that

9.29 UNEMPLOYMENT RATE (LABOUR FORCE SURVEY)

Table 31: Dependent Variable: DLOG(UAKU). LS estimation. Sample size: 144 (1980Q41 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(UR)	0.792659	0.095609	8.290640	0.0000
LOG(UAKU(-1))-LOG(1.5*URMEAN(-1))	-0.320682	0.058725	-5.460730	0.0000
LOG(UR(-1))- LOG(URMEAN(-1)))	0.197929	0.040855	4.844641	0.0000
DLOG(UAKU(-1))	-0.197136	0.074286	-2.653756	0.0089
DLOG(UAKU(-4))	0.282699	0.067233	4.204789	0.0000
D4(NWPF/NW)	-2.337785	0.438805	-5.327614	0.0000
DLOG(UR(-1)	-0.300121	0.082089	-3.656061	0.0004
DLOG(UR(-4)	-0.434000	0.083837	-5.176723	0.0000
CS1	0.016737	0.032984	0.507420	0.6127
CS2	0.132951	0.024113	5.513682	0.0000
CS3	-0.005159	0.027348	-0.188661	0.8506
R-squared	0.759671	Mean dependent var	0.005101	
Adjusted R-squared	0.741601	S.D. dependent var	0.135000	
Sum squared resid	0.626339	Schwarz criterion	-2.220162	
Log likelihood	187.1856	Hannan-Quinn criter.	-2.354839	
Durbin-Watson stat	1.994292			

Notes:
URMEAN is 1.5 until 1982q3, 2.4 until 1996q2
3 until 200q4 and 2.5 after that

9.30 VALUE ADDED IN MANUFACTURING

Table 32: Dependent Variable: DLOG(YFP1). LS estimation. Sample size: 105 (1990Q1 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(YFP1(-1))-0.6LOG(YDP1DEM(-1))-0.4*LOG(AVPB/PYF)-3.3	-0.274110	0.107535	-2.549017	0.0125
DLOG(ARBDAG)	0.492979	0.049838	9.891724	0.0000
DLYFP1DEM(-1)	0.035026	0.015729	2.226915	0.0285
DLOG(JOIL1)	0.069750	0.020889	3.339003	0.0012
DLOG(JOIL1(-2))	0.118048	0.022838	5.168971	0.0000
DLOG(MII)	0.354976	0.147910	2.399951	0.0185
R-squared	0.903187	Mean dependent var	0.002665	
S.E. of regression	0.023182	Akaike info criterion	-4.603560	
Log likelihood	234.5744	Hannan-Quinn criter.	-4.507538	
Durbin-Watson stat	2.694388			

Additional notes

- $YFP1DEM = 0.10CP + 0.1CO + 0.35JOIL1(-2) + 0.2JFPN + 0.25JBOL + 0.1JO + 0.4ATRAD$
- $AVPB/PYF = 0.5(PB/PYF) + 0.5(PB(-1)/PYF(-1))$.
- $DLYFP1DEM = DLOG(YFP1(-1)) + DLOG(ATRAD) + LOG(JFPN) + DLOG(JBOL(-1))$

9.31 VALUE ADDED PRODUCTION OF OTHER GOODS

Table 33: Dependent Variable: DLOG(YFP2). LS estimation. Sample size: 98 (1990Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(YFP2)	-0.380168	0.080497	-4.722783	0.0000
LOG(YFP2DEM(-1))	0.325461	0.068823	4.728934	0.0000
DLOG(YFP2DEM)	0.251189	0.136151	1.844936	0.0683
DLOG(ARBDAG)	0.342881	0.080590	4.254621	0.0001
CS1	0.012851	0.022225	0.578211	0.5645
CS2	-0.098272	0.018813	-5.223657	0.0000
CS3	0.094983	0.021630	4.391163	0.0000
R-squared	0.930473	Mean dependent var	0.004464	
S.E. of regression	0.027916	Akaike info criterion	-4.250462	
Log likelihood	215.2726	Hannan-Quinn criter.	-4.175779	
Durbin-Watson stat	1.784254			

Additional notes

- $YFP2DEM = 0.25 * ATRAD + 0.85 * CP + 1.0 * JO + 1.1 * JBOL + 0.25 * JFPN + 0.9 * JOIL$

9.32 VALUE ADDED IN PRIVATE SERVICE PRODUCTION

Table 34: Dependent Variable: DLOG(YFP3NET). LS estimation. Sample size: 105 (1985Q1 2014Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
LYFP3ECM(-1)	-0.406222	0.075703	-5.366013	0.0000
DLOG(ARBDAG)				
LOG(YFP3DEM)	0.543317	0.106247	5.113700	0.0000
DLOG(DOMD)	0.066115	0.088673	0.745612	0.4574
DLOG(DOMD(-1))	0.402331	0.089691	4.485727	0.0000
DLOG(YFP3NET(-1)	-0.194076	0.037423	-5.185954	0.0000
DLOG(YFP3NET(-4)	-0.194076	0.037423	-5.185954	0.0000
Constant	-2.112098	0.394885	-5.348647	0.0000
CS1	-0.013479	0.012588	-1.070765	0.2865
CS2	0.045775	0.014347	3.190527	0.0018
CS3	0.046045	0.011244	4.095205	0.0001
R-squared	0.851274	Mean dependent var	0.007858	
S.E. of regression	0.017539	Akaike info criterion	-5.178369	
Log likelihood	327.4697	Hannan-Quinn criter.	-5.094786	
F-statistic	81.56375	Durbin-Watson stat	1.923133	
Prob(F-statistic)	0.000000			

Additional notes

- $LYFP3ECM = LOG(YFP3NET) - 1.1LOG(DOMD) - 0.21LOG(A) - 0.23log(ARBDAG)$

9.33 WAGE AND PRICE SYSTEM (PYF, WPFK AND CPI)

Table 35: Dependent Variable: DLOG(PYF). FIML estimation. Sample size: 140 (1979Q1 2014Q2)

	Coefficient	Std. Error	z-Statistic	Prob.
LOG(PYF(-5))-LOG(WCPFK(-5))+LOG(ZYFP(-5))	-0.065554	0.015426	-4.249676	0.0000
DLOG(WCPFK/ZYFP)	0.085276	0.046057	1.851528	0.0641
D3LOG(WCPFK(-1)/ZYFP(-1))	0.168884	0.044895	3.761742	0.0002
D3LOG(PYF(-1))	-0.428640	0.053909	-7.951173	0.0000
DLOG(PYF(-5))	-0.119154	0.066237	-1.798909	0.0720
DLOG(PB)	0.086662	0.038743	2.236866	0.0253
(1/(UAKU(-1)*UAKU(-1)))	0.129231	0.025776	5.013591	0.0000
T3(-2)	0.313203	0.046344	6.758281	0.0000
CS2	0.012255	0.003918	3.128245	0.0018
CS3	0.019203	0.006230	3.082284	0.0021
Constant	-0.015589	0.004284	-3.639150	0.0003
PYFDUM	1	–	–	–
R-squared	0.762303	Mean dependent var	0.010735	
S.E. of regression	0.011154	Sum squared resid	0.016049	
Durbin-Watson stat	1.896921			

Additional notes

- PYFDUM is given in the code of the Eviews program file for NAM estimation and simulation.

Table 36: Dependent Variable: DLOG(WPFK). FIML estimation. Sample size: 140 (1979Q1 2014Q2)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{WCPFK}	-0.046284	0.007533	-6.143876	0.0000
DLOG(CPI)	0.118956	0.114541	1.038550	0.2990
D3LOG(CPI(-1))	0.293297	0.050216	5.840710	0.0000
D3LOG(WPFK(-1))	-0.276369	0.053693	-5.147244	0.0000
D(T1FK)	-0.048826	0.025349	-1.926174	0.0541
D4LOG(PYF(-1)ZYFP(-1))	0.088626	0.022256	3.982124	0.0001
WBI1	-0.006528	0.001591	-4.104020	0.0000
CS2	0.012345	0.001815	6.801389	0.0000
WPFDUM	1	–	–	–
WPFDUMS1	0.028689	0.005377	5.335464	0.0000
IMR	-0.023383	0.010414	-2.245365	0.0247
R-squared	0.762370	Mean dependent var		0.014199
Adjusted R-squared	0.745918	S.D. dependent var		0.013442
S.E. of regression	0.006776	Sum squared resid		0.005968
Durbin-Watson stat	1.754621			

Notes:
$ECM_{WCPFK} = LOG(WCPFK(-5)) - LOG(ZYFP(-5)) - LOG(PYF(-5))$
$-0.73LOG(CPI(-5)/PYF(-5)) + 0.12LOG(UR(-1)))$

Additional notes

- WPFDUM and WPFDUMS1 are given in the code of the EViews program file.

Table 37: Dependent Variable: DLOG(CPI). FIML estimation. Sample size: 140 (1979Q1 2014Q2)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{CPI}	-0.030801	0.007598	-4.053775	0.0001
DLOG(CPIEL)	0.022972	0.002852	8.055415	0.0000
DLOG(CPIEL(-1))	0.011720	0.002998	3.908638	0.0001
DLOG(PCKONK)	0.477010	0.058137	8.204886	0.0000
DLOG(PYF)	0.095030	0.016688	5.694575	0.0000
DLOG(PYF(-1))	0.044583	0.015902	2.803666	0.0051
(1/(UR(-2)*UR(-2)))	0.012842	0.002867	4.479502	0.0000
T3(-1)	0.120831	0.029463	4.101125	0.0000
CS2	0.001598	0.000880	1.816370	0.0693
CS3	-0.003822	0.000860	-4.444063	0.0000
Constant	-0.003822	0.000860	-4.444063	0.0000
CPIDUM	—	—	—	
R-squared	0.934008	Mean dependent var	0.009530	
S.E. of regression	0.002618	Sum squared resid	0.000884	
Durbin-Watson stat	1.973789			
System statistics:DL(PYF), DL(WPFK), DL(CPI)				
Log likelihood	1017.401	Schwarz criterion	-13.44008	
Avg. log likelihood	2.422384	Hannan-Quinn criter.	-13.82675	
Akaike info criterion	-14.09145			
Determinant residual covariance	3.00E-14			

Notes:
$ECM_{CPI} = LOG(CPI(-1)) - 0.8LOG(PB(-1)) - 0.19LOG(PYF(-1))$
$-0.01LOG(PH(-4))$

Additional notes

- CPIDUM is given in the code of the EViews program file.

9.34 WAGES IN CENTRAL CIVIL ADMINISTRATION

Table 38: Dependent Variable: DLOG(WHGSC). LS estimation. Sample size: 80 (1996Q1 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WPFK/WPFK(-4))	0.239356	0.017918	13.35855	0.0000
OPPGJ	0.010085	0.003295	3.060395	0.0030
WHGSCDUM	1.034776	0.150090	6.894357	0.0000
R-squared	0.407250	Mean dependent var	0.010380	
Adjusted R-squared	0.391854	S.D. dependent var	0.009446	
S.E. of regression	0.007366	Akaike info criterion	-6.947011	
Log likelihood	280.8804	Hannan-Quinn criter.	-6.911197	
Durbin-Watson stat	1.952737			

Notes:
OPPGJ and WHGSCDUM are defined in the code of the EViews program file.

9.35 WAGES IN LOCAL ADMINISTRATION

Table 39: Dependent Variable: DLOG(WHGL). LS estimation. Sample size: 80 (1996Q1 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WHGL(-1))-LOG(WHGSC(-1))	-0.551900	0.098260	-5.616740	0.0000
DLOG(WHGSC)	0.962780	0.047136	20.42546	0.0000
WHGLDUM	0.966285	0.229935	4.202418	0.0001
R-squared	0.728950	Mean dependent var	0.010097	
Adjusted R-squared	0.722174	S.D. dependent var	0.011285	
S.E. of regression	0.005948	Akaike info criterion	-7.376058	
Log likelihood	309.1064	Hannan-Quinn criter.	-7.340934	
Durbin-Watson stat	1.868962			

Notes:
WHGLDUM is defined in the code of the EViews program file.

9.36 HOUSING PRICES AND CREDIT TO HOUSEHOLDS

Table 40: Dependent Variable: DLOG(PH). FIML estimation. Sample size: 102 (1989Q1 2015Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{PH}	-0.082154	0.018186	-4.517518	0.0000
DLOG(BGH)	1.073444	0.215455	4.982218	0.0000
DLOG(PH(-4)/CPI(-4))	0.300121	0.074807	4.011939	0.0001
DLOG(BGH(-4)/CPI(-4))	-0.165424	0.161580	-1.023790	0.3059
PHDUM	1.662762	0.329616	5.044548	0.0000
CS1	0.032792	0.007819	4.194168	0.0000
CS2	0.022246	0.006206	3.584403	0.0003
CS3	0.017461	0.006605	2.643702	0.0082
Constant	-0.868869	0.193564	-4.488791	0.0000
R-squared	0.723700	Mean dependent var	0.013471	
S.E. of regression	0.028302	Sum squared resid	0.020105	
Durbin-Watson stat	0.023460			

Notes:

$ECM_{PH} = LOG(PH(-1)/CPI(-1)) - 0.87LOG(BGH(-1)/CPI(-1))$
$+0.15(LOG(0.6HS(-1) + 0.4HS(-2)) - LOG(BEF1574(-1)))$
$+0.26((1/(1 + EXP(-200.0(RUH(-1)/(YDCD(-1) + RUH(-1)) - 0.13)))$
$+0.09((1/(1 + EXP(-50(0.6 * UAKU(-1) + 0.4 * UAKU(-2) - 0.13)))$

Additional notes

- PHDUM and CRISIS08Q4 are given in the code of the EViews program file.

Table 41: Dependent Variable: DLOG(BGH). FIML estimation. Sample size: 102 (1989Q1 2015Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{BGH}	-0.024302	0.004290	-5.664632	0.0000
DLOG(BGH(-1)/CPI(-1))	0.118699	0.054492	2.178269	0.0294
DLOG(BGH(-2)/CPI(-2))	0.190316	0.033543	5.673888	0.0000
DLOG(BGH(-3)/CPI(-3))	0.122317	0.038199	3.202108	0.0014
BGHDUM	4.205258	0.410062	10.25518	0.0000
CS1	-0.017856	0.002268	-7.873968	0.0000
CS2	0.003202	0.002047	1.564262	0.1178
CS3	-0.014250	0.002788	-5.110468	0.0000
Constant	0.292930	0.050347	5.818221	0.0000
R-squared	0.894610	Mean dependent var	0.016429	
S.E. of regression	0.005600	Sum squared resid	0.003011	
Durbin-Watson stat	1.729360			
System statistics:DL(PH), DL(BGH)				
Log likelihood	-699.6699	Schwarz criterion	13.99504	
Avg. log likelihood	-3.269486	Hannan-Quinn criter.	13.68312	
Akaike info criterion	13.47047			
Determinant residual covariance	6.17E-09			

Notes:

$ECM_{BGH} = -0.88 * LOG(PH(-1)/CPI(-1)) + LOG(BGH(-1)/CPI(-1))$
$+0.88 * (LOG(YDCD(-1)/CPI(-1)) - LOG(HK(-1)))$
$+0.167RL(-1) * (1 - T2CAP) - (CPI(-1) - CPI(-5)) * 100/CPI(-5))$

9.37 WAGE INCOME TO HOUSEHOLDS

Table 42: Dependent Variable: LOENNH. LS estimation. Sample size: 55 (2002Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
(WFK/HPF)*(TWF+TWOSJ)	0.482411	0.000622	775.1321	0.0000
R-squared	0.998310	Mean dependent var	263422.3	
Adjusted R-squared	0.998310	S.D. dependent var	62994.55	
S.E. of regression	2590.007	Akaike info criterion	18.57472	
Log likelihood	-509.8049	Hannan-Quinn criter.	18.58884	
Durbin-Watson stat	1.233191			

9.38 INCOME FROM OPERATING SURPLUS TO HOUSEHOLDS

Table 43: Dependent Variable: $\Delta log(DRIFTH)$. LS estimation. Sample size: 55 (2002Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	4.667206	2.296616	2.032210	0.0476
LOG(WFK))	0.360493	0.089234	4.039851	0.0002
LOG(TSF)	0.801082	0.435120	1.841062	0.0717
CS1	-0.049966	0.031097	-1.606761	0.1145
CS2	-0.231194	0.034264	-6.747465	0.0000
CS3	0.167435	0.044568	3.756886	0.0005
R-squared	0.815263	Mean dependent var	10.16583	
Adjusted R-squared	0.796412	S.D. dependent var	0.160858	
S.E. of regression	0.072580	Akaike info criterion	-2.305575	
Log likelihood	69.40332	Hannan-Quinn criter.	-2.220893	
F-statistic	43.24840	Durbin-Watson stat	0.855457	
Prob(F-statistic)	0.000000			

9.39 INCOME FROM INTEREST, HOUSEHOLDS

Table 44: Dependent Variable: RENTEINNH. LS estimation. Sample size: 55 (2002Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	81.55221	55.64797	1.465502	0.1487
RIH	0.565867	0.005400	104.7911	0.0000
R-squared	0.995197	Mean dependent var	5564.327	
Adjusted R-squared	0.995106	S.D. dependent var	2009.217	
S.E. of regression	140.5575	Akaike info criterion	12.76480	
Log likelihood	-349.0319	Hannan-Quinn criter.	12.79302	
F-statistic	10981.17	Durbin-Watson stat	0.429738	
Prob(F-statistic)	0.000000			

9.40 INTEREST PAYMENTS, HOUSEHOLDS

Table 45: Dependent Variable: RENTEUTH. LS estimation. Sample size: 55 (2002Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	57.06180	134.7676	0.423409	0.6737
RUH	0.923558	0.005419	170.4339	0.0000
R-squared	0.998179	Mean dependent var	22257.25	
Adjusted R-squared	0.998144	S.D. dependent var	5952.479	
S.E. of regression	256.4147	Akaike info criterion	13.96716	
Log likelihood	-382.0968	Hannan-Quinn criter.	13.99538	
F-statistic	29047.71	Durbin-Watson stat	1.348442	
Prob(F-statistic)	0.000000			

9.41 TAXES ON INCOME AND WEALTH, HOUSEHOLDS

Table 46: Dependent Variable: SKATTH. LS estimation. Sample size: 55 (2002Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-8135.713	1380.888	-5.891652	0.0000
INNT	0.237532	0.004688	50.67123	0.0000
SKATTNED14*INNT	-0.009954	0.002126	-4.680975	0.0000
R-squared	0.986365	Mean dependent var	63727.49	
Adjusted R-squared	0.985840	S.D. dependent var	13957.84	
S.E. of regression	1660.895	Akaike info criterion	17.72110	
Log likelihood	-484.3303	Hannan-Quinn criter.	17.76344	
F-statistic	1880.846	Durbin-Watson stat	1.068916	
Prob(F-statistic)	0.000000			

Notes:
$INNT = LOENNH + PENSJONH + RENTEINNH - RENTEUTH$
+RESINNTH+DRIFTH

Additional notes

- SKATTNED14 is a step dummy related to the general reductuon in income tax i 2014. Code is in the Eviews program file.

9.42 HOURS WORKED BY WAGE EARNERS IN PRIVATE SECTOR MAINLAND-NORWAY

Table 47: Dependent Variable: DLOG(TWPF). LS estimation. Sample size: 148 (1980Q1 2016Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(TWPF(-1))	-0.155004	0.038632	-4.012281	0.0001
DLOG(ARBDAG)	0.726334	0.050956	14.25419	0.0000
DLOG(YFP1+YFP2+YFP3)	0.186544	0.041694	4.474151	0.0000
DLOG(YFP1(-1)+YFP2(-1)+YFP3(-1))	0.156187	0.034467	4.531442	0.0000
LOG(YFP1(-1) +YFP2(-1)+YFP3(-1))	0.090590	0.021033	4.306955	0.0000
LOG(WCPFK/PYF)	-0.206805	0.051626	-4.005809	0.0001
DLOG(TWPF(-1))-DLOG(TWPF(-4))	-0.167913	0.028911	-5.807979	0.0000
CS1	0.054043	0.009891	5.463739	0.0000
CS2	0.078934	0.011821	6.677340	0.0000
CS3	0.046642	0.012300	3.792143	0.0002
Constant	0.021996	0.081025	0.271475	0.7864
R-squared	0.973085	Mean dependent var	0.001696	
Adjusted R-squared	0.971121	S.D. dependent var	0.085614	
S.E. of regression	0.014549	Akaike info criterion	-5.5511439	
Log likelihood	421.7846	Hannan-Quinn criter.	-5.458437	
F-statistic	-5.4606348	Durbin-Watson stat	2.346482	
Prob(F-statistic)	0.000000			

9.43 HOURS WORKED IN GOVERNMENT ADMINISTRATION

Table 48: Dependent Variable: LOG(TWO). LS estimation. Sample size: 143 (1980Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(CO)	0.631010	0.010350	60.96930	0.0000
Contant	-2.023529	0.120496	-16.79327	0.0000
CS1	-0.005200	0.007952	-0.653896	0.5143
CS2	-0.048979	0.007953	-6.158303	0.0000
CS3	-0.156380	0.007952	-19.66444	0.0000
R-squared	0.99686	Mean dependent var	5.320667	
Adjusted R-squared	0.967697	S.D. dependent var	0.18637	
S.E. of regression	0.033497	Akaike info criterion	-3.920370	
Log likelihood	285.3064	Hannan-Quinn criter.	-3.878273	
F-statistic	1064.481	Durbin-Watson stat	0.957064	
Prob(F-statistic)	0.000000			

9.44 HOURS WORKED IN OIL AND GAS AND INTERNATIONAL TRANSPORT

Table 49: Dependent Variable: LOG(TWOSJ). LS estimation. Sample size: 103 (1990Q1 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.320253	0.265081	1.208132	0.2299
LOG(maJOIL1)	0.024263	0.009478	2.559927	0.0120
DLOG(ARBDAG)	0.437327	0.029791	14.68001	0.0000
LOG((SPOILUSD*SPUSD)/PYF)	0.024263	0.009478	2.559927	0.0120
LOG(YUSF)	0.027493	0.012027	2.285982	0.0244
LOG(TWOSJ(-1))	0.695425	0.052339	13.28702	0.0000
R-squared	0.788654	Mean dependent var	3.328178	
Adjusted R-squared	0.780028	S.D. dependent var	0.056943	
S.E. of regression	0.026707	Akaike info criterion	-4.360472	
Log likelihood	229.5643	Hannan-Quinn criter.	-4.308668	
F-statistic	91.42389	Durbin-Watson stat	2.025738	
Prob(F-statistic)	0.000000			

Notes:
LOG(maJOIL1)=LOG(JOIL1+JOIL1(-1)+JOIL1(-2)+JOIL1(-3)+JOIL1(-4)+0.9*JOIL1(-5)
+JOIL1(-4)+0.9JOIL1(-5)

9.45 WAGE EARNERS IN PRIVATE MAINLAND-NORWAY

Table 50: Dependent Variable: DLOG(NWPF). LS estimation. Sample size: 152 (1979Q1 2016Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
D4LOG(TWPF)	0.749273	0.029860	25.09307	0.0000
D4LOG(ARBDAG)	-0.661784	0.029960	-22.08918	0.0000
D3LOG(NWPF(-1))	-0.784908	0.033531	-23.40848	0.0000
LOG(NWPF(-4))-LOG(TWPF(-4)/ARBDAG(-4))	-0.091092	0.020062	-4.540425	0.0000
Constant	0.462443	0.101271	4.566387	0.0000
R-squared	0.826627	Mean dependent var	0.002296	
Adjusted R-squared	0.821909	S.D. dependent var	0.015543	
Sum squared resid	0.006324	Schwarz criterion	-7.084071	
Log likelihood	550.9491	Hannan-Quinn criter.	-7.1431335	
Durbin-Watson stat	1.256639			

9.46 WAGE EARNERS IN GOVERNMENT ADMINISTRATION

Table 51: Dependent Variable: DLOG(NWO). LS estimation. Sample size: 84 (1995Q1 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(NWO(-1))-LOG(TWO(-1))	-0.093436	0.027697	-3.373551	0.0012
DLOG(TWO)	0.289707	0.052860	5.480663	0.0000
DLOG(NWO(-1))	-0.122557	0.083799	-1.462513	0.1478
DLOG(NWO(-2))	-0.302069	0.069770	-4.329476	0.0000
DLOG(ARBDAG)	-0.162165	0.049841	-3.253654	0.0017
Constant	0.102585	0.029182	3.515383	0.0007
CS1	0.004731	0.004126	1.146629	0.2552
CS2	0.010864	0.004709	2.307004	0.0238
CS3	0.025297	0.005268	4.802259	0.0000
R-squared	0.570277	Mean dependent var	0.003762	
Adjusted R-squared	0.524440	S.D. dependent var	0.008166	
S.E. of regression	0.005631	Akaike info criterion	-7.419986	
Log likelihood	320.6394	Hannan-Quinn criter.	-7.315290	
F-statistic	12.44137	Durbin-Watson stat	2.097328	
Prob(F-statistic)	0.000000			

9.47 WAGE EARNERS IN OIL AND GAS PRODUCTION AND INTERNATIONAL TRANSPORTATION

Table 52: Dependent Variable: LOG(NWOSJ). LS estimation. Sample size: 104 (1990Q1 2015Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.135493	0.216239	0.626590	0.5324
LOG(TWOSJ)	0.374129	0.116585	3.209058	0.0018
LOG(TWOSJ(-1))	-0.457876	0.105546	-4.338152	0.0000
LOG(TWOSJ(-3))	0.218979	0.059360	3.689022	0.0004
LOG(NWOSJ(-1))	0.857231	0.048449	17.69338	0.0000
DLOG(ARBDAG)	-0.307250	0.061535	-4.993087	0.0000
R-squared	0.880512	Mean dependent var		4.081254
Adjusted R-squared	0.874416	S.D. dependent var	0.0876426	
S.E. of regression	0.031058	Akaike info criterion	-4.0499276	
Log likelihood	216.5962	Hannan-Quinn criter.	-3.988120	
F-statistic	144.4333	Durbin-Watson stat	2.373739	
Prob(F-statistic)	0.000000			

9.48 AVERAGE WORKING TIME FOR WAGE EARNERS IN PRIVATE MAINLAND-NORWAY

Table 53: Dependent Variable: DLOG(FHWPF). LS estimation. Sample size: 142 (1980Q2 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(ARBDAG)	0.869780	0.031341	27.75176	0.0000
DLOG(YFPBASIS(-1)/TWPF(-1))	0.187150	0.039028	4.795219	0.0000
DLOG(NH)	0.567471	0.273229	2.076906	0.0397
CS1	0.009951	0.006535	1.522650	0.1302
CS2	0.009404	0.007106	1.323487	0.1879
CS3	-0.021383	0.007414	-2.884318	0.0046
R-squared	0.982140	Mean dependent var	-0.001553	
Adjusted R-squared	0.981484	S.D. dependent var	0.093835	
S.E. of regression	0.012769	Akaike info criterion	-5.842309	
Log likelihood	420.8040	Hannan-Quinn criter.	-5.791558	
Durbin-Watson stat	2.680020			

9.49 AVERAGE WORKING TIME FOR SELF EMPLOYED

Table 54: Dependent Variable: DLOG(FHSF). LS estimation. Sample size: 82 (1995Q2 2015Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(FHWPF)	0.846155	0.033833	25.00995	0.0000
CS1	-0.000248	0.005504	-0.045023	0.9642
CS2	0.002447	0.006914	0.353959	0.7243
CS3	0.004745	0.007293	0.650663	0.5172
R-squared	0.979505	Mean dependent var		-0.001666
Adjusted R-squared	0.978717	S.D. dependent var	0.070316	
S.E. of regression	0.010258	Akaike info criterion	-6.273932	
5				
Log likelihood	261.2312	Hannan-Quinn criter.	-6.226797	
Durbin-Watson stat	2.188091			

A APPROXIMATION TO AN UNKNOWN DYNAMIC FUNCTION

This appendix draws on Bårdsen et al. (2004).

A.1 LINEARIZATION

Consider a very simple example of an economic model in the form of the differential equation

$$\frac{dy}{dt} = f(y, x) \ , \qquad x = x(t) \ , \tag{73}$$

in which a constant input $x = \bar{x}$ induces $y(t)$ to approach asymptotically a constant state $\bar{y}$ as $t \to \infty$. Clearly $\bar{x}$ and $\bar{y}$ satisfy $f(\bar{y}, \bar{x}) = 0$. For example, standard DSGE models usually take this form, with the models having deterministic steady state values. The usual procedure then is to expand the differential (or difference) equation about this steady-state solution (see, for example, Campbell (1994) or Uhlig (1999)). Employing this procedure yields

$$f(y, x) = f(\bar{y}, \bar{x}) + \frac{\partial f(\bar{y}, \bar{x})}{\partial y}(y - \bar{y}) + \frac{\partial f(\bar{y}, \bar{x})}{\partial x}(x - \bar{x}) + R \tag{74}$$

where

$$R = \frac{1}{2!}\left(\frac{\partial^2 f(\xi, \eta)}{\partial x^2}(x - \bar{x})^2 + 2\frac{\partial^2 f(\xi, \eta)}{\partial x \partial y}(x - \bar{x})(y - \bar{y}) + \frac{\partial^2 f(\xi, \eta)}{\partial y^2}(y - \bar{y})^2\right)$$

and (ξ, η) is a point such that ξ lies between y and $\bar{y}$ while η lies between x and $\bar{x}$. Since $\bar{y}$ and $\bar{x}$ are the steady-state values for y and x respectively, then the expression for $f(y, x)$ takes the simplified form

$$f(y, x) = a\,(y - \bar{y}) + \delta\,(x - \bar{x}) + R \tag{75}$$

where $a = \partial f(\bar{y}, \bar{x})/\partial y$ and $\delta = \partial f(\bar{y}, \bar{x})/\partial x$ are constants.

If f is a linear function of y and x then $R = 0$ and so

$$f(x, y) = a\left(y - \bar{y} + \frac{\delta}{a}(x - \bar{x})\right) = a\,(y - bx - c) \ , \tag{76}$$

in which $b = -\delta/a$ and $c = \bar{y} + (\delta/a)\bar{x}$.

A.2 DISCRETIZATION

For a macroeconometric model, a discrete representation is usually practical, and it can be worked out as follows. Let $t_1,\ t_2,\ \cdots,\ t_k,\ \cdots$ be a sequence of times spaced h apart and let $y_1,\ y_2,\ \cdots,\ y_k,\ \cdots$ be the values of a continuous real variable $y(t)$ at these times. The backward-difference operator $\triangle$ is defined by the rule

$$\triangle y_k = y_k - y_{k-1} \ , \qquad k \geq 1 \ . \tag{77}$$

By observing that $y_k = (1-\triangle)^0 y_k$ and $y_{k-1} = (1-\triangle)^1 y_k$, the value of y at the intermediate point $t = t_k - sh$ $(0 < s < 1)$ may be estimated by the interpolation formula

$$y(t_k - sh) = y_{k-s} = (1-\triangle)^s y_k\,, \qquad s \in [0,1]\,. \tag{78}$$

When s is not an integer, $(1-\triangle)^s$ should be interpreted as the power series in the backward-difference operator obtained from the binomial expansion of $(1-x)^s$. This is an infinite series of differences. Specifically

$$(1-\triangle)^s = 1 - s\triangle - \frac{s(1-s)}{2!}\triangle^2 - \frac{s(1-s)(2-s)}{3!}\triangle^3 - \cdots. \tag{79}$$

With this preliminary background, the differential equation

$$\frac{dy}{dt} = f(y,x)\ , \qquad x = x(t)\ , \tag{80}$$

may be integrated over the time interval $[t_k, t_{k+1}]$ to obtain

$$y(t_{k+1}) - y(t_k) = \triangle y_{k+1} = \int_{t_k}^{t_{k+1}} f(y(t), x(t))\, dt \tag{81}$$

in which the integral on the right hand side of this equation is to be estimated by using the backward-difference interpolation formula given in equation (79). The substitution $t = t_k + sh$ is now used to change the variable of this integral from $t \in [t_k, t_{k+1}]$ to $s \in [0,1]$. The details of this change of variable are

$$\int_{t_k}^{t_{k+1}} f(y(t), x(t))\, dt = \int_0^1 f(y(t_k+sh), x(t_k+sh))\,(h\,ds) = h\int_0^1 f_{k+s}\, ds$$

where $f_{k+s} = f(y(t_k+sh), x(t_k+sh))$. The value of this latter integral is now computed using the interpolation formula based on (79). Thus

$$\begin{aligned}
\int_0^1 f_{k+s}\, ds &= \int_0^1 (1-\triangle)^{-s} f_k\, ds \\
&= \int_0^1 \left(f_k + s\triangle f_k + \frac{s(1+s)}{2!}\triangle^2 f_k + \frac{s(1+s)(2+s)}{3!}\triangle^3 f_k + \cdots \right) ds \\
&= f_k + \frac{1}{2}\triangle f_k + \frac{5}{12}\triangle^2 f_k + \frac{3}{8}\triangle^3 f_k + \cdots\,.
\end{aligned}$$

The final form for the backward-difference approximation to the solution of this differential equation is therefore

$$\triangle y_{k+1} = h f_k + \frac{h}{2}\triangle f_k + \frac{5h}{12}\triangle^2 f_k + \frac{3h}{8}\triangle^3 f_k + \cdots\,. \tag{82}$$

A.3 EQUILIBRIUM CORRECTION REPRESENTATIONS AND COINTEGRATION

The discretization scheme (82) applied to the linearized model (75), with $k = t - 1$ and $h = 1$, gives the equilibrium correction model, ECM, representation

$$\begin{aligned}\triangle y_t = a\,(y - bx - c)_{t-1} + R_{t-1} + \frac{1}{2}\,a(\triangle y_{t-1} - b\,\triangle x_{t-1}) + \frac{1}{2}\,\triangle R_{t-1} \\ + \frac{5}{12}\,a(\triangle^2 y_{t-1} - b\,\triangle^2 x_{t-1}) + \frac{5}{12}\,\triangle^2 R_{t-1} + \cdots .\end{aligned}$$

A.4 SYSTEM REPRESENTATIONS

The approach easily generalizes to a system representation. For ease of exposition, we illustrate the two-dimensional case for which $y_1 \to \bar{y}_1$ and $y_2 \to \bar{y}_2$ as $t \to \infty$. Expanding with respect to y_1 and y_2 about their steady-state values yields

$$\begin{bmatrix} f_1\left(y_1, y_2\right) \\ \\ f_2\left(y_1, y_2\right) \end{bmatrix} = \begin{bmatrix} f_1\left(\bar{y}_1, \bar{y}_2\right) \\ \\ f_2\left(\bar{y}_1, \bar{y}_2\right) \end{bmatrix} + \begin{bmatrix} \dfrac{\partial f_1(\bar{y}_1, \bar{y}_2)}{\partial y_1} & \dfrac{\partial f_1(\bar{y}_1, \bar{y}_2)}{\partial y_2} \\ \dfrac{\partial f_2(\bar{y}_1, \bar{y}_2)}{\partial y_1} & \dfrac{\partial f_2(\bar{y}_1, \bar{y}_2)}{\partial y_2} \end{bmatrix} \begin{bmatrix} y_1 - \bar{y}_1 \\ \\ y_2 - \bar{y}_2 \end{bmatrix} + \begin{bmatrix} R_1 \\ \\ R_2 \end{bmatrix},$$

where $[R_1, R_2]'$ denotes the vector

$$\frac{1}{2!}\begin{bmatrix} \dfrac{\partial^2 f_1(\zeta,\eta)}{\partial y_1^2}\left(y_1 - \bar{y}_1\right)^2 + 2\dfrac{\partial^2 f_1(\zeta,\eta)}{\partial y_1 \partial y_2}\left(y_1 - \bar{y}_1\right)\left(y_2 - \bar{y}_2\right) + \dfrac{\partial^2 f_1\left(\zeta,\eta\right)}{\partial y_2^2}\left(y_2 - \bar{y}_2\right)^2 \\ \dfrac{\partial^2 f_2\left(\zeta,\eta\right)}{\partial y_1^2}\left(y_1 - \bar{y}_1\right)^2 + 2\dfrac{\partial^2 f_2\left(\zeta,\eta\right)}{\partial y_1 \partial y_2}\left(y_1 - \bar{y}_1\right)\left(y_2 - \bar{y}_2\right) + \dfrac{\partial^2 f_2\left(\zeta,\eta\right)}{\partial y_2^2}\left(y_2 - \bar{y}_2\right)^2 \end{bmatrix}$$

so that

$$\begin{bmatrix} \dfrac{\partial y_1}{\partial t} \\ \dfrac{\partial y_2}{\partial t} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} y_1 - \bar{y}_1 \\ \\ y_2 - \bar{y}_2 \end{bmatrix} + \begin{bmatrix} R_1 \\ \\ R_2 \end{bmatrix}.$$

The backward-difference approximation to the solution of the system of differential equations gives the system in ECM form[42], namely,

$$\begin{bmatrix} \triangle y_1 \\ \triangle y_2 \end{bmatrix}_t = \begin{bmatrix} -\alpha_{11}c_1 \\ -\alpha_{22}c_2 \end{bmatrix} + \begin{bmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{bmatrix} \begin{bmatrix} y_1 - \delta_1 y_2 \\ y_2 - \delta_2 y_1 \end{bmatrix}_{t-1} + \begin{bmatrix} R_1 \\ \\ R_2 \end{bmatrix}_{t-1}$$
$$+ \frac{1}{2} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} \Delta y_1 \\ \Delta y_2 \end{bmatrix}_{t-1} + \begin{bmatrix} \Delta R_1 \\ \\ \Delta R_2 \end{bmatrix}_{t-1}$$
$$+ \frac{5}{12} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} \Delta^2 y_1 \\ \Delta^2 y_2 \end{bmatrix}_{t-1} + \begin{bmatrix} \Delta^2 R_1 \\ \\ \Delta^2 R_2 \end{bmatrix}_{t-1}$$
$$+ \frac{3}{8} \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} \Delta^3 y_1 \\ \Delta^3 y_2 \end{bmatrix}_{t-1} + \begin{bmatrix} \Delta^3 R_1 \\ \\ \Delta^3 R_2 \end{bmatrix}_{t-1} + \cdots .$$

with

$$c_1 = (\bar{y}_1 + \delta_1 \bar{y}_2), \quad \delta_1 = \tfrac{\alpha_{12}}{\alpha_{11}}$$
$$c_2 = (\bar{y}_2 + \delta_2 \bar{y}_1), \quad \delta_2 = \tfrac{\alpha_{21}}{\alpha_{22}}$$

As noted above, the variables y_1 and y_2 can be considered as stationary functions of non-stationary components—cointegration is imposed upon the system. Consider the previous example, assuming linearity, so $R_i = 0$, and ignoring higher order dynamics for ease of exposition:

$$\begin{bmatrix} \triangle y_1 \\ \triangle y_2 \end{bmatrix}_t = \begin{bmatrix} -\alpha_{11}c_1 \\ -\alpha_{22}c_2 \end{bmatrix} + \begin{bmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{bmatrix} \begin{bmatrix} y_1 - \delta_1 y_2 \\ y_2 - \delta_2 y_1 \end{bmatrix}_{t-1}$$
$$\begin{bmatrix} \triangle(rw - \beta z) \\ \Delta^2 z \end{bmatrix}_t = \begin{bmatrix} -\alpha_{11}c_1 \\ -\alpha_{22}c_2 \end{bmatrix} + \begin{bmatrix} \alpha_{11} & 0 \\ 0 & \alpha_{22} \end{bmatrix} \begin{bmatrix} (rw - \beta z) - \delta_1 \Delta z \\ \Delta z - \delta_2 (rw - \beta z) \end{bmatrix}_{t-1}$$

or multiplied out:

$$\triangle rw_t = -\alpha_{11}c_1 + \alpha_{11}(rw - \beta z)_{t-1} + \beta \Delta z_t - \alpha_{12}\Delta z_{t-1}$$
$$\Delta z_t = -\alpha_{22}\left(\bar{y}_2 + \frac{\alpha_{21}}{\alpha_{22}}\bar{y}_1\right) + (\alpha_{22} - 1)\ \Delta z_{t-1} - \alpha_{21}(rw - \beta z)_{t-1}$$

So if $\alpha_{21} = 0$ and $|\alpha_{22} - 1| < 1$ the system simplifies to the familiar exposition of a bivariate cointegrated system with z being weakly exogenous for β:

$$\triangle rw_t = -\alpha_{11}c_1 + \alpha_{11}(rw - \beta z)_{t-1} + \beta \Delta z_t - \alpha_{12}\Delta z_{t-1}$$
$$\Delta z_t = -\alpha_{22}\,\bar{z} + (\alpha_{22} - 1)\ \Delta z_{t-1}$$

and where the common trend is a productivity trend.

[42] See Bårdsen et al. (2004) for details.

B REVISION LOG

17 November 2015. Model updated with data until 2015q2, to include simulation start in 2015q3.

6 November 2015. Model for gross capital formation in private business sector in Mainland-Norway, $JFPN$, revised to distinguish between short-run effects of credit expansion (positive) and long term negative effects of high debt relative to nominal valued added creation. Other core aspects of the econometric equation: Market growth (sales opportunities for new capacity) and real interest rate, was unaffected by the the revision.

22 November 2015. Imports (B) and import prices index (PB). Model for import prices reestimated in the light of revised data series for foreign producer prices ($PPIKONK$). No significant changes to the equation. Model for import volume (B) changed to include calibrated (by Statistics Norway) import-propensities for the different components of aggregate demand.

12 December 2015. Respecified model for MSCI (stock price indices) for Norway (PA) and "world" (PAW). Main effect is to tie down the drift-term of $log(PAW)$ to 4 %. $log(PA)$ is cointegrated with $log(PAW)$ as before, and affected by the real oil price.

5 February 2016. Respecified model of $YFP3NET$. Use domestic demand ($DOMD$) as main explanatory variable. Effect is to improve forecast performance. Previous version overestimated trend.

6 February 2016. Minor change in specification of model for $K2HUS$

6 February 2016. Minor respecification of system for PH and BGH.

19 February 2016. Major model revision. a) Private disposable income modelled in terms of $LOENNH, DRIFTH, RENTEINNH, RENTEUTH, SKATTH$.

b) Hours worked ('man hours') variables (endogenous): $TWPF, TWO, TWOSJ$

c) Number of employed wage earners (endogenous): $NWPF, NWO, FHWOSF, NWOSJ$ and total and number of self-employed.

As a consequence, labour productivity $ZYFP$ and ZYF are now endogeous by definitional equations. And the number of employed wage earners (in private mainland economy, government administration, petroleum sector) and self-employed are also endogenous by definitional equations. Another consequence is that models for UR and $UAKU$ have been re-specified with the aid of the new included employment variables.

14 May 2016 Variable RW (Euro area 10-year Government Benchmark bond yield) calculated as mean of three months in quarter instead of as the third month observation of each quarter.

19 May 2016 Minor change in specification of UR-equation. Tables with estimation results for WHGSC (wage level in central administration) and WHGL (wage level in local administration) added.

21 June 2016 $PCKONK$ changed status from exogenous to endogenous. Modelled in terms of $PCEURO$ (the euro area consumer price index) which is a new exogenous variable, and $PPIKONK$ and $SPOILUSD$. (existing variables).

15 September 2016 Model updated with data that allows simulation start in 2015q3.

26 October 2016 Threshold coefficients for consumption function and housing price and loans sub-system renamed: CPTRH -> THCP, PHTRH1 -> THPHRUH, PHTRH2 -> THPHAKU.

17 November 2016 Re-estimation of model for $ATRAD$ with data that ends in 2016(3). Motivation: Model overestimated $ATRAD$ significantly so far in 20016. Result: Same long-run relationship, but longer lag in the real exchange rate. Introduced negatively signed step-dummy ($ACOSTCUT$) for three quarters in 2016. Tentative interpretation is that 2016 has been a 'cost cut year' for oil related businesses, and that development of new products for new world market segments may have suffered.

28 February 2017 Re-specification of $JFPFN$ that includes a measure of 'disposable income', $YDFIRMS$ to firms. $YDFIRM$ is therefore a new definition variable in the model.

18 May 2017 Renaming of two definition variables: $PBGR$ changed to $PBINF$ $NORPOOLGR$ changed to $NORPOOLINF$ This is done to maintain the convention that annual changes in percent of nominal variables have "INF" at the end of the variable names, while percent changes in real variables has "GR"at the end of the variable name.

19 May 2017 Changed definition of $WPINF$ from:

$$WPFINF = ((WCPFK/WCPFK(-4)) - 1)100, \tag{83}$$

to:

$$WPFINF = ((WPFK/WPFK(-4)) - 1)100 \tag{84}$$

This is done to avoid any influence from changes in payroll-taxes on the model's definition variable for annual percent change in the wage hourly wage rate in private Mainland-Norway.

16 September 2017 Re-modelled the equation for the import price index (PB) and imports (B) after change in data source (from KVARTS database to SSB-Statistikkbanken). Numerical changes in point estimates, but no changes that affect the interpretation of the model equations.

19 September 2017 Defined a new endogenous variable for income: YDH = Household disposable income (mill. NOK) and changed the definition of YD (Private disposable income) to: YD = YDH + YDORG.

24 September 2017 Defined new endogenous variables for private saving as SAVINGPH (households), SAVINGPORG (ideal organizations), SAVINGP (private savings); and savings rates: SPH (households), SPORG (ideal organizations), SP (private)

One new exogenous variable: KORRSPH (households' new deposits in pension funds).

References

Admati, A., P. DeMarzo, M.-F. Hellwig and P. Pfleiderer (2013). Fallacies, Irrelevant Facts, and Myths in the Discussion of Capital Regulation: Why Bank Equity if Not Socially Expensive (October 22, 2013). Tech. rep., Max Planck Institute for Research on Collective Goods 2013/23; Rock Center for Corporate Governance at Stanford University Working Paper No. 161; Stanford University Graduate School of Business Research Paper No. 13-7.

Akram, Q. F. and R. Nymoen (2009). Model Selection for Monetary Policy Analysis—How Important is Empirical Validity? *Oxford Bulletin of Economics and Statistics*, *71*, 35—68.

Aldrich, J. (1989). Autonomy. *Oxford Economic Papers*, *41*, 15–34.

Andersen, T. M. (1994). *Price Rigidity. Causes and Macroeconomic Implications*. Claredon Press, Oxford.

Anderson, P. W. (1972). More is different. *Science*, *117*(4047), 393–396.

Anundsen, A. (2014). *Housing markets and financial stability*. Ph.D. thesis, University of Oslo.

Anundsen, A., T. Krogh, R. Nymoen and J. Vislie (2014). Overdeterminacy and Endogenous Cycles: Trygve Haavelmo's Business Cycle Model. *Meteroeconomica*, *65*(3), 460–486.

Anundsen, A. K. and E. S. Jansen (2013). Self-reinforcing Effects Between Housing Prices and Credit. *Journal of Housing Economics*, *22*(3), 192–212.

Aron, J., J. V. Duca, J. Muellbauer, K. Murata and A. Murphy (2012). Credit, Housing Collateral and Consumption: Evidence from the UK, Japan and the US. *Review of Income and Wealth*, *58*(3), 397–423.

Bårdsen, G., Ø. Eitrheim, E. S. Jansen and R. Nymoen (2005). *The Econometrics of Macroeconomic Modelling*. Oxford University Press, Oxford.

Bårdsen, G. and L. Fanelli (2015). Frequentist evaluation of small DSGE models. *Journal of Business & Economic Statistics*. Forthcoming.

Bårdsen, G. and P. G. Fisher (1993). The Importance of Being Structured. Discussion paper 02/93, Institute of Economics, Norwegian School of Economics and Business Administration.

Bårdsen, G. and P. G. Fisher (1999). Economic Theory and Econometric Dynamics in Modelling Wages and Prices in the United Kingdom. *Empirical Economics*, *24*(3), 483–507.

Bårdsen, G., P. G. Fisher and R. Nymoen (1998). Business Cycles: Real Facts or Fallacies? In Strøm, S. (ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*, no. 32 in Econometric Society Monograph Series, chap. 16, 499–527. Cambridge University Press, Cambridge.

Bårdsen, G., S. Hurn and K. Lindsay (2004). Linearizations and equilibrium correction models. *Studies in Nonlinear Dynamics and Econometrics*, *8*(5).

Bårdsen, G., E. S. Jansen and R. Nymoen (2003). Econometric Inflation Targeting. *Econometrics Journal*, *6*, 429—460.

Bårdsen, G. and J. T. Klovland (2000). Shaken or Stirred? Financial Deregulation and the Monetary Transmission Mechanism in Norway. *Scandinavian Journal of Economics*, *102*(4), 563–583.

Bårdsen, G. and R. Nymoen (2001). Rente og Inflasjon[Interest Rate and Inflation]. *Norsk Økonomisk Tidsskrift*, *115*(2), 125—148.

Bårdsen, G. and R. Nymoen (2003). Testing Steady-State Implications for the NAIRU. *Review of Economics and Statistics*, *85*(3), 1070—1075.

Bårdsen, G. and R. Nymoen (2009a). Macroeconometric modelling for policy. In Patterson, K. and T. Mills (eds.), *The Palgrave Handbook of Econometrics*, vol. 2. Palgrave.

Bårdsen, G. and R. Nymoen (2009b). Macroeconometric Modelling for Policy. In Mills, T. and K. Patterson (eds.), *Palgrave Handbook of Econometrics Vol 2*, chap. 17, 851—916. Palgrave Mac-Millan.

Bårdsen, G. and R. Nymoen (2009c). U.S. Natural Rate Dynamics Reconsidered. In Castle, J. and N. Shephard (eds.), *The Methodology and Practise of Econometrics. A Festschrift in Honour of David F. Hendry*, chap. 16, 389–414. Oxford University Press, Oxford.

Bårdsen, G. and R. Nymoen (2011). *Innføring i økonometri*. Fagbokforlaget.

Bårdsen, G. and R. Nymoen (2014). *Videregående emner i økonometri*. Fagbokforlaget.

Bårdsen, G., A. Reijer, P. Jonasson and N. R. (2012). MOSES: Model for studying the economy of Sweden. *Economic Modelling*, *29*(6), 2566–2582.

Barker, T. and W. Peterson (eds.) (1987). *Multisectoral Dynamic Model of the British Economy*. Cambridge University Press.

Bernanke, B. and M. Gertler (1989). Agency costs, net worth, and business fuctuations. *American Economic Journal*, *79*, 14—31.

Bjerkholt, O. (1998). Interaction Between Model Builders and Policy Makers in the Norwegian Tradition. *Economic Modelling*, *15*, 317–339.

Blanchard, O. and J. Galí (2010). Labor Markets and Monetary Policy: A New Keynesian Model with Unemployment. *American Economic Journal: Macroeconomics*, *2*(2), 1–30.

Blanchard, O. J. and L. Katz (1999). Wage Dynamics: Reconciling Theory and Evidence. *American Economic Review*, *89*(2), 69–74.

Blanchflower, D. G. and A. J. Oswald (1994). *The Wage Curve*. The MIT Press, Cambridge, Massachusetts.

Blinder, A. (1998). *Asking About Prices: A New Approach to Price Stickiness*. Russel Sage Foundation.

Brodin, P. A. and R. Nymoen (1992). Wealth Effects and Exogeneity: The Norwegian Consumption Function 1966.1-1989.4. *Oxford Bulletin of Economics and Statistics*, *54*, 431–454.

Calmfors, L. and R. Nymoen (1990). Nordic Employment. *Economic Policy*, *5*(11), 397–448.

Calvo, G. (1983). Staggered Prices in a Utility Maximizing Framework. *Journal of Monetary Economics*, *12*, 383–98.

Campbell, J. (1994). Inspecting the mechanism: an analytical approach to the stochastic growth model. *Journal of Monetary Economics*, *33*(3), 463–506.

Campbell, J. Y. (1987). Does Saving Anticipate Declining Labor Income? An Alternative Test of the Permanent Income Hypothesis. *Econometrica*, *55*, 1249–73.

Campbell, J. Y. and N. G. Mankiw (1989). Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence. In Blanchard, O. J. and S. Fisher (eds.), *NBER Macroeconomics Annual 1989*, 185–216. MIT Press, Cambridge, Mass.

Cappelen, Å. (1991). Macroeconomic Modeling: The Norwegian Experience. *Scandinavian Journal of Economics*, *92*(2), 323–330. Proceedings of a Conference on New Approaches to Empirical Macroeconomics (Jun., 1991).

Castle, L., J, J. Doornik, D. Hendry and R. Nymoen. (2014). Mis-specification testing: Non-invariance of ecpectations models of inflation. *Econometric Reviews*, *33*(5-6), 553–574. DOI:10.1080/07474938.2013.825137.

Clarida, R., J. Gali and M. Gertler (1999). The Science of Monetary Policy: A New Keynesian Perspective. *Journal of Economic Literature*, *37*(4), 1661–1707.

Clements, M. P. and D. F. Hendry (1999). *Forecasting Non-stationary Economic Time Series*. The MIT Press, Cambridge, MA.

Cloyne, J., R. Thomas, A. Tuckett and S. Wills (2015). A sectoral framwork for analysing money, credit and unconventional monetary policy. Staff Working Paper 556, Bank of England.

Davidson, J. E. H., D. F. Hendry, F. Srba and S. Yeo (1978). Econometric Modelling of the Aggregate Time-Series Relationship between Consumers' Expenditure and Income in the United Kingdom. *Economic Journal*, *88*, 661–692.

DeJong, D. and C. Dave (2007). *Structural Macroeconometrics*. Princeton University Press, Princeton and Oxford.

Doornik, J. A. (2009). Autometrics. In Castle, J. and N. Shephard (eds.), *The Methodology and Practice of Econometrics*, chap. 8, 88—121. Oxford University Press, Oxford.

Doornik, J. A. and D. F. Hendry (1997). The Implications for Econometric Modelling of Forecast Failure. *Scottish Journal of Political Economy*, *44*, 437–461.

Doornik, J. A. and D. F. Hendry (2009). *Empirical Econometric Modelling PcGive 143. Volume 1*. Timberlake Consultants, London.

Doornik, J. A. and D. F. Hendry (2013). *Modelling Dynamic Systems PcGive 14. Volume 2*. Timberlake Consultants, London.

Dougherty, A. and R. Van Order (1982). Inflation, housing costs, and the consumer price index. *American Economic Review*, *72*(1), 154–164.

Eika, K. H. and R. Nymoen (1992). Finansiell konsolidering som en konjunkturfaktor [Financial Consolidation as a Business Cycle Factor]. *Penger og Kreditt*, *21*(1), 29–38.

Eitrheim, Ø., T. A. Husebø and R. Nymoen (1999). Equilibrium-Correction versus Differencing in Macroeconomic Forecasting. *Economic Modelling*, *16*, 515–544.

Eitrheim, Ø., E. S. Jansen and R. Nymoen (2002). Progress from Forecast Failure: The Norwegian Consumption Function. *Econometrics Journal*, *5*, 40–64.

Engle, R. F. and D. F. Hendry (1993). Testing Super Exogeneity and Invariance in Regression Models. *Journal of Econometrics*, *56*, 119–139.

Ericsson, N. R. and D. Hendry (1999). Encompassing and Rational Expectations: How Sequential Corroboration Can Imply Refutation. *Empirical Economics*, *24*(1), 1—21.

Ericsson, N. R. and J. S. Irons (1995). The Lucas Critique in Practice: Theory Without Measurement. In Hoover, K. D. (ed.), *Macroeconometrics: Developments, Tensions and Prospects*, chap. 8. Kluwer Academic Publishers.

Erlandsen, S. and R. Nymoen (2008). Consumption and population age structure. *Journal of Population Economics*, *21*(3), 505—520.

EViews (2014a). *EViews 8.1 User's Guide I*. IHS Global Inc., 4521 Campus Drive,336, Irvine CA, 92612-2621. USA. Www.eviews.com.

EViews (2014b). *EViews 8.1 User's Guide II*. IHS Global Inc., 4521 Campus Drive,336, Irvine CA, 92612-2621. USA. Www.eviews.com.

Evju, S. (2003). Arbeidsrett og styringsrett—et perspektiv. *Arbeidsrett og arbeidsliv*, *Bind 1*, 3–32.

Falch, N. S. and R. Nymoen (2011). The Accuracy of a Forecast Targeting Central Bank. *Economics: The Open-Access, Open-Assessment E-Journal*, *5*(15), 1–36.

Finanstilsynet (2014a). Finansielt utsyn 2014. Tech. rep., Finanstilsynet.

Finanstilsynet (2014b). Finansielt utsyn 2015. Tech. rep., Finanstilsynet.

Forder, J. (2014). *Macroeconomics and the Phillips Curve Myth*. Oxford Studies in the History of Economics. Oxford University Pres, Oxford.

Forslund, A., N. Gottfries and A. Westermark (2008). Prices, Productivity and Wage Bargaining in Open Economies. *Scandinavian Journal of Economics*, *110*((1)), 169—195.

Garratt, A., K. Lee, M. H. Pesaran and Y. Shin (2006). *Global and National Macroeconometric Modelling: A Long-Run Structural Approach*. Oxford University Press.

Gertler, M. and A. Trigari (2009). Unemployment Fluctuations with Staggered Nash Wage Bargaining. *Journal of Political Economy*, *177*(1), 38–86.

Goodhart, C. and B. Hofmann (2007). *House Prices and the Macroeconomy: Implications for Banking and Price Stability*. Oxford University Press, Oxford.

Granger, C. W. (1992). Fellow's Opinion: Evaluating Economic Theory. *Journal of Econometrics*, *51*, 3–5.

Granger, C. W. J. (1990). General Introduction: Where are the Controversies in Econometric Methodology? In Granger, C. W. J. (ed.), *Modelling Economic Series. Readings in Econometric Methodology*, 1–23. Oxford University Press, Oxford.

Granger, C. W. J. (ed.) (1999). *Empirical Modeling in Economics. Specification and Evaluation*. Cambridge Universty Press, Cambridge.

Haavelmo, T. (1944). The Probability Approach in Econometrics. *Econometrica*, *12*, 1–118. Supplement.

Hahn, F. R. S. (1997). *A Critical Essay on Modern Macroeconomic Theory*. MIT Press, Cambridge.

Hall, R. E. (2005). Employment Fluctuations with Equilibrium Wage Stickiness. *American Economic Review*, *95*(1), 50–65.

Hendry, D. F. (1988). The Encompassing Implications of Feedback verus Feedforward Mechanisms in Econometrics. *Oxford Economic Papers*, *40*, 132–149.

Hendry, D. F. (1995a). *Dynamic Econometrics*. Oxford University Press, Oxford.

Hendry, D. F. (1995b). *Dynamic Econometrics*. Oxford University Press, Oxford.

Hendry, D. F. (1995c). Econometrics and business cycle empirics. *Economic Journal*, *105*, 1622–1636.

Hendry, D. F. (2001). How Economists Forecast. In Ericsson, N. R. and D. F. Hendry (eds.), *Understanding Economic Forecasts*, chap. 2, 15—41. The MIT Press, Cambridge, Massachusetts.

Hendry, D. F. (2004). Robustifying Forecasts from Equilibrium-Correction Models. Working Paper 14/2004, Univeristy of Oxford, Department of Economics.

Hendry, D. F. and J. A. Doornik (2014). *Empirical Model Discovery and Theory Evaluation. Automatic Selection Methods in Econometrics*. Arne Ryde Memorial Lectures. MIT Press, Cambridge,Massachusetts.London, England.

Hendry, D. F. and H.-M. Krolzig (1999). Improving on 'Data mining reconsidered' by K. D. Hoover and S. J. Perez. *Econometrics Journal*, *2*, 202–219.

Hendry, D. F. and G. E. Mizon (2010). On the Mathematical Basis of Inter-temporal Optimization. Working Paper 497, Economics Department, Oxford University.

Hendry, D. F. and B. Nielsen (2007). *Econometric Modeling*. Princeton University Press, Princeton and Oxford.

Hicks, J. (1955). Economic Foundations of Wages Policy. *Economic Journal*, *65*(259), 388–404.

Hofmann, B. (2004). The Determinants of Private Sector Credit in Industrialised Countries: Do Property Prices Matter? *International Finance*, *7*(203-34).

Hoover, K. D. and S. J. Perez (1999). Data Mining Reconsidered: Encompassing and the General-to-Spesific Approach to Specification Search. *Econometrics Journal*, *2*, 1–25.

Hsiao, C. (1997). Cointegration and Dynamic Simultaneous Equations Model. *Econometrica*, *65*(3), 647–670.

Jansen, E. S. (2013). Wealth Effects on Consumption in Financial Crises: the Case of Norway. *Emprical Economics*, *45*(2), 873–904.

Johansen, K. (1995a). Norwegian Wage Curves. *Oxford Bulletin of Economics and Statistics*, *57*, 229—247.

Johansen, L. (1977). *Lectures on Macroeconomic Planning.1. General Aspects.*. North-Holland, Amsterdam.

Johansen, S. (1995b). *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*. Oxford University Press, Oxford.

Johansen, S. (2006). Cointegration: an overview. In Mills, T. C. and K. Patterson (eds.), *Palgrave Handbook of Econometrics*, vol. 1 of *Econometric Theory*. Palgrave-MacMillan.

Johansen, S. and A. R. Swensen (1999). Testing exact rational expectations in cointegrated vector autoregressive models. *Journal of Econometrics*, *93*, 73–91.

Johansen, S. and A. R. Swensen (2004). More on testing exact rational expectations in cointegrated vector autoregressive models: Restricted constant and linear term. *Econometrics Journal*, *7*, 389–397.

Juselius, K. (2007). *The Cointegrated VAR Model: Methodology and Applications*. Oxford University Press.

Keen (2011). *Debunking Economics – Revised, Expanded and Integrated Edition: The Naked Emperor Dethroned?*. Zed Books.

Kiyotaki, N. and J. Moore (1997). Credit cycles. *Journal of Political Economy*, *105*, 211–48.

Klein, L. R. (1962). *An Introduction to Econometrics. A Non-Technical Treatment of Apllications and Methods Based on Classical Studies in the Field.*. Prentice-Hall.

Kolsrud, D. and R. Nymoen (1998). Unemployment and the Open Economy Wage-Price Spiral. *Journal of Economic Studies*, *25*, 450–467.

Kolsrud, D. and R. Nymoen (2014). Macroeconomic Stability or Cycles? The Role of the Wage-Price Spiral. *Australian Economic Papers*, *53*(1-2), 41–68. DOI: 10.1111/1467-8454.12020.

Kolsrud, D. and R. Nymoen (2015). Heuristic vs formal dynamics of the wage- and price-curve model of equilibrium unemployment. *Journal of economic studies*, *42*(2), 186–206.

Krogh, T. (2015). Real wage rigidity and the unemployment volatility puzzle in small open economies. Statistics Norway and Norges Bank.

Layard, R., S. Nickell and R. Jackman (1991). *Unemployment*. Oxford University Press, Oxford.

Layard, R., S. Nickell and R. Jackman (1994). *The Unemployment Crises*. Oxford University Press, Oxford.

Layard, R., S. Nickell and R. Jackman (2005). *Unemployment*. Oxford University Press, Oxford, 2nd edn. First published 1991.

Lucas, R. E., Jr. (1976). Econometric Policy Evaluation: A Critique. In Brunner, K. and A. H. Meltzer (eds.), *Carnegie-Rochester Conference Series on Public Policy:The Phillips Curve and Labor Markets, Volume 1*, 19–46. Journal of Monetary Economics, Supplement.

Lütkepohl, H. (2006). Vector autoregressive models. In Mills, T. C. and K. Patterson (eds.), *Econometric Theory*, vol. 1 of *Palgrave Handbook of Econometrics*, 287–325. Palgrave MacMillan.

Muellbauer, J. (2012). When is a housing market overheated enough to threaten stability? In Heath, F. P., A. and C. Windsor (eds.), *Property Markets and Financial Stability*, RBA Annual Conference Volume. Reserve Bank of Australia.

Naug, B. and R. Nymoen (1996). Pricing to Market in a Small Open Economy. *Scandinavian Journal of Economics*, *98*(329—350).

Nickell, S. (1988). The Supply Side and Macroeconomic Modelling. In Bryant, R. C., D. W. Henderson, G. Holtham., P. Hooper and S. A. Symansky (eds.), *Empirical Economics for Interdependent Economies*, chap. 9. The Brookings Institution, Washington, D.C.

Nickell, S., L. Nunziata and W. Ochel (2005). Unemployment in the OECD Since the 1960s. What Do We Know? *The Economic Journal*, *115*, 1—27.

Nymoen, R. (1989a). Modelling Wages in the Small Open Economy: An Error-Correction Model of Norwegian Manufacturing Wages. *Oxford Bulletin of Economics and Statistics*, *51*, 239–258.

Nymoen, R. (1989b). Wages and the Length of the Working Day. A Empirical Test Based on Norwegian Quarterly Manufacturing Data. *Scandinavian Journal of Economics*, *91*, 599–612.

Nymoen, R. (1991). A Small Linear Model of Wage- and Price-Inflation in the Norwegian Economy. *Journal of Applied Econometrics*, *6*, 255–269.

Nymoen, R. and A. Rødseth (2003). Explaining Unemployment: Some Lessons from Nordic Wage Formation. *Labour Economics*, *10*, 1—29.

Nymoen, R. and V. Sparrman (2015). Equilibrium Unemployment Dynamics in a Panel of OECD Countries. *Oxford Bulletin of Economics and Statistics*, *77*(2), 164–190.

OECD (2012). OECD Economic Outlook Norway. Tech. rep., OECD.

Pedersen, L. H. (2009). When Everyone Runs for the Exit. *International Journal of Central Banking*, *5*, 177—199.

R., N. and N. S. Falch (2011). The Accuracy of a Forecast Targeting Central Bank. *Economics: The Open-Access, Open-Assessment E-Journal*, *5*(2011-15).

Reiersen, J. (2015). From Conflict to Cooperation. Norwegian Labor Market Institutions in The Making. Unpublished. Department of Business and Management. Buskerud and Vestfold University College.

Rødseth, A. (2000). *Open Economy Macroeconomics*. Cambridge University Press, Cambridge.

Samuelson, P. A. (1951). Economic Theory and Wages. In Wright, D. (ed.), *The Impact of the Union*, 312–43. Harcourt Brace & Company.

Sargan, J. D. (1964). Wages and Prices in the United Kingdom: A Study of Econometric Methodology. In Hart, P. E., G. Mills and J. K. Whitaker (eds.), *Econometric Analysis for National Economic Planning*, 25–63. Butterworth Co., London.

Sargan, J. D. (1980). A Model of Wage-Price Inflation. *Review of Economic Studies*, *47*, 113–135.

Solow, R. M. (1990). *The Labour Market as a Social Institution*. Basil Blackwell, Oxford.

Spanos, A. (2008). Suffiency and ancillarity revisited: testing the validity of a statistical model. In Castle, J. L. and N. Shephard (eds.), *The Methodology and Practice of Econometrics*. Oxford Univeristy Press, Oxford.

Stanley, T. D. (2000). An Empirical Critique of the Lucas Critique. *Journal of Socio-Economics*, *29*, 91–107.

Stiglitz, J. E. (2014). The Lessons from the North Atlantic Crisis for Economic Theory and Policy. In Akerlof, G., O. Blanchard, D. Roemer and J. Stiglitz (eds.), *What Have We Learned? Macroeconomic Policy after the Crisis.*, chap. 29. MIT Press.

Svensson, L. (1997). Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets. *European Economic Review*, *41*, 1111–1146.

Uhlig, H. (1999). A toolkit for analysing nonlinear dynamic stochastic models easily. In Marimon, R. and A. Scott (eds.), *Computational Methods for the Study of Dynamic Economies*, 30–61. Oxford University Press, Oxford.

Usher, D. (2012). Bargaining Unexplained. *Public Choice*, *151*(1/2), 23–41.

Wallis, K. F. (1977). Multiple time series analysis and the final form of econometric models. *Econometrica*, *45*, 1481–97.

Wallis, K. F. (1995). Large-Scale Macroeconometric Models. In M.H., P. and M. Wickens (eds.), *Handbook of Applied Econometrics*, vol. 1 Macroeconomics. Blackwell Pulishers.

Wolden Bache, I. (2002). Empirical Modelling of Norwegian Import Prices. Working Paper 2002/1, Norges Bank.